Department of Energy

Research & Development Electrical Safety Meeting & Workshop Report

March 1 – 4, 2004
Albuquerque, New Mexico

March 31, 2004

ACKNOWLEDGEMENTS

The Workshop was made possible largely by the support and generosity of the Los Alamos National Laboratory's management commitment to attaining excellence in electrical safety.

The workshop attendees contributed their time, talents, knowledge, skills and abilities in an effort to enhance electrical safety for all. Their participation is greatly appreciated.

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SUMMARY

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The Department of Energy (DOE) Research & Development Electrical Safety Meeting and Workshop was held March 1-4, 2004 at Albuquerque, New Mexico. The purpose of the meeting was, (1) to present methods and successes from various sites in R&D electrical safety topics and (2) to conduct a workshop on the revision of Chapters 9 & 10 of the DOE Electrical Safety Handbook. The R&D community has needed to share and discuss electrical safety issues for several years due to code changes, incidents, operating experience, concerns . . . The need to revise the DOE Handbook 1092-98 Electrical Safety was largely based on Defense Nuclear Facilities Safety Board's concern that the DOE needed to update the Manual to reflect current code changes. The task to update the Manual is being led by the DOE Headquarters Office Environment, Safety & Health. The Los Alamos National Laboratory staff committed to provide support to the effort in updating Chapter 9 & 10. Chapters 9 & 10 principally deal with electrical safety in the R&D environment.

The meeting and workshop were held March 1-4, 2004 in Albuquerque New Mexico. In attendance were over fifty participants representing eleven contractor sites and four DOE Site Offices. The need to update Chapters 9 & 10 was confirmed by the meeting attendees. The attendees also stated that additional chapters were needed to more fully address R & D electrical safety. Technical presentations covered several areas and methods used at their respective sites. Workshop Panels formed to specifically address areas identified for improvement. The Panels presented their results regarding improving electrical safety and Handbook updates.

The workshop was deemed a success by the attendees and further workshops were requested. The workshop DOE R&D community identified numerous electrical safety opportunities for improvement. Communication and interactions of DOE R&D sites performing electrical work needs to be continued in order enhance electrical safety. Representatives from the DOE NNSA stated that they would be supportive in fostering more communication and interaction.

AGENDA

R&D Electrical Safety Meeting and Workshop
March 1 – 4, 2004
Albuquerque, New Mexico

R&D Electrical Safety Meeting and Workshop
The R&D Electrical Safety Meeting and Workshop will be the first of its kind. The purpose will be to engage all DOE laboratories and sites that perform research and development activities in an exchange of information and workshop on electrical safety in the R&D environment.

Goal #1 – To present methods and successes from the various sites in R&D Electrical Safety Topics

Goal #2 – To conduct a workshop on the revision of Chapters 9 and 10 of the DOE Electrical Safety Handbook.

Location –
DOE Energy Complex Training Center
Kirtland AF Base – at intersection of Maxwell and Gibson
Albuquerque, New Mexico

Date – March 1 through March 4, 2004

General Conference Chair
Willy Molina
DOE Los Alamos Site Office
wmolina@doeal.gov

Technical Program Chair
Lloyd Gordon
Los Alamos National Laboratory
lbgordon@lanl.gov

Workshop Chair
Terry Fogle
Los Alamos National Laboratory
tfogle@lanl.gov

Program and Workshop Topics
Electrical Hazard Classification
Electrical Safety Training for R&D Workers
Unlisted Electrical Equipment Inspection and Approval
2004 NFPA 70E – Electrical Safety in the Workplace
Electrical Personal Protective Equipment in the R&D Environment
Methods of Electrical Energy Isolation and Verification
Integrated Safety Management for Electrical Hazards
Accelerator Electrical Safety

Preliminary Agenda

Monday, March 1 – 2:00- 5:00 PM – Meeting of the DOE Electrical Safety Handbook R&D Subcommittee

Tuesday, March 2 – 8:00 AM Opening Session of the R&D Electrical Safety Conference. Expected Feature Speaker. 8:45 AM- 5:00 PM Topics as presented by participants.

Wednesday, March 3 – 8:00 AM Continuation of the R&D Electrical Safety Conference. Second Featured Speaker. 8:45 AM – 12:00 PM Topics as presented by participants. 1:30 –5:00 PM Workshop on Revision of Chapters 9 & 10 of the DOE Electrical Safety Handbook

Thursday, March 4 – 8:00 AM– 1:30 PM. Working Groups for the DOE Electrical Safety Handbook Revision Efforts. 2:00-5:00 PM Conclusions and Recommendations Out Briefing. Session Ends at 5:00 PM.

INVITATION – We would like to solicit contributions on R&D electrical safety programs from the various DOE sites. Please submit an abstract at your earliest convenience. Tentatively we would propose and 30 to 45 minutes presentation time.

FURTHER INFORMATION – will be forthcoming next week.

Please contact any or all of the above three conference chairs for further information.

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March 1-4, 2004
Albuquerque, New Mexico

General Meeting Chair: Willy Molina, DOE Los Alamos Site Office
Technical Program Chair: Lloyd Gordon, Los Alamos National Laboratory
Workshop Chair: Terry Fogle, Los Alamos National Laboratory

Locations: DOE Energy Training Complex and Albuquerque NNSA Service Center
Kirtland Air Force Base, Albuquerque, New Mexico

Monday, March 1, 2004
Kickoff Meeting of the DOE E.S. Handbook R&D Subcommittee
2:00 – 5:00 PM
Agenda

1. Welcome

2. Introductions of Key Program Personnel

3. Introductions of Attendees - Getting Acquainted

4. Discussion:
   A. What do attendees think of the present Handbook? Is it useful?
   B. What needs improvement or revision?
   C. What new sections are needed?
   D. What relevant knowledge and expertise do attendees have?
   E. How do you use the Handbook? For training, for reference, for requirements?
   F. Thoughts on structuring the workshop for maximum benefit?
   G. Assignments and Participation after the Meeting and Workshop.
   H. R&D Revision Sections for the DOE Electrical Safety Handbook – Chapters 9 & 10.
   I. Section Leaders.

5. Getting Started.

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Tuesday, March 2, 2004
Technical Presentations on R&D Electrical Safety
8:00 AM – 5:00 PM
Agenda

8:00 am	Welcome, DOE	Willy Molina, DOE
8:10 am	Conference Attendees	Lloyd Gordon, LANL
8:20 am	Workshop Goals	Terry Fogle, LANL
8:30 am	Welcome, LANL	Rick Brake, LANL
8:50 am	Introductions	all
9:15 am	History of Electrical Safety Handbook	Willy Molina, DOE
9:30 am	History of Electrical Safety	Lloyd Gordon, LANL
10:00 am	BREAK	
10:30 am	Physiology of Electrical Shock	Lloyd Gordon, LANL
11:00 am	Electrical Hazard Classification	Lloyd Gordon, LANL
11:30 am	Multiple Hazards	Scott Walker, LANL
12:00 pm	LUNCH	
1:00 pm	PPE in R&D	Clark Thompson, LANL
1:30 pm	Lightning Safety	Bob Daley, LANL
2:00 pm	Mixed skills	Tom Hardek, LANL
2:30 pm	Jefferson National Lab program	Bob May, TJNL
2:45 pm	Spallation Neutron Source at ORNL	David Anderson, SNS/ORNL
3:00 pm	BREAK	
3:30 pm	Brookhaven NL/NSCL (MSU)	Terry Monahan, NSCL
3:45 pm	Bechtel Neveda	Ed Laner, BN
4:00 pm	Savannah River Technology Center	Larry Zalants, SRTC
4:15 pm	BWXT Pantex	Tony Birkenfeld
4:30 pm	Oak Ridge National Lab	Jim Blankenship, ORNL

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Wednesday, March 3, 2004
Technical Presentations on R&D Electrical Safety
8:00 AM – 5:00 PM
Agenda

8:00 am	Review and Update	Lloyd Gordon, LANL
8:15 am	Comments from NNSA	David Chaney, NNSA HQ
8:30 am	Savannah River Technology Center	Larry Zalants, SRTC
8:45 am	BWXT Pantex	Tony Birkenfeld, Pantex
9:00 am	Oak Ridge National Lab	Jim Blakenship, ORNL
9:15 am	Idaho National Engineering Lab	Doug Ardary, INEL
9:30 am	Lawrence Berkeley National Lab	Tom Caronna, LBNL
9:45 am	R&D Grounding	Lloyd Gordon, LANL
10:00 am	BREAK	
10:15 am	Sandia National Lab	Jeff Downs, SNL
10:30 am	Los Alamos National Lab	Terry Fogle, LANL
10:45 am	Lawrence Livermore National Lab	Lloyd Gordon, LANL
10:55 am	Stanford Linear Accelerator Center	Lloyd Gordon, LANL
11:00 am	Pulsed Power and RF Safety	David Anderson, SNS/ORNL
11:30 am	Unlisted Electrical Equipment	Patrick Lara, LANL
12:00 pm	LUNCH	
1:00 pm	Workshop Opening and Plan	Terry Fogle, LANL

CHAPTER 9 & 10 SECTIONS
(EXISTING)

R&D Revision Sections
for the
DOE Electrical Safety Handbook
Chapters 9 and 10

March 1-4, 2004

I. 9.0 Enclosed Electrical/Electronic Equipment
- 9.1 Purpose
- 9.2 Scope
- 9.3 Grounding and Bonding
  - 9.3.1 Objectionable Current Over Grounding Conductors
  - 9.3.2 Equipment Grounding Conductor
  - 9.3.3 Enclosure Grounding and Bonding
  - 9.3.4 Special Considerations

II. 9.4 Rack Power Distribution
  - 9.4.1 General Requirements Applying to all AC Power Equipment Within or Attached to Instrument Racks
    - 9.4.1.1 Loads
    - 9.4.1.2 Other General Equipment Requirments
  - 9.4.2 Conductors and Cables Specific Requirements
    - 9.4.2.1 Flexible Cables
    - 9.4.2.2 Strain Relief
    - 9.4.2.3 Separation of Voltages
    - 9.4.2.4 Other Concerns
  - 9.4.3 Power Switches and Interlock Devices
- 9.5 Chassis Power Distribution
  - 9.5.1 AC Power Distribution
    - 9.5.1.1 Chassis Bonding and Grounding
    - 9.5.1.2 Connections, Connectors, and Couplings
    - 9.5.1.3 Terminals / Live Parts
  - 9.5.2 DC Power Distribution
- 9.6 Protective Devices for Enclosed Electrical/Electronic Equipment
  - 9.6.1 Surge Arrestors
  - 9.6.2 Fuses
  - 9.6.3 Circuit Breakers
  - 9.6.4 Power Interlock Devices
- 9.7 Disconnecting Means
  - 9.7.1 General
  - 9.7.2 Emergency Shutdown
  - 9.7.3 Special Considerations

V. 9.13 Non-Ionizing Radiation
- 9.13.1 Electromagnetic Radiation
- 9.13.2 Electromagnetic Radiation Threat to Electroexplosive Devices

10.8 Generic R&D Equipment
- 10.8.4 Radio-Frequency / Microwave Radiation and Fields
  - 10.8.4.1 Hazards
  - 10.8.4.2 Design and Construction
    - 10.8.4.2.1 Exemptions to RFMW Exposure Limits
    - 10.8.4.2.2 Exposure Criteria for Pulsed RFMW Radiation

10.9 Methods
- 10.9.1 Wiring Methods
  - 10.9.1.1 Hazards
  - 10.9.1.2 Design and Construction
    - 10.9.1.2.1 Design and Construction as an Integral Part of Equipment
    - 10.9.1.2.2 Power Supply Interface Between Utility Systems and R&D Equipment
  - 10.9.1.3 Operation and Maintenance

VI. 10.9 Methods
- 10.9.2 Unconventional Practices
  - 10.9.2.1 Grounding
    - 10.9.2.1.1 Hazards
    - 10.9.2.1.2 Design and Construction
    - 10.9.2.1.3 Noise Coupling Mechanisms
    - 10.9.2.1.4 Operation and Maintenance
  - 10.9.2.2 Materials Used in an Unconventional Manner
    - 10.9.2.2.1 Hazards
    - 10.9.2.2.2 Design and Construction
    - 10.9.2.2.3 Operation and Maintenance
- 10.9.3 Work on Energized or De-Energized Electrical Equipment

VII. 10.10Requirements for Specific R&D Equipment
- 10.10.1 Capacitors
  - 10.10.1.1 Hazards
  - 10.10.1.2 Design and Construction
    - 10.10.1.2.1 Automatic Discharge Devices
    - 10.10.1.2.2 Safety Grounding
    - 10.10.1.2.3 Ground Hooks
    - 10.10.1.2.4 Discharge Equipment with Stored Energy in Excess of 10 Joules
    - 10.10.1.2.5 Fusing
  - 10.10.1.3 Operation and Maintenance

10.10.2 Inductors
- 10.10.2.1 Hazards
- 10.10.2.2 Design and Construction
- 10.10.2.3 Operation and Maintenance

10.10.3 Electrical Conductors and Connectors
- 10.10.3.1 Hazards
- 10.10.3.2 Design and Construction
- 10.10.3.3 Operation and Maintenance

10.10.4 Induction and Dielectric Heating Equipment
- 10.10.4.1 Hazards
- 10.10.4.2 Design and Construction
- 10.10.4.3 Operation and Maintenance

10.10.5 Lasers and X-Ray Equipment
- 10.10.5.1 Hazards

VIII. New Material to be Added

1.
2.
3.
4.
5.

TECHNICAL PRESENTATIONS

A Century of Electrical Safety

March 2, 2004

R&D Electrical Safety Meeting

Lloyd B. Gordon

Los Alamos National Laboratory

LAUR-05-2116

A Brief History of Electrical Safety

- 1880 - first electrical codes (NEC and UL) (NEC 2 pages)
- 1945 - first DOE R&D labs
- 1960s - first studies on the effects of electricity
- 1960s - *equipment ground implemented*
- 1970 - OSHA established
- 1970s - *GFCIs added to NEC*
- 1990 - "tiger teams"
- 1990s - DOE Electrical Safety Handbook started
- 1996 - ISM
- 1998 - DOE Electrical Safety Handbook released
- 2002 - *arc fault interrupter in NEC* (NEC 711 pages)

A Brief History of Electrical Safety Training in DOE

- pre 1990 - very basic electrical awareness
- 1990 - 2000 Comprehensive R&D class briefly covering everything, used DOE handbook extensively, not lab specific (LLNL, SNL, SLAC)
- since 2000 - core class specific to a lab's program, specific short classes on special R&D topics (LANL, SNS/ORNL, NTS, JNL, SLAC)

Recent Evolution in U.S. Electrical Safety

- 1990 - tiger teams, focus on safety in DOE
- 1993 - first drafts of DOE Handbook
- 1996 - DOE ISM process developed
- 1998 - DOE Electrical Safety Handbook published
  - non listed equipment issue
  - model electrical safety program
  - training and qualification section
  - R&D sections
- 1999 - NEC significantly revised
  - redone grounding section
  - redefinition of "qualified person", including training
  - increased emphasis on warning signs, e.g., High Voltage
- 2000 - NFPA 70E significantly revised - Electrical Safety in the Workplace
  - PPE a major issue
- 2002 - NEC - continuing emphasis on warning and labeling
- 2003 - 2004 - OSHA inspections of DOE labs
- 2004 - NFPA 70E - upcoming revision, could affect R&D work significantly

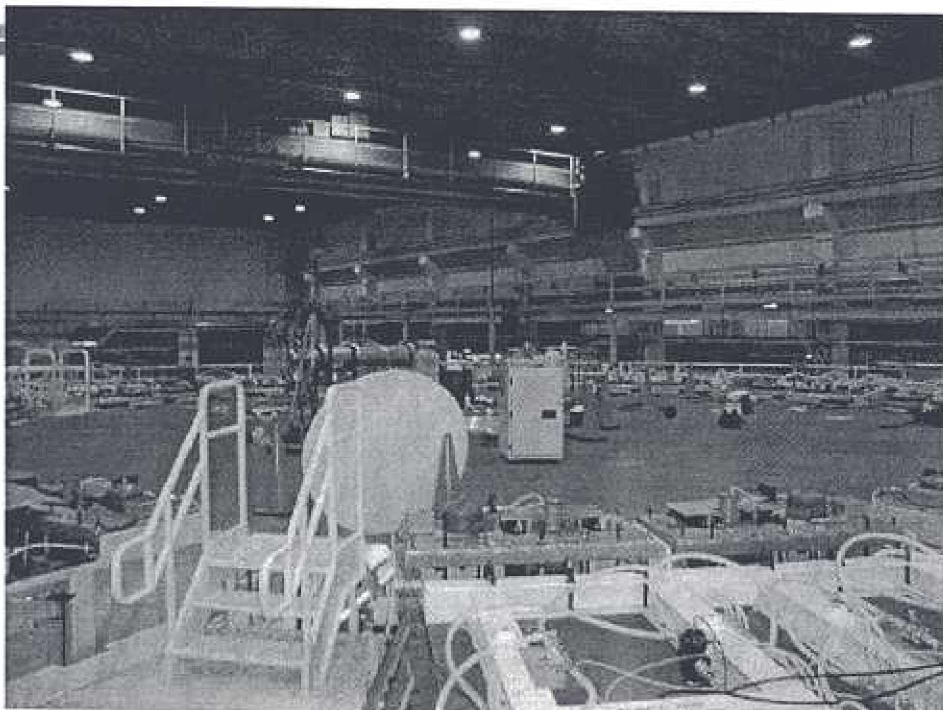
Electrical hazards in the R&D laboratory are unique due to:

- the application of many unusual, hazardous forms of electrical energy.
  - voltage (mV to MV)
  - current (mA to MA)
  - waveform (DC, 60 Hz, MHz, GHz, pulsed)
  - stored energy (batteries, capacitors, inductors)
- the requirement to often interact with the system in various states of energization to
  - operate
  - design and build
  - test and observe
  - maintain and/or modify
  - to de-energize and verify

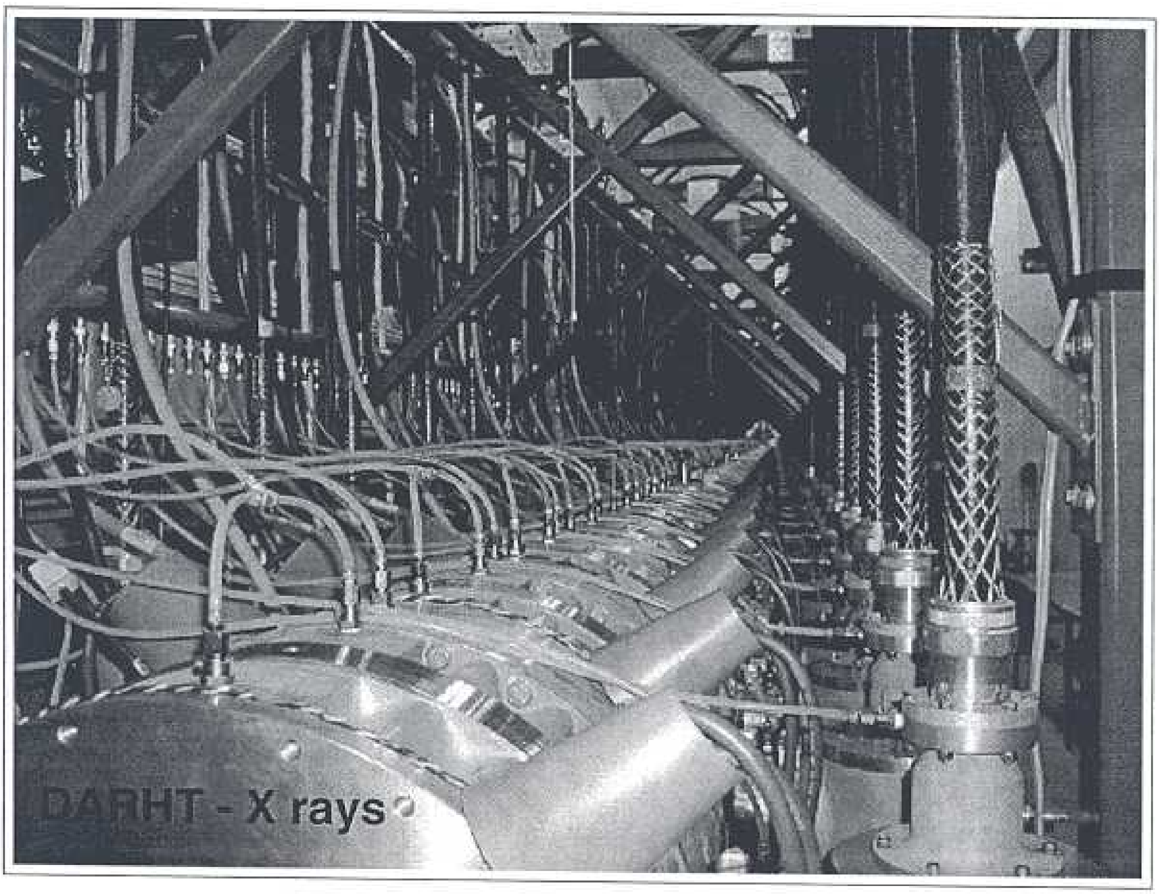
> At home you are a user (operator) of listed (approved) equipment, in a facility (your home) that was inspected and approved by the local Authority Having Jurisdiction (the electrical inspector). You are largely protected by design and are do NOT need to be an electrical worker.

- the uniqueness of the laboratory systems making standardization and code application difficult
- unlisted equipment

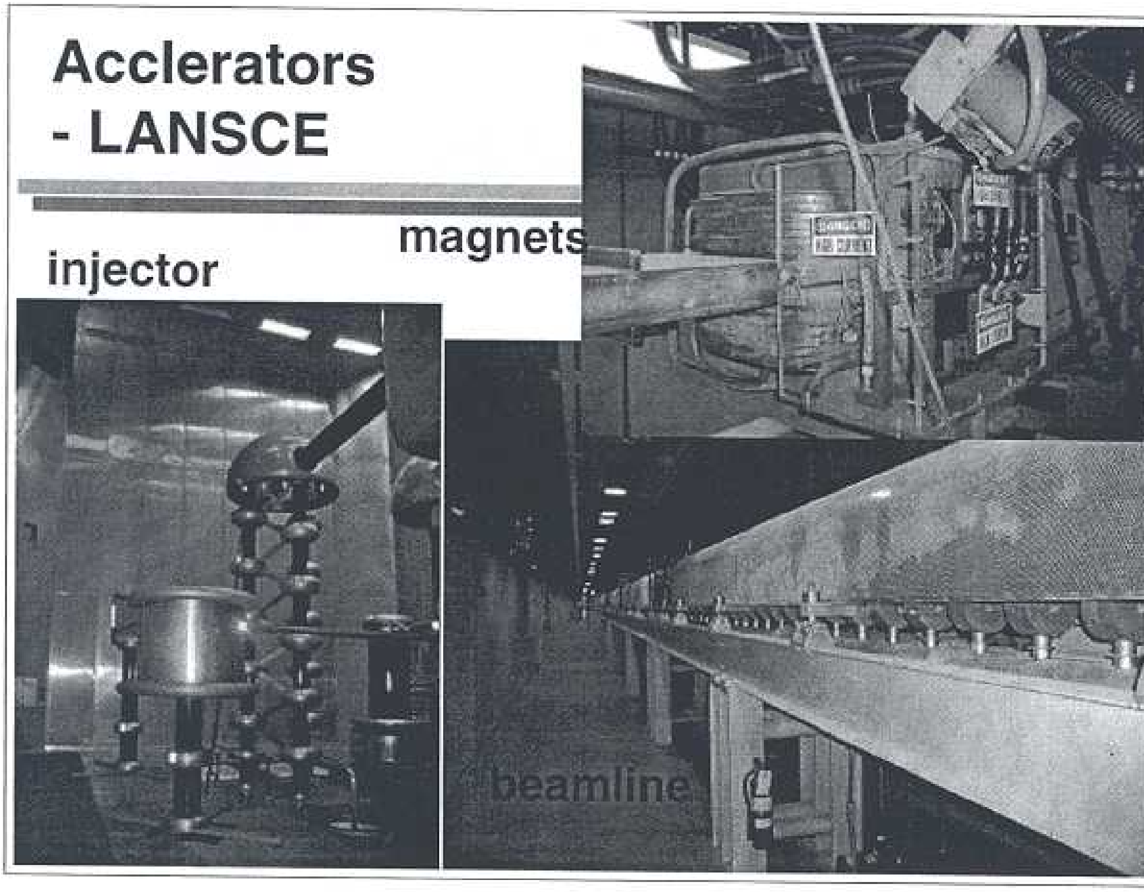
Atlas - 30,000,000 Amps



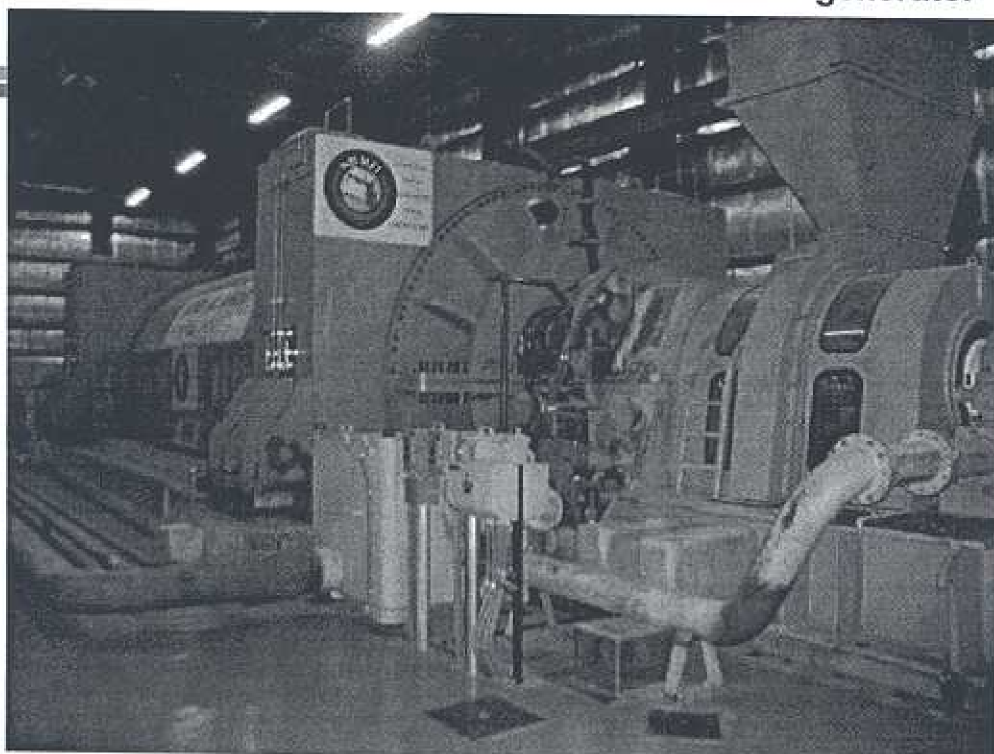

Lasers
COHERENT
COHERENT
MAY 7 2001


DARHT - X rays

Acclerators - LANSCE



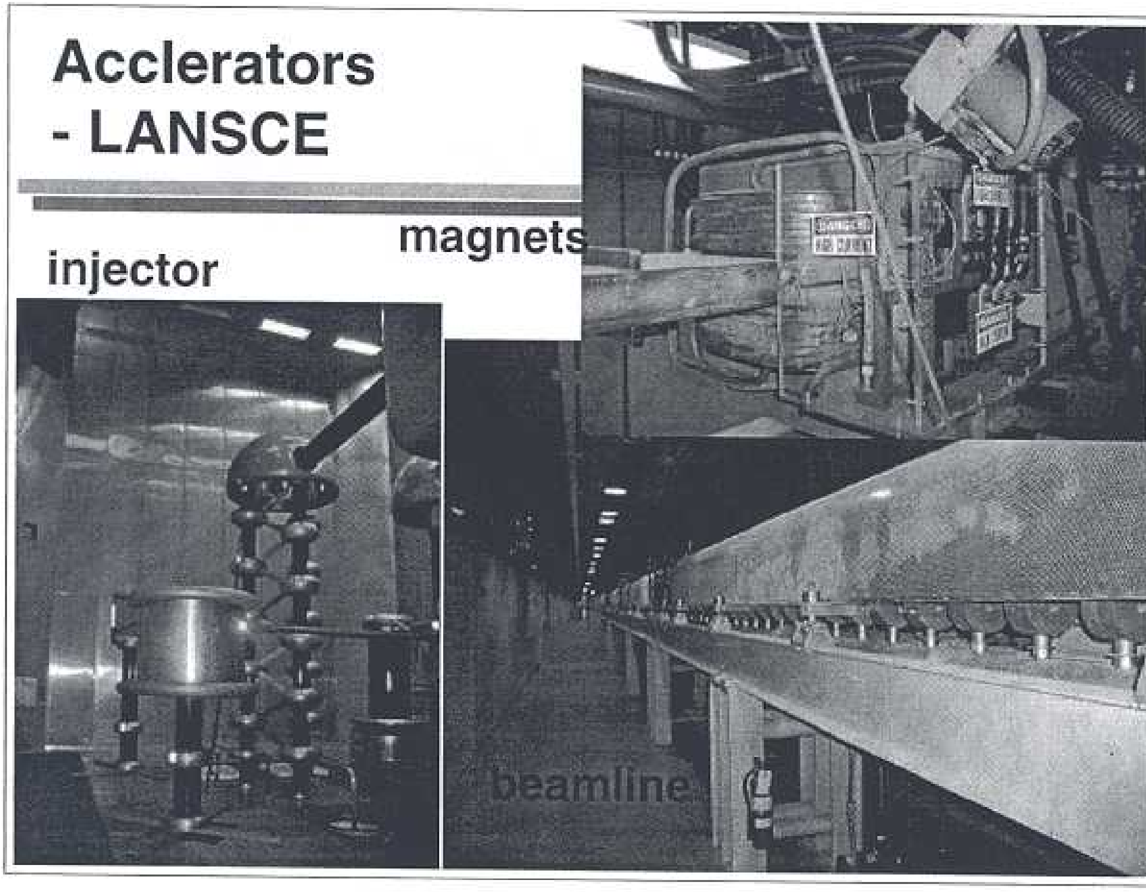
NHMFL - 100 Tesla



Acclerators
- LANSCE

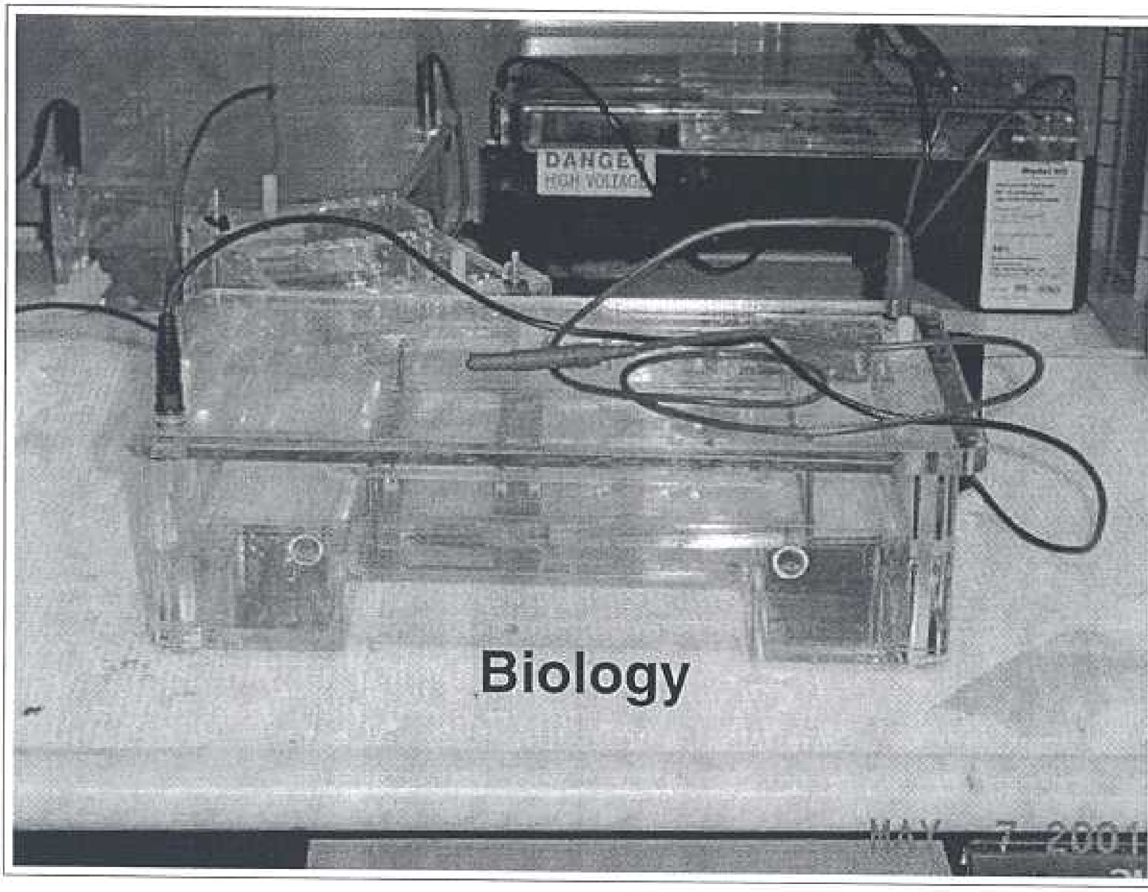
injector

magnets



NHMFL - 100 Tesla

generator



Significant Codes and Standards

Code of Federal Regulations (including OSHA)
29 CFR 1904 - Reporting Injuries
29 CFR 1910 - Occupational Safety and Health Standards
- Subpart I - 1910.137 - Personal Protective Equipment
- Subpart J - 1910.147 - Lockout/ Tagout
- Subpart R - 1910.269 - Electric Power G, T, and Dist.
- Subpart S - Electrical

29 CFR 1926 - Construction
- Subpart K - Electrical
- Subpart V - Power Transmission and Distribution

30 CFR - Mine Safety and Health

National Fire Protection Association (NFPA)
70 - National Electrical Code
70B - Electrical Equipment Maintenance
77 - Static Electricity
780 - Lightning Protection

DOE Handbook of Electrical Safety
1 - Introduction
2 - General Requirements
3 - Electrical Preventive Maintenance
4 - Grounding
5 - Special Occupancies
6 - Specific Equipment
7 - Work in Excess of 600 Volts
8 - Temporary Wiring
9 - Enclosed Electrical/ Electronic Equip.
10 - Research and Development

Los Alamos National Laboratory
LIR 402-600-01.1 - Electrical Safety
LIG 402-600-01.1 - Electrical Safety Implementation Guide
LIR 201-00-04 - Incident Reporting Process
LIR 230-03-01 - Facility Management Work Control
LIR 300-00-01 - Safe Work Practices
LIR 401-10-01 - Stop Work and Restart
LIR 402-10-01 - Hazard Analysis and Control for Facility Wor
LAUR 98-2837 - Integrated Safety Management

UL - Underwriters Laboratory, Inc.
UL 45 - Portable Electric Tools
UL 508 - Industrial Control Equipment
UL 698, 877, 886 - Equipment in Hazardous Locations
UL 1244 - Measuring and Testing Equipment

ANSI and IEEE
IEEE/ ANSI C2 - National Electrical Safety Code
IEEE 80, 142, 524A, 1048, 1100 - various grounding
IEEE 142 - Electrostatic Discharge Protection
IEEE/ ANSI C95.1 - Exposure to Electromagnetic Fields

NEMA - National Electrical Manufacturers Association
280-1990 - Ground Fault Circuit Interrupters

Government Codes and Standards for Electrical Safety

- Title 29, Parts CFR 1910 and 1926
- NEC (National Electrical Code) 2002
- NFPA 70E - Standard for Electrical Safety Requirements for Employee Workplaces 2000
- NESC (National Electrical Safety Code Handbook) 1997
- DOE Electrical Safety Handbook - 1998
- ASTM, ANSI, and IEEE Standards
- NRTL Standards (e.g., UL)
- LANL Electrical Safety Program (LIR 402-600.01.1)
- Other LANL documents

Key Sections relevant to Electrical Safety

CFR Title 29 - LABOR

Parts 1900 to 1990 - Chapter XVII - OSHA Regulations

29 CFR Part 1904 - Recording and Reporting Occupational Injuries and Illnesses

29 CFR Part 1910 - Occupational Safety and Health Standards

29 CFR Part 1926 - Safety and Health Regulations for Construction

CFR Title 30 - MSHA

Parts 1 to 199 - Chapter I - Mine Safety and Health Administration

57 - Safety and health standards - underground metal and nonmetal mines

75 - Mandatory safety standards - underground coal mines

77 - Mandatory safety standards, surface coal mines and surface work areas of underground coal mines

29 CFR Part 1910 - Occupational Safety and Health Standards

Subpart I - Personal Protective Equipment

1910.137 - Electrical Protective Equipment

Subpart J - General Environmental Controls

1910.147 - The control of hazardous energy (lockout/tagout)

Subpart R - Special Industries

1910.269 - Electric Power Generation, Transmission, and Distribution

Subpart S - Electrical (32 pages)

General
- 1910.301

Design Safety Standards for Electrical Systems
- 1910.302 - .308

Safety-Related Work Practices
- 1910.331 - 335

Definitions
- 1910.399

The blue indicates OSHA sections included in your notebook

1910 Subpart S - Electrical

- 301 - Introduction
- 302 - 308 Design safety standards for utilization systems
  - 302 - Electric Utilization Systems
  - 303 - General Requirements
  - 304 - Wiring design and protection
  - 305 - Wiring methods, components, and equipment for general use
  - 306 - Specific purpose equipment and installations
  - 307 - Hazardous (classified) locations
  - 308 - Special systems
- 331 - 335 Electrical safety work practices
  - 331 - Scope
  - 332 - Training
  - 333 - Selection and use of work practices
  - 334 - Use of equipment
  - 335 - Safeguards for personnel protection
- 361 - 380 reserved for safety-related maintenance requirements
- 381 - 398 reserved for safety requirements for special equipment
- 399 - Definitions applicable to this subpart

29 CFR Part 1926 - Safety and Health Regulations for Construction

- Subpart K - Electrical
  - 1926.400-449
- Subpart V - Power Transmission and Distribution
  - 1926.950-960

NFPA 70 - The National Electrical Code
(2002 Edition released 1 year ago) (711 pages)

1 - General
2 - Wiring and Protection
3 - Wiring Methods and Materials
4 - Equipment for General Use
5 - Special Occupancies
6 - Special Equipment
7 - Special Conditions
8 - Communications Systems

NFPA 70E - Standard for Electrical Safety Requirements for Employee Workplaces
(2000 edition released 2 years ago) **(98 pages)**

- Tailored to fulfill OSHA's responsibilities, that is fully consistent with the NEC
- Deals with Electrical Safety!!

Note: some significant changes have been made in the 2000 version dealing with PPE, including when it is required. This includes fire retardant clothing requirements.

NFPA 70E - Standard for Electrical Safety Requirements for Employee Workplaces

Introduction (Scope and Definitions)

Part I - Installation Safety Requirements

Part II - Safety-Related Work Practices

Part III - Safety-Related Maintenance Requirements

Part IV - Safety Requirements for Special Equipment

Appendix A - Tables, Notes and Charts

Appendix B - Referenced Publications

Comparison of the three standards

number of pages in each code

code	design	Safe Work Practices	Maintenance
OSHA	18	7	7
NEC	711	0	0
NFPA 70E	35	27	3

DOE Electrical Safety Handbook - Contents

1 - Introduction
2 - General Requirements
3 - Electrical Preventive Maintenance
4 - Grounding
5 - Special Occupancies
6 - Requirements for Specific Equipment
7 - Work in Excess of 600 Volts
8 - Temporary Wiring
9 - Enclosed Electrical/Electronic Equip.
10 - Research and Development

Chapters 1 and 2

1 - Introduction
- 1.1 Purpose
- 1.2 Scope
- 1.3 AHJ

2 - General Requirements
- 2.1 Electrical Maintenance or Repairs
- 2.2 Basic Safeguards
- 2.3 Responsibilities
- 2.4 Reviews/Inspections
- 2.5 Approval of Electrical Equipment
- 2.6 Codes, Standards, and Regulations
- 2.7 GFCIs
- 2.8 Training and Qualifications
- 2.9 Working Space
- 2.10 Identification of Disconnecting
- 2.11 Work Instructions
- 2.12 PPE
- 2.13 Work Practices

Chapter 9 - Enclosed Electrical/Electronic Equipment

- 9.1 Purpose
- 9.2 Scope
- 9.3 Grounding and Bonding
- 9.4 Rack Power Distribution
- 9.5 Chassis Power Distribution
- 9.6 Protective Devices for Enclosed Electrical/Electronic Equipment
- 9.7 Disconnecting Means
- 9.8 Marking and Labeling Requirements
- 9.9 Working Clearances
- 9.10 Cable/Utility Management System
- 9.11 Electrical Safety Requirements for Tester Facilities
- 9.12 Enclosed Powre Electronics
- 9.13 Non-ionizing Radiation

In-house fabricated equipment - DOE Ch. 9

9.1 Purpose

complement existing electrical codes and recommend industry standards

improve electrical safety in the work environment for personnel within the DOE complex

eliminate the ambiguity and misunderstanding in design, construction and implementation requirements for electrical/electronic equipment

assist the AHJ in providing information for acceptance of equipment within the scope of this document

9.2 Scope

instrumentation and test consoles

enclosed electrical/electronic equipment

diagnostic equipment

enclosure or chassis

9.3 Grounding and Bonding

metal parts of the enclosures and chassis shall be bonded and grounded as per the NEC

methods chosen to avoid ground loops and reduce noise shall meet NEC

Enclosure Grounding and Bonding (DOE 9.3.3)

- bridges between NEC and NRTL
- enclosure houses utilization equipment
- techniques
  - have a common grounding or bonding bus
  - bond the grounding or bonding busses for several bays together
  - each piece of utilization equipment (chassis) installed shall have a grounding conductor attached unless it is properly grounded through the power cord
  - grounding or bonding conductor permanent and continuous
  - subassemblies properly grounded
  - if chassis moveable, grounding should be braided or stranded
- isolation transformers, must
  - continue the equipment grounding conductor, OR
  - the equipment must be guarded and labeled

9.4 Rack Power Distribution

- Loads
- Conductors and Cables Specific Requirements
  - flexible cables
  - strain relief
  - separation of voltages
  - cable bundles, splices
- Power Switches and Interlocks

DOE 9.4 Rack Power Distribution

- may contain a power distribution unit
  - a main overcurrent protection device
  - multiple branch circuits, individually overcurrent protected
- otherwise is a part of one branch circuit
- branch circuit loading should meet all NEC requirement
- external convenience outlets should be connected to a separate circuit breaker
- distribute phase loads, properly size neutral (e.g., for harmonics)
- components listed by NRTL

Rack Power Distribution - cont.

- Conductors and Connectors
  - wires rated per voltage and temperature (ANSI standards)
  - insulating tubing, sleeving, and tape similarly rated
  - power and signal wires should be routed separately within a chassis
  - good workmanship (mechanical considerations)
    - no sharp edges, burrs, screw threads, moving parts
    - holes smooth or use bushings
    - proper use of clamps
    - no damage to wires, cables and cords
- Flexible cables
  - may be used:
    - when a part of utilization equipment furnished by manufacturer
    - to facilitate frequent interchange of stationary equipment
    - to prevent transmission of mechanical vibration
    - for data processing cables approved
    - for temporary wiring
- Strain relief
- Separation of Voltages

Other Rack Considerations

- **provide interlocks where exposed conductors over 50 V exist and access is not controlled**
- **circuit breakers properly rated for switching under load**
- **provide provisions for Lockout/Tagout requirements**

9.5 Chassis Power Distribution

- AC Power Distribution
  - chassis bonding and grounding
  - connections, connectors, and couplings
  - terminals/live parts
- DC Power Distribution
  - metal chassis or cabinet should not be used as a return path
  - high current analog or switching dc power supplies should use separate return paths from digital circuits
  - all of the guidelines pertaining to ac power such as grounding, proper wire size, high voltage, etc., should apply to dc circuits as well
  - all accessible terminals charged by an internal capacitor should be below 50 V within 10 seconds after interruption of the supply
- references NEC, ANSI, and ISA standards

9.6 Protective Devices

- surge arrestors
  - MOV
  - avalanche diodes
  - spark gap arrestors
- fuses
- circuit breakers
- power interlock devices

In-house fabricated equipment - DOE Ch. 9

9.8 Marking and Labeling
- manufacturer's info
- voltage, max current, power, frequency, other (NEC)
- hazards
- special considerations

9.9 Working Clearances
- meet NEC requirement
- during maintenance, repair, or calibration use appropriate warnings, barriers

9.10 Cable/Utility Management System

9.11 Electrical Safety Requirements for Tester Facility (portable)
- ampacity of facility
- facility grounding
- lightning protection
- surge protection
- UPS

9.12 Enclosed Power Electronics
- power supplies and modulators for laser systems
- accelerators, magnets, x-ray systems, other R&D
- radio and radar transmitters
- variable speed motor drives

9.13 Non-Ionizing Radiation

- **health hazards**
- **threat to electroexplosive devices**
- **Electromagnetic Interference (EMI)**
  - **shielding**
  - **grounding**
  - **isolation, separation**
  - **filter**
  - **minimal power**
  - **labeling**

10.0 Research and Development

10.1 Purpose

10.2 Scope

10.3 Compliance with OSHA and other regulations

10.4 Standarized Safety Practices and Procedures

10.5 Equipment not listed by an NRTL

10.6 Operation and Maintenance

10.7 Employee Qualifications

10.8 Generic R&D Equipment

10.9 Methods

10.10 Requirements for Specific R&D Equipment

10.1 Purpose

- to maintain workplace free of electrical hazards that can cause injury or death
- ensure adequate safety during: design, development, fabrication, construction, modification, installation, inspection, testing, operation, maintenance, decommissioning
- to complement existing electrical codes and recognized industry standards in conformance with DOE, OSHA, NEC, NESC, etc.

Injury from Electrical Energy

March 2, 2004

R&D Electrical Safety Meeting

Lloyd B. Gordon

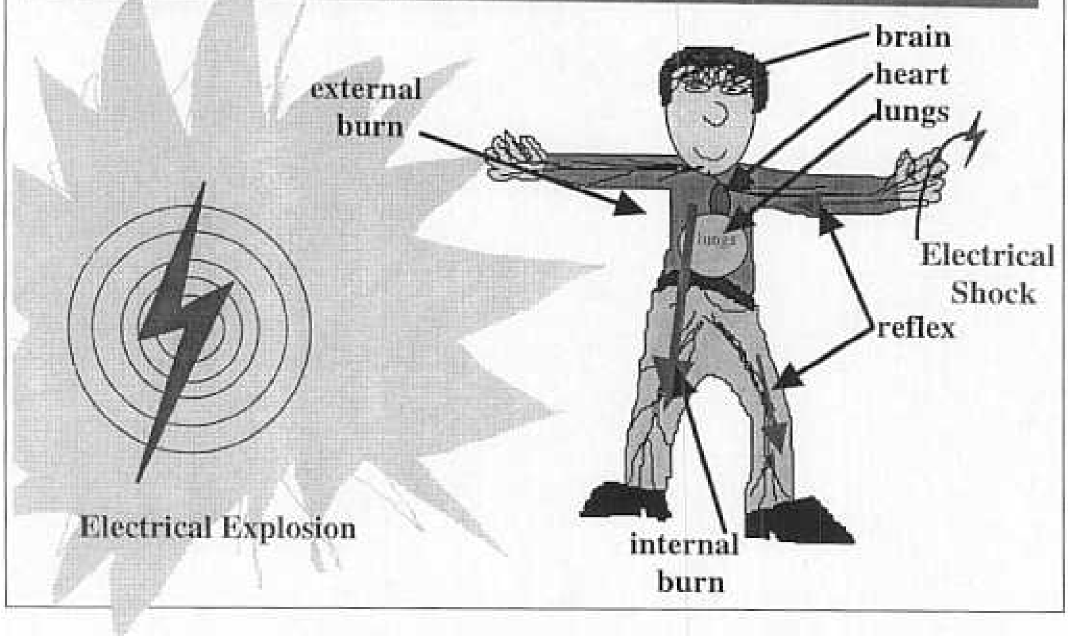
Los Alamos National Laboratory

LA-UR-05-2115

Physiology of electric shock

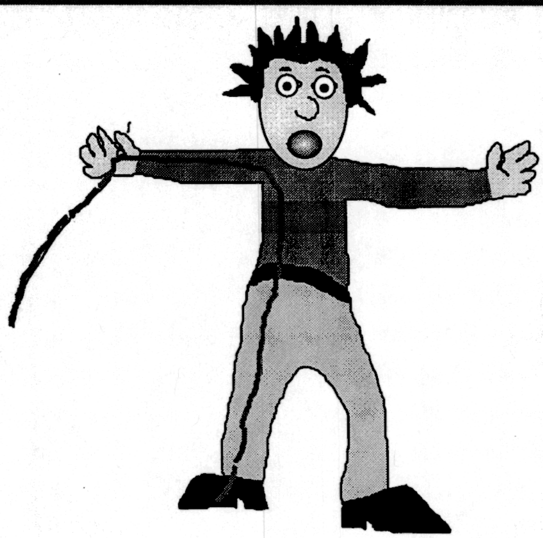
- What is electric shock ?
- What does it do to the human body ?
- What kinds of injury result ?
- What factors affect the severity of a shock ?
- What determines the current level in a shock ?
- What are the effects of waveform?

Injury to the body from electricity.



What is Electric Shock ?

The passage of electric current through the body from an external source

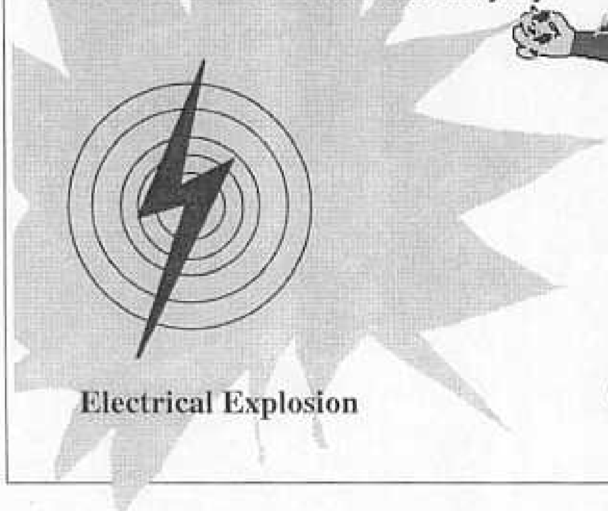


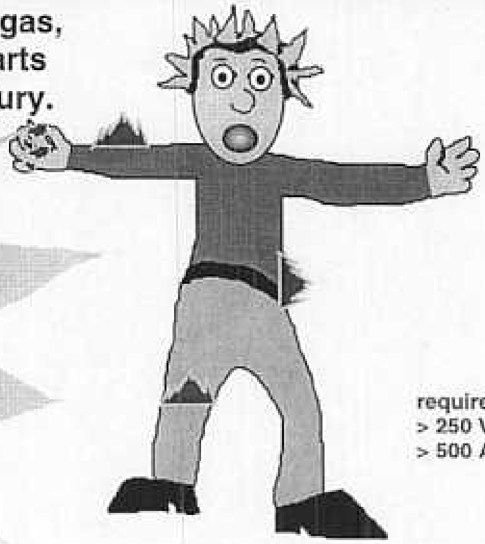
Electric shock may be caused by
- **ac**
- **dc**
- **rf**
- **impulse**

currents.

What is an Electric Arc Flash and Blast ?

An expanding "fireball" of hot gas, molten metal, and energetic parts that can cause severe burn injury.



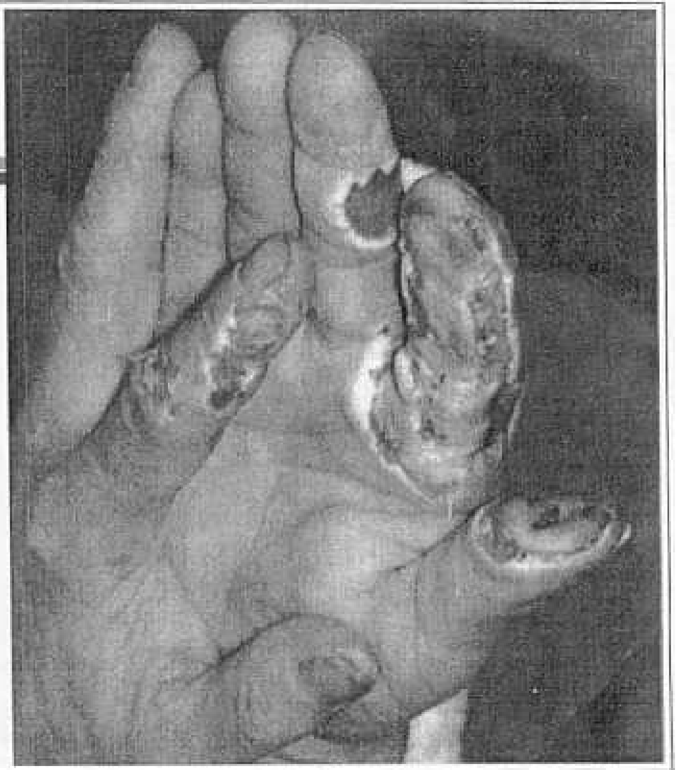


requires
> 250 V &
> 500 A

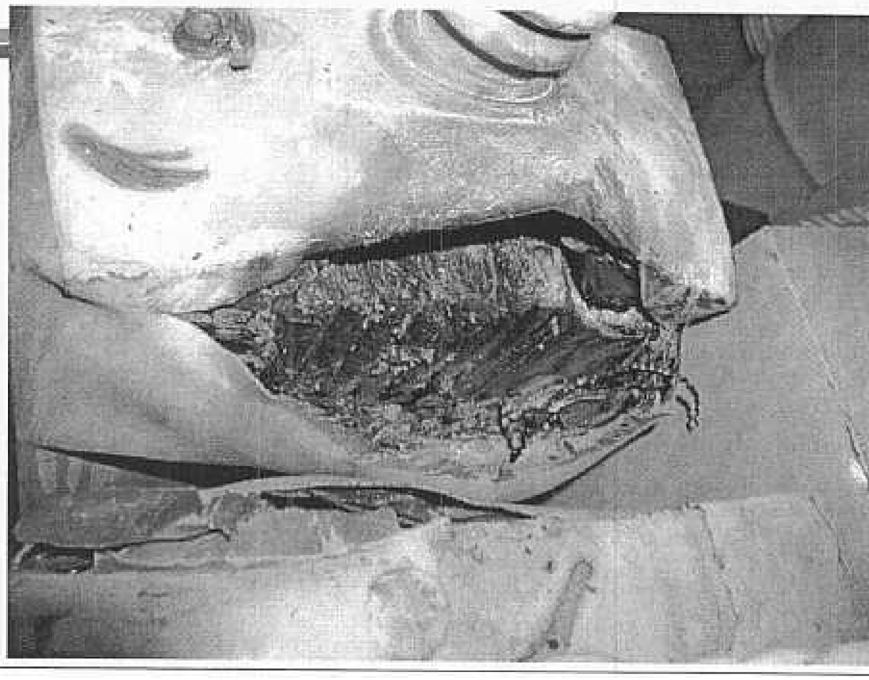
Electrical Burn Injury

- no Lockout/Tagout
- no verification
- no PPE

from an energized fluorescent light fixture



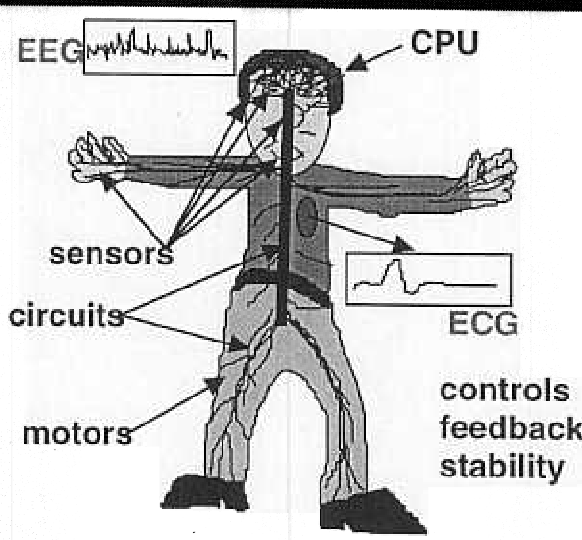
R&D Equipment Blows Up !



The Human Body is a Complex Electrical System

The body has elements of
- circuitry
- control
- feedback
- memory
- calculation
- motion
- sensing

It operates at mV and less than mA levels.



Medical Definitions

burn - The damage received to skin or other tissue by excessive heat. Can be caused by the passage of large electric currents.
duration - The length of the time interval during which a specified waveform or feature exists. For an electric shock it is the length of time that the victim is exposed to the shock.
fibrillation - Also known as ventricular fibrillation. Failure of the heart to contract regularly resulting in an irregular often rapid contraction. Death will result if ventricular fibrillation is not stopped and normal contraction of the heart re-initiated.
let-go-current - The level of current at which a person can release a live wire of his own free will. At currents above the let-go-current muscle contraction prevents voluntary release of the conductor.
resuscitation - Reviving someone from unconsciousness. Sometimes used equivalently to CPR (Cardio Pulmonary Resuscitation)
shock - Sudden stimulation of nerves and contraction of muscles due to electric current passing through living tissue.

Why are we susceptible to injury by electric shock ?

During a shock, current:

(1) interacts with the very small electrical signals that the body uses to control muscular action, and

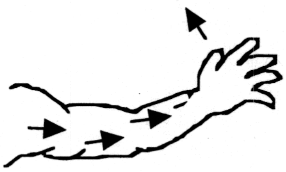
(2) dissipates energy by resistive heating of body tissues.

The human body has little ability to withstand an electric shock because:

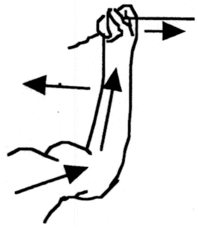
(1) the neural signals are very susceptible to disruption, and

(2) tissue is very sensitive to heat damage.

Electric current passing through the body causes muscle contraction.

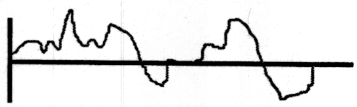


Normal nerve impulses are very small electric signals travelling down the neural pathways to the muscle tissues.



An electric shock overrides normal nerve impulses and totally dominates muscle action. This is known as the reflex action.

Technical Terms - Waveforms



Voltage or Current

waveform - the shape of a parameter (such as voltage or current), when displayed as a function of time

alternating current (ac) - a periodic current, the average value of which over a period is zero.

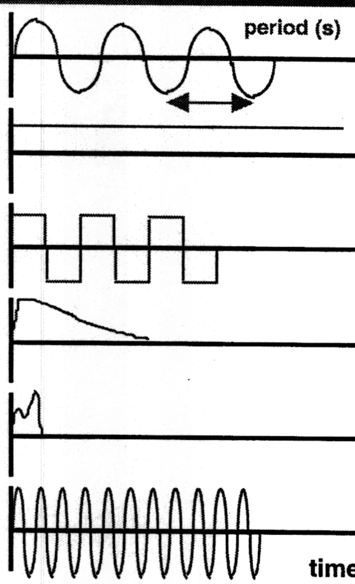
direct current (dc) - usually indicates a constant, non-time varying current or voltage. It may be positive or negative.

pulse - The variation of a quantity having a normally constant value. An abrupt change in voltage, or current, either positive or negative, which conveys information or transfers power to a circuit.

impulse - A pulse that begins and ends within a short time period. Although the time duration may be short, in high power impulses the current, voltage, and power can be very large.

transient - A momentary surge on a signal or power line. It may produce false signals or triggering impulses and cause insulation or component breakdowns and failures or may result in a prefire.

radiofrequency (rf) - A special term for high frequency (kiloHertz to gigaHertz) ac signals.



Three basic types of injury.

Three types of injury often need to be treated for serious electric shock:

- Shock to the nervous system, such as muscle contraction, breathing stoppage, and heart stoppage.
- Burns to tissue, especially dangerous if the tissue affected includes organs or bones.
- Mechanical injury from reflex action, such as being thrown, or falling.

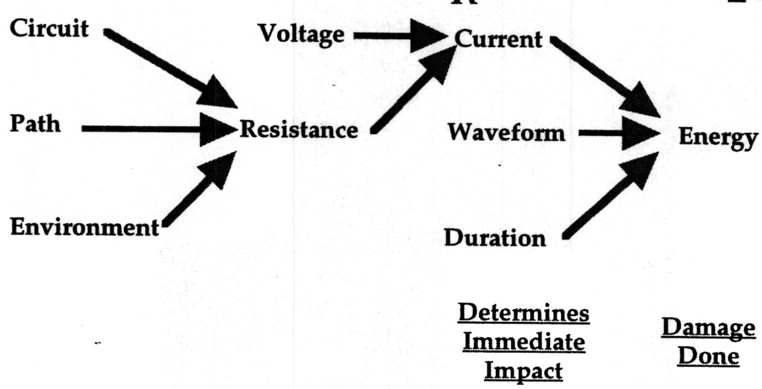
Factors affecting the severity of electric shock

- Current - determines muscle, cardiovascular, & brain response
- Voltage - determines skin breakdown (resistance), & current level
- Energy - determines total damage done
- Resistance - with voltage determines current and energy
- Current pathway - defines regions effected

Important Parameters for Electric Shock

$$I = \frac{V}{R}$$

P = I x V
E = P x t



NOTE: It is current and energy that directly determine injury.

Various types of electric shock

- ac power frequency - 50/60 Hz ← most national electrical safety codes and standards
- ac (1 Hz to 3 kHz)
- direct current (dc)
- rf (3 kHz - 100 MHz)
- capacitor shock

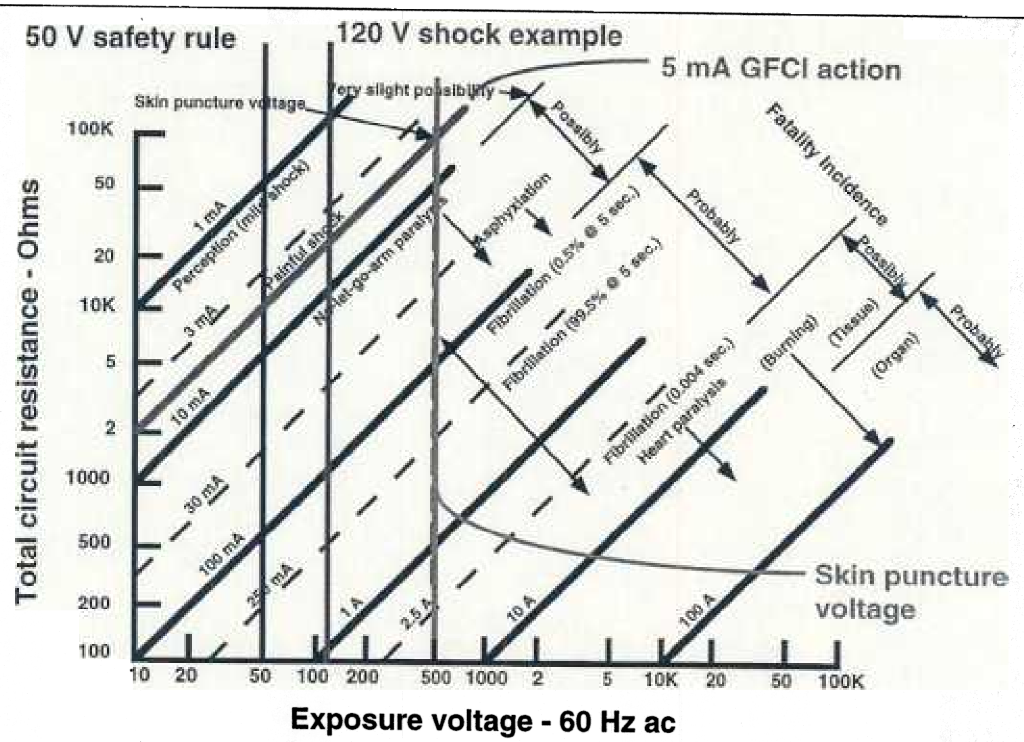
AC power frequency shock (50/60 Hz)

- the most common hazard to the public is from ac power distribution
- always on, everywhere
- causes violent continuous contraction of muscles, e.g., the "no-let-go" effect
- causes heart fibrillation at the lowest current levels and shortest durations
- most of the research on electric shock has occurred on this form of electricity
- resulted in electrical safety innovations, e.g., the equipment ground and the GFCI
- The MOST dangerous form of electricity to the body

Electric shock can have many dangerous effects on the body.

Approximate thresholds for 60 Hz for a healthy adult.

- Muscle contraction, which can:
  - prevent release of the circuit — 10 mA
  - cause serious reflex action resulting in bodily injury
- Breathing stops due to: — 50 mA
  - paralysis of the chest muscles
  - nerve damage
- Heart malfunction: — 100 mA
  - fibrillation (very difficult to restore normal beating)
  - complete stoppage
- Internal burns cause tissue and bone damage due to heating. — 1 A



Ventricular Fibrillation

- Ventricular fibrillation occurs when the heart receives an electrical stimulus during the T-wave portion of its cycle. This is the beginning of the repolarization of the ventricular myocardium and the cells are very sensitive to stimulation (25 % of the cycle).
- A brief shock (ac, dc, or impulse) is less likely to stimulate the heart.
- A few seconds of 60 Hz ac is the most dangerous.
- DC, impulse, and high frequency ac require considerably more current to cause fibrillation.

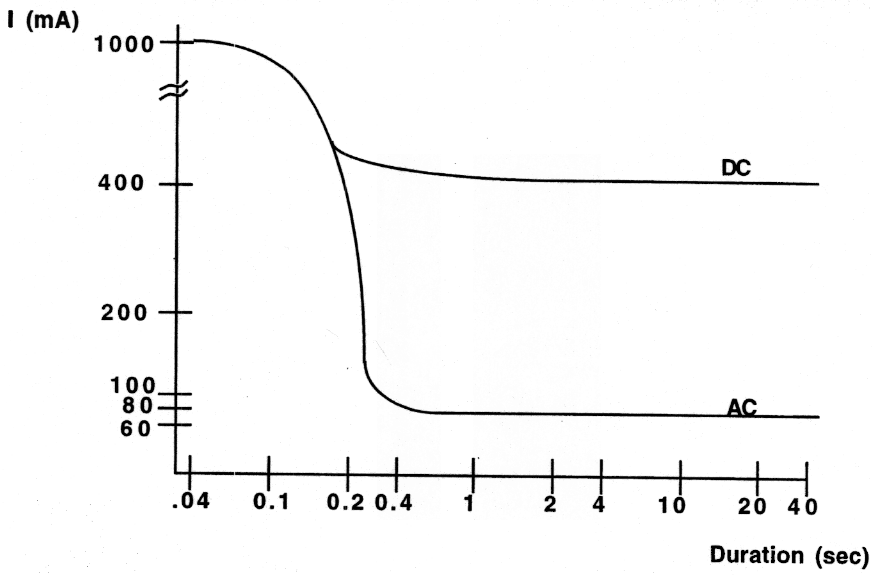
low frequency shock

- 1 Hz to 3000 Hz
- varying degrees of susceptibility to latching on and fibrillation
- no thorough research as a function of frequency

DC electric shock

- there is no true "no-let-go" threshold with dc
- 70 mA "no-let-go" was a misinterpretation of the research
- a reflex action does occur upon contact (start of current flow) and let go (cessation of current flow)
- energy deposition heats the tissues
- prolonged exposure fatigues the heart muscle and can lead to malfunction, including fibrillation
- although some institutions have set higher allowable levels for dc, as compared to 60 Hz ac, in DOE generally we use the same limits, e.g., 50 V and 5 mA

Fibrillation Threshold as a Function of Duration of Shock for AC and DC



rf (3 kHz - 100 MHz)

- often called rf burn
- but there can be low frequency components upon contact which cause a reflex action
- not found in classical electric safety codes and standards, e.g., not in UL or NFPA standard
- IEEE/ANSI C95.1-1999
- there is no skin resistance at rf........... it is skin impedance. Capacitive coupling can lower the effective impedance to 50 Ohms, even for dry skin. In other words, the "50 V rule" is meaningless.

Standards as a function of frequency

- Static or dc
- Sub-Radiofrequency (1 Hz - 3 kHz)
- 50/60 Hz
- Radiofrequency (3 kHz - 300 GHz)

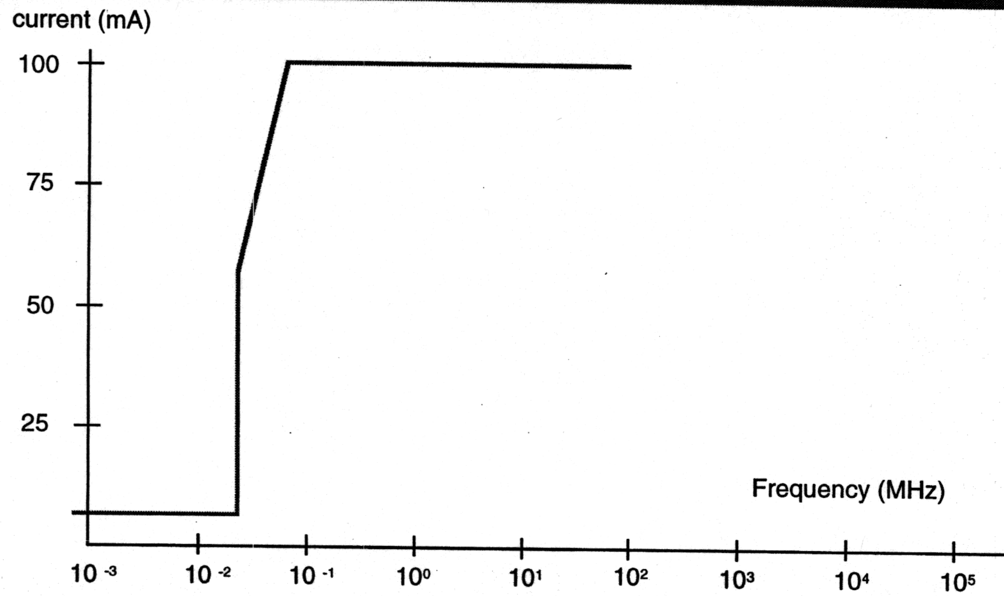
Induced and Contact RF Currents (IEEE/ANSI)

Frequency (MHz)	both feet max (mA)	one foot max (mA)	contact max (mA)
0.03 - 0.1	2,000f	1,000f	1,000f
0.1 - 100	200	100	100

- the injury mechanism is tissue heating
- note the much higher values that 60 Hz (5 mA)
- does NOT account for shock due to transient phenomena

Allowed contact shock current

from various standards



Impulse or capacitive discharge shock

Very little research has been done.

10 J has been chosen to be the threshold of dangerous energy

Over 50 J may be lethal.

Defibrillators use around 200 J.

A brief impulse discharge must occur during the T-wave to stimulate fibrillation and even then it must be a large current.

The most significant danger from capacitive discharge in the laboratory is from the large dissipated energy in a shock. Significant burn injury can result, especially to nerves.

Energy - does work, or destroys

How does electrical energy delivered quickly affect me?

energy	example	result
0.01 J	a carpet shock	harmless
0.1 J	stored in the tube of a tv	reflex action
1 J	a 3 kV cap., size of a C-cell battery	hurts a lot!
10 J	in a microwave oven	will incapacitate you
100 J	delivered by a defibrillator	can stop and start heart
1000 J	energy storage caps, or a utility arc	blows off body parts

Some affects of current waveform on electric shock effects

- **AC** causes ventricular fibrillation and clamping of the muscles.
- **AC** sources often are on continuously, increasing the chance for prolonged exposure.
- **DC** can cause muscle clamping and/or stop the heart.
- **RF** immediately passes through the skin, and can shock and burn at much lower voltages; also, the burns are deeper.
- **Pulsed** power capacitive discharges usually involve very large currents, voltages, and energy. Energy deposited is important.
- High voltages (>1000 V) result in a large current, but may throw the person away from the circuit; lower voltages (<1000 V) result in lower currents, but may cause muscle clamping leading to long exposures or allowing time for the current to increase as the skin resistance breaks down.

Comparison of some shocks

Form of electricity	Effects
• 60 Hz power	100 mA for 3 seconds - lethal
• dc	500 mA for ~ minute - lethal
• carpet shock	10 A for 1 μs - harmless
• 1 MHz rf	200 mA for seconds - allowable

Summary

- There is a considerable variation in the effects of the electrical hazard depending on the nature of the energy.
- Proper understanding of the electrical hazard requires consideration of:
  - voltage
  - current
  - power
  - stored energy
  - energy in an arc
  - duration
  - waveform

10.2 Examples of R&D Equipment and Systems

- Control racks
- Capacitor Banks
- Pulse forming networks
- Accelerators
- Lasers
- Guiding magnets
- RF modulators, acceleration cells, plasma heating
- ??

10.5 Non NRTL listed equipment

- reviewed by AHJ
- Design and Construction
  - failure modes
  - heat effects
  - magnetic effects
  - grounding and bonding
  - leakage currents
  - dieletric testing
  - access to serviceable parts
  - overcurrent and overtemperature protection
  - clearances and spacing
  - interlocks
  - design and procedural documentation
  - signs, labels, and administrative controls
  - mechanical motion
  - stored energy
- Documentation:
  - tests performed
  - conditions of acceptability
  - applicable standards to which the equipment was evaluated
  - limitations of approved use, if any

General Safety Criteria for Design and Construction (material from 1990)

1. Buy **good equipment** (UL label, etc.); use the right equipment for the job (rated for the service).
2. Provide **barriers** to prevent personnel from contacting energized conductors; enclose equipment that operates at **50 V** or above.
3. Use protective covers or **barriers** for high-voltage terminals and for low-voltage terminals that can supply high current.
4. For serious electrical hazards, enclose and provide **interlocks** to prevent access when energized.
5. **Identify** hazardous areas and the nature of the hazard using warning signs, flashing lights, and/or audible signals.
6. Design all systems and protective devices to be **fail-safe**, if practical.

General Safety Criteria for Design and Construction - cont.

7. Design and maintain **sufficient access** and work space around electrical equipment for personnel safety during operation and maintenance; allow space for **emergency exits**. Especially, maintain access around breakers and other disconnect devices.
8. Provide adequate normal operation and emergency **lighting** in all areas where exposed electrical hazards might be encountered.
9. Provide adequate **ventilation** where high voltages might produce ozone, or where electrical arcs might produce toxic gases.
10. Use adequate power sources; **do not overload** the breaker or push the current-carrying capacity of the conductors to their limit.

General Safety Criteria for Design and Construction - cont.

11. **Prevent** the exposure of components and personnel to **water** near any electrical hazard; provide drainage to prevent water accumulation.

12. Provide adequate **grounding** to all metal enclosures, equipment, cabinets, and structural components with permanent external grounding conductors; they must be large enough in current-carrying ability to ensure that the maximum available fault current can be carried. In addition, the impedance (resistance and inductance) must be low enough to prevent a hazardous potential gradient in the ground conductors.

13. Provide **safety ground hooks** in the vicinity of all high-voltage equipment that must be accessed regularly (such as R&D equipment).

General Safety Criteria for Design and Construction - cont.

14. Install **emergency shutdown switches** in locations of system operation and in other necessary locations.

15. For energy-storage devices, provide a convenient **discharge point** for contact with a ground hook; provide crowbar relays or ground hooks with current-limiting resistors to prevent large discharge currents.

16. Provide **power disconnects** for all equipment and systems; design any system that will be worked on with the capability to lock out the power disconnect.

17. Clearly **label** the location and purpose of all power disconnects.

General Safety Criteria for Design and Construction - cont.

18. Provide **emergency communication** near hazardous electrical systems; provide proper emergency numbers at the communication site.

19. Include **maintenance** considerations in the design process; completed designs should include the provisions for safe maintenance.

20. Have **designs reviewed**.

21. Make sure **all documentation** is complete and current.

10.8 Generic R & D Equipment

- Power Sources
- Low Voltage and High Current
- High Voltage and Low Current
- Radio-Frequency/Microwave Radiation and Fields

Low Voltage and High Current

- < 50 V AND >10 A or >1000 W
- Examples:
  - power supply: 20 V and 400 A
  - magnet supply: 40 V and 200 A
  - magnetron filament supply: 5 V and 8000 A
  - automobile battery: 12 V and 500 A
- hazards
  - contact burns
  - mechanical injury
  - inability to open circuit (voltage buildup on high L circuits)
- design techniques
  - protective covers and/or barriers
  - identify the hazard at the power source and other places (loads) with appropriate markings
  - consider conductor heating and magnetic forces in normal and short-circuit operation, strength
- procedures
  - work on such circuits de-energized
  - when working in Mode 2 or Mode 3 use Class 2.2 Hazard

High Voltage and Low Current

- > 50 V and < 5 mA
- Examples:
  - photo detector bias supplies
  - electrostatic charge buildup on dielectric surfaces
  - accelerating and deflection fields
- hazards
  - reflex action (>0.5 mA or > 0.25 J)
  - gradual energy buildup (e.g., long cables)
  - effect of V squared
  - ignition or detonation of explosive or flammable devices
  - failure of insulation or low voltage components
- design techniques
  - adequate warning
  - protection if required
- procedures
  - qualified person
  - after careful review this hazard may fall into Classification 2.1
  - consider secondary hazard of reflex action

Radio-Frequency/Microwave Radiation and Fields

- > 3 kHz, varying powers and field strengths
- Examples
  - communications equipment
  - radar
  - rf heaters - materials and plasmas
  - dielectric furnaces
  - accelerators, klystrons, magnetrons
  - medical applications
  - effects
- Hazards
  - burns (different, can be severe even at low voltage)
  - Electromagnetic Interference (EMI)
  - detonation
  - x-rays
  - exposure to fields
- Unique problems
  - shielding, grounding
  - reflection
  - induced voltages and currents

10.9 Methods

- Wiring
- Grounding
- Unconventional Use of Materials

10.10 Specific R&D Equipment

- Capacitors
- Inductors
- Conductors and Connectors
- Induction and Dielectric Heating Equipment
- Lasers and X-ray Equipment
- Batteries

Electrical Energy Storage

- Even after a system or circuit is de-energized (the power source is turned off), you may still find electrical energy stored in:
  - Capacitors - in the electric field (can store a long time)
  - Inductors - in the magnetic field (must have current flow)
  - Batteries - as chemical energy (always on)

Electrical Hazard Classification

March 2, 2004

R&D Electrical Safety Meeting

Lloyd B. Gordon

Los Alamos National Laboratory

LA-UR-05-2117

Integrated Safety Management - for Electrical Hazards

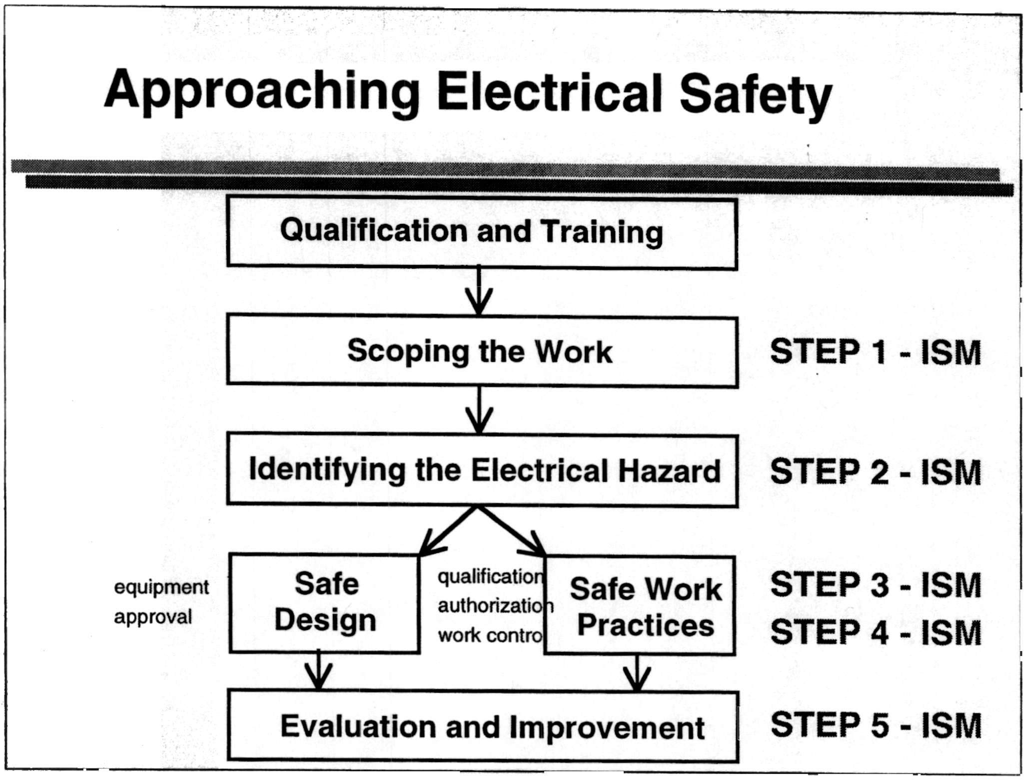
Step 1 - Scope of Electrical Work

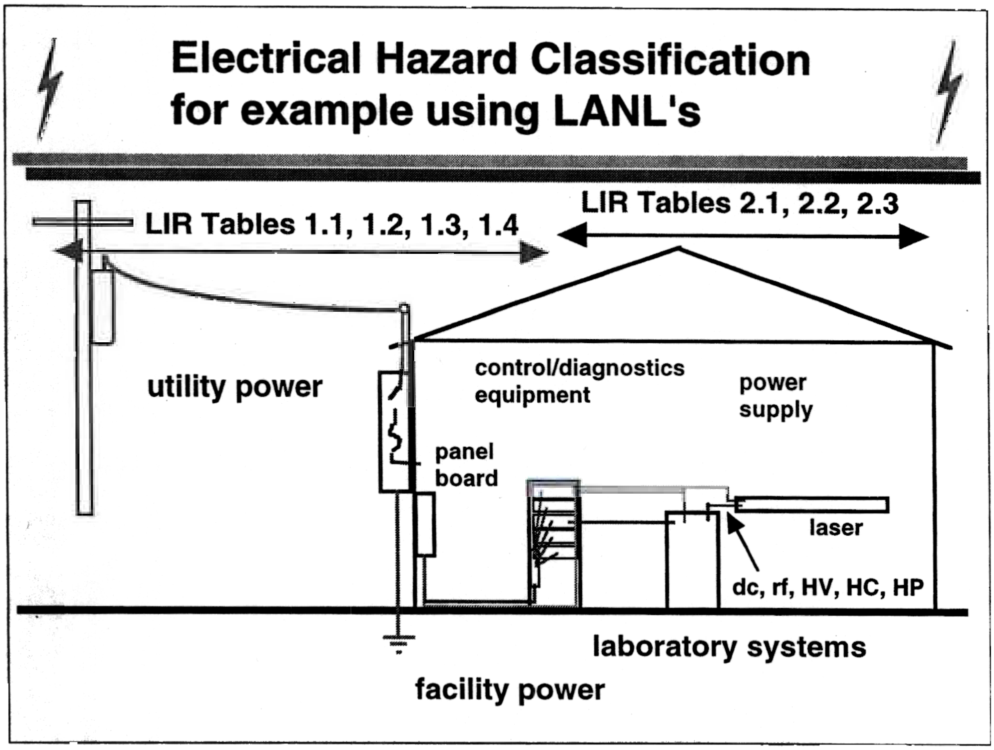
Step 2 - Electrical Hazard Assessment

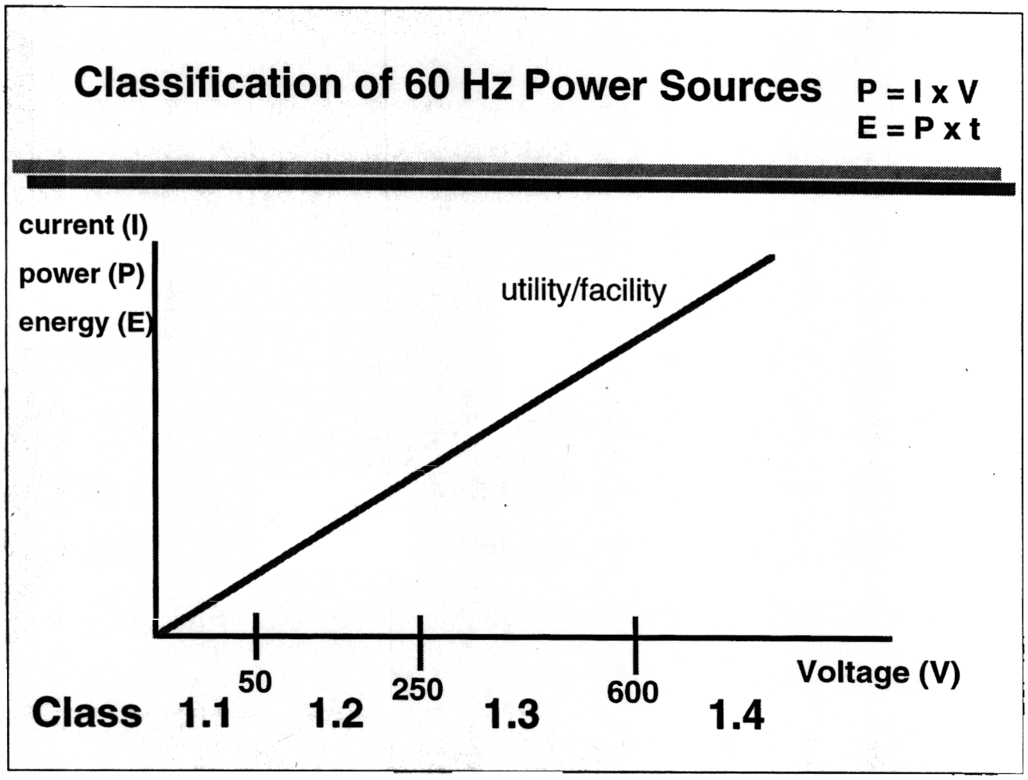
Step 3 - Hazard Mitigation

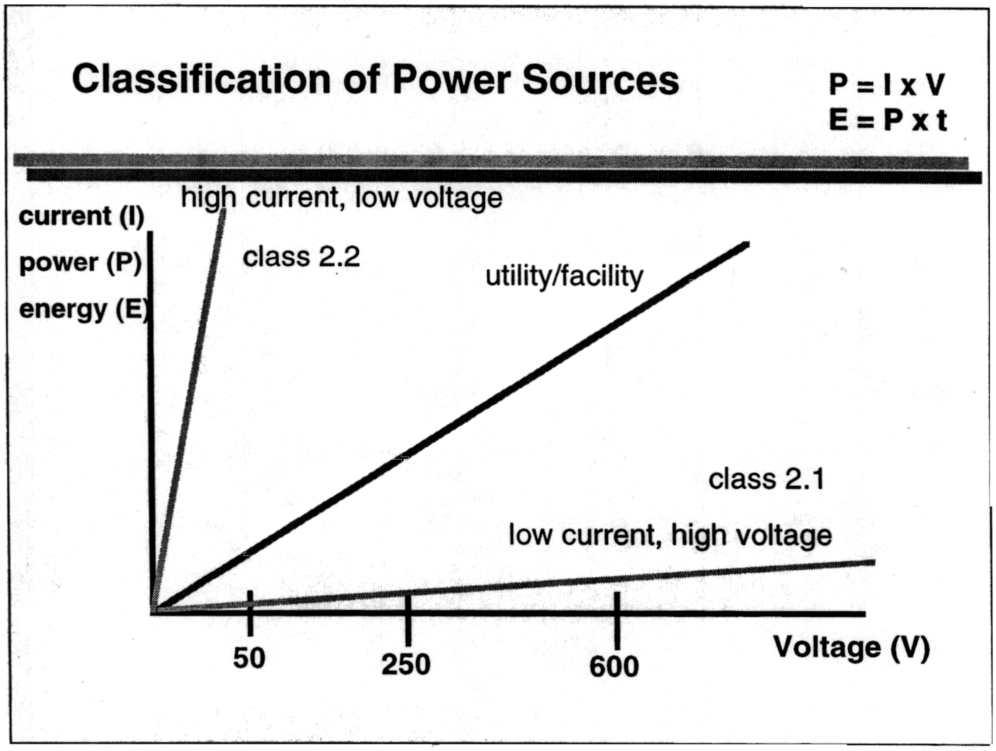
Step 4 - Safe Electrical Work, General Requirements

Step 5 - Electrical Safety Improvement Process


Approaching Electrical Safety
Qualification and Training
Scoping the Work
STEP 1 - ISM
Identifying the Electrical Hazard
STEP 2 - ISM
equipment
approval
Safe
Design
qualification
authorization
work control
Safe Work
Practices
STEP 3 - ISM
STEP 4 - ISM
Evaluation and Improvement
STEP 5 - ISM


Electrical Hazard Classification
for example using LANL's
LIR Tables 1.1, 1.2, 1.3, 1.4
LIR Tables 2.1, 2.2, 2.3
utility power
control/diagnostics
equipment
power
supply
panel
board
laser
dc, rf, HV, HC, HP
laboratory systems
facility power

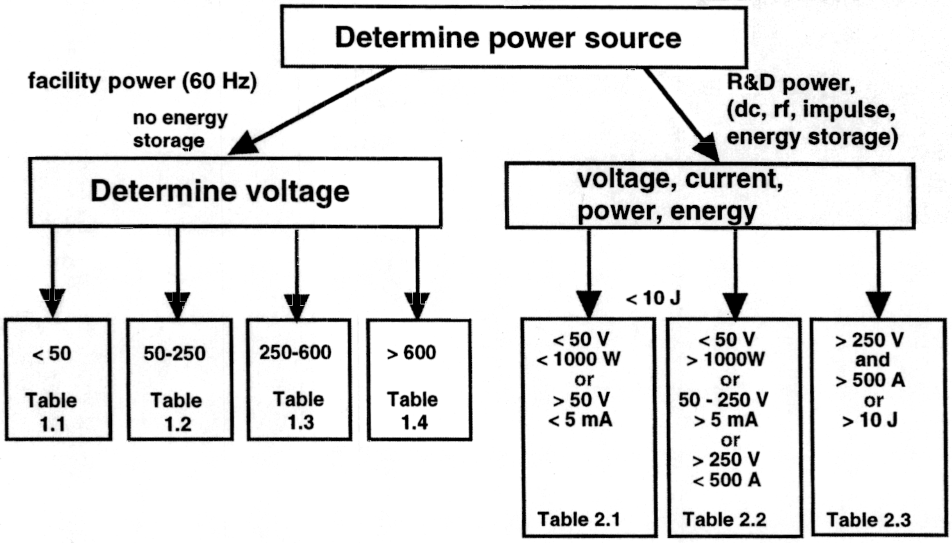

Classification of 60 Hz Power Sources
P = I x V
E = P x t
current (I)
power (P)
energy (E)
utility/facility
50
250
600
Voltage (V)
Class 1.1
1.2
1.3
1.4

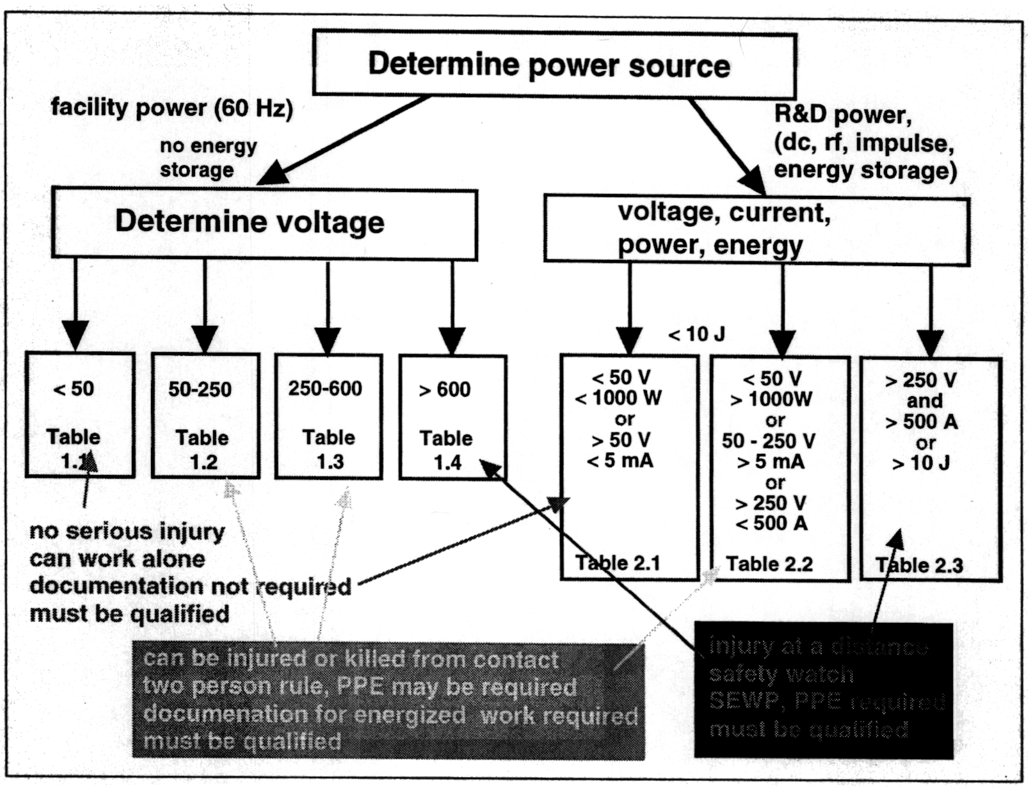

Classification of Power Sources
P = I x V
E = P x t
high current, low voltage
class 2.2
current (I)
power (P)
energy (E)
utility/facility
class 2.1
low current, high voltage
50
250
600
Voltage (V)

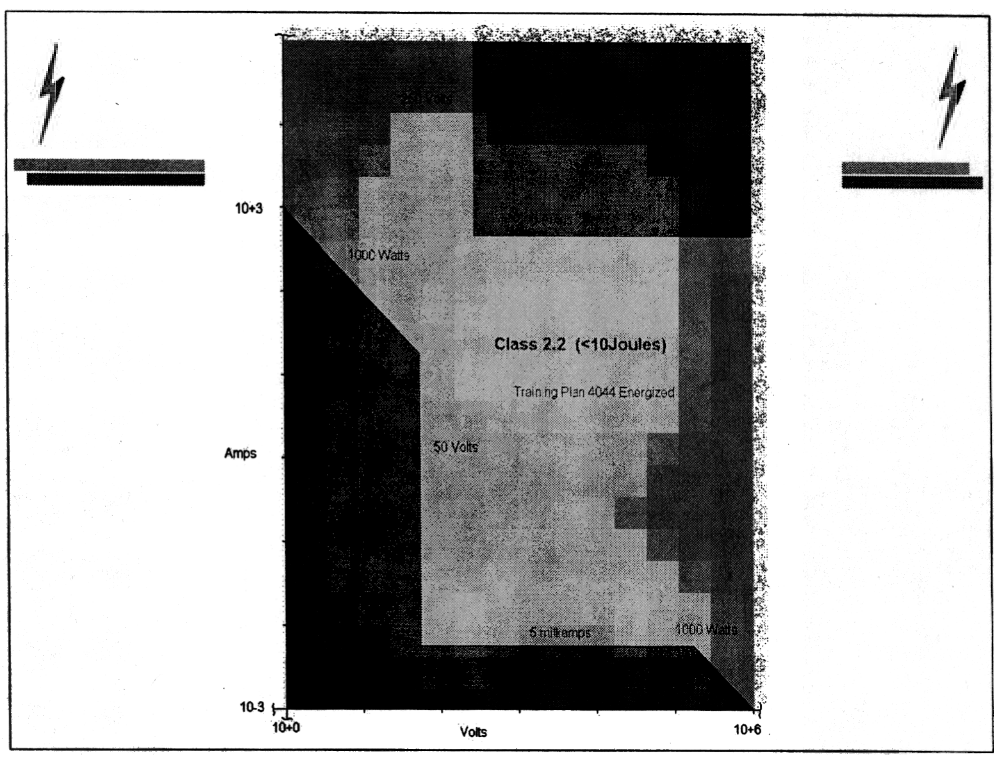
Conclusions on Electrical Hazard Classification

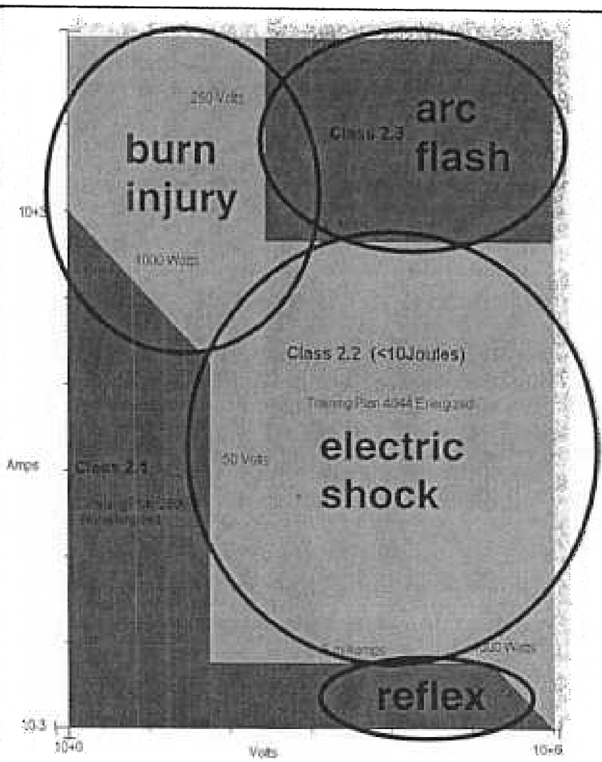
- the "50 V" rule is insufficient for R&D
- low voltage can severly injure, the burn hazard
- high voltage can be harmless, if the current is very low
- to properly understand and classify all electrical hazards one must understand Voltage, Currrent, Power, Energy, and Waveform

Electrical Hazard Classification




Determine power source
facility power (60 Hz)
no energy storage
R&D power, (dc, rf, impulse, energy storage)
Determine voltage
voltage, current, power, energy
< 10 J
< 50 Table 1.1
50-250 Table 1.2
250-600 Table 1.3
> 600 Table 1.4
< 50 V < 1000 W or > 50 V < 5 mA Table 2.1
< 50 V > 1000W or 50 - 250 V > 5 mA or > 250 V < 500 A Table 2.2
> 250 V and > 500 A or > 10 J Table 2.3
no serious injury
can work alone
documentation not required
must be qualified
can be injured or killed from contact
two person rule, PPE may be required
documenation for energized work required
must be qualified
injury at a distance
safety watch
SEWP, PPE required
must be qualified


10+3
1000 Watts
Class 2.2 (<10Joules)
Training Plan 4044 Energized
50 Volts
Amps
5 milliamps
1000 Watts
10-3
10+0
Volts
10+6



Modes of Electrical Work

- **Operation of unlisted equipment**
- **Mode 1 - De-energized**
  - external sources of electrical energy disconnected by some positive action (e.g., lockout/tagout)
  - all internal energy sources rendered safe
- **Mode 2 - Diagnostics and Testing**
  - some or all of the normal protective barriers removed
  - interlocks bypassed
  - measurements, diagnostics, testing, observation
  - no physical moving of conductors and parts near energized conductors
- **Mode 3 - Energized**
  - the physical movement of energized conductors and parts, or
  - moving parts that are near energized conductors
  - some or all of the normal protective barriers removed

ISM Step 2 - Electrical Hazard Assessment

- Classify the hazard based on the potential for injury, use the Hazard Identification Tables in the LIR. There are seven Tables for use:
  - 4 for Facility and Utility Sources
  - 3 for R&D and Electronic Work
- Determine the Mode of Electrical Work
  - Operation (listed/approved? or unlisted)
  - Mode 1 - De-energized
  - Mode 2 - Diagnostics and Testing
  - Mode 3 - Energized
- Determine the safe work practices needed, including
  - qualification requirements
  - PPE
  - procedures (work control)
  - documentation
  - alone, 2nd person, or safety watch

Step 3 - Hazard Mitigation

- Hierarchy of Controls

  1 - De-energize the circuit, and verify

  2 - Engineering controls

  barriers, insulation, interlocks

  3 - Administrative controls

  work control, warning signs, access control

  training, SOPs, SEWPs, HCPs, design reviews

  4 - Personal Protective Equipment (PPE)

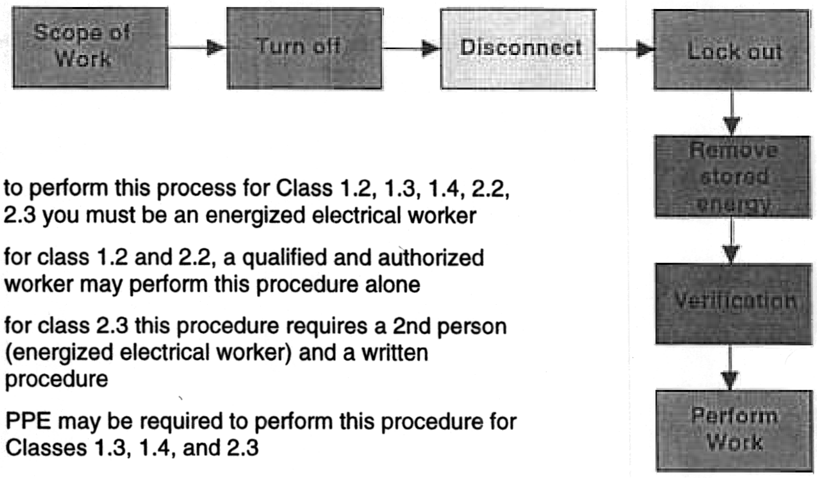
  safety glasses, protective gloves

- Safe-process and documentation approval
- Work authorization

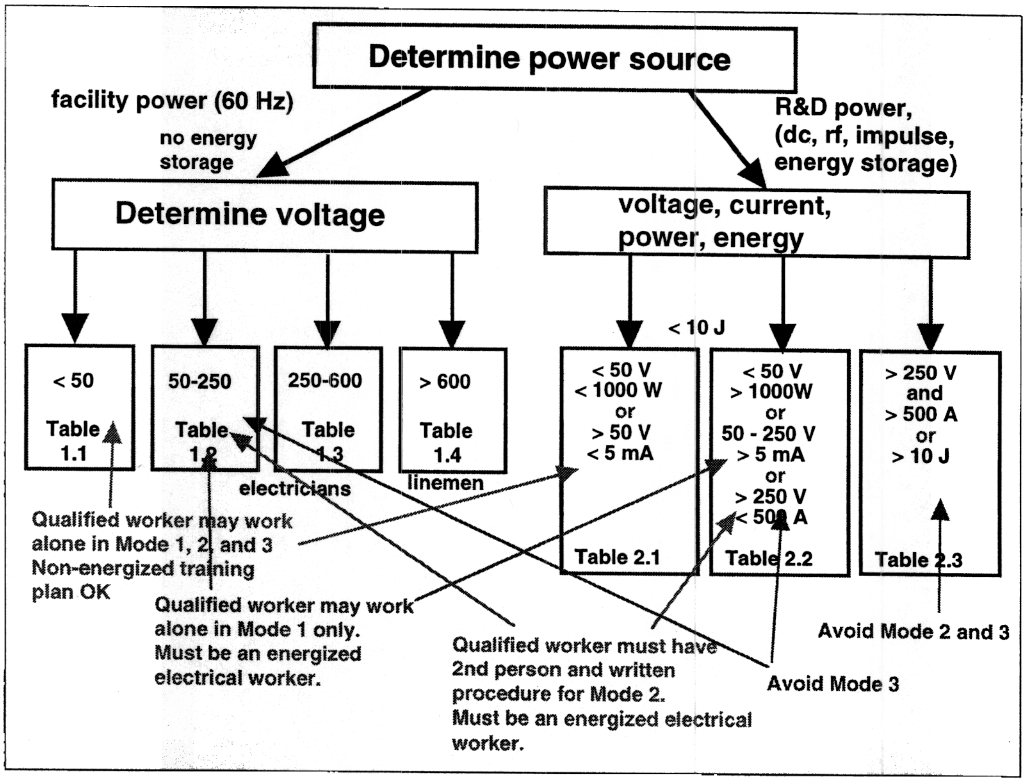
Hierarchy of Controls - (1) De-energized

- De-energization is a 6 step process
  - Scope of Work
  - Turn off equipment/system
  - Disconnect from energy source
  - Control disconnect (e.g., LOTO, plug, remove key, etc.)
  - Remove barrier, remove stored energy
  - Verify a zero energy state
- Electrical Equipment is NOT De-energized until all 6 steps have been completed.
- Opening up electrical equipment to remove stored energy and verify a zero energy state exposes the worker to electrical hazards!
- This process may require
  - a written procedure (e.g., HCP or SEWP)
  - a second person
  - PPE

The Process of Opening Electrical Equipment to Achieve a De-energized State



- to perform this process for Class 1.2, 1.3, 1.4, 2.2, 2.3 you must be an energized electrical worker
- for class 1.2 and 2.2, a qualified and authorized worker may perform this procedure alone
- for class 2.3 this procedure requires a 2nd person (energized electrical worker) and a written procedure
- PPE may be required to perform this procedure for Classes 1.3, 1.4, and 2.3



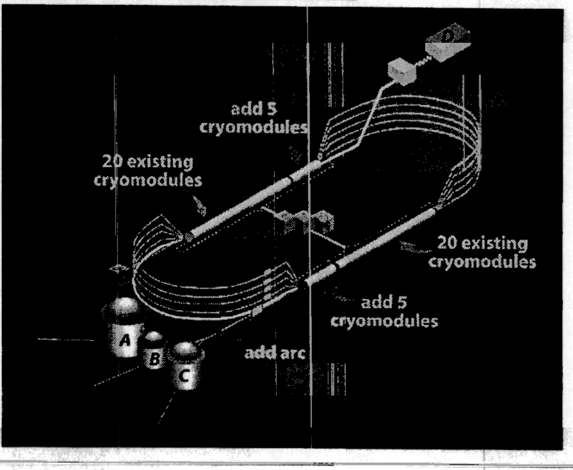
Hierarchy of Controls - (2) Engineering Controls

- In normal use engineering controls (design) protects the operator.
- Such engineering controls include:
  - enclosures and other barriers
  - insulation and distance
  - interlocks
- Engineering Controls are assured by:
  - NRTL listing, or
  - ESO approval
- In systems these engineering controls may be documented in the HCP or other ISM document

Hierarchy of Controls - (3) Administrative Controls

- Once the engineering controls area removed, insufficient, or not yet in place, administrative controls protect the worker
- Administrative controls, or work control may include:
  - increased qualification requirements
  - a work control document such as an HCP or SEWP
  - details on the task
  - 2nd person
  - PPE requirements

Jefferson Lab
Overall accelerator diagram



Arc section

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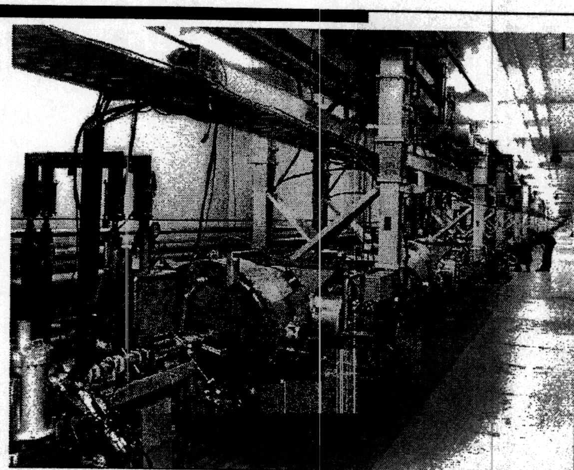
Linac section



Jefferson Lab

- Environment, Health and Safety Committee
  - Lab Wide safety concerns
  - Chaired by the Office of Assessment (Lab Directorate)
  - Safety Officers from each Lab Division
  - Experts called as needed
  - Several standing subcommittees
    - Electrical, Radiation, General Policy and EH&S Manual Development
- Electrical Safety Subcommittee

Jefferson Lab

- **Electrical Safety Subcommittee**
  - has members from all divisions
  - promotes electrical safety at the Lab
  - provides interpretations to electrical codes and standards, reviews proposed changes to Lab electrical policies and practices
  - serves as the technical advisor to the Facilities Management Director who serves as the on-site electrical authority having jurisdiction.

Jefferson Lab

- Membership of the Electrical Safety Subcommittee (ESS) shall consist of representatives appointed by each Associate Director,
  - Each has recognized experience in the design and use of electronic or electrical equipment, and associated codes and standards.
  - The membership shall elect a chairperson from within, who becomes the Laboratory's Subject Matter Expert for electrical hazard issues
- The subcommittee responds to requests from and suggests topics for review to the chairperson of Jefferson Lab EH&S Committee. The chairperson ensures that minutes of the meetings are recorded and forwarded to the chairperson of the Jefferson Lab EH&S Committee
- The subcommittee also proactively initiates improvements to Lab electrical safety policies and procedures.
- This subcommittee meets as needed.

CEI IEC 61010-1 second edition, 2001-2002

Safety Requirements for electrical equipment for measurement, control, and laboratory use

- International warning symbols
- Marking Switch and circuit breaker with clear on-off position
- Minimum temperature rating of cable connected to terminals in field wired terminal boxes
- Protective bonding integrity, bonding impedance of permanently connected and indirectly connected MTE
- Physical tests on power supply cords
- General safety requirements
  - Protection against mechanical hazards
  - Provisions for lifting and carrying
  - Equipment containing or using flammable liquids

JLab EH&S Manual

- **Chapter 6200 Electrical Safety**
  - 6210 General Electrical Safety
  - 6220 AC Electrical Power Distribution Safety
    - describes the responsibilities for and restrictions placed on work involving AC line power distribution equipment.
    - Appendix 6220-T1 Use of Electrical Service Work Permits
  - 6230 Electronic Equipment Safety
    - addresses the service restrictions for work on all electronic equipment
  - 6240 Electrical and Electronic Equipment Construction and Maintenance Practices Chapter
    - details techniques used to ensure that electrical and electronic equipment remains safe and establishes restrictions on work involving electrical utilization equipment.

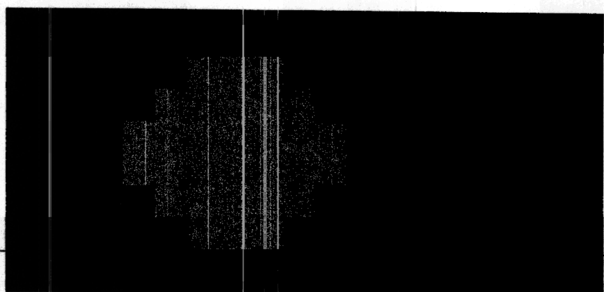
Coaxial Cable Concerns

- Uses: HV for ion pumps, cold cathode gauges, PMTs and other radiation detectors.
- Bonding: We currently do not require a third conductor to "bond" the load to the power supply. Shield is DC return and load can float if shield is disconnected.
- Terminations match: should their be a visual difference between load abd supply terminations? (Loads are down stairs and supplies are upstairs).
- Connector availability: some cable mounted receptacles no longer manufactured.
- Cable durability: cable in use is not "tray approved" should pass vertical flame test and have UV resistance.
- Labeling: What's nominal requirement? What's required for >600 V?

WHAT IS A "QUALIFIED WORKER?"

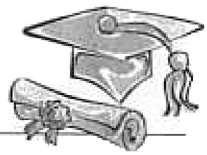
Someone recognized by JLAB Management as

1. Knowing a device/system well enough to recognize and control any hazards it may present
2. Have qualifications for operating or servicing hazardous devices, systems, and facilities documented by department management



unqualified on others.

YOU ARE A QUALIFIED WORKER IF YOU...



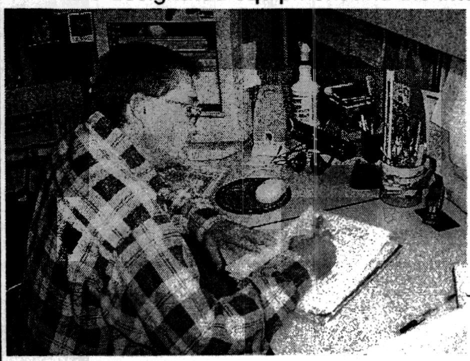
- ☐ have been trained on the operation and/or servicing of the specific equipment involved.
- ☐ can recognize and avoid the hazards associated with this equipment
- ☐ can distinguish exposed energized parts from other parts of the equipment
- ☐ can determine the nominal voltage and current capacities of exposed energized parts
- ☐ know the Hazard Class of the equipment and the Risk Modes for the operations you intend to perform
- ☐ can determine the degree and extent of the hazard and the personal protective equipment (PPE) necessary to perform the task safely
- ☐ know the emergency procedure to respond effectively to a mishap

Your qualifications to do all of the above must be documented by your supervisor and he/she must have authorized you to do this work

RESPONSIBILITIES

SUPERVISOR

- ☐ must document the qualifications for employees operating or servicing all hazardous devices
  - ■ For purposes of meeting this requirement, any Class II, III, or IV electrical or electronic equipment is considered hazardous
- ☐ must notify employees that they are qualified workers with respect to the designated equipment and the intended operation



	Mode of Work		
Hazard Class	1 De-energized equipment, LO/TO in place	2 Measurement, troubleshooting of energized equipment	3 Manipulative, hands-on tasks on energized equipment
I Low hazard ≤50V & ≤50A (low voltage, low power) >50V & <5mA stored energy < 1 Joule	A qualified person may work alone.	A qualified person may work alone.	A qualified person may work alone.
Medium hazard 50-120 VAC/DC line-to-neutral 208/220 VAC line-to-line > 50 amperes stored charge >10 Joules	2 qualified persons (QP) must be present until equipment is verified as de-energized. One QP may then work alone.	At least 2 QPs must be present. Management approval and general supervision required.	
III High hazard 277 VAC line-to-neutral 480 VAC line-to-line	2 qualified persons (QP) must be present until equipment is verified as de-energized. One QP	At least 2 QPs must be present. Management approval and general supervision required.	
IV Extreme hazard ≥ 600 VAC line-to-line			

RESPONSIBILITIES

YOU, THE WORKER

- must not operate or service any hazardous equipment, device, or system unless
  - you have been trained specifically for that equipment
    - includes positively identifying and controlling hazards which may be present
  - you have been informed by your supervisor that you are a "qualified worker" with respect to that equipment

Hazard Class and Risk Mode

E. Martin 1/227/03

Hazard Class	Risk Mode of Work		
	1 De-energized equipment, LO/TO in place	2 Measurement, troubleshooting of energized equipment	3 Manipulative, hands-on tasks on energized
I **Low hazard** ≤50V & ≤50A AC & DC (low voltage, low power) also >50V & <5mA	A qualified person may work alone.	A qualified person may work alone.	A qualified person may work alone.
II **Medium hazard** 50-250VDC 120VAC line-to-neutral 208/240 VAC line-to-line > 50 amperes DC capability stored charge <10 Joules	2 qualified persons (QP) must be present until equipment is verified as de-energized. One QP may then work alone.	At least 2 QPs must be present. Management approval and general supervision required.	
III **High hazard** > 250VDC 277 VACline-to-neutral 480 VACline-to-line stored charge >10 Joules	2 qualified persons (QP) must be present until equipment is verified as de-energized. One QP may then work alone.	At least 2 QPs must be present. Management approval and general supervision required.	
IV **Extreme hazard** Medium Voltage AC Switchgear ≥ 600 VAC line-to-line			

Note: Class is determined by the highest voltage or current to which personnel *may* be exposed during servicing operations.

HAZARD CLASSES

Hazard Class
I **Low hazard** ≤50V & ≤50A (low voltage, low power) also >50V & <5mA
II **Medium hazard** 50-120 VAC/DC line-to-neutral 208/240 VAC line-to-line >50 amperes stored charge >10 Joules
III **High hazard** 277 VAC line-to-neutral 480 VAC line-to-line
IV **Extreme hazard** ≥ 600 VAC line-to-line

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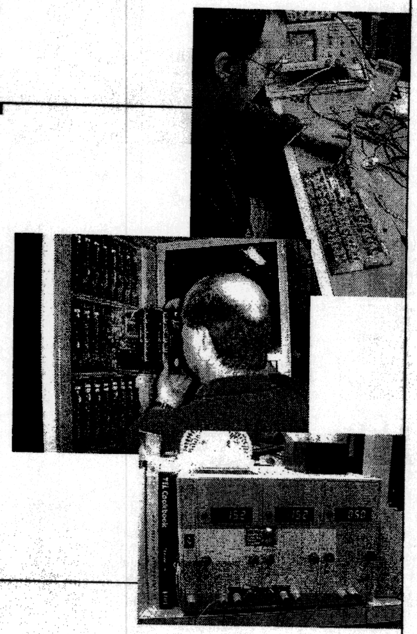
HAZARD CLASSES



CLASS 1: Hazard = Low

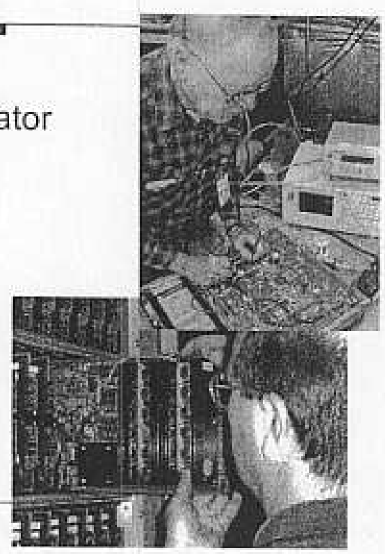
- ☐ Exposed Voltages less than 50 volts AC & DC (e.g. logic circuitry, 24V relay logic, low voltage motor controls)

  or

- ☐ Current availability in exposed conductors less than 50 amp (e.g. trim boards, bench power supply)

Exception: Voltages >50 volts are okay if maximum available current <5 milliamp

EXAMPLES -HAZARD CLASSES



- ☐ Class I
  - ■ Open Chassis,RF Separator Amplifier (48VDC)
  - ■ Trim power supplies (30V @ 10 amp)

HAZARD CLASSES

CLASS II: Hazard = Medium

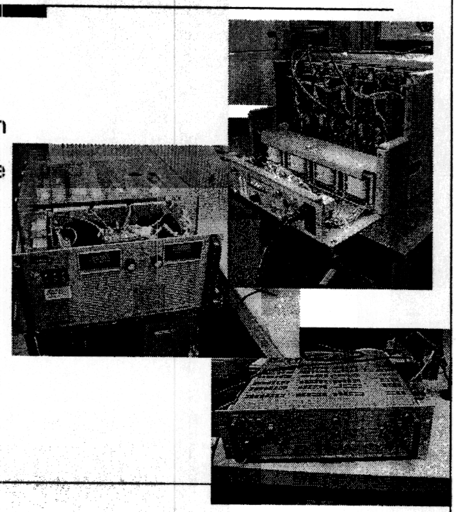
- ☐ Exposed AC or DC Voltages greater than 50V but less than<250V (e.g. exposed 120VAC in a chassis, 300VDC interstage circuitry, or 208VAC breaker panel)

  or

- ☐ DC Current availability in exposed conductors > 50 amp (e.g. small magnet power supplies)

  or

- ☐ Available Stored Energy less than 10 Joules.

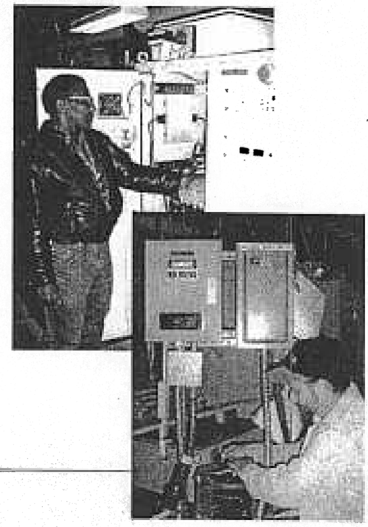


EXAMPLES -HAZARD CLASSES

- ☐ Class II
  - ■ Magnet Supply, 60V @ 50 amp
  - ■ Open chassis with exposed 120VAC terminals

HAZARD CLASSES

CLASS III: Hazard = High
(DANGER)



- ☐ Exposed AC & DC Voltages exceed 250 volts
  (e.g. 277VAC/480 VAC variac, 840VDC box supplies)

  or
- ☐ Available Power exceeds 500 VA (e.g. a 300 volt, 2 amp power supply)

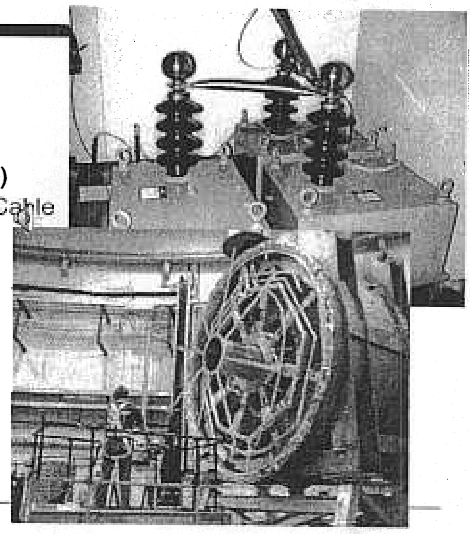
  or
- ☐ Available Stored Energy greater than 10 Joules

EXAMPLES -HAZARD CLASSES

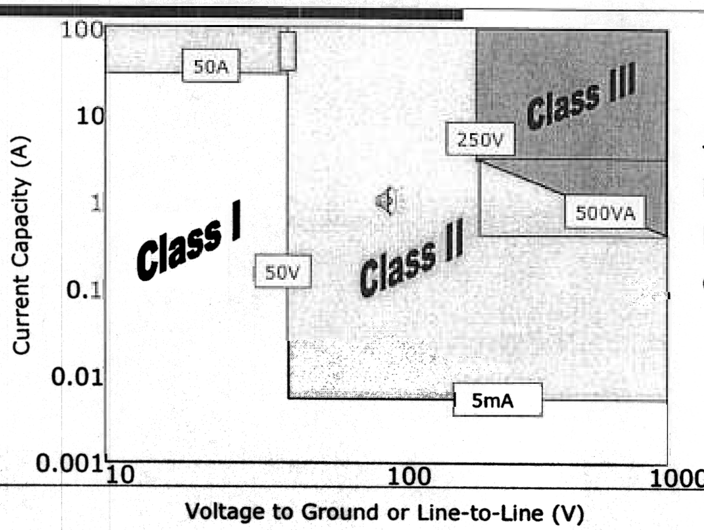
- ☐ Class III
  - ■ Box supplies
    - ☐ 840VDC @ 320A
    - ☐ 480VAC
  - ■ CPS/HPA
    - ☐ 12kV @ 10amp
    - ☐ 480VAC
  - ■ Fluorescent Fixture
    - ☐ 277VAC

EXAMPLES -HAZARD CLASSES

- Stored Energy
  - Capacitors
    - Joules = 1/2 (C * E²)
    - 10 J = 1/2 (2,000 uF * 100V²)
    - Beware: H.V. Caps & Coax Cable
  - Inductors
    - Joules = 1/2 (L * I²)
    - 10 J = 1/2 (1mH * 141A²)
    - Beware: Superconducting Magnets



ELECTRONIC HAZARD CLASSES



JLab Electronic Hazard Classes

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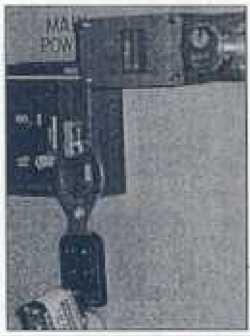
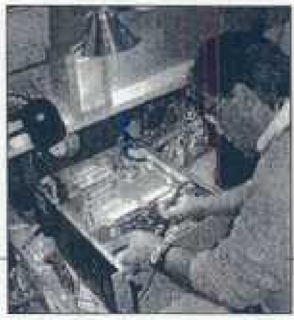
RISK MODES

1	2	3
De-energized equipment LOTO in place	Measurement, Troubleshooting Energized equipment	Manipulative, hands-on tasks on energized equipment (including removing panel covers)


RISK MODES

MODE 1:

- All operations to be conducted with equipment positively de-energized
  - All external sources of electrical energy isolated by some positive action (e.g. LOTO)
  - All internal energy sources rendered safe


RISK MODES

MODE 2:

- Equipment measurements, observations, adjustments may be conducted by qualified persons with equipment energized, normal protective barriers removed, interlocks bypassed

but

- Any manipulative operations, such as connecting or altering normally-energized components or working in close proximity to them, conducted with equipment positively de-energized

and

- Probes, test leads, adjustment tools, & other diagnostic devices must
  - have insulation intact
  - be rated for voltages and currents present
  - configured to maintain adequate distance between hands & energized surfaces

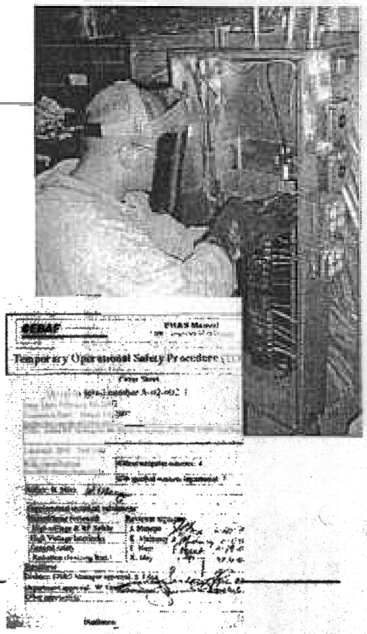
RISK MODES

MODE 3:

- Manipulative operations are conducted with equipment fully energized & with normal protective barriers removed
- Requires written approval of a documented justification & plan of work (OSP,TOSP, or Electrical Service Work Permit).

Notes:

For Class III and above equipment, Mode 3 work is permissible only when task is necessary & it is not feasible to de-energize the equipment for servicing



WORK RULES
Class 1

	Voltage*	Current capacity	Hazard	Remarks
Class 1**	≤ 50 V	≤ 50 A	Low	Low voltage, low power
	> 50 V	≤ 5 mA		High voltage, very low current
Mode 1	A qualified person may work alone.			
Mode 2	A qualified person may work alone.			
Mode 3	If exposed voltages are less than 50 volts differential or to ground, a qualified person can work alone with implied approval and general supervision. Otherwise, a qualified worker with implied approval and general supervision, must be in the presence of another individual who can provide or summon assistance.			

WORK RULES
Class 2

	Voltage	Hazard	Remarks
Class II	120 line to neutral 50 VDC <V<250VDC VA <500VA	Medium	Low power control circuit with limited power; low power utility
	208 or 240 line to line		
Mode 1	At least two qualified persons must be present until it has been clearly verified that the equipment has been de-energized. Then one qualified person may work alone.		
Mode 2	At least two qualified persons must be present. Implied approval and general supervision are required.		
Mode 3	At least two qualified persons--including the worker(s)--must be in continuous sight and sound communication, wear eye protection, use insulated tools or insulated gloves.		
	There must be an applicable written and approved plan (SOP or *Electrical Service Work Permit*) for all work.		

WORK RULES
Class 3

	Voltage	Hazard	Remarks
Class III	277 line to neutral >250VDC VA>500VA 480 line to line	High	Medium power utility (< 600V)
Mode 1	At least two qualified persons must be present until it has been clearly verified that the equipment has been de-energized. Then one qualified person may work alone.		
Mode 2	At least two qualified persons must be present throughout the Mode 2 operation. Implied approval and general supervision are required.		
Mode 3	At least two qualified persons--including the worker(s)--must be in continuous sight and sound communication. For AC power work, wearing appropriate PPE including eye protection, use insulated tools or insulated gloves, and use an insulating floor mat is required.		
	There must be an applicable written and approved plan (SOP or *Electrical Service Work Permit*) for all work.		

ELECTRICAL WORK RULES
Class 4

	Voltage	Hazard	Remarks
Class IV	≥ 600 line to line	Extreme	High power utility
Mode 1	At least two qualified persons must be present until it has been clearly verified that the equipment has been de-energized. Then, one qualified person may work alone.		
Mode 2	Workers must wear eye protection, use insulated tools or insulated gloves, and use an insulating floor mat. All equipment must be rated for use with the expected hazards.		
	At least two qualified persons are required, one as a Safety Watch, stationed outside normal protective barriers and with continuous sight and sound communication with the worker(s). The Safety Watch shall not be distracted from this assignment at any time. Implied approval and general supervision must exist.		
[redacted]			

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LANL Electrical Safety Program

March 3, 2004

Lloyd B. Gordon
Los Alamos National Laboratory

LA-UR-05-2114

How does safety work at LANL?

- ISM = Integrated Safety Management (DOE wide)
  - (1) Scope of Work
  - (2) Identify the Hazards
  - (3) Develop the controls to protect the worker
  - (4) Using the controls do the work safely
  - (5) Review and Improve the Process
- LIRs define specific controls for certain areas at LANL
- LIGs may add additional guidance
- HCPs apply ISM to a specific system or task implementing the applicable LIRs
- Approval and Authorization
- IWM = Integrated Work Management (NEW)

WHAT is this program ?

- Electrical Safety Laboratory Implementation Requirements LIR402-600-01.1
  - Issued December 24, 1996
  - Revised December 18, 1998
  - **Revised February, 2003**
- Electrical Safety Implementation Guide LIG402-600-01.0
  - Issued December 24, 1996
  - Revised February 2000

Some History of Electrical Safety at LANL

- **January 17, 1996** - Type A Accident
- **February 16, 1996** - first R&D training class
- **July, 1996** - Microwave Oven Accident to summer intern
- **August 1996** - Establishment of the Electrical Safety Task Force
- **Aug/Sept 1996** - 679 R&D workers trained
- **Dec 1996** - LANL Electrical Safety LIR/LIG released
- **Mar/Apr 1997** - 792 R&D workers trained
- **August 15, 1997** - Establishment of the Electrical Safety Committee (appointed by lab Director and ESH Division Director)
- **January 26, 1998** - First ESO class
- **October 1, 2003** - Unlisted equipment milestone
- **Today** - YOU are here!

WHAT does it do?.... PURPOSE

- Promote an electrically safe workplace, free from unauthorized exposure to electrical hazards.
- Reduces or eliminates the dangers associated with the use of electrical energy.
- Provide implementation requirements for electrical safety consistent with the Integrated Safety Management five-step process.
- Establish requirements and controls for implementation.
- During
  - construction
  - modification
  - maintenance
  - utilization, including research and development (R&D) activities
  - decontamination and decommissioning of Laboratory facilities and equipment

PURPOSE - cont.

- Complies with applicable OSHA, NFPA, NEC, NESC, ANSI and other established safety standards.
- Establishes the AHJ and AHJ hierarchy of authorities for
  - interpreting these codes
  - approving equipment, assemblies, and materials
  - determining the acceptability of electrical installations.
- Develops responsibilities, and clear lines of authority for the performance of electrical work

Purpose of the Electrical Safety Committee (ESC)

- The LANL Electrical Safety Program establishes the ESC for
  - evaluating, updating, and improving electrical safety requirements
  - evaluating each Laboratory organization against the stated implementation requirements
  - serving as the site-wide AHJ
  - providing assistance when there are disputes over electrical safety decisions, clarifications, and interpretations.

4.2 Important Terms

Know these terms!

- alternate method
- approved
- approved equipment
- authorized work
- barricade
- barrier
- clarify
- compelling reason
- conductive
- contract worker
- critical system
- de-energized
- electrical hazard
- electrical safety
- electrical work
- electrically qualified worker
- energized
- exception/variance
- flash hazard
- hazardous electrical work
- insulated
- interpret
- listed equipment
- live parts
- safety responsible line manager
- safety watch
- shock hazard
- subcontractors
- two-person rule
- unlisted equipment
- working near
- working on
- 100% rule

Definitions

electrical work

(1) working on or near energized electrical parts

(2) assembly or fabrication of potentially hazardous electrical equipment

(3) working with unlisted or unapproved electrical equipment, and/or

(4) using listed or approved equipment in a manner not consistent with the listing, or approval.

hazardous electrical work - All electrical operations in which workers may be exposed to an electrical hazard.

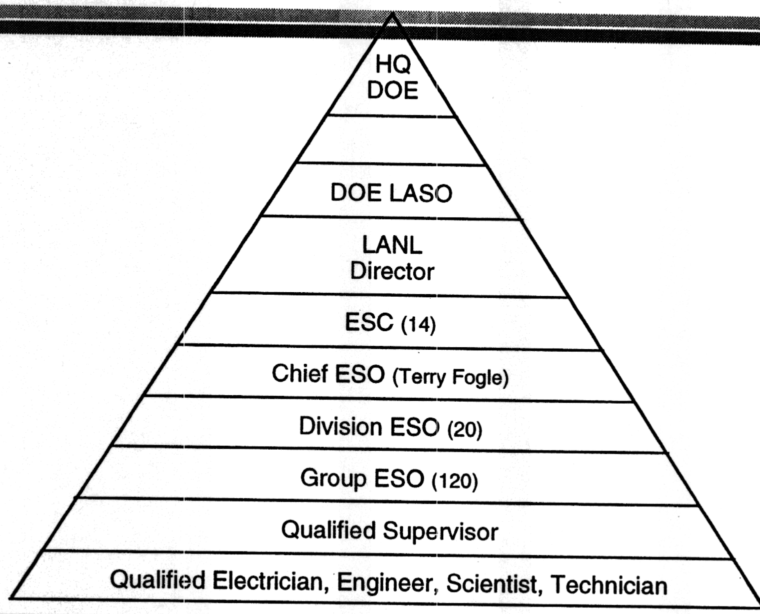
working on - Coming in contact with exposed energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment a person is wearing.

working near - Any activity inside the limited approach boundary or the flash protection boundary (see NFPA 70E) of exposed energized electrical conductors or circuit parts that are not put into an electrically safe work condition.

Definitions

- **alternate method** - A deviation from an electrical requirements document or subtier document that includes compensatory measures that assure equivalent objectives can be achieved by establishing and maintaining effective safety.
- **barricade** - A physical obstruction (such as tapes, cones, or A-frame-type structures) intended to provide warning about and to limit access to a hazardous area. Barricades are generally temporary.
- **barrier** - A physical obstruction that is intended to prevent contact with exposed energized electrical conductors or circuit parts. Barriers can be temporary of permanent (i.e., a part of the design)

Clear Lines of Authority



AHJ - What does it do?

- Enforce all electrical code requirements
- Clarify electrical code requirements
- Provide advice and consultations on how to meet electrical requirements
- Manage the electrical inspection program
- Issue formal interpretations
- Final technical arbiter on electrical safety issues
- Assure that employees work freely from unmitigated exposure to electrical hazards

Graded Approach to Electrical Worker On-the-Job Training

	Classes 1.1 and 2.1	Classes 1.2 and 2.2	Classes 1.3 and 2.3	Class 1.4
Mode 1: De-energized and checked	Level 1 OJT is optional	Level 1 OJT is optional	Level 2 OJT	Level 3 OJT
Mode 2: Diagnostics and Testing	Level 1 OJT is optional	Level 1 OJT	Level 3 OJT	Level 3 OJT
Mode 3: Energized	Level 1 OJT is optional	Level 2 OJT	Level 3 OJT	Level 3 OJT

	Level 1 (Low and Minimal Initial Risk)	Level 2 (Medium Initial Risk)	Level 3 (High Initial Risk)
Formality of Training	*Read, Observe, Walk-Through, & Sign*	*Read, Observe, Walk-Through, & Evaluation*	*Read, Practice under supervision & Demonstration/Evaluation*
Training Outcome	**Communication**	**Coaching**	**Mastery**
Justification	- Low/some health/safety risk to workers or public - No/little risk of damage to equipment - No significant degradation of security system - Decreased efficiency - Possible employee disciplinary action - No/small potential for regulatory fines/penalties and/or corrective actions.	- Health/safety risk to workers or public - Some risk of damage to equipment - May lead to vulnerability leading to significant degradation in the security system or a component part thereof, or compensatory measures, or systems correcdtions - Potential for moderate regulatory fines/penalties, stand-down, accident, damage to equipment facility, or threat to other operational activity	- Greater risk to worker safety with possiblity of acute or long-term damage to workers or public - Moderate risk of damage to equipment - Long-term or irreversible damage to environment, damage to equipment/facility, or other operational activities High probability that vulnerability exists that leads to a significant degradation in the security system, which will result in compensatory measures or system correction - Large regulatory fine, shut down of Lab, operator deaht/injury, great damage to equipment/facility, or threat to other major operational activity

Electrical Safety Training Plans

from LIG 402-600-01.1, Feb. 2000, Attachment C, pages 22 - 44

- R&D Electrical Worker: Energized Using Lockout/Tagout
- R&D Electrical Worker: Energized NOT Using Lockout/Tagout
- R&D Electrical Workers: Non-energized
- Electrical Designers/Electrical Engineers: Energized
- Electrical Designers/Electrical Engineers: Non-energized
- Electronic/Computer Technicians: Non-energized
- Electricians/Apprentice Electricians
- Non-Electrician Crafts: Energized
- Crafts Workers: Non-energized/Non-electrical
- Linemen & Utility Engineers
- General Workers: Electrical Hazards
- Supervisors: Authorize Electrical Work
- Electrical Safety Officer

Evolution of R&D Courses

Course	Period
??	prior to 1996
↓ Electrical Safety in the R&D Laboratory	Feb 1996 - Feb 1999
↓ - LANL Electrical Safety Program - Electrical Injury Mechanisms - at least 1 optional module	after Feb 1999

R&D Elective Choices

- Pulsed Power Safety
- Radiofrequency and Microwave Safety
- Computer Safety
- Batteries and Battery Bank Safety
- Basic Facility Wiring Principles
- Basics of R&D Grounding and Shielding
- Introduction to Electrical Theory
- Designing Safe Electrical Equipment
- Electrical Injury Mechanisms

each 2 hours long

R&D Electives

Electrical Injury Mechanisms (# 16749)

Addresses the injury mechanisms of electrical shock, classification of electrical hazards, and examples of hazardous situations in the R&D laboratory.

Pulsed Power Safety (# 16747)

Covers the unique hazards in the Pulsed Power Laboratory, including capacitors, transients, magnetic forces, potential gradients, and induced voltages and currents.

Radiofrequency and Microwave Safety (#16748)

Presents the effects of rf shock and burn, and the dangers of rf electromagnetic fields. Identification of the rf and microwave hazard is discussed. Design techniques and safe work practices are presented.

Basics of R&D Grounding and Shielding (#16743)

Covers the basics of electromagnetic interference (EMI), including conductive and radiative coupling. Basic techniques are presented for controlling EMI, including grounding, shielding, filtering, and component configuration.

Computer Safety (#16746)

Hazard identification and safe work practices for working with computers are presented, including shock, electrostatic discharge, and UPSs.

R&D Electives - cont.

Batteries and Battery Bank Safety (#16745)

Covers the multitude of hazards associated with batteries and battery banks, including shock, burn, explosion, chemicals, and contamination. Proper design and safe work practices are presented.

Basic Facility Wiring Principles (#16744)

Addresses the basic principles and requirements for facility wiring, including overcurrent protection, types of outlets and plugs, single and three phase circuits, and grounding.

Introduction to Electrical Theory (# 16742)

Covers the basics needed to understand and control the electrical hazard. It includes electrical parameters, electromagnetic fields, Ohm's Law, impedance, induction, energy storage, resistive heating, conductors and dielectrics, and dielectric breakdown. Completion of this course will better enable the laboratory worker to assess, understand, and implement electrical hazard mitigation techniques.

Designing Safe Electrical Equipment (#16751)

Covers guidelines to design and fabricate electrical equipment for laboratory use, that meets OSHA, NEC, and NRTL safety standards. Includes topics of overcurrent protection, enclosure, grounding, and protection of the operator. This material will help the electrical worker meet requirements for the approval of electrical equipment for safe use.

Training Requirements for Qualified Electrical Workers (from LIR Attachment E-1.2)

The degree of training is determined by the risk to the employee. Individuals who work on or near de-energized systems shall receive electrical safety training, but possible to a lesser extent than those who work on energized systems. Required OJT shall be listed in the SOP, SEWP, or HCP. Training for electrically qualified workers must include, but not limited to, the following:

- relevant electrical safe-work practices, including lockout/tagout
- PPE
- ability to distinguish exposed energized parts from other parts
- ability to determine nominal voltage, current, power and energy of exposed parts
- minimum approach distances, flash boundaries, etc.
- CPR

Equipment approval —According to OSHA

Definition of Acceptable

- Determined to be safe by a nationally recognized testing laboratory (NRTL)
- Inspected or tested by an "authority" responsible for enforcing occupational safety
- Manufacturer self-certification of custom-made equipment based on test data, available for review

NRTL Registered Certification Marks

Responsibilities for Equipment

- qualified worker
  - to purchase listed equipment, if possible
  - to properly design and document equipment
  - to seek ESO approval
- Electrical Safety Officers
  - assist in identifying NRTL listed equipment for purchase, if available
  - review and approve unlisted equipment

All new electrical equipment

- new, modified, or moved
  - Examination and approval required prior to use
- All new electrical equipment that contains electrical hazards (i.e., higher than class 1.1 and 2.1) MUST be approved by an ESO prior to use, unless the use is specifically covered under an HCP (for example, a prototype circuit).
- New equipment includes:
  - built in-house
  - ordered through buyer
  - JIT, credit card, etc.
  - modified equipment

OSHA and NEC requirements

equipment approval checklist from the LANL LIG, p. 41

1 Suitability for installation and use in conformity with 29 CFR 1910 Subpart S and/or the NEC.

2 Mechanical strength and durability, including parts designed to enclose and protect other equipment, the adequacy of the protection thus provided.

3 Wire bending and connection space.

4 Electrical insulation.

5 Heating effects under normal conditions of use and also under abnormal conditions likely to arise in service.

6 Arcing effects.

7 Classification by type, size, voltage, current capacity, and specific use.

8 Other factors that contribute to the practical safeguarding of persons using or likely to come in contact with the equipment, including non-electrical considerations and hazards.

Special Notes

- A piece of equipment is approved for its INTENDED USE
- Approved equipment shall be installed and used in accordance with the instructions provided by the the designer/builder or ESO
- Equipment is approved for installation and use at LANL
- If the equipment is modified, relocated, damaged, repaired, or utilized for other than the intended use stated, the approval is void, pending re-examination

Label for Approved Equipment

1. Identifying number referencing equipment approval checklist and/or database entry.

2. Orgranization that owns or used the equipment item, either a LANL group or division.

3. Signature of the Electrical Safety Officer that approved the equipment item.

4. Date that the item equipment was approved.

5. Self-laminating, write-on, adhesive-backed Mylar lable, approximately 6 cm x 2.5 cm with green shading. Label is available from HSR-5.

Electrical Safety Handbook

(R&D Workshop)

David A. Chaney

NNSA SC ESHD Senior Advisor/Technical Director

March 3, 2004

DOE-HDBK-1092-98

Electrical Safety Handbook (R&D Workshop)

- **DNFSB Interest Item**

  June 21, 2001 DNFSB Letter: HNDBK Not being Used (PX, LLNL, Y-12, SRS) and in need of Upgrade
  - Electrical Safety during Excavation and D&D
  - Noncompliant/Non-listed Electrical Equipment
  - AHJ/ESC inadequacies

  August 7, 2003 DNFSB Letter:
  - Increase in Electrical Near Miss events/shocks/injuries in 2003
  - Greater effort needed in Electrical Safety Programs
  - Importance of Code references and DOE-unique applications

Electrical Safety Handbook (R&D Workshop)

- **DOE Response to DNFSB (9/5/03; 12/15/03)**

  DOE ESG to Update DOE-HDBK-1092-98 for use in both training and the workplace by April 2004

  - Electrical Safety Issues addressed comprehensively
  - Current Codes/Standards Maintained/Referenced
  - Consistency between Classroom and Workplace

  HDBK Appendix A retained (Electrical Safety Program Criteria)

  DOE ESG Formed: Training Framework Development/Unique DOE Work Requirements/Guidance

Electrical Safety Handbook (R&D Workshop)

- **Recent NNSA Events**:

  NNSA Service Center ABQ: February 18, 2004

  - Bldg 387: D&D Work on Conduit Unknown to be Energized resulted in 3 Hr. Loss of Power
  - Personnel Injury Near Miss

  LANL TA-3/490 NSSB D&D: March 1, 2004

  - FWO Integrated Work Document: No Reference of As-Built Drawings. 2-3" Energized Temporary/ Secondary Utility Line (110/208V) Conduits Severed during Excavation

PANEL PRESENTATIONS

Research & Development
Electrical Safety
Workshop Panels

Panel 1: Unlisted Electrical Equipment Approval

Team Leader: Ed Laner, Bechtel Neveda
Presenter: Larry King, SNL
Members:
- Ben Gomez, LANL
- Jesse Mendez, LANL
- Scott Semonisian, LANL
- Bob Weiss, LANL
- Jim Blankenship, ORNL/UTB
- Ed Henderson, LANL

Panel 2: Qualification & Training and Mixed Hazards

Team Leader Jeff Downs Sandia NLNM
Presenter Jeff Downs
Members:
- Y. T. Wang, NNSA-LSO
- Doug Ardary, INEEL
- Scott Walker, LANL
- Sam McKenzie, SNS/ORNL
- Bob May, Jefferson Lab
- Travis Admundsen,

Panel 3: Standards for Design & Chapter 10 R&D

Team Leader: Thomas Caronna, LBNL
Presenter: Thomas Caronna, LBNL
Members:
- Clark thonpson, LANL
- Grant Lockwood, SNLNM
- Larry Zalants, SRTC
- David Harkleroad, LANL
- Terry Monahan, NSCL
- Dennis Collins, LBNL
- Patrick Lara, LANL

Panel 4: Chapter 9 Enclosed Electrical/Electronic Equipment

Team Leader: Jim Anderson, LANL
Presenter: Jim Anderson, LANL
Members:
- Sandy Turner, LANL
- Alan Gibson, LANL

Tony Birkenfeld, BWXT Pantex
Mike Frisch, SNL Livermore
Chris Pantellas,
Kim Gwinn, NSCL
Doug Harris, NSCL

Workshop Panels

Panel 1: Unlisted Electrical Equipment Approval

Discussion: Listed and labeled Nationally Recognized Test Laboratory (NRTL) electrical equipment is the preferred choice in selecting R&D equipment if it is adequate for its intended use. Unlisted electrical equipment is often found in research and development laboratories. Electrical equipment is sometimes designed, fabricated and operated in unique applications. Often listed equipment is unavailable for the intended application. Sometimes foreign made equipment is brought into the laboratory. Often equipment is designed and built for unusual parameters such as high voltages with low currents, low current with high voltages, energy storage, frequencies (radio frequency operation, microwaves) other than sixty cycle, direct currents, electromagnetic fields and environmental conditions (radiological, temperature, pressures . . .) unique to R&D.

Established statutory regulatory, industry codes and standards are to be applied wherever possible to ensure safety. In those cases where unique operating parameters makes these requirements not directly applicable, then, the requirement's intent must be met to ensure equivalent safety is maintained. Many industry codes and standards such as the NEC, NESC, NFPA 70E were written principally for the sixty-cycle frequency facility or power distribution industry. The direct application of these codes is often not practical. It is the responsibility of the researcher and workers to ensure the R&D hazard is adequately abated. The equipment owner is the first individual responsible for its safety and must examine or have the equipment be examined by a qualified person to determine the electrical hazard and develop/establish the appropriate hazard controls. The tailored application of safety requirements may be needed. The site Authority Having Jurisdiction is responsible and accountable for the approval process.

Non-NRTL electrical equipment can be off-the-shelf, legacy, custom built, homemade, modified, limited use, stored equipment, spare, replacement-in-kind, used other than its intended use listing, or foreign built. The list is but a sample of possible non-NRTL equipment commonly found in the R&D environment. The classification of equipment maybe NRTL unmodified, NRTL modified, or Non-NRTL.

The concept of understanding the electrical hazard must be based on a hazard categorization method coupled with a clear understanding of physiology of electric energy imparted on the human body. Integrated Safety Management (ISM) requires that 1) the scope of the electrical work be determined, 2) the electrical hazard be fully assessed, 3) hazard mitigation be established, 4) perform the work safely within established requirements/standards, and finally 5) improve electrical safety thru feedback. Imbedded in the ISM is that the workers be appropriately trained and qualified. The modes of electrical work are de-energized, diagnostic & testing and performing energized work. The hazard must be classified based on potential for injury from shock, flash arc, arc blast, or reflex action. The hazard assessment must consider voltage, current, power, frequency, and waveform to determine the available energy that maybe deposited on the body. The Los Alamos National Laboratory has developed Hazard Classification Tables to aid in the classification process (see L. B. Gordon Hazard classification Process Presentation). Once the electrical hazard is understood the hazard must be mitigated. Hazard mitigation hierarchy is 1) eliminate the hazard by de-energizing, 2) barriers such as insulation, interlocks, 3) administrative controls such as hazard control plans, safe operating procedures, access control, 4) Personal protective equipment such as gloves, fire resistant clothing, eye protection.

The inspection process level of rigor should be commensurate with the hazard risk. The inspection process should consider requirements contained in the NEC article 110. The inspection may require an external visual or internal visual process. The external visual inspection may include exposed live parts, polarity, ground continuity, bonding, workmanship, labeling, or damage. The internal visual inspection may include workmanship, damage, ratings, or barriers. Leakage testing may be considered as an additional inspection when applicable.

The inspection process may consider the inspector's independence, sampling, judgment, or statistical samples. The inspection process may determine the precautions needed to operate the equipment such as lockout capability, PPE required, or training. The disposition of failed equipment must also be considered. The inspection process should consider the necessary documentation required such as labels, report make-up, and equipment identification.

Once the equipment inspection process has been formalized interactions with other organizations using the equipment may require a reciprocity agreement be developed.

The Panel recommended that a separate chapter be developed in the Handbook to address unlisted equipment approval.

Workshop Panel
Panel 1: Unlisted Electrical Equipment Approval

Purpose, Scope and Philosophy

- **Equipment owner is responsible to have equipment examined**
- **Tailored application of Standards**
- **Subjective in some cases**
- **AHJ responsible and accountable for approval process**
- **Use NRTL if available**
- **Involvement of designers, engineers, scientist early on – communicate with AHJ**
- **Minimum requirements**
- **To be made site specific – adapted**
- **Minimize electrical risks & hazards to personnel**
- **Separate chapter**
- **Based on OSHA, NEC, added to by DOE**

Non-NRTL Equipment Approval

Definitions

- NRTL
- Off-the-shelf
- Legacy
- Custom
- In-house homemade
- Modified
- Prototype
- Limited use – One shot
- Stored equipment
- Reciprocity
-
- Replacement-in-kind
- Exempt
- System
-
- Intended use
- Workmanship

  Safing Equipment

Classification of Equipment

Classification

NRTL Unmodified

NRTL Modified

Non-NRTL

OTS or Custom

- QSL Vendor
- Non-QSL Vendor

In-house

- DOE AHJ Approval
- Non-DOE AHJ Approval

Proto type

Modified

Repaired

Change in function

Exempt

Usage

As intended/Designed/Listed

Un-intended

Hazard Category

USE LANL METHOD

Level of Rigor

.0 – No Action

.1 – Visual External
- Exposed live parts
- Polarity
- Ground continuity
- Bonding
- Workmanship
- Labeling
- Damage (obvious)

.2 – Leakage Testing

.3 – Visual Internal
- Workmanship
- Damage
- Ratings
- Barriers
- S/C

Examination Process

Independence (Design, Fabricator, Installer)

Sampling
- Option
- AHJ Judgement
- Statistical Sample – zero failure

Precautions
- Work Authorization
- Electrical Safe work Practices
- LOTO
- PPE
- Training

Acceptance Criteria
- AHJ Judgement
- No Standard
- Pick Best Standard or Best Practice
- Disposition of Failed Equipment
  - Mitigation
  - Appeal
  - Fix
  - Notification/Tagging
  - Excess/Salvage
  - Temporary Use & Variance

Documentation

Labels

- Date
- Unique ID Number per Piece of Equipment
- Inspector
- Durable Suitable for the Environment
- Readily Accessible (per QA plan if applicable)

Report

- Minimum Information
- Level of Rigor
- Label Information
- Examiner
- Date
- Disposition
- Restriction of Use
  - Temporary
  - Location
  - Personnel
  - Administrative
- Classification
- Owner

Equipment ID

- Make
- Model
- Serial Number
- Nameplate

Reciprocity

Streamline

Voluntary

Review of Other Organizations Program
MOU

Document the Equipment

Re-labeling – up to Individual Org/Lab

Recommend Central Database

END Panel 1

Workshop Panel
Panel 2: Qualification & Training and Mixed Hazards

Panel 2: Qualification & Training and Mixed Hazards

Discussion: The training & qualification of R&D electrical workers is sometimes not well delineated to address unique hazards in their environment. The R&D electrical worker may be exposed to electrical sixty cycle power and needs training in this area. Some electrical workers also need to be trained and qualified in unique non-sixty cycle power applications. R&D electrical workers may be categorized in groups such as unexposed, exposed working near, exposed working on, or electrical subject matter expert. Potentially exposed non-electrical workers may also include students, visitors, ancillary workers, and primary experiment workers. Qualified workers have the skills and knowledge regarding the design, construction and operation of equipment and installations. The qualified worker should receive safety training on the hazards involved with the equipment and the tasks they are assigned to perform on that equipment. It is suggested that workers receive training that is general electrical safety and also specific equipment, task, hazard and exposure.

The electrical safety subject matter expert (SME) should be available for consultation and assistance. The SME duties and responsibilities should be delineated and documented.

The R&D environment often contains many hazards other than electrical. Hazards may include lasers, chemicals, temperatures, pressures, noise, or radiation (ionizing and non-ionizing). Qualified electrical workers may need additional training for these non-electrical hazards

The Panel recommended that qualification and training of R&D workers be developed for a complex wide approach.

LANL Electrical Safety Workshop

Team 2

Qualifications for R&D Workers

Training Plans

Mixed Hazards

03-04-04

Jeff Downs

Team Leader

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
for the United States Department of Energy's National Nuclear Security Administration
under contract DE-AC04-94AL85000.

NNSA

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Qualification of R&D Workers (Section 10.7)

- Divide R&D workers into groups
  - Unexpos ed
  - Exposed by working *near* (i.e., close to limited area boundary)
  - Exposed by working *on* (i.e., crossing the restricted and prohibited area boundaries)
  - ESO
- Potentially Exposed Workers
  - Students
  - A ncillary Workers (i.e,. RCTs, facilities electricians, facilities maintenance workers, supervisors and managers etc.)
  - Primar y workers (i.e.,Principle Experimentalists, equipment technicians, etc>)
- Define type of work task for each kind of worker

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Qualification of R&D Workers (Sections 10.7 and 10.10)

- Qualified Worker
  - Skills and knowledge regarding construction and operation of equipment and installations
  - Has received safety training on the hazards involved with the equipment and the tasks they are assigned to perform on that equipment
    - measurement and adjustment
    - Maintenance
    - trouble shooting
    - repair

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Definition from 70E

Qualification of R&D Workers (Sections 10.7 and 10.10)

- Qualified workers receive training in two parts
  - Part 1. Requirements/General Electrical Safety training from corporation via general DOE Site wide training program
  - Part 2. Equipment/Task/hazard/exposure specific training from design engineer and or principle researcher or experimentalist, and ESO.

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Define ESO in handbook

ESO like LaserSafOf (ANSI Z136.1,

Qualification of R&D Workers

- ESO – New part for Section 10.7.1
  - AHJ determines qualification commensurate with hazard exposure, and specific role and responsibility (appropriate OJT and education)
  - Line organization selects ESOs based on AHJ qualifications.
  - Qualifications based on role and responsibility
    - Ensures exercise of site's non-NRTL evaluation process developed by the ESC and approved by AHJ
    - Provide support to line organizations to help ensure safe electrical work practices are utilized
    - Ensures site's training program is exercised at task level.
    - Ensures adequate procedure review
    - Assists management with integration and implementation of safety requirements (70, 70E, 29 CFR 1910-S, etc.)

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Qualification of R&D Workers

- ESO
  - Recommend deletion of "....within his or her own organization." from Section 1.3, second paragraph, third sentence.

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Mixed Hazards

- Edit 10.7.1
  - Add a statement to help R&D electrical workers realize that potential exposure to other non-electrical hazards exists when preparing to de-energize equipment or when working energized (i.e., test, measurement, adjusting, calibrating, troubleshooting, repair).
  - Add statement that exposure analysis for non-electrical hazards must occur during electrical hazard analysis.
  - Exposure to non-electrical hazards could occur
    - When de-energizing
    - As a result of a mistake (I.e., no shock or flash but exposure to chemicals, oxygen deficient atm., rad., etc.)

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Mixed Hazards

- Qualified Electrical Workers may need training for non-electrical hazards including:
  - Haz. Comm.
  - Laser Safety
  - Rad Con
  - Hearing Conservation
  - PPE — different hazard types
  - Thermal (heat and cryogenic)
  - Pressure (pneumatic and hydraulic)

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Site/Equipment/Task Specific Training Plans

- Address worker levels (Slide 2)
- Detail commensurate with exposure and consequence
- Result in a list of equipment worker is qualified to work on.
- Generated by principle experimentalist or equipment designer with help from ESO
- Include verification (i.e., observation, testing, etc.)
- Include other non-electrical topics
  - Hazards associated with potential consequences of de-energizing electrical equipment.

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in some cases this may be too restrictive.

– may use haz class restrictions.

Part I – one set of qualifi training across the DOE complex

Part II – site specific

Recommended Path Forward

- Complex Wide Electrical Worker Training Program/Manual
  - Developed by:
    - Team of recognized DOE experts
    - Consultation with individuals from DOE site R&D Program owners and workers
  - Includes set of topical electives for selection by DOE sites
  - Develop a directory of available DOE complex experts relative to delivery of topical electives
  - Delivered to ESOs for delivery to their audience(s)

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- Benefits - Complex Wide Electrical Worker Training Program
  - Shared Knowledge
  - Lessons learned from other sites brought to specific site as applicable
  - Uses DOE endorsed systematic approach to training
  - Provides complex wide consistency for both ESP and EST

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Panel 3: Standards for Design & Chapter 10

The Panel suggested several changes to Handbook Chapter 10 that would enhance electrical safety knowledge. The Panel also suggested some editorial changes to be considered. The BNL Document 1.5.3 authored by Terry Monahan was suggested to be used as a model for improving design standards. The panel enumerated several areas of concern where additional guidance needs to be developed.

The Panel recommended that Chapter 10 be re-written to upgrade the information presently covered in the chapter.

Panel 3: Standards for Design and Chapter 10

Separate Chapter on Interlocking/Hazard Controls

Use BNL Document 1.5.3 as a Model Terry Monahan , Author

Areas of Concern
Documentation
Redundancy
Indicators (state)
Failsafe (goals)
Fault Latching/Recovery
Search/Sweep Chains
Tamper Resistance
Modifications
Configuration Controls
Testability/Periodic Testing

Recommendations
L.V. D.C.
Proven Reliability

Power Sources 10.8.1
Insert Electrical Hazard Classification Charts below 10.8.1(5)
Avoid multi sources of power if possible
Label Foreign Power Sources
Provide Separation and/or Barriers
Different Voltages 10.8.1.2(2)
Indicators for ON and OFF (different states) 10.8.1.2.(3)
SCRAM and CRASH OFF Switch Clearly Labeled 10.8.1.2(6)

Low Voltage High Current
Add Hazard Evaluation Statements
Shorting/Fire
Total Power
Flash hazard
Load Reactance
Magnetic Forces on High Current Cables Cause Motion
Add Safety Practices Section

H.V. L.I.
Review Charts from 10.8.1
Include
10.8.3.2 Where Possible Provide Discharge Path
If Not Possible Re-evaluate Risk
Address Special Environmental Considerations (altitude, humidity)

Design should incorporate where practicable current limiting device
Add Section on Maintenance (per LV HI Section
Inside Supply Current May Not Be limited
10.8.4 Radio Frequency & Microwave
10.8.4.1 Add Cataracts Hazards
10.8.4.2(1) Delete Irradiated replace with RF and shield Design must Consider Skin Effects
10.8.4.3 Operation & Maintenance Section should be Added
10.8.4.2(6) Statement Should Be Moved to This Section (PPE Statement Only)
Measure RF Intensity Prior to Entering Area

Design & Construction for Grounding
10.9.2.1.2 2nd Paragraph
Grounding see IEEE Emerald Book 1st Paragraph
See IEEE Green Book
Conducted Noise Text Change
10.9.2.1.2

10.3 Documentation
10.9.3 All Equipment Needs Posted LOTO Procedures if More Than One Operation Required
10.101.2.3 High Impedance Ground Hooks are For Slow Energy Discharge Only
Low Impedance for Grounding Positive Strap for Safety
All Equipment/Apparatus Should Have a Full Documentation Package That Preceeds Shipment to Other Labs/Divisions
High Voltage Connectors Need to be Addressed Time Constraints
Containment of Haz Mats under Fault Conditions

Workshop Errata

Authority Having Jurisdiction
Training
Unlisted Equipment
Hazard Categorization

Define Temporary & Qualified
Handbook should written for R&D Audience
R&D Does Not Need Chapters 1-8 due to codes redundancy
Chapter 9 needs detail to improve grounding, portable carts, PPE and Flash Hazard Analyses
Define Electrical Work Tasks & Variations From NFPA 70E
Qualification of R&D Workers
Skill of The Craft
Access Control
Lightning Protection
Fiber Optics
Uniformity in Reporting
Sharing Knowledge
DOE Lessons Learned
Inter-lab Training
Equipment Design
Equipment Approval
Reciprocity
Problems with Listed Equipment
Reputable Manufactures
Working Abroad
Protective Devices
Utility/Facility/R&D Electrical
Unlisted Equipment
NEC/R&D
Processes
Foreign Equipment Labeling Marking
Hazard Classification
Proscriptive Examples for High Voltage etc
Color Codes
Mixed Hazards
Standardization
Redundancy of Safety Systems
Interlocks
EML/EMI
Coaxial Cables
Alternate Grounding Methods
Documentation

In-house Equipment
Failure Recovery
Define AHJ
R&D Community
Leadership
Communication
EFCOG
Topical Committees
Landlord/Tenants
5480.19

Panel 4: Chapter 9 Enclosed Electrical/Electronic Equipment

The Panel suggested several changes to Handbook Chapter 9 that would enhance electrical safety knowledge. The technical areas they felt could be improved included grounding (see L. B. Gordon presentation), power distribution circuits, disconnecting means, protection devices for individual pieces of equipment, larger neutrals, Uninterruptible Power Supplies (UPS), protective devices, surge arrestors, interlocks, emergency shutdown, labeling, cable management systems, lightning protection, electronics . . . The Panel also suggested some editorial changes to be considered.

The Panel recommended that Chapter 9 be re-written to upgrade the information presently covered in the chapter.

Chapter 9 R&D Electrical/Electronic Equipment

3/4/04

Section 9.1 Purpose

- Typo "Recommended"
- "Minimize" instead of eliminate

Section 9.2 Scope

- ⌘Enclosed to R&D (global change)

Section 9.3 Approval

- From 9 4 1 2 and 2 5

Section 9.4 Grounding

- Need to nc ude more nformat on from L oyd Gordon's c ass

Section 9.5 Power Distribution

- Single source with obvious disconnect if possible
- Protection for individual pieces of equipment
- Larger Neutrals

Section 9.5 Power Distribution (2)

- UPS considerations
  - Maintenance
  - Visual and audible alarms
  - Warning Labels
  - Disconnecting
  - Minimum quality requirement
  - Disposal
  - Location concerns
  - Remote communication interface
  - Heat dissipation

Section 9 6 Chassis Power Distribution

- No Change

Section 9.7 Protective Devices

- Surge Arresters
  - Maintenance
  - Monitoring
  - Distributed through system depending on environment and value or risk
- Power Interlocks
  - Fail Safe
  - Procedure and approval for bypass

Section 9 8 D sconnec ng Means

Several R&D applications problems here.

- Need AHJ
- Need rcc ccess
- Need good
- Need good tr

- Emergency wn

Section 9.9 Labeling

- Needs to be Maintained
- Needs to reference disconnecting means
- More consistency
- Section 9.8.2 needs to go further. Follow NFPA 70E

Section 9.11 Cab e Management Systems

- Cable Tray Use in &D A cations
  - Bonding
  - Segregation Issues
  - p port u
  - Fire Wall
  - No Home Made
  - es
  - Weight loading

Section 9.12 Product Testing Facilities

- Change to product testing

Section 9.13 User Facilities

- Similar to 9 12
- Lightning Protection is recommended depending on risks or value

Section 9.14 Power Electronics

- Heat Dissipation
- Altitude

Section 9 15 Non ionizing Radiation

- No expertise

Section 9 16 Computing Equipment

- Power
- Heat
- No se
- Space
- VAC

Section 9.17 Misc ssues

- Lighting
  - Receptacle and plug sta
- Heat Dissipation issues
  - Altitude/humidity
  - Interface between sa ty ty
    - Bonding
    - Isolation of Cables
    - Location
    - Grounding

Questions?

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WORKSHOP ERRATA

Workshop Errata

Authority Having Jurisdiction
Training
Unlisted Equipment
Hazard Categorization

Define Temporary & Qualified
Handbook should written for R&D Audience
R&D Does Not Need Chapters 1-8 due to codes redundancy
Chapter 9 needs detail to improve grounding, portable carts, PPE and Flash Hazard Analyses
Define Electrical Work Tasks & Variations From NFPA 70E
Qualification of R&D Workers
Skill of The Craft
Access Control
Lightning Protection
Fiber Optics
Uniformity in Reporting
Sharing Knowledge
DOE Lessons Learned
Inter-lab Training
Equipment Design
Equipment Approval
Reciprocity
Problems with Listed Equipment
Reputable Manufactures
Working Abroad
Protective Devices
Utility/Facility/R&D Electrical
Unlisted Equipment
NEC/R&D
Processes
Foreign Equipment Labeling Marking
Hazard Classification
Proscriptive Examples for High Voltage etc
Color Codes
Mixed Hazards
Standardization
Redundancy of Safety Systems
Interlocks
EML/EMI
Coaxial Cables
Alternate Grounding Methods
Documentation

In-house Equipment
Failure Recovery
Define AHJ
R&D Community
Leadership
Communication
EFCOG
Topical Committees
Landlord/Tenants
5480.19

Results of March 1, 2004 Kickoff Session
On the DOE E. S. Handbook Chapters 9 & 10

Discussion and Review
March 3, 2004

A. General Comments

1 History of the DOE ES Handbook.
2 Why the Handbook should be revised.
3 Chapters 3-8 have substantial redundancy to NEC and OSHA.
4 Some labs use the Handbook extensively; others do not.
5 More on unlisted electrical equipment approval is desired.
6 Application of NFPA 70E to the R&D lab.
7 The Department of **Energy** should be more involved in setting safety standards for electrical energy – utilities, facilities, R&D.
8 More on AHJs.
9 Sharing, communicating.
10 Alternate grounding methods for R&D.
11 Standardization, with deviations allowed, for equipment design, construction, and approval.
12 Dealing with foreign-made electrical equipment.
13 Working overseas with electrical equipment.
14 Many new items on definitions.
15 Define how the ES Handbook is expected to be used.
16 Chapters 9 and especially 10 are unique.
17 Is the audience for the Handbook primarily the R&D community?

Results of March 1, 2004 Kickoff Session On the DOE E. S. Handbook Chapters 9 & 10

Discussion and Review March 3, 2004

B. Proposed New Items for the Handbook - Rank Ordered (Votes)

1 Unlisted electrical equipment approval (7)
2 Definitions and Acronyms (6)
3 Qualifications to do R&D electrical work (5)
4 Standards for design of electrical equipment (4)
5 Alternate grounding methods for R&D (3)
6 Communications, Lesson Learned, EFCOG, Equipment Approval and Disapproval Database(s) (3)
7 Eliminate redundant material in the Handbook that is covered elsewhere, e.g. NEC and OSHA (3)
8 Add specific descriptions and hazards of more high voltage systems (2)
9 Define R&D Work Tasks, hazard levels, and PPE, for inclusion in addendum table, in the style of NFPA 70E (2)
10 Describe Documentation for uniformity of style (2)
11 Describe how to do arc-flash hazard analysis (2)
12 Include Training Plan standards for electrical workers (2)
13 Include universal electrical hazard classification (1)
14 Add fiber optics as method to control EMI and eliminate concerns about improper grounding and bonding (1)
15 Describe universal electrical incident reporting (1)
16 Lightning Protection (1)
17 Much more on the AHJ (1)
18 Standardization of Connectors, especially HV (1)
19 Define Skill of Craft and how it should be used (1)
20 Working Abroad with electrical equipment (1)

Useful Electrical Safety Web Sites

<u>LANL</u>
LANL Electrical Safety
http://int.lanl.gov/safety/esc/index.shtml
ESH-13 Registration for Ele:trical Safety Classes
http://eshtraining.lanl.gov/pls/ ;encouraxs/cour_by_topic?Cat=Safety&course_topic=Electric.il
LANL Electrical Equipment Database
https://remedyw1.lanl.gov/Remedy/Apps/ESO/ESOHome.htm

<u>DOE</u>
DOE Electrical Safety Program
http://tis.eh.doe.gov/whs/electrical/
DOE Electrical Safety Hanı'book (clicking on this will download the DOE manual, ȷ 1f format)
http://tis.eh.doe.gov/techstds/ ʻandard/hdbk1092/hdbk1092.pdf

<u>OSHA</u>
OSHA - home page
http://www.osha.gov/index.html
OSHA - NRTLs
http://www.osha.gov/dts/otpca/nrtl/index.html
OSHA – 29 CFR 1910.269 – Electrical Power Generation, Transmission, and Distribution
http://www.osha-slc.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9868
OSHA - 29 CFR 1910 Subpart S - Electrical General
http://www.osha-slc.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10135

<u>Codes and Standards</u>
National Fire Protection Association (NFPA)
http://www.nfpa.org/
National Electrical Manufacturer's Association (NEMA)
http://www.nema.org/
IEEE Standards
http://standards.ieee.org/
American National Standards Institute (ANSI)
http://www.ansi.org/
Instrument Society of America
http://www.isa.org
American Society for Testing and Materials (ASTM)
http://www.astm.org

<u>NRTLs</u>
Underwriters Laboratories Inc.
http://www.ul.com/
Factory Mutual
http://www.fmglobal.com/research_standard_testing/index.html
Intertek Testing Services (ITS)
http://www.etlsemko.com/
TUV Rheinland of North America
http://www.us.tuv.com/welcome.html
CSA International
http://www.csa-international.org/default.asp?language=english

<u>Nationally Recognized NEC Experts (excellent books available)</u>
Mike Holt
http://www.mikeholt.com/
James Stallcup'
http://www.grayboyassociates.com

<u>Other Electrical Safety Links</u>
The Safety Link
http://www.safetylink.com/
European Electrical Standards
http://www.iec.ch

<u>Electrical Safety Products</u>
Aldan Industries
http://www.aldanonline.com/

<u>Lightning Safety</u>
National Lightning Safety Institute
http://www.lightningsafety.com/
Lightning Technologies, Inc.
http://www.lightningtech.com/intro.html
Research at Langmuir Laboratories
http://bat.nmt.edu/

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NSCL = National Superconducting Cyclotron Laboratory
LANL = Los Alamos National Laboratory
SNL = Sandia National Laboratory
LBNL = E.O. Lawrence Berkeley National Laboratory
SNS = Spallation Neutron Source
ORNL = Oak Ridge National Laboratory
INEEL = Idaho National Engineering Laboratory
SRTC = Savannah River Technology Center
Pantex
BN NTS = Bechtal Nevada, Nevada Test Site
DOE Oakland

END