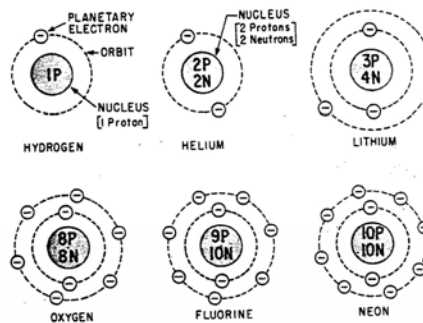


Electrical Safety Subpart S



Electrical Standards Fundamentals

- **Electricity is best described as the flow of electrons**
 - **Electrons tend to seek a balanced state**
 - **As electrons move from one orbit to another they release energy**



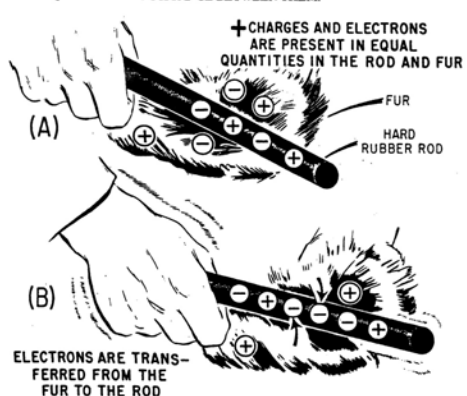
Electrical Standards
Fundamentals

- **Electrons seek a balanced state**
- **Electricity seeks the easiest path to common ground**
- **Lightning strikes**
 - **Electrons build up in clouds**
 - **Discharge to earth**
 - **(Or other way around, depending on the theory you subscribe to....)**



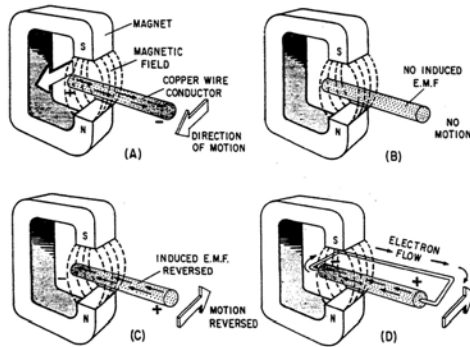
Electrical Standards
Fundamentals

- **Static Electricity can be made easily**
- **Usually low voltage**



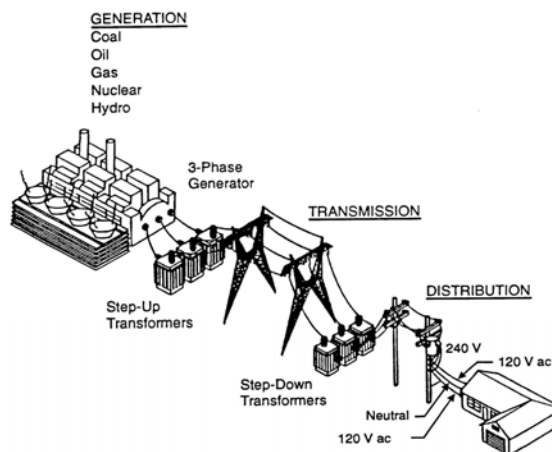
Electrical Standards
Fundamentals

- **Using magnetic fields allows us to create electricity simply by moving or rotating metals**



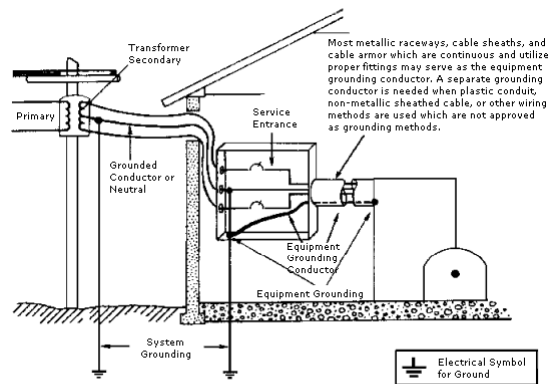
Electrical Standards
Fundamentals

- **Power is transmitted to our buildings through a power grid**



Electrical Standards Fundamentals

- **Grounding is built into delivery systems**



SYSTEM AND EQUIPMENT GROUNDING

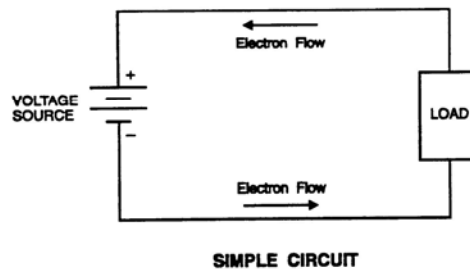
Electrical Standards Fundamentals

- **Any material that allows electrons to flow through it is called a conductor.**
 - Usually contains many free electrons
 - Metal and water a conductors
 - Gold, silver, aluminum and copper are good conductors
 - Earth, concrete, human body are fair conductors
 - Non-metallic material, wood rubber, glass are insulators



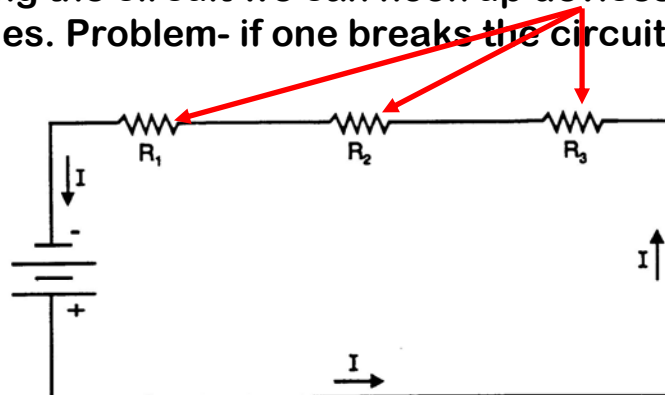
Electrical Standards
Fundamentals

- In order for electricity to “flow” it must have a complete path for the electrons to follow
- We call this a circuit



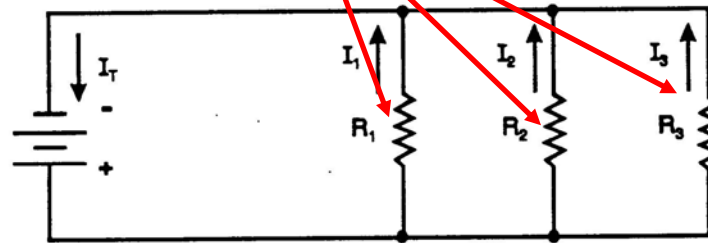
Electrical Standards
Fundamentals

- Along the circuit we can hook up devices in a series. Problem- if one breaks the circuit...



Electrical Standards Fundamentals

- We can hook up devices in a parallel circuit.



PARALLEL CIRCUIT

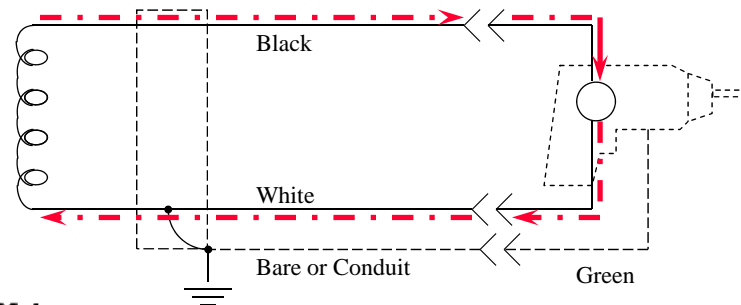


Electrical Safety Grounds



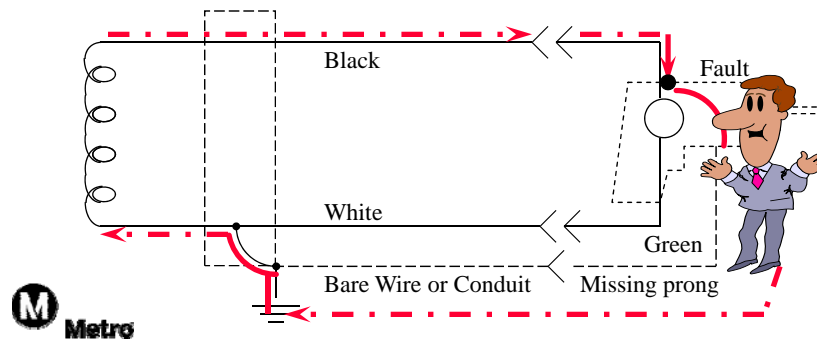
Normal current carrying loop

Ground not used



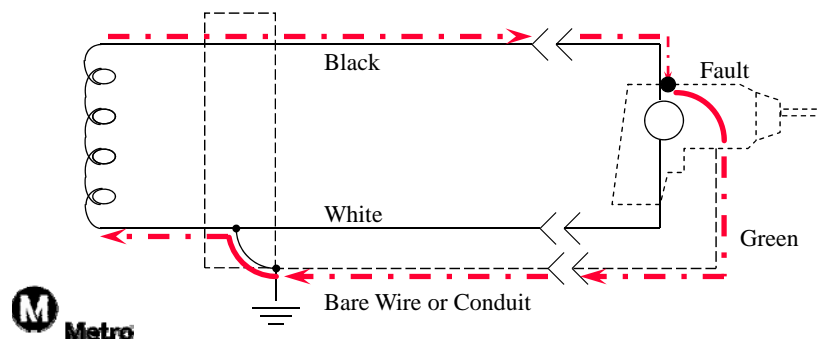
Electrical Safety Missing Prong?

Body may provide path back to source
Ground fault current low - no breaker tripped



Electrical Safety Effective Grounding

Prevents voltage flow to surroundings
Provides path for fault or overload current



Electrical Standards Fundamentals

• Voltage

- Unit of measure for the electromotive force (EMF) of electrons moving through a conductor.
- Symbol is the letter E
- Measured with a voltmeter



Electrical Standards Fundamentals

• Current

- Electrons move as a result of a potential difference existing between points that could bring them to a neutral state.
- Measuring the flow past a given point is the current
- Measured in Amperes
- Symbol is the letter A
- Measured by an ammeter



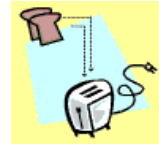
Electrical Standards Fundamentals

- **Resistance**

- **Opposition to moving electrons is called resistance.**

- **Resistance**

- **creates heat,**
 - **controls the flow of current and**
 - **supplies correct voltage to a device**



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 Standards Fundamentals

- **Resistance Depends On The:**
 - **Material the conductor is made of**
 - **Length of the conductor**
 - **Cross-sectional area**
 - **Temperature of the conductor**



Electrical Standards Fundamentals

1. MATERIAL

In decreasing value of resistance:

- Iron
- Aluminum
- Copper
- Silver

2. LENGTH

The longer the conductor, the greater the resistance



3. CROSS-SECTIONAL AREA

The smaller the cross-sectional area, the greater the resistance

- LESS RESISTANCE
- MORE RESISTANCE

4. TEMPERATURE



For metals - generally, the higher the temperature, the greater the resistance

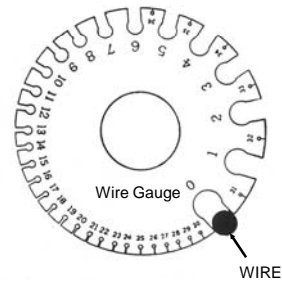
For non-metals - usually the reverse!



Electrical Standards

Fundamentals

- **Wire Gauge is standardized**
- **Using a tool/extension cord that has a wire too small for can create a hazard**
 - The tool will draw more current than the cord can handle, causing overheating without tripping the circuit breaker
 - The circuit breaker could be the right size for the circuit but not for the smaller-wire extension cord



Wire gauge measures wires ranging in size from number 36 to 0 American wire gauge (AWG)



Electrical Standards

Fundamentals

- **Larger wires can carry more current**
- **Measured in amps**



Wires come in different sizes. The maximum current each size can conduct safely is shown.



OHM's LAW

- **Discovered in 1827 by George S. Ohm**
- **There is a relationship between:**
 - **Current**
 - **Voltage**
 - **Resistance**
 - **Voltage =**
 - **Current multiplied by Resistance**



OHM's LAW

- **Voltage =**
 - **Current multiplied by Resistance**
- **E(volts) =**
 - **I(amps) R(ohms)**
- **E = IR**

$$E = I R$$

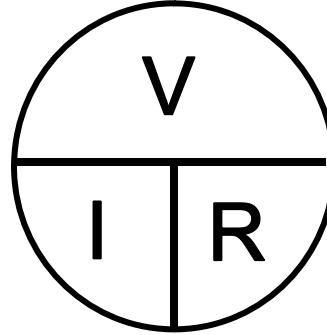
**If the current is 5
amps and the
cable has 20 ohms
of resistance,
what is the applied
voltage?**



OHM's LAW

Can be Re-arranged

- **Current =**
 - I(amps) = 5
- **Resistance=**
 - R(ohms)=20
- **IR = (5)(20) = 100**
- **Voltage = 100 volts**



$$E = I R \quad R = \frac{E}{I} \quad I = \frac{E}{R}$$



Metro

Electrical Standards

Power company worker electrocuted

ISSAQUAH – A lineman for Puget Sound Energy was electrocuted yesterday when he came in contact with energized overhead equipment, a company spokeswoman said.

The accident occurred around 9:30 a.m. in the 700 block of East Sunset Way, PSE spokeswoman Dorothy Bracker said.

Bracken declined to identify the accident victim, who she said had worked for the power company for 11 years. She said the state Department of Labor and Industries is investigating the accident.



Metro

WYOMING

2 workers electrocuted

RECLUSE — Two construction workers were electrocuted while trying to unload pipe in Campbell County, police said.

The accident occurred Monday when the workers were delivering pipe to a methane-gas pipeline project, said Capt. Ron Stugart of the Campbell County Sheriff's Department.

The workers were using a steel cable from an extension boom of a Caterpillar to help get the pipe off the truck when the cable touched an overhead power line.

- **Overhead Power Lines**
 - Ten feet safety distance
 - De-Energize them!
 - Don't become a statistic!

Electrical Standards

Woman electrocuted while trimming her lawn

CHICAGO — An elementary-school teacher and mother of two was electrocuted while using an electrical trimmer on her lawn when an exposed part of an extension cord touched wet grass, authorities said.

Cecelia Castillo, 45, was found dead by her brother Thursday in her yard, said a spokesman for the Cook County medical examiner.

The extension cord had been repaired with electrical tape, but a piece was exposed.



POWER OUTAGE: Power to 5,900 Seattle customers was knocked out for about two hours yesterday after a crane struck some overhead power lines.

The accident happened about 4 p.m. near Eighth Avenue North and Roy Street, Seattle City Light spokesman Larry Vogel said. The crane operator was not hurt in the accident. Homes and businesses in the Magnolia and Queen Anne neighborhoods were affected, he said. Power was restored shortly after 6 p.m.

"We were very lucky the damage was minimal," Vogel said.

Effects of Electricity On Humans

- **Electrical Accidents**
 - Happen at the speed of light!
 - Are unforgiving



Hazards Of Electricity

- **Shock**
 - Direct (Flow through body)
 - Indirect (Reaction due to shock)
- **Burns (Typically on hands)**
- **Arc-blast**
 - Thermal radiation (Burn)
 - Pressure wave (Ear damage & concussion)
 - Projectiles (Molten metal and other objects)



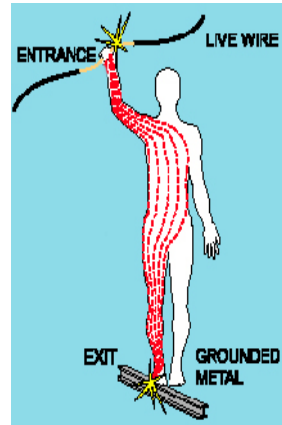
Hazards of Electricity

- **Explosions**
 - Ignition of explosive mixture
 - Precise requirements for such areas
- **Fires**
 - Electricity most common cause of fires
 - Bad connections or repairs create heat



Effects of Electricity On Humans

- 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**



Effects of Electricity On Humans



Arm with third degree burn from high-voltage line.



Effect on Human Body ma=1/1000th of an amp

- 3 ma- painful shock - cause indirect accidents
- 10ma- muscle contraction..."no let go" danger
- 30ma- lung paralysis- usually temporary
- 50ma- possible ventricular fibrillation (heart dysfunction, usually fatal)
- 100 ma- certain ventricular fibrillation, fatal
- 4 amps- heart paralysis, severe burns



Electrical Burns

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



Effect on Human Body

Human Resistance to Electrical Current

<u>Body Area</u>	<u>Resistance (ohms)</u>
Dry Skin	600,000 to 1,000,000
Wet skin	1,000
Internal body-hand to foot	400-600
Ear to Ear	(about) 100

Note: Data is based on limited experimental tests, and is not intended to indicate absolute values.



Effects of Electricity On Humans 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



Effects of Electricity On Humans



- **Underestimating electrical potential can be fatal!**

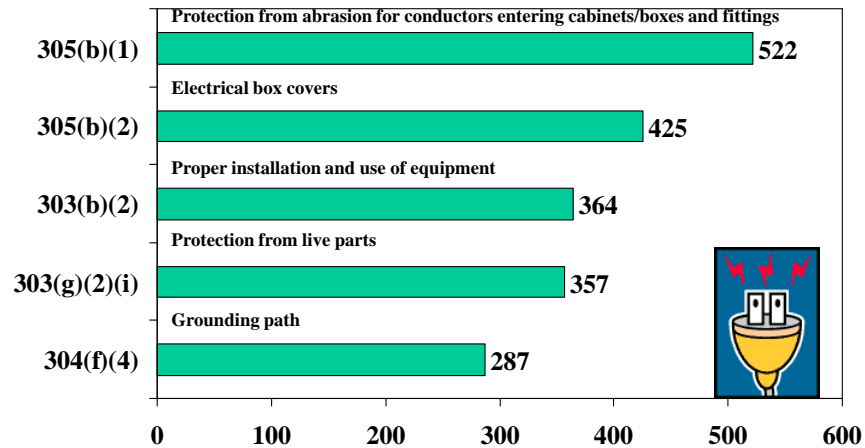


Electrical Safety

- **Live parts operating at 50 volts or more must be guarded.**
- **Bonding, grounding and the speed of interruption permit a circuit to be broken very quickly.**

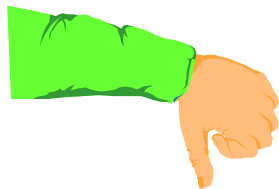


2006 Subpart S 1910.301-309
Electrical

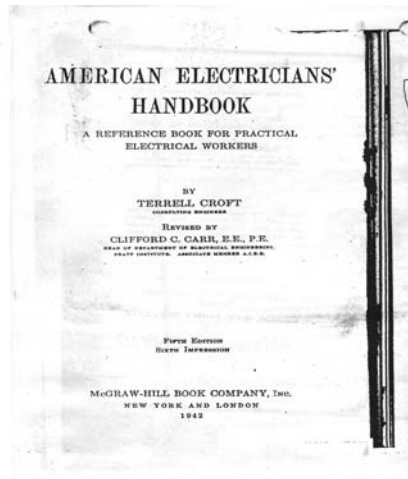


Electrical Safety

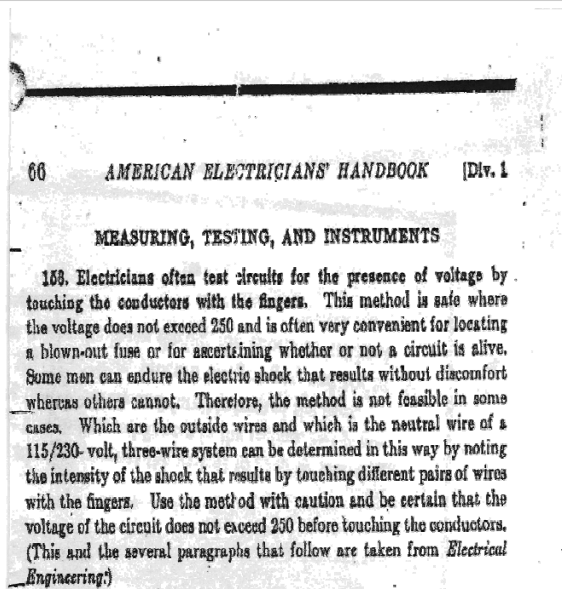
- Employers who use defective electrical wiring will probably be cited if their employees are exposed...
- **whether they created the unsafe electrical condition or not!**



Changing Profession --- Changing Attitudes



Changing Profession --- Changing Attitudes



Changing Profession --- Changing Attitudes

159. The presence of low voltages can be determined by tasting. The method is feasible only where the pressure is but a few volts and hence is used only in bell and signal work. Where the voltage is very low, the bared ends of the conductors constituting the two sides of the circuit are held a short distance apart on the tongue. If voltage is present a peculiar mildly burning sensation results, which will never be forgotten after one has experienced it. The taste is due to the electrolytic decomposition of the liquids on the tongue which produces a salt having a taste. With voltages of 4 or 5 volts, due to as many cells of a battery, it is best to test for the presence of voltage by holding one of the bared conductors in the hand and touching the other to the tongue. Where a terminal of the battery is grounded, often a taste can be detected by standing on moist ground and touching a conductor from the other battery terminal to the tongue. Care should be exercised to prevent the two conductor ends from touching each other at the tongue, for if they do a spark can result that may burn.



Electrical Subpart

- **Subpart S of 1910**
 - Addresses electrical safety requirements for safeguarding employees in the workplace
 - Applies to every electric utilization system designed or installed after March 1972



Electrical Standards

General Requirements

- **(a) Design Safety Standards for Systems**
1910.302-308 – (1910.309-330 future design)
- **(b) Safety-Related Work Practices**
1910.331-360
- **(c) Safety-Related Maintenance Requirements**
1910.361-380
- **(d) Safety Requirements for Special Equipment**
1910.381-398
- **(e) Definitions - 1910.399**



1910.301 Introduction



- **Two main groups:**
- **1. Design safety standards for electrical systems.**
 - Standards found in 1910.302-308 are design safety standards
- **2. 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



Electrical Standards

General Requirements .303

- (a) Only approved conductors & equipment
- (b) Examination, installation & use of equipment
 - (1) Electrical equipment free from recognized hazards likely to cause death/serious physical harm to employees [5(a)(1)]
 - (2) Installation & use - listed labeled equipment used & installed



Electrical Safety

Equipment Examination

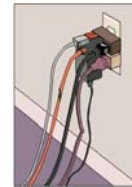
- Free of recognized hazards
- Suitability for purpose
- Mechanical strength/durability
- Electrical insulation
- Heating
- Arcing effects
- Classification by type, size, voltage, capacity



Electrical Safety

Installation and Use

- **Splices** - devices or braze, weld, solder
- **Arcing parts** - enclosed or separated from combustibile materials
- **Marking** - voltage, current, wattage
 - Violent failure or overheat
 - Cause burns and/or fire
- **ID of disconnecting means**
 - Labeling of switches and breakers



1910.303 General Requirements

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

- **1910.303(a) Approval**

– All electrical conductors and equipment shall be approved.



1910.303(a)
NEC Article 110-2



1910.303 (b) Examination, installation and use

- **Employer Obligation:**

- (1) Electrical equipment shall be free from recognized hazards that are likely to cause death or serious physical harm to employees



1910.303 (b) Examination, installation, and use

- (1) Examination. Safety of equipment shall be determined using the following considerations:
 - (i) **Suitability of equipment** for an identified purpose may be evidenced by listing or labeling for that identified purpose



1910.303(d) Arcing parts

- Parts of electric equipment which in ordinary operation produce arcs, sparks, flames, or molten metal shall be enclosed or separated and isolated from all combustible material



1910.303 (e) Marking

- Electrical equipment may not be used unless the manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified is placed on the equipment



1910.303 (e) Marking

- Other markings shall be provided giving voltage, current, wattage, or other ratings as necessary. The marking shall be of sufficient durability to withstand the environment involved



1910.303 (f) Identification of Disconnecting Means and Circuits

- Each disconnecting means (dm) legibly marked to indicate its purpose
 - (Unless so arranged so the purpose is evident)
- A dm is a switch used to disconnect the conductors of a circuit from the source of current

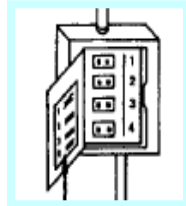


Disconnect switch for
motor number 3



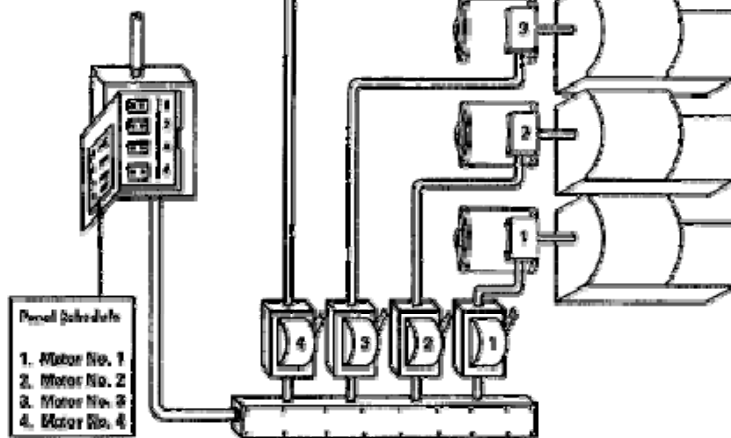
1910.303 (f) Identification of Disconnecting Means and Circuits

- Each service, feeder, and branch circuit, at its origin or overcurrent device, legibly and durably marked to indicate its purpose
- Switches and circuit breakers must be clearly labeled to indicate its circuit's function



Circuit breaker for motors
1,2,3, and 4

Example of properly labeled electric service: motors, disconnects and breakers



1910.303(g) Working Space about Electric Equipment


- (1) Sufficient access and working space around all electrical equipment, provided & maintained to provide ready and safe operation and maintenance
- (ii) Not used  for storage
- (ii) If located in aisle or general open area, working space shall be suitably guarded



TABLE S-1 - WORKING CLEARANCES

Nominal voltage to ground	Minimum clear distance for condition (2)(ft)		
	(a)	(b)	(c)
0-150	(1)3	(1)3	3
151-600	(1)3	3 1/2	4

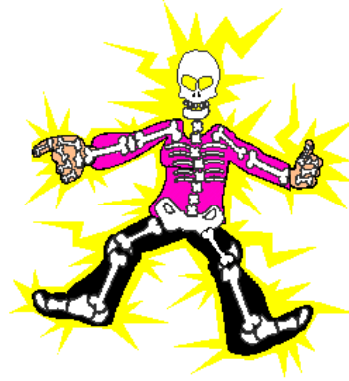
Footnote(1) Minimum clear distances may be 2 feet 6 inches for installations built prior to April 16, 1981.



Electrical Safety

Installation and Use

- **600 Volts, Nominal, or Less**
 - Working clearances
 - Guarding of live parts
- **Over 600 Volts, Nominal**
 - Enclosures
 - Workspace
 - Entrance and access



Electrical Standards

General Requirements .303

- (c) Splicing
 - Conductors joined or spliced by
 - Brazing
 - Welding
 - Soldering
 - Covered by insulation
- (d) Arcing parts shall be enclosed



Electrical Standards
General Requirements .303

(e) Electrical equipment shall be marked:

- Manufacturer's name
- Trademark
- Voltage
- Current
- Wattage
- Durable markings



Electrical Standards
General Requirements .303

• (f) Identification of disconnecting means & circuits for the following shall be legibly marked & durable:

- Motors
- Appliances
- Each service
- Each feeder
- Each branch circuit



Electrical Standards

General Requirements .303

- (g) 600 V or less
 - (1)(i) Working space about electrical equipment (Table S-1)
 - (ii) Clear spaces: working space/no storage
 - (2) Guarding of live parts
 - (i) 50 V or more guarded against accidental contact by:
 - Approved cabinets/enclosures
 - Location in room/vault
 - Partitions/screens (only qualified persons)
 - Location on balcony, gallery, platform
 - Elevation: 8 feet or more above floor

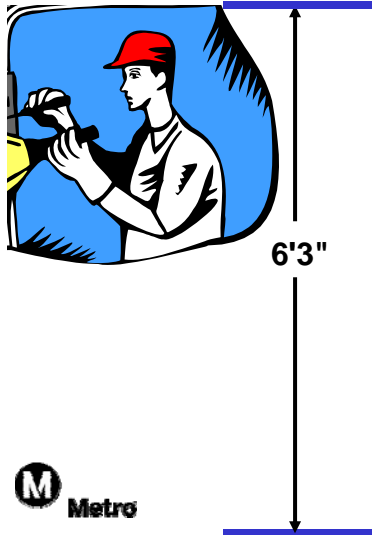


1910.303(g)(1)(v) Illumination

- Illumination provided for all working spaces about service equipment, switchboards, panelboards, and motor control centers installed indoors.



1910.303(g)(1)(vi) Headroom



- The minimum headroom of working spaces about service equipment, switchboards, panelboards, or motor control centers shall be 6 feet 3 inches

1910.303(g) Guarding of live parts

- (2)(i) Live parts of electric equipment operating at 50 volts or more guarded against accidental contact by approved cabinets



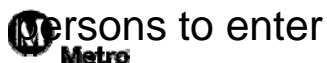
1910. 303 Guarding live parts

- (g)(2)(i) or other forms of approved enclosures, or by any of the following means:
 - (A) By location in a room, vault, accessible only to qualified persons
 - (B) By permanent, substantial partitions or screens
 - (C) By location on a suitable balcony or platform as to exclude unqualified persons
 - (D) By elevation of 8 feet or more above the floor or other working surface



1910. 303(g) Guarding live parts

- (2)(iii) Entrances to rooms and other guarded locations containing exposed live parts shall be marked with conspicuous warning signs forbidding unqualified



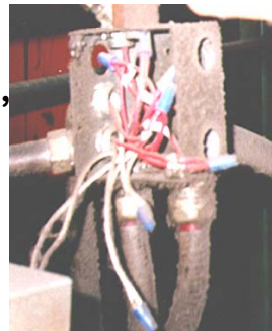
1910.303(h)(3)(ii) Illumination

- Adequate illumination for all working spaces about electric equipment



Cabinets, Boxes, and Fittings

- Junction boxes, pull boxes and fittings must have approved covers
- Unused openings in cabinets, boxes and fittings must be closed (no missing knockouts)
- Photo shows violations of these two requirements



Hand-Held Electric Tools

- Hand-held electric tools pose a potential danger because they make continuous good contact with the hand
- To protect you from shock, burns, and electrocution, tools must:
 - Have a three-wire cord with ground and be plugged into a grounded receptacle, or
 - Be double insulated, or
 - Be powered by a low-voltage isolation transformer



Guarding of Live Parts

- Must guard live parts of electric equipment operating at 50 volts or more against accidental contact by:
 - Approved cabinets/enclosures, or
 - Location or permanent partitions making them accessible only to qualified persons, or
 - Elevation of 8 ft. or more above the floor or working surface
- Mark entrances to guarded locations with conspicuous warning signs



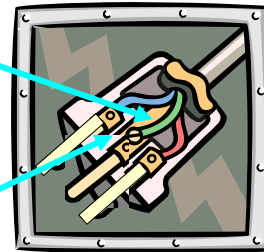
Guarding of Live Parts

- **Must enclose or guard electric equipment in locations where it would be exposed to physical damage**
- **Violation shown here is physical damage to conduit**



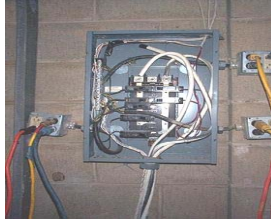
1910.304(a)(1) Identification of Conductors

- A conductor used as a grounded conductor shall be identifiable and distinguishable from all other conductors.
- A conductor used as an equipment grounding conductor shall be identifiable and distinguishable from all other conductors



Identification of Conductors

- Grounded conductor and equipment grounding conductors marked or color coated
- So that employees can i.d. and tell apart
- **Grounded conductor is an energized circuit** (conductor that is connected to earth through the system ground) Commonly referred to as the *neutral*



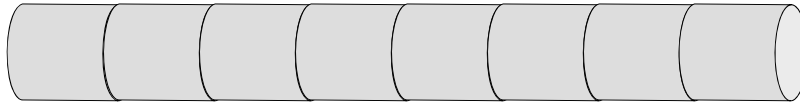
Grounding Conductors

- **Equipment grounding conductor** acts as a safeguard against insulation failure or faults in the other circuit conductors
- **Not an energized conductor** under normal conditions.
- Energized if a leak or fault in the normal current path
- Directs current back to the source
- Enabling fuses or circuit breakers to operate

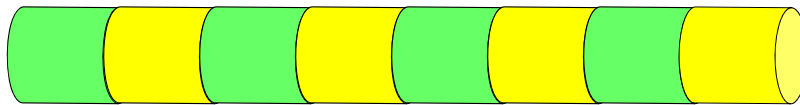


Identification of Conductors

- **Grounded conductor** i.d. and distinguished from other conductors w/ white or gray



- Equipment **grounding conductor** i.d. and distinguished w/ **green**, green w/ yellow stripes, or bare



Standard Interpretations

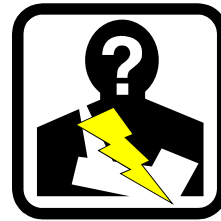
12/18/1997 - Electrical Conductor Identification

- The use of a diagram not an acceptable form of identifying and distinguishing grounded circuit conductors and equipment grounding circuits
- Under paragraph 1910.304(a), a grounded conductor and an equipment grounding conductor must be identifiable and distinguishable from all other conductors
- Employee must be able to distinguish an equipment grounding conductor from any other type of conductor in a plant



Standard Interpretations 12/18/1997 - Electrical Conductor Identification

- If a wiring diagram were the only means of identifying these conductors, an employee (to perform work safely) would have to look up the color coding each time there is need to identify circuit or equipment conductors



Standard Interpretations 12/18/1997 - Electrical Conductor Identification

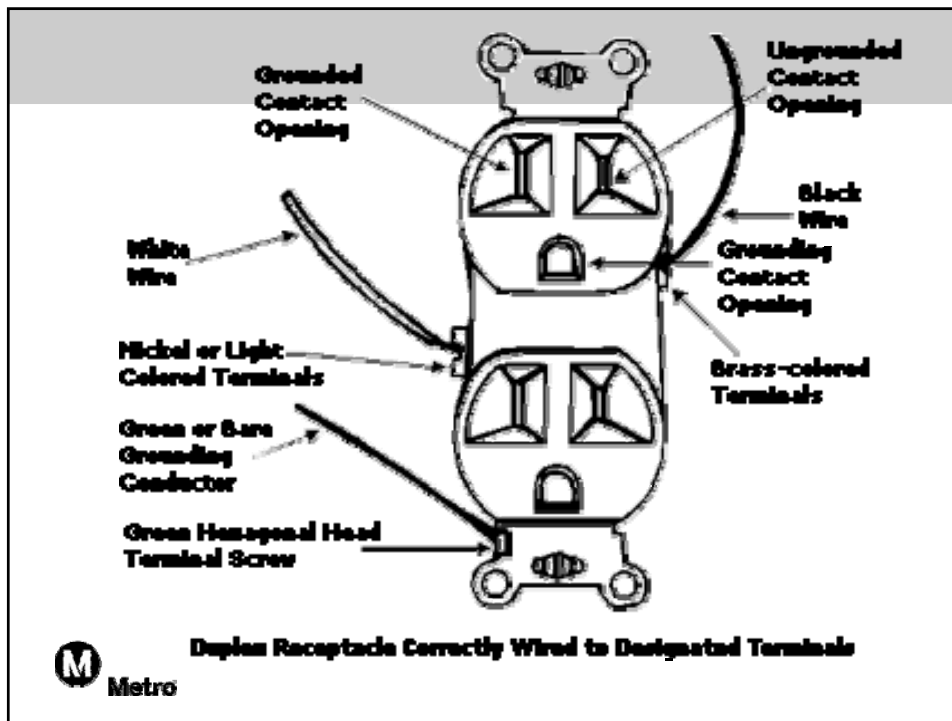
- Non-standardized use of colors makes it much more likely that an employee would confuse a red ungrounded circuit conductor with an equipment grounding conductor in a similar panel
- Such a mistake could lead to an employee being exposed to hazardous electrical energy
- Of particular concern are employees of electrical contractors, who are familiar with *standard color coding schemes*, making this mistake



1910.304(a) Use and identification of grounded and grounding conductors

- (2) No grounded conductor may be attached to any terminal or lead so as to reverse polarity

correct polarity between the ungrounded (hot) conductor, the grounded (neutral) conductor, and the grounding conductor must be maintained



1910.305(a)(1)(ii) Wiring in ducts

- No wiring systems of any type installed in ducts used to transport dust, loose stock or flammable vapors



1910.305(a)(2) Temporary wiring

- (iii)(F) Lamps for general illumination shall be protected from accidental contact or breakage
- Protection shall be provided by elevation of at least 7 feet from normal working surface or by a suitable fixture or lampholder with a guard



1910.305(a)(2) Temporary wiring

- (iii)(G) Flexible cords and cables shall be protected from accidental damage
- Sharp corners and projections shall be avoided.
- Where passing through doorways or other pinch points, flexible cords and cables shall be provided with protection to avoid damage



1910.305(a)(2)(iii)(G) Flexible Cords

- Where passing through doorways or other pinch points, flexible cords and cables shall be provided with protection to avoid damage



1910.305 (b) Conductors Entering Boxes, Cabinets or Fittings

- Conductors can be damaged if they rub against the sharp edges of cabinets, boxes, or fittings
- Where they enter they must be protected by some type of clamp or rubber grommet
- The device used must close the hole through which the conductor passes as well as provide protection from abrasion



1910.305 (b) Conductors Entering Boxes, Cabinets or Fittings

- If the conductor is in a conduit and the conduit fits tightly in the opening, additional sealing is not required
- The knockouts in cabinets, boxes, and fittings should be removed only if conductors are to be run through them
- Open knockouts and other holes must be closed



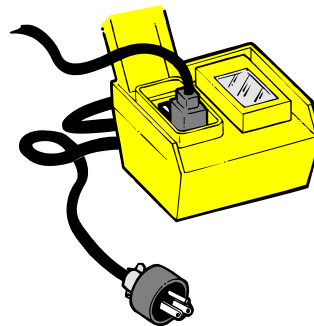
1910.305 (c) Conductors Entering Boxes, Cabinets or Fittings

- All pull boxes, junction boxes and fittings must be provided with approved covers
- If covers are metal they must be grounded.
- Each outlet box must have a cover, faceplate or fixture canopy



1910.305(e) Enclosures for damp or wet locations

- Cabinets, cutouts boxes, fittings, and panelboards weatherproof
- Switches, circuit breakers, and switchboards in weatherproof enclosures



Use of Flexible Cords

- More vulnerable than fixed wiring
- Do not use if one of the recognized wiring methods can be used instead
- Flexible cords can be damaged by:
 - Aging
 - Door or window edges
 - Staples or fastenings
 - Abrasion from adjacent materials
 - Activities in the area
- Improper use of flexible cords can cause shocks, burns or fire



1910.305 (g)(1) Use of Flexible Cords & Cables

- Flexible cords and shall be approved and suitable for conditions of use and location*

Underwriters Laboratories
Inc. (UL)



* The OSHA electric standard
(1910.305) lists specific situations in
which flexible cords may be used



Standard Interpretations

09/09/1997 - Clarification of the Electrical Standard as it applies to flexible power cords on appliances

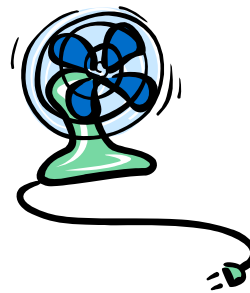
- Under paragraph 1910.303(a), electrical conductors and equipment are acceptable for use in the workplace only if approved
- An electrical appliance which is certified by a NRTL is considered to be approved by the Occupational Safety and Health Administration (OSHA) *as long as it is used in accordance with the condition(s) of NRTL certification*

Standard Interpretations

09/09/1997 - Clarification of the Electrical Standard as it applies to flexible power cords on appliances

- Can I put a longer cord on a portable fan?
- Replacing the existing cord (with a longer cord, perhaps 15-25 feet long) *is a violation of the NRTL certification of the appliance*

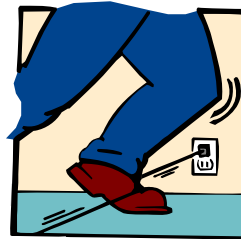
Flexible cords and cables may not be used as a substitute for the fixed wiring of a structure
A new receptacle, readily accessible to the fan, must be provided



Standard Interpretations

09/09/1997 - Clarification of the Electrical Standard as it applies to flexible power cords on appliances

- Use of an appliance with flexible cord and cable as short as possible plugged into a nearby receptacle promotes workplace safety by reducing the likelihood of being a tripping hazard and being damaged



Standard Interpretations

09/09/1997 - Clarification of the Electrical Standard as it applies to flexible power cords on appliances

- Can electrical tape be used to cover minor nicks and abrasions in the outer jacket of a flexible cord? Under what circumstances, if any, may "electrical tape" be used to repair the outer cover of a flexible cord?
- Nicks and abrasions which do not penetrate completely through the outer jacket of a flexible cord are not considered a safety concern for which corrective action, that is, repair or replacement of the flexible cord, would be required.



Standard Interpretations

09/09/1997 - Clarification of the Electrical Standard as it applies to flexible power cords on appliances

- **Repair or replacement of the flexible cord is required when the outer jacket is penetrated or the conductors or their insulation, inside are damaged.**
- **Flexible cord not less than No. 12 American Wire Gauge (AWG) may be repaired by splicing the conductors with a suitable vulcanized or molded splice.**



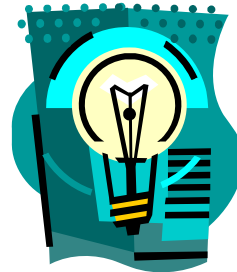
1910.305 (g)(1) Use of Flexible Cords & Cables

- (i) Flexible cords and cables shall be used only for:
- (A) Pendants (a lampholder or cord-connector body suspended by a length of cord properly secured and terminated directly above the suspended device);
- (B) Wiring of fixtures;



1910.305 (g)(1) Use of Flexible Cords & Cables

- (C) Connection of portable lamps or appliances;
- (D) Elevator cables;
- (E) Wiring of cranes and hoists;



1910.305 (g)(1) Use of Flexible Cords & Cables

- (F) Connection of stationary equipment to facilitate their frequent interchange (equipment which is not normally moved, but might be on occasion);
- (G) Prevention of the transmission of noise or vibration (In such cases vibration might fatigue fixed wiring and result in a more hazardous situation);



1910.305 (g)(1) Use of Flexible Cords & Cables

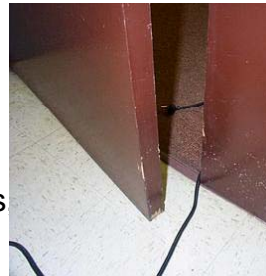


- (H) Appliances where the fastening means and mechanical connections are designed to permit removal for maintenance (e.g. water coolers, exhaust fans);
- Data processing cables

1910.305 (g)(1)(iii) Prohibited uses of flexible cords

- Except for the previously listed exemptions, flexible cords ***may not be used for***:
 - (A) As a substitute for fixed wiring of the structure;
 - (B) Where run through holes in walls, ceilings, or floors;

- (C) Where used as a substitute for fixed wiring



Identification, Splices and Terminations

- Flexible cords shall be connected to devices and fittings so that strain relief is provided which will prevent pull from being directly transmitted to joints or terminal screws



1910.305 (g)(2)(ii)

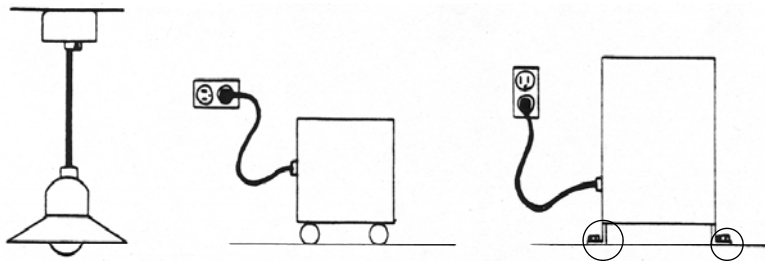
- Flexible cords shall be used only in continuous lengths without splice or tap.
- Hard service flexible cords No. 12 or larger may be repaired if spliced so that the splice retains the insulation, outer sheath properties, and usage characteristics of the cord being spliced.



Note: The National Electric Code allows splice in 14 gauge or greater wire

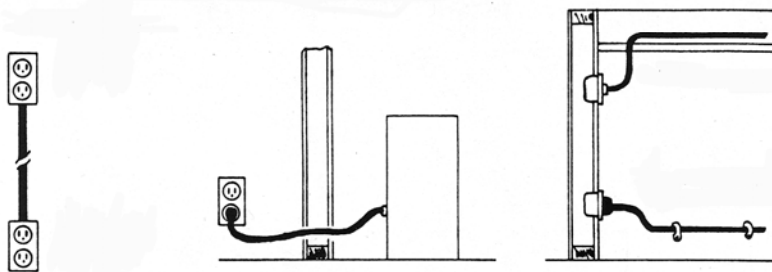
Permissible Uses of Flexible Cords

Examples



Prohibited Uses of Flexible Cords

Examples



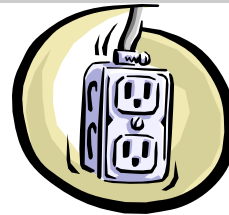
Wiring Design and Protection
Section 1910.304

- **Use & identification of ground conductors**
 - Identification (Color coding)
 - Polarity
 - Use of grounding terminals and devices
- **Services**
 - Disconnecting means (Switch box)
 - Over 600 volts (Guarding & warning signs)



Electrical Safety
Section 1910-304

- **Over current Protection**
 - 600 Volts or less
 - Over 600 Volts
 - Short circuit protection
- **Grounding**
 - Circuit/system & equipment
- **Grounding path**
 - Permanent, continuous, capacity, impedance



Electrical Safety
Section 1910-304

- **Identifies supports, enclosures, & equipment to be grounded**
 - Range, washer & dryer, refrigerator, freezer, fixed equipment, other appliances, power tools
- **Methods of grounding fixed equipment**



Methods, Components, & Equip
Section 1910.305

- **Wiring Methods**
 - General requirements (Continuity & ducts)
 - Temporary wiring (Renovation & carnivals)
- **Cabinets, boxes, & fittings**
 - Entrances (Grommets & knock-outs)
 - Pull box (Approved & grounded)
 - Boxes over 600 Volts (Enclosure & marked)



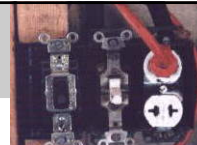
Electrical Safety
Section 1910.305



- **Switches**
 - Single knife switches (Fall to lock)
 - Double throw knife switch
- **Switch & Panel Boards (Location)**
- **Enclosures for Damp Locations**
- **Conductors (Color coding)**
- **Flexible Cords & Cables (Elevators)**



Electrical Safety
Section 1910.305



- **Portable Cables Over 600 Volts**
(Conductor size, insulation, marking, accessibility)
- **Equipment for General Use**
 - Lighting, lamps, receptacles
 - Cord connectors & attachment plugs
 - Appliances (No exposed wires)
 - Motors (Disconnect, overload/short circuit, guarded)

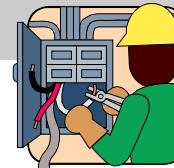


Electrical Safety
Section 1910.305

- **Transformers**
 - Signs
 - Location (Vaults)
 - Away from combustible materials
 - Containment
- **Capacitors (Discharge system when not in use)**



Electrical Safety
Section 1910.331



- **Electrical safety-related work practices for qualified and unqualified personnel**
- **Working on or near**
 - Premises wiring (Buildings & yards)
 - Wiring for connections to supply
 - Other wiring (Outside conductors)
 - Optical fiber cable (Along with conductors)



Electrical Safety
Section 1910.331

- **Other work by unqualified persons**
 - Generation, transmission, & distribution installations
 - Communications installations
 - Vehicle installations
 - Railway installations
- **Excluded work by qualified persons**
(Standards don't apply to the above)



Electrical Safety
Selection & Use of Work Practices

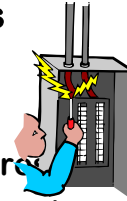
- **Working with exposed energized parts**
 - Only qualified personnel on live parts
 - Overhead lines - established clearances for qualified & unqualified persons and vehicles
 - Illumination - adequate
 - Confined space - shields, barriers, insulation
 - Non-Conductive materials or apparel



Electrical Safety
Section 1910.333

Selection and Use of Work Practices

- **General**
 - De-energize parts if at all possible
 - Energized parts (Other protective measures)
- **Working with exposed de-energized parts**
 - Lockout/tagout procedures apply
 - Parts without lockout/tagout procedures will be treated as energized



Electrical Safety
Section 1910.334

Use of Equipment

- **Portable electric equipment**
 - Handling
 - Visually inspect
 - Grounding-type equipment (3 prong)
 - Connecting attachment plugs
 - Conductive locations (Special equipment)



Electrical Safety
Use of Equipment



- **Electric power & lighting circuits**
 - Routine opening & closing of circuits
 - Reclosing circuits after protective device operation
 - Overcurrent protection modification
- **Test instruments & equipment**
 - Only qualified personnel can test
 - Visual inspection of equipment
- **Rating of equipment**



Electrical Safety
Grounding and Bonding

- **Path to ground must be:**
 - Permanent and continuous
 - Ample current carrying capacity
- **Bonding**
 - Electrical continuity of grounding circuit through proper connections



Grounding Path

- The path to ground from circuits, equipment, and enclosures must be permanent and continuous
- Violation shown here is an extension cord with a missing grounding prong



Electrical Safety

Electrical Protective Devices

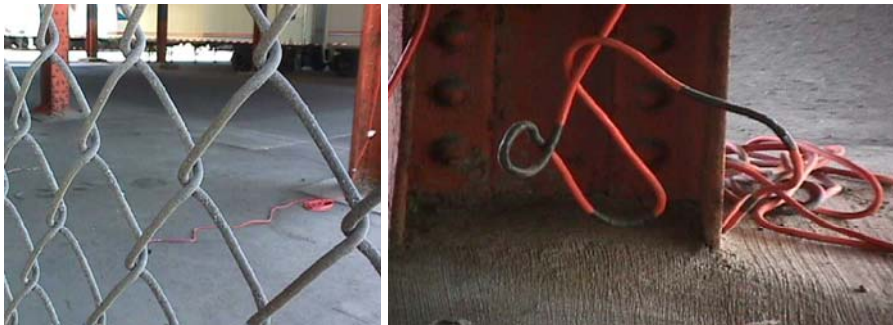
- **Fuses**
 - Opens circuit by melting metal strip
- **Circuit breakers**
 - Trips when current flow is excessive
 - Magnetic and thermal
- **Ground fault circuit interrupters**
 - Not an over current device
 - Opens circuit if load return route is incorrect



Electrical Safety



Electrical Safety Electrical Cords



Watch out for illegal electrical splices!

Electrical Safety



- Extension cords take a lot of abuse.
- Protect your cords or get heavy duty cords more suited to the working environment.



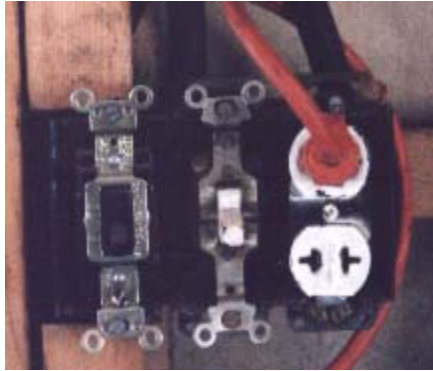
Electrical Safety



- The orange wire is a simple extension cord.
- The blue wire is a heavier duty, industrial strength cord.



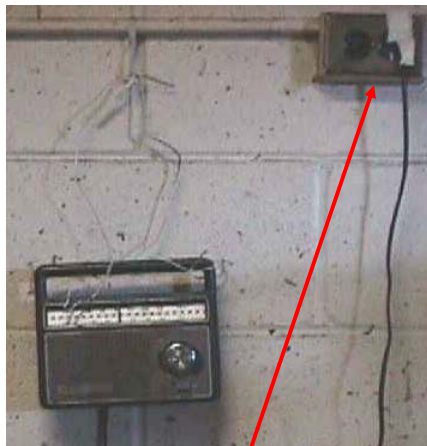
Electrical Safety



- Watch out for unguarded electrical circuits.
- Can a grounded appliance even be plugged into this outlet?



Electrical Safety



This employee wanted to listen to his radio, but the plug broke off... what to do????



Safeguards for Personnel Protection

- **Use of protective equipment**
- **Personal protective equipment**
 - Provided & use PPE
 - Safe & reliable (1910.137)
 - Protection from insulating material
 - Head gear / eye & face protection



Safeguards for Personnel Protection

- **General protective equipment and tools**
 - Insulated tools where tools may contact conductors
 - Insulation material subject to damage will be protected
 - Fuse handling equipment with proper rating
 - Non-conductive ropes and hand lines
 - Protective shields, barriers, and insulation



Insulating Gloves
OSHA 1910.333(a)(1)

Rubber Insulating Gloves are among the most important articles of personal protective equipment for electrical workers

They are the first line of defense for contact with any energized components or lines



Linemen Gloves

- Available in six classes
- 500 volts AC through 36,000 volts AC
- Two types
 - Type I – Natural Rubber
 - Type II – EPDM Rubber (Low-Volt)
- Sizes 8 through 12, including half sizes
- Various styles and



SALIBROY LINEMEN'S GLOVES

Selecting the right size, length and style
Linemen's gloves are available in a full range of sizes, from 8 through 12, including half sizes. Proper fit is important to maximize dexterity and fatigue. To determine glove size, measure the circumference of the hand between the thumb and index finger and add one inch. Allow for additional wear if fabric glove liners are to be worn, especially with thermal liners.



Class 0 and 00 gloves are available in 11 and 14 inch lengths. Class 00 Electrical Insulating Rubber Gloves are made from cotton and Type I natural rubber or blue Type II SAE COR®. Both are extremely flexible to make working with small parts easy. The gloves meet or exceed ASTM D120 and IEC 901 Standards.

Hand Length in	Dist	Color	Size
11	10	BL or R	8, 8 1/2
14	10	BL or R	10, 10 1/2
		BL-blue Type II SAE COR	11, 11 1/2
		BL-blue Type II SAE COR	12

Example: 11-10BL, R



Hand Length in	Dist	Color	Size
11	11	Y, B or R	8, 8 1/2
14	11	Y, B or R	10, 10 1/2
		Y-yellow	11, 11 1/2
		Y-yellow	12

Example: 11-11Y

Dist. size indicates an available. Contact your local Salibroy representative for details.



Insulated Tools

Insulated tools that meet ASTM F1505 and OSHA 1910.333 (c)(2)

The tools are rated 1000V to be used on working with energized equipment



Electrical Safety



Electrical Safety



- **This electrical cord has no ground prong.**
- **In case of an over current situation, where will the electricity go?**

Electrical Safety Ground-Fault Circuit-Interrupters

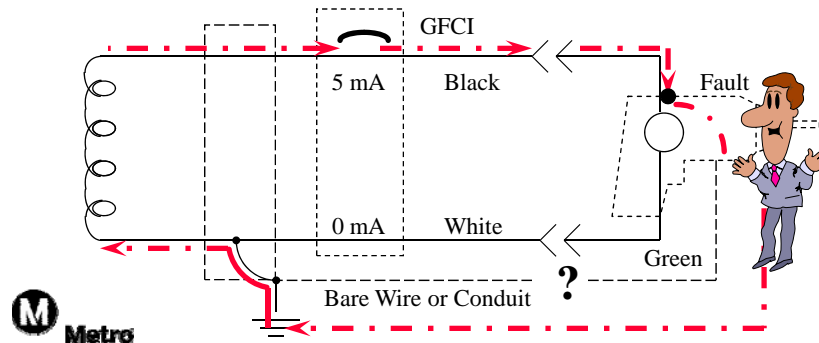


- **Not an overcurrent device**
- **Senses magnetic field created by current**
- **Opens circuit when imbalance occurs**
- **Used when double insulation and grounding cannot provide adequate protection**
- **Used in areas where equipment can be dropped in water**



Electrical Safety
Ground-Fault
Circuit-Interrupters

**GFCI senses imbalance in current
and opens circuit**



Electrical Safety
Types of GFCI

- **Circuit breaker type - mounts in panel**
- **Receptacle type - one or more outlets**
- **Permanently mounted - wired to power supply**
- **Portable type - attach to outlet**
- **Cord connected type - attached to cord**



Electrical Safety



- **Ground Fault Circuit Interrupter**

- Monitors the difference in current flowing into the hot and out to the grounded neutral conductors.
- Provides protection against ground fault hazards
- “Trips” at 5 ma!!
- Not a substitute for Grounding!! Equipment must still be grounded!

Electrical Safety

Reversed Polarity

- Section 1910.304(a)(2) and Section 200-11 National Electrical Code
- Improper termination of any conductor may create a serious hazard
- Reverse polarity may by-pass in-line switches



Electrical Safety



Electrical Safety



Electrical Safety



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



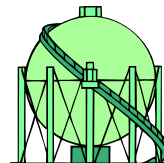
Electrical Definitions 1910.339

- **Acceptable**
 - Accepted, certified, listed, labeled or otherwise determined to be safe by a nationally recognized testing laboratory
- **Accessible**
 - Admitting close approach
 - Not guarded by locked doors, elevation or other effective means



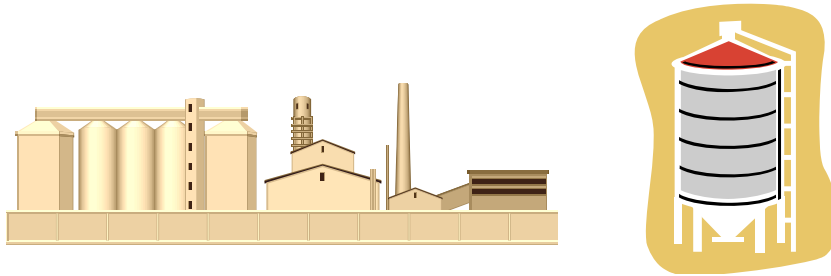
Electrical Definitions 1910.339

- **Class I location**
 - Location where flammable gases or vapors may be present
 - Division 1 is a condition where gases or vapors exist under normal operating conditions
 - Division 2 is a condition where gases or vapors are normally confined but may escape



Electrical Definitions 1910.339

- **Class II location**
 - Location that may be hazardous due to combustible dust



Electrical Definitions 1910.339

- **Class III location**
 - Location where easily ignitable fibers or flyings may be in the air.



Electrical Definitions 1910.339

- **Ground**

- A conducting connection between an electrical circuit or equipment and the earth.

- **Guarded**

- Covered, shielded, fenced, enclosed or otherwise protected by means of suitable covers, casings, barriers, rails, screens mats or platforms to remove the likelihood of approach to a point of danger.



Electrical Definitions 1910.339

- **Ground fault circuit interrupter**

- A device which interrupts the electric circuit to the load when a fault current to ground exceeds a value that is less than that required to operate the over current protective device.



Electrical Definitions 1910.339

- **Location**
 - **Damp** – partially protected under canopies, marquees, roofed open porches
 - **Dry** – not normally subject to dampness or wetness
 - **Wet**- Underground or in concrete slabs or masonry in direct contact with earth subject to saturation with water such as vehicle washing areas, locations exposed to weather



Electrical Definitions 1910.339

- **Watertight**
 - So constructed that moisture will not enter the enclosure
- **Weatherproof**
 - So constructed or protected that exposure to the weather will not interfere with successful operation. Rainproof, rain tight or watertight enclosures.



General Requirements 1910.303

- Suitability of equipment may be evidenced by listing or labeling
- Safety of equipment may be determined by:
 - Mechanical strength
 - Electrical insulation
 - Heating or arcing effects
 - Classification by type, size, or capacity



General Requirements 1910.303

- Electrical equipment may not be used unless it is suitably marked



General Requirements 1910.303

- Each disconnecting means legibly marked to indicate its purpose
- Switches and circuit breakers legibly marked
- Guarding of live parts >50 V by:
 - Approved cabinets
 - Room, vault, partitions or location
 - Elevations greater than eight feet



General Requirements 1910.303

- Illumination provided for all working spaces

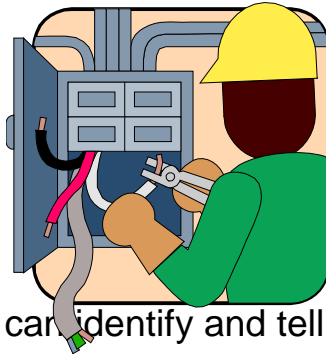


- Minimum headroom 6 feet, three inches



Identification Conductors 1910.304

- Grounded and grounding conductor marked or color coded

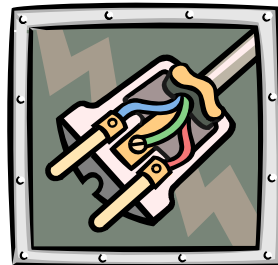


- Employees can identify and tell apart



Identification Conductors 1910.304

- Grounded conductor is an energized conductor
- Grounding conductor acts as a safeguard:
 - Not normally energized
 - Energized for fault or leak in current path
 - Enables fuses or circuit breakers to operate
- Conductor colors:
 - Black or bare
 - Green or green with yellow
 - White or gray



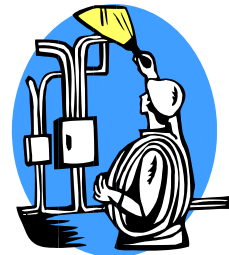
1910.305 (g) Flexible cords

- Flexible cords and cables shall be approved and suitable for conditions of use and location
- Flexible cords and cables shall be used only for:
 - Pendants;
 - Wiring of fixtures;
 - Connection of portable lamps or appliances;
 - Elevator cables;
 - Wiring of cranes and hoists;
 - Connection of stationary equipment to facilitate their frequent interchange;
 - Prevention of the transmission of noise or vibration;



1910.331 Scope

- Covers:
 - Qualified persons (those who have training in avoiding the electrical hazards)
 - Unqualified persons (those with little or no such training)
- Working on or near the following:
 - Premises wiring
 - Wiring for connection to supply
 - Other wiring



1910.332 Training

- Scope:
 - Applies 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
 - Employees trained in and familiar with the safety-related work practices that pertain to their jobs



TABLE S-4. -- Typical Occupational Categories of Employees Facing a Higher Than Normal Risk of Electrical Accident

Occupation

- Blue collar supervisors(1)
- Electrical and electronic engineers(1)
- Electrical and electronic equipment assemblers(1)
- Electrical and electronic technicians(1)
- Electricians
- Industrial machine operators(1)
- Material handling equipment operators(1)
- Mechanics and repairers(1)
- Painters(1)
- Riggers and roustabouts(1)
- Stationary engineers(1)



Footnote to Table S-4

- (1) Workers in these groups do not need to be trained if their work or the work of those they supervise does not bring them or their employees close enough to exposed parts of electric circuits operating at 50 volts or more to ground for a hazard to exist.



1910.332 Training

- (b)(3) **Qualified persons:** (i.e. those permitted to work on or near exposed energized parts) shall, at a minimum, be trained in and familiar with the following:
 - (i) The skills and techniques necessary to **distinguish exposed live parts** from other parts of electric equipment
 - (ii) The skills and techniques necessary to **determine the nominal voltage** of exposed live parts
 - (iii) The **clearance distances** specified in 1910.333(c)



1910.333 (a)(1) Deenergized parts

- Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them:
 - Unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible
 - Live parts that operate at less than 50 volts to ground need not be deenergized if there will be no increased exposure to electrical burns or to explosion due to electric arcs



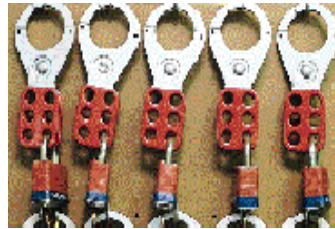
1910.333 (a)(1) Deenergized parts

- Examples of increased or additional hazards include:
 - Interruption of life support equipment,
 - Deactivation of emergency alarm systems,
 - Shutdown of hazardous location ventilation equipment, or;
 - Removal of illumination for an area.



1910.333(b) Working on or near exposed deenergized parts

- (1) Conductors and parts of electric equipment that have been deenergized but have not been locked out or tagged in accordance with paragraph (b) of this section shall be treated as energized parts



1910.333(b) Working on or near exposed deenergized parts

- (2) While any employee is exposed to contact with parts of fixed electric equipment or circuits which have been deenergized, the circuits energizing the parts shall be locked out or tagged or both*



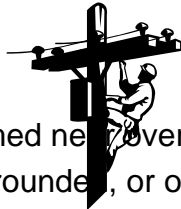
1910.333(b) Working on or near exposed deenergized parts - Note 2

- *Lockout and tagging procedures that comply with paragraphs (c) through (f) of 1910.147 will also be deemed to comply with paragraph (b)(2) of this section provided that:
 - [1] The procedures address the electrical safety hazards covered by this Subpart; and
 - [2] The procedures also incorporate the requirements of paragraphs (b)(2)(iii)(D) and (b)(2)(iv)(B) of this section (tags w/out locks & testing)



1910.333 (c)(2) Work on energized equipment

- Work on energized equipment:
 - Only qualified persons may work on electric circuit parts
- Overhead lines:
 - If work is to be performed near overhead lines, the lines shall be deenergized and grounded, or other protective measures shall be provided before work is started



1910.333 (c)(3)(i) Selection and use of work practices

- Unqualified person working near overhead lines, the person and the longest conductive object they may contact cannot come closer to any energized overhead line than the following distances:
 - For voltages to ground 50kV or below - 10 feet
 - For voltages to ground over 50kV - 10 feet plus 4 inches for every 10kV over 50kV

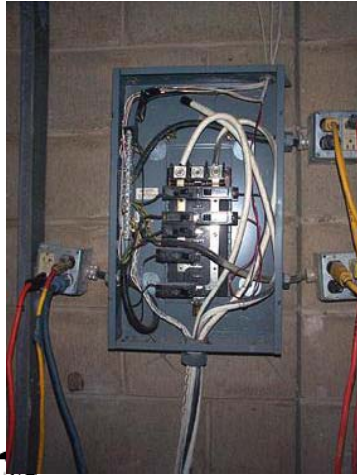


1910.333(c)(4) Illumination

- Employees may not enter spaces containing exposed energized parts, unless illumination is provided that enables the employees to perform the work safely



1910.333(c)(4) Illumination

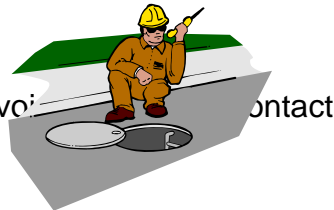


 Metro

- Employees may not reach blindly into areas which may contain energized parts.

1910.333(c)(5) Confined spaces

- When an employee works in a confined or enclosed space (such as a manhole or vault) that contains exposed energized parts, the employer shall provide, and the employee shall use:
 - Protective shields,
 - Protective barriers, or;
 - Insulating materials as necessary to avoid contact with these parts



 Metro

1910.333(c)(7) Portable ladders

- Portable ladders shall have nonconductive siderails if they are used where the employee or the ladder could contact exposed energized parts



1910.333(c)(8) Conductive apparel

- Conductive articles of jewelry and clothing (such a watch bands, bracelets, rings, key chains, necklaces, etc...) may not be worn if they might contact exposed energized parts



1910.333(c)(10) Interlocks

- Only a qualified person following the requirements of paragraph (c) of this section may defeat an electrical safety interlock,
- and then only temporarily while he or she is working on the equipment



1910.334 Use of equipment

- Portable equipment shall be handled in a manner which will not cause damage
- Flexible electric cords connected to equipment may not be used for raising or lowering the equipment
- Flexible cords may not be fastened with staples or otherwise hung in such a fashion as could damage the outer jacket or insulation



1910.334 (a)(2)(i) Use of equipment

- Portable cord and plug connected equipment and flexible cord sets (extension cords) **visually inspected before use for external defects** (such as loose parts, or damage to outer jacket or insulation) and for evidence of possible internal damage (pinched or crushed outer jacket)
- Extension cords which remain connected once they are put in place and are not exposed to damage need not be visually inspected until they are relocated



1910.334 Use of equipment

- A flexible cord used with grounding type equipment shall contain an equipment grounding conductor
- Attachment plugs and receptacles may not be connected or altered in a manner which would prevent proper continuity of the equipment grounding conductor at the point where plugs are attached to receptacles



1910.334 Use of equipment

- (a)(4) Portable electric equipment and flexible cords used in highly conductive work locations, or in job locations where employees are likely to contact water or conductive liquids, shall be approved for those locations



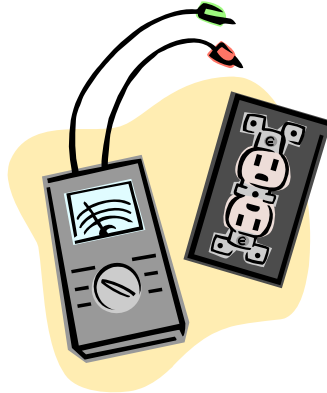
1910.334 Use of equipment

- (a)(5)(i) Employees' hands may not be wet when plugging and unplugging flexible cords and cord and plug connected equipment, if energized equipment is involved



1910.335 (c)(1) Use

- Only qualified persons may perform testing work on electric circuits or equipment



1910.335 Safeguards for personnel protection

- (a)(1) 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



1910.335 Safeguards for personnel protection

- Protective equipment shall be maintained in a safe, reliable condition and shall be periodically inspected or tested, as required by 1910.137 *



Metro

*1910.137 Electrical protective devices

1910.335 Safeguards for personnel protection

- Employees shall wear nonconductive head protection wherever there is a danger of head injury from electric shock or burns due to contact with exposed energized parts



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1910.335 Safeguards for personnel protection

- Employees shall wear protective equipment for the eyes or face wherever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from electrical explosion



1910.335 Safeguards for personnel protection

- When working near exposed energized conductors or circuit parts, each employee shall use insulated tools or handling equipment if the tools or handling equipment might make contact with such conductors or parts



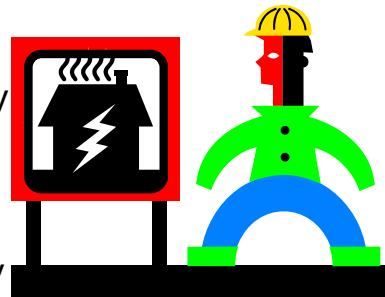
1910.335 Safeguards for personnel protection

- The following alerting techniques shall be used to warn and protect employees from hazards which could cause injury due to electric shock, burns, or failure of electric equipment parts:
 - Safety signs and tags
 - Barricades
 - Attendants



1910.335 Safeguards for personnel protection

- Safety signs, safety symbols, or accident prevention tags shall be used where necessary to warn employees about electrical hazards which may endanger them, as required by 1910.145



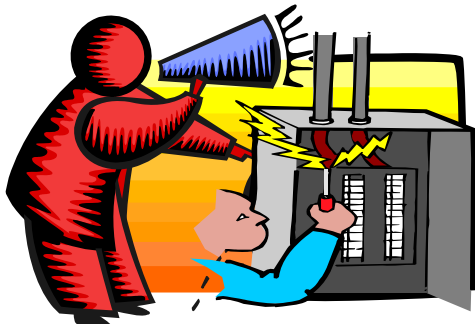
1910.335 Safeguards for personnel protection

- Barricades shall be used in conjunction with safety signs where it is necessary to prevent or limit employee access to work areas exposing employees to uninsulated energized conductors or circuit parts



1910.335 Safeguards for personnel protection

- If signs and barricades do not provide sufficient warning and protection from electrical hazards, an attendant shall be stationed to warn and protect employees

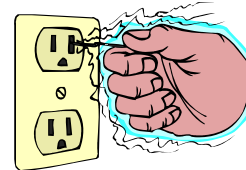


Safety Related Work Practices 1910.331-335

- Covers:
 - Qualified persons (those who have training in avoiding the electrical hazards

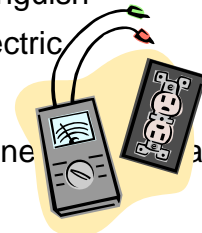


- Unqualified persons (those with little or no such training)



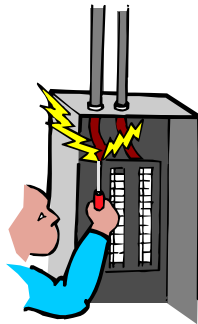
Safety Related Work Practices 1910.331-335

- **Qualified persons:** (i.e. those permitted to work on or near exposed energized parts) shall, at a minimum, be trained in and familiar with the following:
 - The skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment
 - The skills and techniques necessary to determine voltage of exposed live parts



Safety Related Work Practices 1910.331-335

- 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



Safety Related Work Practices 1910.331-335

- Employees shall be trained in and familiar with the safety-related work practices required by 1910.331 through 1910.335 that pertain to their respective job assignments; examples include:
 - Blue collar supervisors(1)
 - Electrical and electronic engineers(1)
 - Electrical and electronic equipment assemblers(1)
 - Electrical and electronic technicians(1)
 - Electricians
 - Industrial machine operators(1)



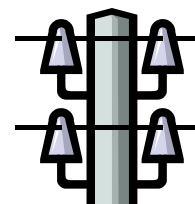
Safety Related Work Practices 1910.331-335

- While any employee is exposed to contact with parts of fixed electric equipment or circuits which have been deenergized, the circuits energizing the parts shall be locked out or tagged or both*



Safety Related Work Practices 1910.331-335

- Unqualified person working near overhead lines, the person and the longest conductive object they may contact cannot come closer to any energized overhead line than the following distances:
 - For voltages to ground 50kV or below - 10 feet
 - For voltages to ground over 50kV - 10 feet plus 4 inches for every 10kV over 50kV



Safety Related Work Practices 1910.331-335

- Conductive articles of jewelry and clothing (such as watch bands, bracelets, rings, key chains, necklaces, etc...) may not be worn if they might contact exposed energized parts



Safety Related Work Practices 1910.331-335

- Portable electric equipment and flexible cords used in highly conductive work locations, or in job locations where employees are likely to contact water or conductive liquids, shall be approved for those locations



Electrical Safety Training



- **Content of training - familiar with practices in section 1910.331-.355**
- **Minimum training (skills) for qualified persons**
 - Distinguish exposed live parts from others
 - Determine nominal voltage of exposed parts
 - Clearance distances & voltage exposure levels
- **Type of training - classroom or OJT**



Training

- **Train employees working in safe work practices, including:**
- **Deenergizing electric equipment before inspecting or making repairs**
- **Using electric tools that are in good repair**
- **Using good judgment when working near energized lines**
- **Using appropriate protective equipment**



Hazard Violation Workshop



Hazard Violation Workshop



Hazard Violation Workshop



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Hazard Violation Workshop



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What is an electric arc?

- The passage of a substantial electric current through ionized air
 - An electric arc...
 - Typically lasts less than one second
 - Has an extremely high percentage of radiant energy
 - Is explosive in nature
 - Can ignite and/or melt every day clothing

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What determines the intensity of an electric arc exposure?

- The electric arc itself
- Its fault current
- Its duration
- Its configuration or enclosure
 - Also known as “Arc-in-a-Box”
- The number of phases involved
- The system you’re working on
 - Its electrode gap
 - Its available voltage
- Your location
 - How close or far you are from the electric arc when it occurs



What risks are possible with electric arc exposures?

- **Electrocution**
- **Physical injury resulting from explosive forces**
- **Burn injuries (without electrical contact) resulting from:**
 - Intense radiant energy
 - Molten metal splatter
 - Secondary fires (e.g., from transformer oils)
- **The ignition or melting of clothing**



How do electric arc exposures compare to those of flash fires?

Exposure Elements	Electric Arcs	Flash Fires
Incident Energy (cal/cm ²)	1 to > 100	1 to 30
Radiant Heat Energy (%)	90	30-50
Convective Heat Energy	10	50-70
Exposure Time	0.01 > 1	1 to 15
Concussive Forces	High	Variable
Ionized Air Generation	High	Moderate
Smoke/Fumes	Yes	Yes
Molten Metal Splatter	Yes	No
Reoccurrence Potential	Re-Closing	Re-ignition
Intensity Limiting Factors	Electrical System	Fuel, Air
Exposure Level Estimation	System Parameters Permit Estimates	Unpredictable, difficult to estimate



Simulated Electric Arc Blast – Untreated Cotton Shirt (5.7 oz/yd²)



Before Electric Arc Blast



During Electric Arc Blast



After Electric Arc Blast



Simulated Electric Arc Blast: NOMEX® Workwear (4.5 oz/yd²)



Before Electric Arc Blast



During Electric Arc Blast



After Electric Arc Blast



Basic Definitions and Terms

- **Arc Thermal Protective Value (ATPV)** The incident energy in Calories/squared cm on a fabric that results in a 50% probability of the onset of 2nd degree burn based on the Stoll Curve
- **Arc Flash hazard** A dangerous condition associated with the release of energy caused by an electric arc Note that this explosive condition includes a broad spectrum of radiating energy, plasma, fragments and a spray of molten materials
- **Cal/cm²** (Calories per Sq. Centimeter) The total energy on a surface area. It is the unit used for Arc Ratings
- **Energy multiplier (Arc-in a- Box)** The increase of energy directed towards the worker if various factors are present such as walls, electrical enclosures or secondary phase to phase



Basic Definitions and Terms

- **Hazard Risk Category Classification** NFPA 70E table 3-3.9.1 Defines typical tasks for electrical workers and assigns Hazard/Risk Category values
- **Hazard Risk Protection Category** NFPA 70E table 3-3.9.3 defines the ATPV for each Hazard/Risk Category Note that the ATPV is 8 for Hazard/Risk Category 2
- **Plasma** Superheated gas that is created by the arc flash and expands rapidly from the Arc location
- **Protective clothing and PPE Matrix** NFPA 70E Table 3-3.2 defines the PPE requirements for each Hazard/Risk category Note that this matrix determines when Face Shields can be used and when Hoods must be deployed
- **Stoll Curve** A prediction at which one would expect to receive a second degree burn The model is based on a function of time and heat

What are the hazards?

Electrical Shock — When electrical current enters and exits the body creating a path



Arc-Flash — A dangerous condition associated with the release of energy caused by an electric arc
Note that this explosive condition includes a broad spectrum of electromagnetic energy, plasma, fragments and a spray of molten materials



Arc-Blast — Pressure wave caused by the expansion of gases and conducting materials with flying molten materials



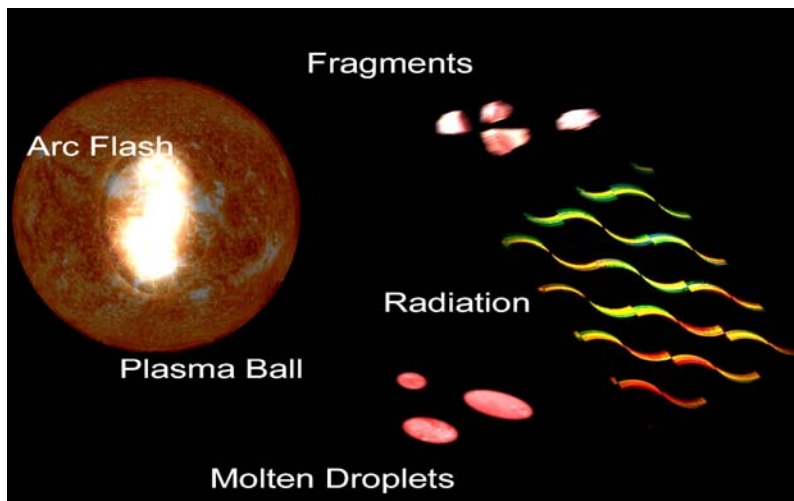
Shock

Current, Not Voltage causes Electric Shock

<u>mA</u>	<u>Affect on Person</u>
0.5 - 3	Tingling sensations
3+	Shock
10+	Muscle contractions and pain
30+	Respiratory paralysis
60+	Heart Paralysis (may be fatal)
100+	Ventricular fibrillation (usually fatal)
4+ Amps	Heart Paralysis
5+ Amps	Tissue and Organs start to burn



Arc-Flash Explosion



Arc-Flash Explosion

- As much as *80% of all electrical injuries are burns* resulting from an arc-flash and ignition of flammable clothing
- Arc temperature can reach 35,000°F - this is *four times hotter than the surface of the sun*
- *Fatal burns can occur at distances over 10 ft*
- Over 2000 people are admitted into burn centers each year with severe electrical burns



Example of an arcing fault



Arc-Flash Variables

- **Variables that effect the size and energy of an electric arc flash are:**
 - Amperage
 - Voltage
 - Arc gap
 - Closure time
 - Distance away from arc
 - 3 phase v single phase
 - Confined space
 - Characteristics of equipment



What Causes Arc-Flash?

Electricity travels the path of least resistance

When the path of electricity is suddenly interrupted, a new path is created



The arc can be generated by:

- Mechanical failure
- Current overload
- Accidental contact
- Human error
- Undetermined



Why is this Important ... Burn Injury

Burn Depth is a Measure of Severity

1st Degree: Skin Becomes Red, No Blister

2nd Degree: Skin Blisters, Epidermis Damaged,

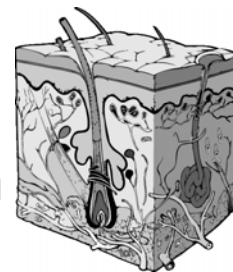
3rd Degree: Full Thickness Destroyed (Dermis)

-Skin cannot Regenerate

-Injury Depth ~1,000 μ

-Scar Tissue Forms

4th Degree: Muscle & Bone Destroyed



Arc-Flash Analysis

- Where work will be performed within the flash protection boundary, the flash hazard analysis shall determine, and the employer shall document, the incident energy exposure to the worker (in cal/cm²)
- Flame resistant (FR) clothing and PPE shall be used by the employee based upon the incident energy exposure associated with the specific task. OSHA 1910.269(I)(6)



Arc-Blast

- Electrical Arc-Flash can create blast in excess of 200 lbs/ft²
- Arc-Blast can cause collateral damage and extreme personal damage
 - Explode switchgear
 - Send molten metal at extreme high velocities
 - Little can be done



Arc Suppression Blanket

- The Arc Suppression Blanket is used as a barrier for protection from the explosive and incendiary effects of electric arcs and flashes.
- *Caution - Because of the unpredictability of electrical discharges, the Arc Suppression Blanket may not totally contain arcs and flashes*
- *May only reduce or limit explosive and incendiary effects.*



NFPA 70E – 2004 Edition Standard

- **Electrical Safety Requirements for Employee Workplaces**
 - Covers all aspects of worker safety associated with electrical hazards in the workplace
 - Recommendations for proper PPE (Personal Protective Equipment)
 - Addresses hazards:
 - Shock
 - Arc Flash
 - Requirements for shock and arc flash boundaries
 - Requirements for personal protective equipment & tools



NEC 2002 – National Electrical Codes

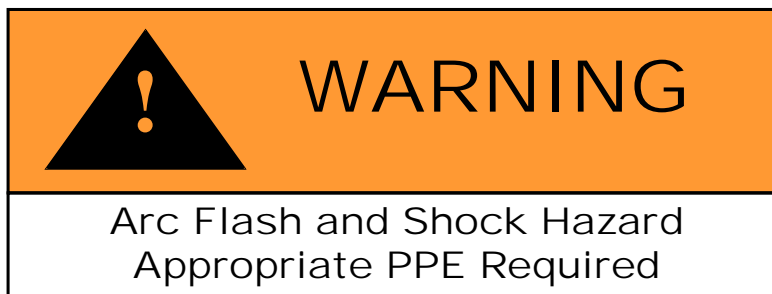
110.16 Flash Protection. Switchboards, panel boards, industrial control panels, and motor control centers in other than dwelling occupancies, that are likely to require examination, adjustment, servicing, or maintenance while energized, shall be field marked to warn qualified persons of potential electric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

FPN No. 1: NFPA 70E-2000, *Electrical Safety Requirements for Employee Workplaces*, provides assistance in determining severity of potential exposure, planning safe work practices, and selecting personal protective equipment.

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



Sample NEC Warning Article 110.16



Who is Required to do What?

- **NFPA 70E 130.7 General:**
- **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**



Who is Required to do What?

- **OSHA 1910.335**
- **Safeguards for personal protection:**
 - (a) **use of protective equipment. (1)**
 - Personal protective equipment. (i)****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**



NFPA 70E Provides Two Choices for Selecting the Appropriate PPE:

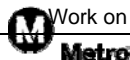
- Do an arc flash hazard analysis, and document the incident energy exposure
 - Duke Flux Software (Freeware)
 - ArcPro II Software
 - IEEE 1584 Standard
- As an alternate, use the “Hazard Risk Category Classifications” table to choose the PPE level required for the task



Hazard Risk Category Tables


Table 130.7(C)(9)(a) Hazard Risk Category Classifications

Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary)	Hazard Category	V-rated Gloves	V-rated Tools
Panelboards rated 240 V and below – Notes 1 and 3	—	—	—
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	0	N	N
Work on energized parts, including voltage testing	1	Y	Y
Remove/install CBs or fused switches	1	Y	Y
Removal of bolted covers (to expose bare, energized parts)	1	N	N
Opening hinged covers (to expose bare, energized parts)	0	N	N
Panelboards or Switchboards rated >240 V and up to 600 V (with molded case or insulated case circuit breakers) — Notes 1 and 3	—	—	—
CB or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y



NFPA Hazard Risk Categories

Table 130.7(C)(11) Protective Clothing Characteristics

Typical Protective Clothing Systems		
Hazard Risk	Clothing Description (Typical number of clothing layers is given in parentheses)	Required Minimum Arc Rating of PPE Joules/cm ² (cal/cm ²)
0	Non-melting, flammable materials (i.e., untreated cotton, wool, rayon, or silk, or blends of these materials) with a fabric weight at least 4.5 oz/yd ² (1)	N/A
1	FR shirt and FR pants or FR coverall (1)	16.74 (4)
2	Cotton underwear - conventional short sleeve and brief/shorts, plus FR shirt and FR pants (1 or 2)	33.47 (8)
3	Cotton underwear plus FR shirt and FR pants plus FR coverall, or cotton underwear plus two FR coveralls (2 or 3)	104.6 (25)
 Metro	Cotton underwear plus FR shirt and FR pants plus multilayer flash suit (3, or more)	167.36 (40)

NFPA 70E – Hazard Risk Category 0

- **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 Panelboards rated 240 V and below**
 - **Contactors 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 Category 1

- 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 Category 2

- 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 Category 3

- **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 Category 4

- **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.



Who Needs Electrical Safety PPE?

OSHA/NFPA 70E states:

“For energized circuits over 50 volts or more, safety tools and personal protective equipment must be used.”



Personal Protective Equipment (PPE) Requirements

Required PPE includes:

- Flame-resistant clothing
 - Flash suits (for high-energy arc exposure)
 - Flash suit hoods
- Insulating gloves
- Insulated tools



This is in addition to normally used hard hat, safety shoes, safety glasses, and hearing protection



What Electrical Safety Products are Available to Protect Workers?

- Voltage rated gloves and protectors
- Insulating sleeves
- Insulated/Insulating tools
- Arc-flash clothing, face shields/hoods
- Insulating blankets/rollout blanket
- Insulating protective shielding
- Rescue hooks
- Dielectric footwear
- Temporary protective grounding
- Voltage detectors



Example of an arcing fault

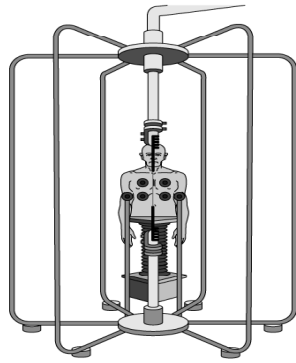


Protective Clothing

- For most low-energy work (240 volts or below), natural-fiber, non-melting clothing is adequate; some higher risk tasks require FR clothing
- Most work on or near systems rated 480 volts and above requires at least one layer of flame-resistant (FR) clothing worn over natural-fiber clothing
- High-energy tasks require FR flash suits and flash hoods worn over FR clothing



ASTM F1958 Ignition Test Method



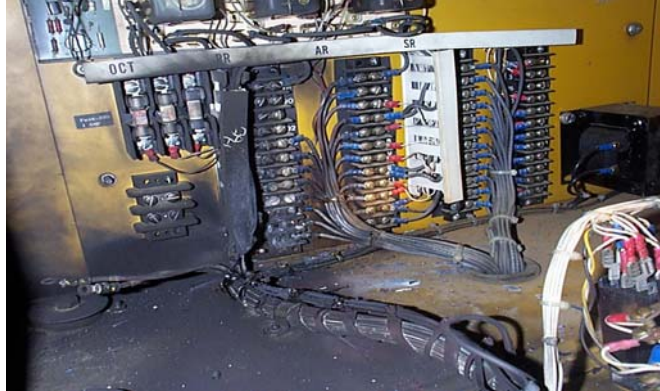
Arc Parameters

- 3kV, 8kA
- 18 cycles
- 12 inches Gap
- 12 inches from Mannequin

Arc Generated Flash
~ 14-16 cal/cm²



Generator Control Panel



Summary

Hazards

- Inadequate wiring
- Exposed electrical parts
- Bad insulation
- Ungrounded electrical systems and tools
- Overloaded circuits
- Damaged power tools and equipment
- Using the wrong PPE and tools
- Overhead powerlines
- Wet conditions



Protective Measures

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