



INTRODUCTION TO ELECTRICAL SAFETY

Introduction

- An average of one worker is electrocuted on the job every day
- There are four main types of electrical injuries:
 - Electrocution (death due to electrical shock)
 - Electrical shock
 - Burns - Falls



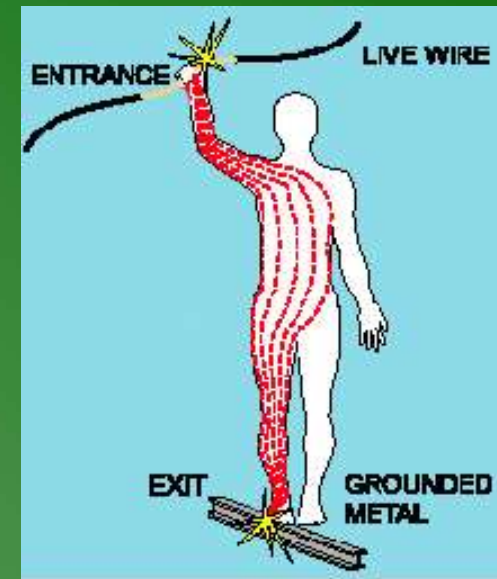
High voltage electrical burn, immediately after (left) and 8 days after (right).
Sandzen, Atlas of Acute Hand Injuries, 1980.

Electrical Terminology

- **Current** – the movement of electrical charge
- **Resistance** – opposition to current flow
- **Voltage** – a measure of electrical force
- **Conductors** – substances, such as metals, that have little resistance to electricity
- **Insulators** – substances, such as wood, rubber, glass, and bakelite, that have high resistance to electricity
- **Grounding** – a conductive connection to the earth which acts as a protective measure

Electrical Shock

- Received when current passes through the body
- Severity of the shock depends on:
 - Path of current through the body
 - Amount of current flowing through the body
 - Length of time the body is in the circuit
- **LOW VOLTAGE DOES NOT MEAN LOW HAZARD**



Dangers of Electrical Shock

- Currents greater than 75 mA* can cause ventricular fibrillation (rapid, ineffective heartbeat)
- Will cause death in a few minutes unless a defibrillator is used
- 75 mA is not much current – a small power drill uses 30 times as much



Defibrillator in use

* mA = milliampere = 1/1,000 of an ampere

How is an electrical shock received?

- When two wires have different potential differences (voltages), current will flow if they are connected together
 - In most household wiring, the black wires are at 110 volts relative to ground
 - The white wires are at zero volts because they are connected to ground
- If you come into contact with an energized (live) black wire, and you are also in contact with the white grounded wire, current will pass through your body and **YOU WILL RECEIVE A SHOCK**

How is an electrical shock received?

(cont'd)

- If you are in contact with an energized wire or any energized electrical component, and also with any grounded object, YOU WILL RECEIVE A SHOCK



- You can even receive a shock when you are not in contact with a ground
 - If you contact both wires of a 240-volt cable, YOU WILL RECEIVE A SHOCK and possibly be electrocuted

Electrical Burns & Arc Flashes

- Most common shock-related, nonfatal injury
- Occurs when you touch electrical wiring or equipment that is improperly used or maintained
- Typically occurs on the hands
- Very serious injury that needs immediate attention



Electrical Hazards - ARC FLASH

- **An arc flash is the energy released as a result of an arcing.**
- **ARC FLASH INJURIES:**
 - **FLASH BURNS**
 - **BURNS from CLOTHING**
 - **BLAST SHRAPNEL**
 - **BLAST PRESSURE**
 - **HEARING LOSS**



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Falls

- Electric shock can also cause indirect or secondary injuries
- Workers in elevated locations who experience a shock can fall, resulting in serious injury or death



Electrical Standards

Standards broken down into 2 groups:

- Design safety standards for electrical systems- 29 CFR 1910.302-308
- Safety-related work practices 29 CFR 1910.331-335
- Definitions applicable are found in 29 CFR 1910.339

Basic Electrical 1910.302-308

:

Design safety standards for electrical systems.

Standards found in 1910.302-308 are design safety standards for electric utilization of all electric equipment used to provide electric power and light for employee workplaces.

Basic Electrical 1910. 331-335

Safety - related work practices.

These regulations are contained in 1910.331-.335 and require the employer to train and equip designated employees to maintain facility's electrical equipment.

Basic Electrical 1910. 301-305

Definitions applicable are found in 1910.399

This standard is used to define common terms used in the electric industry and NEC. It includes the classes of hazardous locations.

Basic Electrical 1910. 302

Practical Safeguarding of employees

Electric utilization systems

- Scope- Covered electrical installations and utilization equipment installed on or used within or on buildings, structures, and other premises.

Basic Electrical 1910. 303

Practical Safeguarding of employees

Design safety standards for electrical systems.

a) Use only approved equipment
(Listed NRTL)

- **1910.303(a) Approval**

– All electrical conductors and equipment shall be approved.



1910.303(a)
NEC Article 110-2

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Basic Electrical 1910. 303

Practical Safeguarding of employees

Examination, installation, and use of equipment

- b) Examination - Electrical equipment shall be free from recognized hazards that are likely to cause death or serious physical harm to employees
 - Suitability for installation

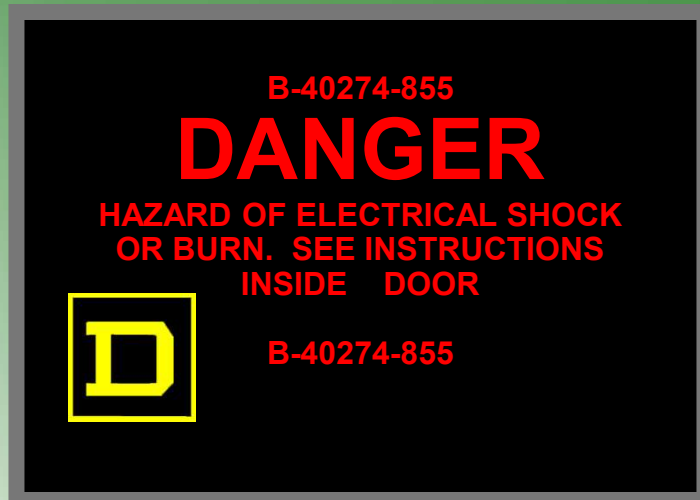


Basic Electrical 1910. 303

Practical Safeguarding of employees

(2) Installation and use

- c) Splices
- d) Arcing parts shall be enclosed
- e) Marking
- f) Identification of disconnecting means



Basic Electrical 1910. 303

Practical Safeguarding of employees

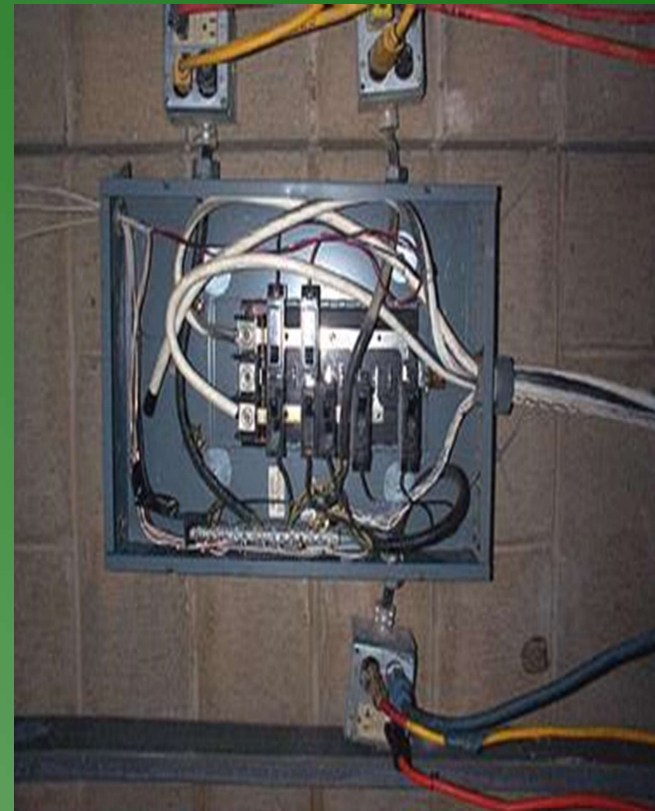
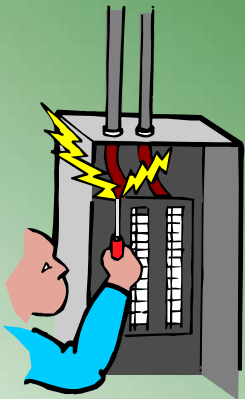
Design safety standards for electrical systems.

g) 600 Volts or less

Working clearances (>3 feet)

(2) Guarding of live parts >50 volts by:

- * Approved cabinets
- * Room or vault
- * Partitions or locations
- * Elevations of 8 feet or more



Basic Electrical 1910. 303

Practical Safeguarding of employees

(h) 600 Volts or More clearances (>3 feet)

(2) Guarding of live parts by enclosures:

- * Approved 8 foot fence area
- * Room or vault with lock & key
- * Accessible to qualified personnel only

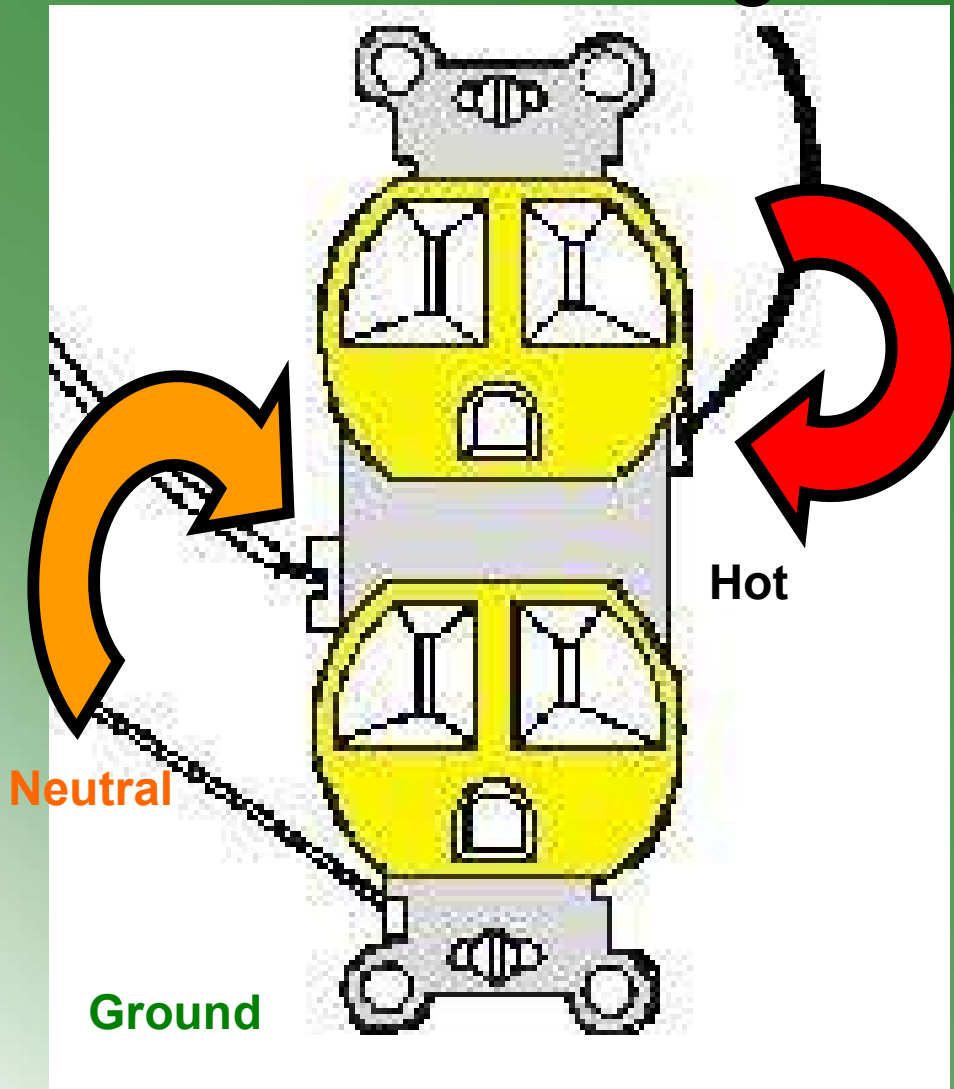
Basic Electrical 1910. 304

Wiring design and protection

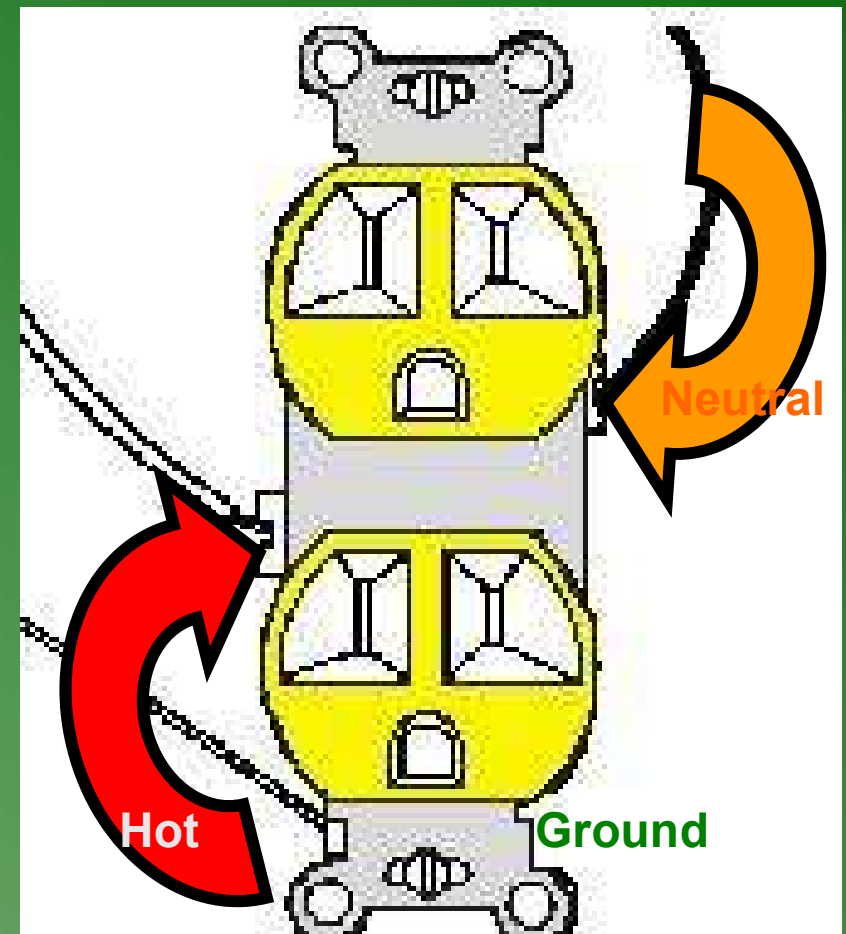
Practical Safeguarding of employees

- a) Use and identification of grounded and grounding conductors.
 1. Identification of grounded and grounding conductors
 2. Polarity of connections
 3. Use of grounding terminals and devices

Normal Wiring



1910.304(a)(2) Reverse Polarity



1910.304(a)(2)
NEC Article 200-11

Basic Electrical 1910. 304

Wiring design and protection

Practical Safeguarding of employees

(b) Branch circuits

1. Reserved
2. Outlet devices

(c) Outside conductors \leq 600 volts

2. Clearances of open conductors
 - * 10 feet - above sidewalks
 - * 12 feet - subjected to traffic
 - * 15 feet - Truck traffic



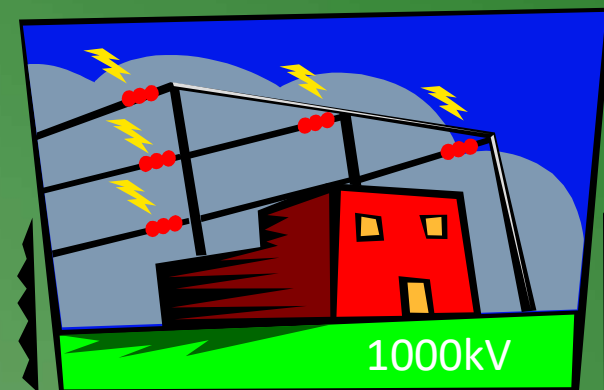
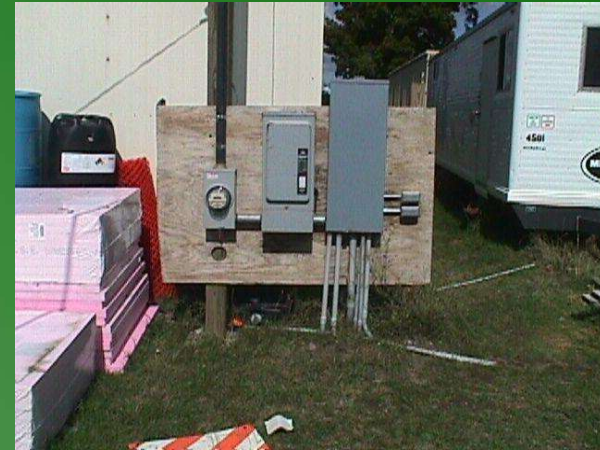
Basic Electrical 1910. 304

Wiring design and protection

Practical Safeguarding of employees

(d) Services

1. Disconnecting means
2. Services over 600 volts
 - * Guarding to allow qualified only
 - * High voltage signs posted



Basic Electrical 1910. 304 Wiring design and protection

Practical Safeguarding of employees

e) Over current protection

1. 600 volts or less
 - * Protection of conductors & equipment
 - * Continuity of grounded conductors
2. Over 600 volts
 - * Short circuit protection



Basic Electrical 1910. 304

Wiring design and protection

- - f) **Grounding**

1. Systems to be grounded

- * All 3 wire DC systems neutral conductor
- * 2 wire DC systems
- * AC circuits of less than 50 volts if.....
- * AC systems of 50-1000 volts

2. Conductors to be grounded

- * For AC premises wiring the identified conductor shall be grounded

Basic Electrical 1910. 304

Wiring design and protection



f) Grounding

3. Grounding connections

* For a grounded system, a grounding electrode conductor shall be used to connect both the equipment grounded conductor and the grounded circuit conductor to the grounded electrode.

4. Grounding path:

* The path to ground from circuits, equipment, and enclosures shall be permanent and continuous.

1910.305(a)(2)(ii)(I)_Flexible cords and cables shall be protected from damage. Sharp corners and projections shall be avoided. Flexible cords and cables may pass through doorways or other pinch points, if protection is provided to avoid damage.



1910.305(b) Cabinets, boxes, and fittings.

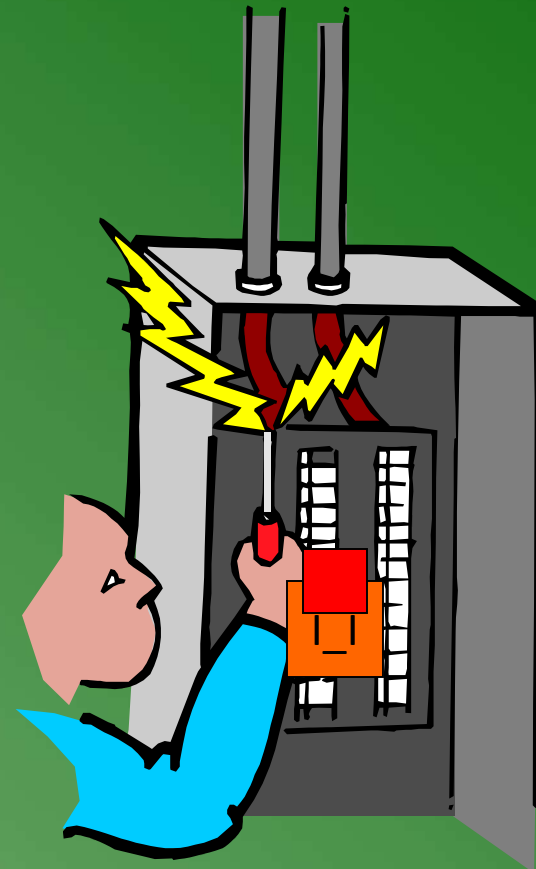
(b)(1) Conductors entering boxes, cabinets, or fittings. Conductors entering boxes, cabinets, or fittings shall be protected from abrasion, and openings through which conductors enter shall be effectively closed.

- **Unused openings in cabinets, boxes, and fittings shall also be effectively closed.**



1910.305(c) Switches

1. Knife switches shall be connected so the blades are dead when the switch is in the open position



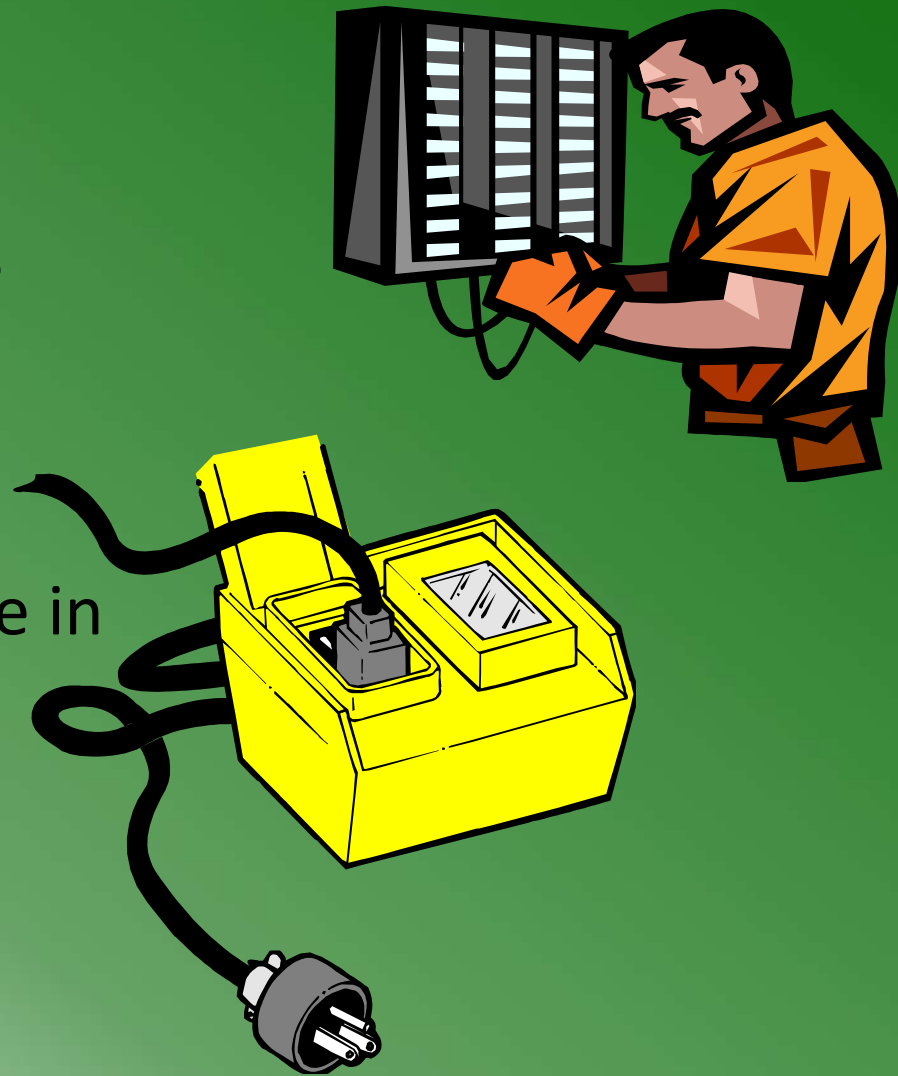
1910.305(d) Switchboards and Panelboards

- Switchboards located in dry areas and assessable to qualified personnel only
- Panelboards shall be mounted in cabinets and have a dead front with no exposed live parts



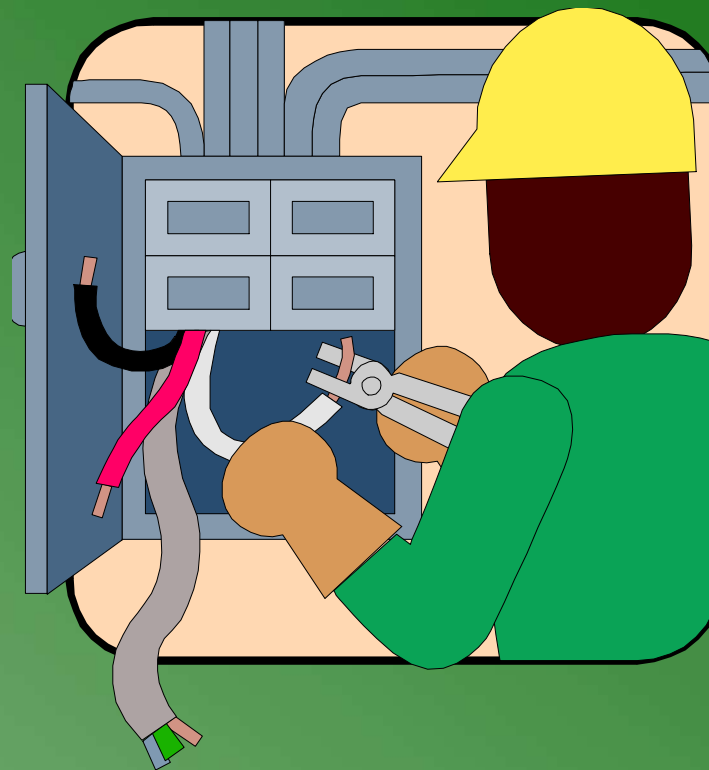
1910.305(e) Enclosures for damp or wet locations

- Cabinets, cutouts boxes, fittings, and panelboards shall be weatherproof
- Switches, circuit breakers, and switchboards shall be in weather proof enclosures



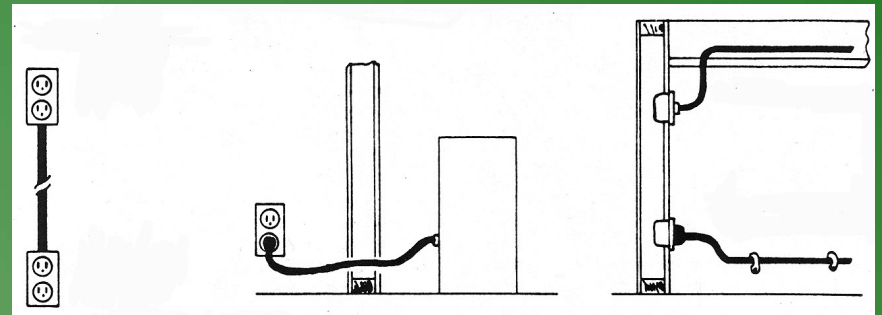
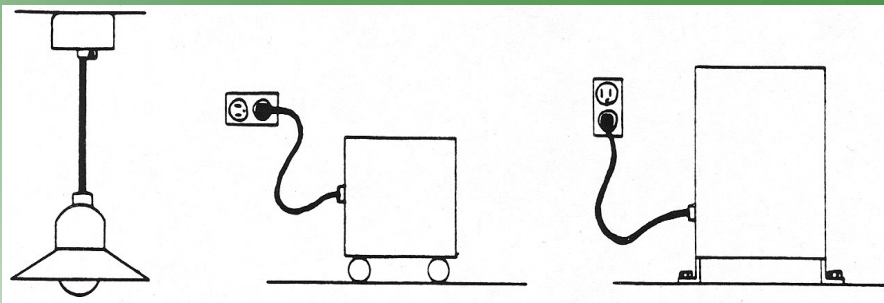
1910.305(f) Conductors for general wiring

- All conductors shall be insulated and approved for the voltage and temperature and distinguishable by color



1910.305(g) Flexible cords and cables

- Shall be approved and suitable for use and conditions
- Shall be used for wiring of fixtures, portable lamps, appliances, pendants, etc
- **Shall Not be used as a substitute for fixed wiring**



1910.305(h) Portable cables over 600 volts

- Multiconductor portable cable shall be No. 8 or larger
- Connectors must be the locking type
- Strain relief shall be provided
- If spliced, shall be of the permanent molded, vulcanized type
- High voltage hazard warnings
- Authorized and qualified personnel only allowed in enclosures



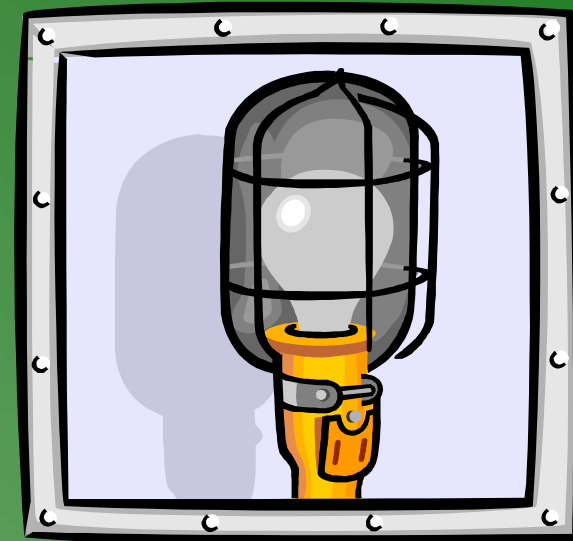
1910.305(i) Fixture wires

- shall be approved for the voltage, temperature and location
- Are permitted for use in enclosed lighting fixtures not subjected to bending or twisting
- Are used for connecting lighting fixtures to the branch- circuit



1910.305(j) Equipment for general use

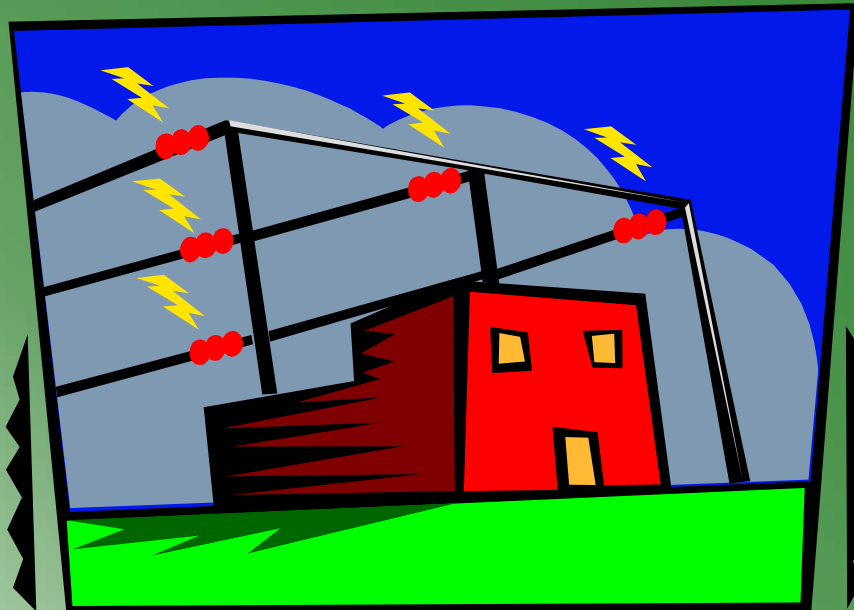
- Lighting fixtures, lampholders, lamps and receptacles shall have no live parts exposed
- Portable handlamps shall have a substantial bulb guard and if used in wet locations shall be approved as such
- Receptacles and cord connectors shall be compatible for the voltage rating
- Receptacles installed in wet or damp locations shall be approved for use



Electrical Safety-related Work Practices

1910.331-335

A performance standard



Electrical Safety-Related Work Practices

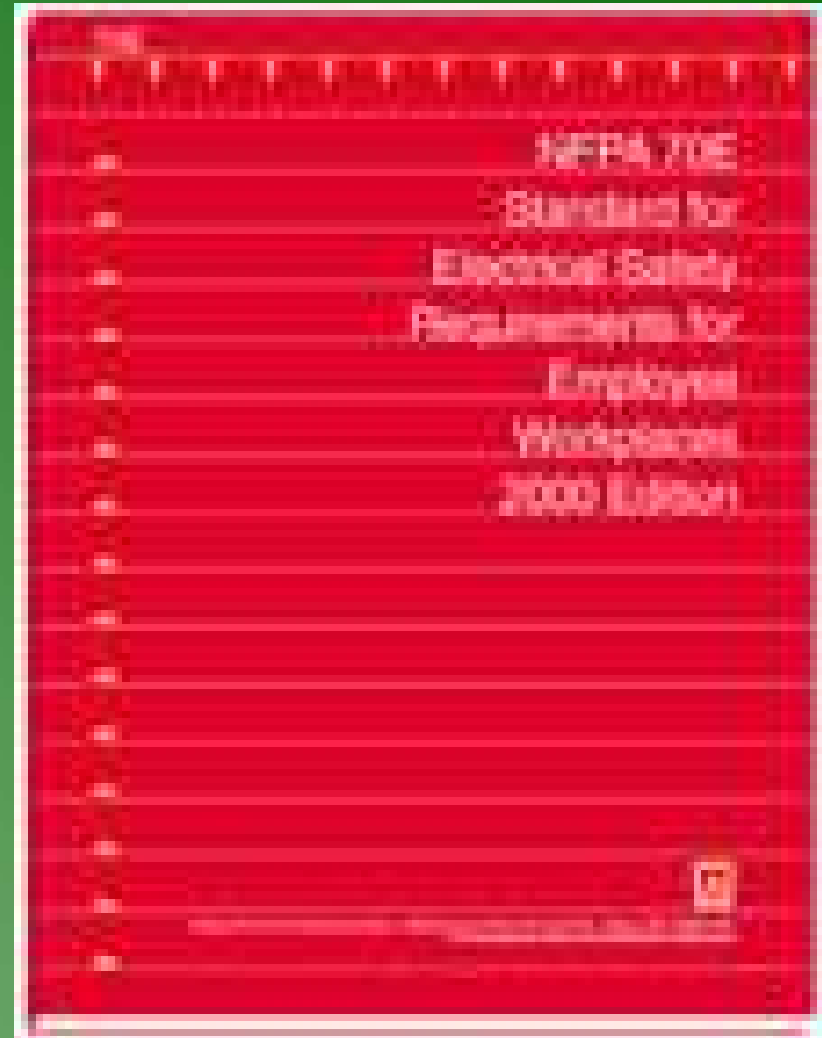
1910.331 - 335

Based in part on

NFPA 70 E

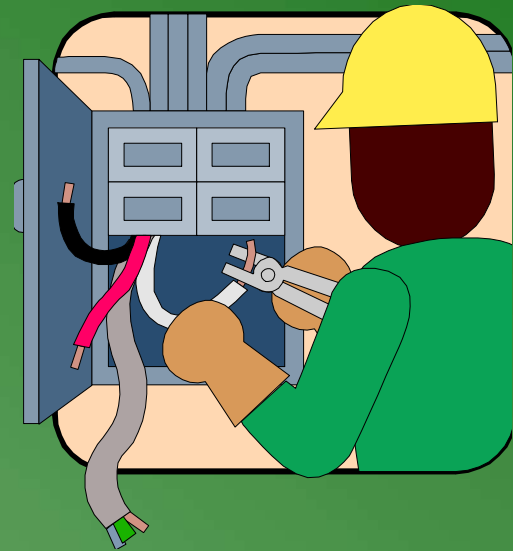
*–National consensus standard and a
“Standard for Electrical Safety in the
Workplace”*

*– and is a part of the National Electrical
Code and has been adopted by OSHA as an
enforcement standard.*



Scope

- 1910.331-335 covers electrical safety-related work practices for both:
 - Qualified and
 - Unqualified persons.



Training for Qualified Worker

1910.332(a) Scope

The training requirements contained in this section apply to employees who face a risk of electric shock that is not reduced to a safe level

THE TRAINING REQUIREMENTS CONTAINED IN THIS SECTION APPLY TO EMPLOYEES WHO FACE A RISK OF ELECTRIC SHOCK THAT IS NOT REDUCED TO A SAFE LEVEL BY THE ELECTRICAL INSTALLATION REQUIREMENTS OF 1910.303 THROUGH 1910.308

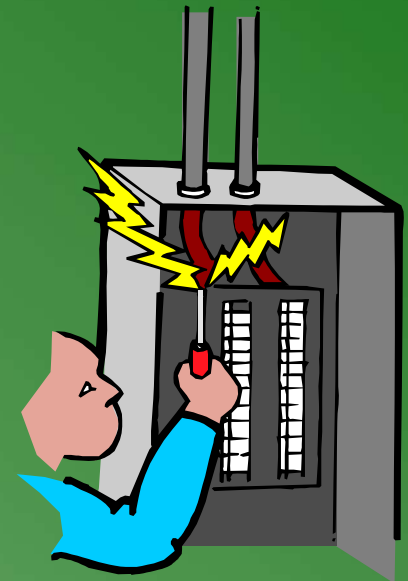
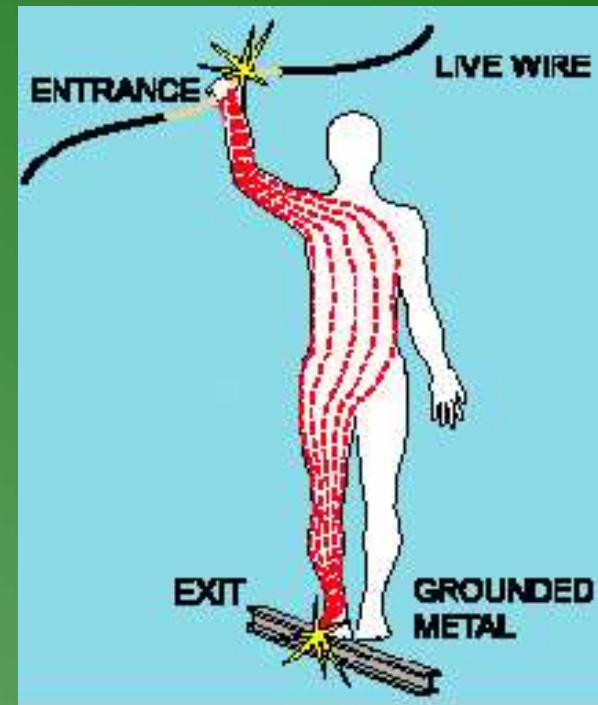


Table S-4

Examples of workers who face increased risk of electric shock includes:

- Blue collar supervisors
- Electrical engineers
- Stationary engineers
- Machine operators
- Tree climbers
- Painters
- Welders
- Material handling equipment operators



Content of Training

All employees shall be trained in and familiar with the safety-related work practices required by .331-.335 that pertain to their respective job assignments.



Content of Training

Qualified persons permitted to work on or near exposed parts shall be trained in and familiar with the following:

- i. **Skills necessary to distinguish exposed live parts from other electrical parts**
- ii. **Be able to determine nominal voltage**
- iii. **The clearance distances specified in 333(c) and the corresponding voltages**

Selection and Use of Work Practices

Consistent with the nature and extent of associated electrical hazards

- Live parts shall be de-energized before the employee works on or near them unless the employer can prove a greater hazard or infeasible
- < 50 volts to ground exempt

Energised Parts-Qualified Person

- If exposed live parts are not de-energized:
 - Other safety-related work practices shall be used to protect employees
 - Work practice shall be suitable for the work conditions and voltages of the exposed electrical conductors
 - Conductors deenergized are required to be locked out or tagged
 - If not LOTO then considered to be energized Lockout and tagging requirements are specified
 - Verification of de-energized condition by qualified person (Live-Dead-Live) They shall be capable of working safely using Proper PPE, tool and insulating materials

Work By Qualified Person

- (1) Work on Energized Equipment
- (2) Capable of working Live & Familiar with techniques, PPE, insulating/shielding materials, insulated tools
- (3) Overhead Lines - MAD (see.332)
- (4) Illumination - & No Blind Reaching
- (5) Enclosed spaces /vaults/manholes
- (6) Conductive Materials & Equipment
- (7) Portable Ladders - Nonconductive
- (8) Conductive Apparel
 - No watches, rings, jewelry..
- (9) Housekeeping - No steel wool or conductive liquid



Use of portable equipment

- (1) Handling cords shall not cause damage
- (2) Visual inspection for defects
- (3) Extension cords shall be grounded unless used with double insulated tools.
- (4) Wet locations require approved equipment.
- (5) Don't plug / unplug with wet hands.
- (6) Twist lock connectors must be locked before use.



Qualified Persons

1910.334(c)

- (1) Test Instruments - Qualified persons only
- (2) Visual inspection before use
- (3) Proper Rating of Equipment

Electrical Protective Equipment

PERSONAL PROTECTION

Qualified Persons & Protective Equipment

- Employees working in areas where there are electrical hazards shall use electrical PPE.

PPE - Subpart I .132 - .138

- Electrical Protective Equipment - ASTM
- Textile Clothing - NFPA 70E & ASTM F1506
 - Conduct Arc Flash Analysis-
 - Arc Thermal Performance Value
 - Heat Attenuation Factor

Personal Protective Equipment

- **Protective Clothing (non melting)**
 - **hazard / risk category to PPE** page 70E-34
 - 0 untreated cotton ATPV n/a
 - 1 FR shirt and FR pants ATPV 4 cal/cm²
 - 2 cotton underwear plus FR shirt and FR pants ATPV 8 cal/cm²
 - 3 cotton underwear plus FR shirt and FR pants plus FR coverall ATPV 25 cal/cm²
 - 4 cotton underwear plus FR shirt and FR pants plus double layer switching coat and pants ATPV 40 cal/cm².
 - » ATPV=arc thermal performance value
 - » Cal/cm². (Calories per Sq. Centimeter)

NFPA 70E – Hazard Risk 0

0-untreated cotton ATPV n/a

- **This hazard risk category poses minimal risk. Some examples of tasks in this category are tasks that involve:**
 - **Circuit breaker or fused switch operation with covers on when working with Panel boards rated 240 V and below.**
 - **Contactor operation with enclosure doors closed when working with NEMA E2 (fused contactor) Motor Starters, 2.3 kV through 7.2 kV.**

NFPA 70E – Hazard Risk 1

1-FR shirt and FR pants ATPV 4 cal/cm²

- **This hazard risk category poses some risk. Some examples of tasks in this category are tasks that involve:**
 - **Circuit breaker or fused switch operation with covers off when working with Panel boards rated 240 V and below.**
 - **Opening hinged covers (to expose bare, energized parts) when working with "Other 600 V Class (277 V through 600 V, nominal) Equipment.**

NFPA 70E – Hazard Risk 2

**2-cotton underwear plus FR shirt and FR pants
ATPV 8 cal/cm²**

- **This hazard risk category involves tasks that pose a moderate risk. Some examples of tasks in this category are tasks that involve:**
 - **Circuit breaker or fused switch operation with enclosure doors closed when working with 600 V Class Motor Control Centers (MCCs).**
 - **Work on control circuits with energized parts 120 V or below, exposed when working on Metal Clad Switchgear, 1 kV and above.**

NFPA 70E – Hazard Risk 3

3-cotton underwear plus FR shirt and FR pants plus FR coverall ATPV 25 cal/cm²

- **This hazard risk category involves tasks that pose a high risk. Some examples of tasks in this category are tasks that involve:**
 - **Insertion or removal of circuit breakers from cubicles, doors open, when working with 600 V Class Switchgear (with power circuit breakers or fused switches).**
 - **Opening hinged covers (to expose bare, energized parts) when working with "Metal Clad Switchgear, 1 kV and above.**

NFPA 70E – Hazard Risk 4

4-cotton underwear plus FR shirt and FR pants plus double layer switching coat and pants ATPV 40 cal/cm²

- This hazard risk category represents tasks that pose the greatest risk. Some examples of tasks in this category are tasks that involve:
 - Removal of bolted covers (to expose bare, energized parts) when working with NEMA E2 (fused contactor) Motor Starters, 2.3 kV through 7.2 kV.
 - Opening voltage transformer or control power transformer compartments when working with Metal Clad Switchgear, 1kV and above.

Personal Protective Equipment

- **Face shields are available that are listed with ATPV ratings from many manufactures... Do not use general duty face shield.**
 - **always wear safety glasses under face shields**
 - **always wear a hard hat**
 - **hearing protection is recommended**
 - **protective hoods or parkas should be worn in conjunction with shields and hard hats**

Personal Protective Equipment

- **Voltage rated gloves**
 - **gloves rated for the proper voltage shall be worn when called for**
 - **leather protectors shall be worn over gloves**
 - ✓ **gloves must be inspected every 6 month by qualified lab**

Personal Protective Equipment

- **Gloves rated by voltage**

- » **Class 00 = 500 volts max**
- » **Class 0 = 1000 volts max**
- » **Class 1 = 10 kV max**
- » **Class 2 = 20 kV max**

- **Shoes**

- **Heavy-duty leather work shoes shall be used for all tasks when ATPV is 5 cal/cm² and above.**

- **insulating soles are recommended**
- **overshoes or dielectric boots are recommended.**

Personal Protective Equipment

- **Voltage rated tools**
 - shall be rated for the voltage on which they are used
 - shall be double insulated
 - built to ATSM F1505 standards(double triangle marking)
 - many tool are available in composite construction
 - rated at 1000 volts, tested to 10,000 volts
 - » 3M 33+ wrapped tool is not an insulated tool
 - tool must be inspected before each use

- **Creating an Electrical Safety Program-OSHA**

29CFR1910.333(a) General. Safety-related work practices shall be employed to prevent electric shock or other injuries resulting from either direct or interact contacts, when work is performed near or on equipment or circuits which are or may be energized. The specific safety-related work practices shall be consistent with the nature and extent of the associated electrical hazards.

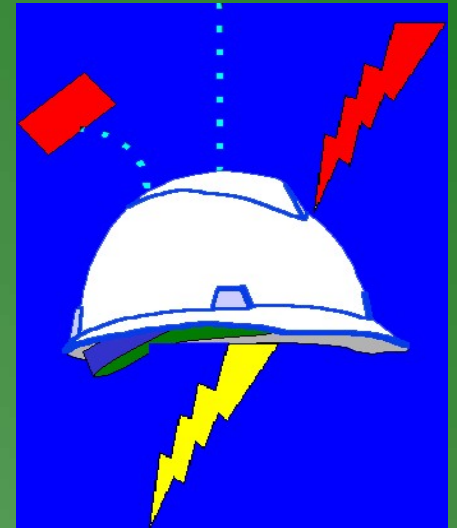
Personal Protective Equipment

- NFPA 70E 130-7(a) General (who's responsible)
“Employees working in areas where there are electrical hazards shall be provided with, and shall use, protective equipment that is designed and constructed for the specific part of the body to be protected and for the work to be performed”
- OSHA 1910.335 Safeguards for personal protection:
(a) use of protective equipment. (1) Personal protective equipment. Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed.

Electrical Protective Equipment PERSONAL PROTECTION

Electrical Protective Equipment

- (ii) Maintained & Periodically tested
- (iii) Protect the insulating capability against damage
- (iv) Nonconductive head protection
- (v) Face & Eye protection for Arc Blast



Electrical Protective Equipment

PERSONAL PROTECTION

Electrical Gloves

- (ii) Daily inspection & Inflation test
 - (A) Hole tear puncture or cut
 - (B) Ozone cutting, ozone checking
 - (C) Embedded foreign object
 - (D) Texture changes - swelling, softening, hardening, sticky or inelastic
 - (E) any other defect that damages insulating properties

Qualified Workers

.335 (a)(2) General PPE - and Tools

(2) (i) Shall use insulated tools & handling equipment

ASTM 1505 Insulated Tools



(A) Fuse pullers

(B) Nonconductive rope

(ii) Protective shields & barriers

1910.335

SAFEGUARDS FOR PERSONAL PROTECTION

ALERTING TECHNIQUES:

- (1) Signs
- (2) Barricades
- (3) Attendants



Summary

Hazards

- Inadequate wiring
- Exposed electrical parts
- Wires with bad insulation
- Ungrounded electrical systems and tools
- Overloaded circuits
- Damaged power tools and equipment
- Using the wrong PPE and tools
- Overhead powerlines
- All hazards are made worse in wet conditions

Protective Measures

- Proper grounding
- Using GFCI's
- Using fuses and circuit breakers
- Guarding live parts
- Proper use of flexible cords
- Training