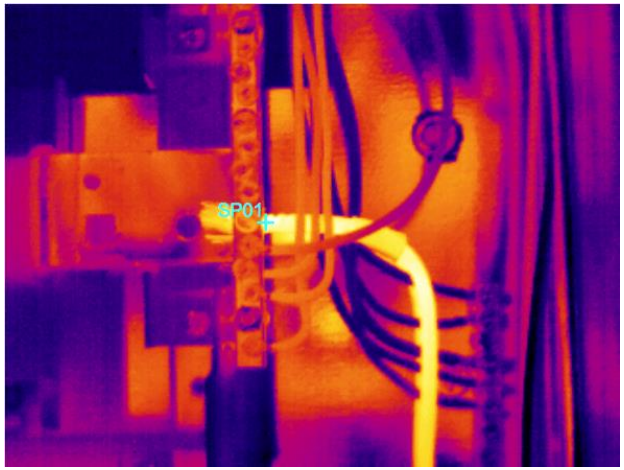
ENVIRONMENTAL HEALTH AND SAFETY

Electrical Safety
NFPA 70E



How Electricity Works

- Operating an electric switch is like turning on a water faucet. Behind the faucet or switch there must be a source of water or electricity with something to transport it, and with a force to make it flow.
- In the case of water the source is a pump, and the force to make it flow through the pipes is provided by the pump.
- For electricity, the source is the power generator. Current travels through electrical conductors (wires) and the force to make it flow, measured in volts, is provided by a generator.

Basic Electrical Terminology

- **Current**: the movement of electrical charge
- **Resistance**: opposition to current flow measured in ohms
- **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

Dangers of Electricity

- On average, a worker is electrocuted every day
- Causes 12% of young worker workplace deaths
- Takes very little electricity to cause harm
- Significant risk of causing fires

Effects on the Human Body

- 1 mA: Can be felt by the body
- 2-10 mA: Minor shock, might result in a fall
- 10-25 mA: Loss of muscle control, may not be able to let go of the current
- 25-75 mA: Painful, may lead to collapse or death
- 75-300 mA: Last for 1/4 second, almost always immediately fatal

Types of Electrical Injuries

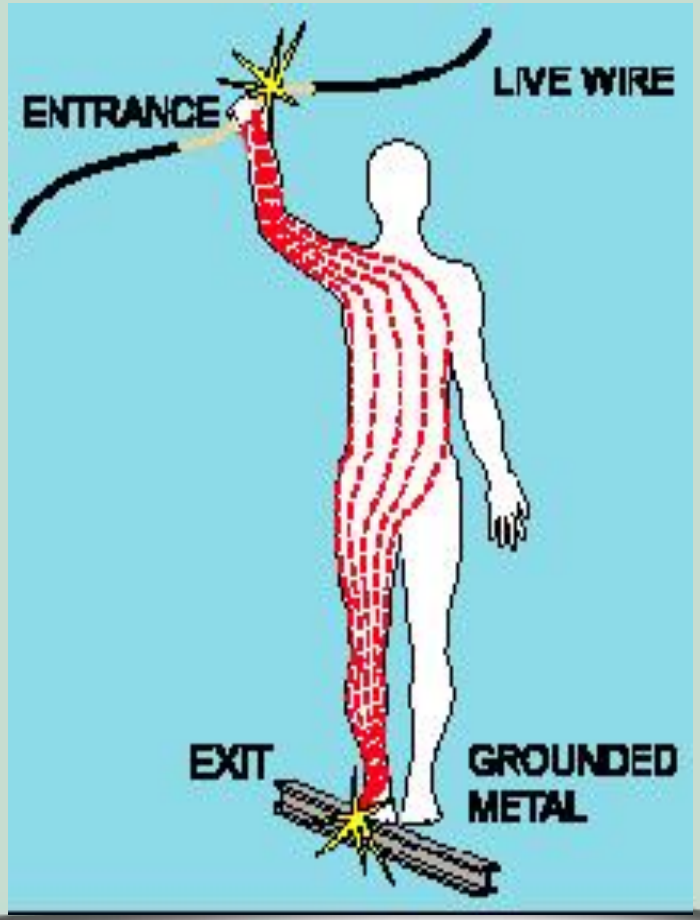
- There are four main types of electrical injuries:
  - Electrocution (death due to electrical shock)
  - Electrical shock
  - Burns
  - Falls

If Electrocution Occurs

- Call for help
- DO NOT touch the victim or the conductor
- Shut off the current at the control box
- If the shutoff is not immediately available, use a non-conducting material to free the victim
- If necessary and you know how, begin CPR when current is stopped
- In dealing with electricity, never exceed your expertise

Electrical Shock

- Received when current passes through the body
- Severity of a 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



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

How Electrical Shock is 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 Electrical Shock is Received

- 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

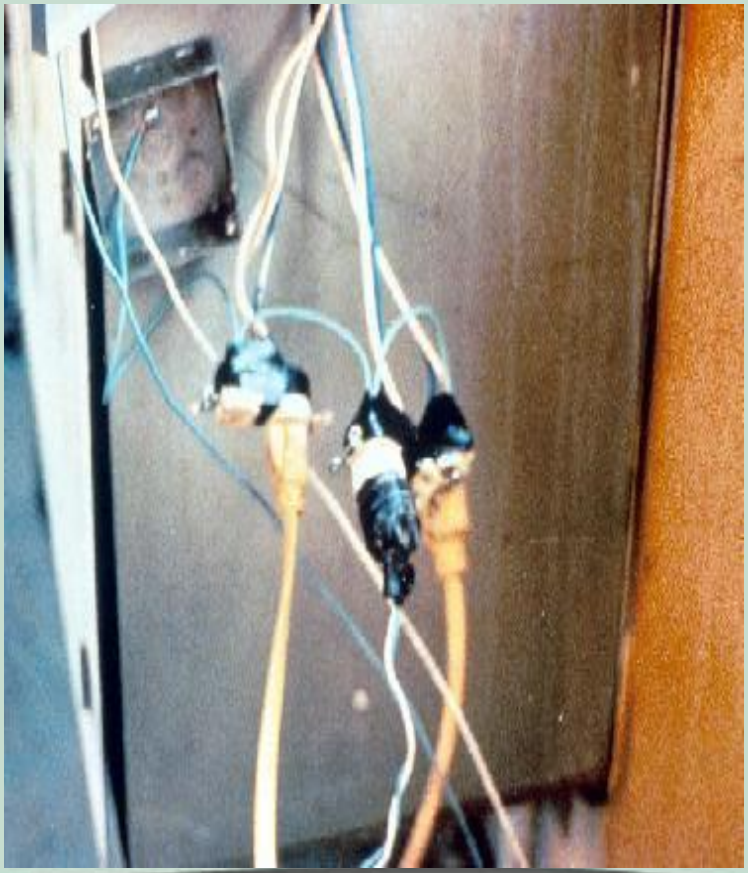
- Most common shock-related, nonfatal injury
- Occurs when you touch electrical wiring or equipment that is improperly used or maintained
- Typically occurs on the hands
- Very serious injury that needs immediate attention

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

Controlling Electrical Hazards

- Most electrical mishaps are caused by a combination of three factors:
  - Unsafe equipment and/or installation,
  - Workplaces made unsafe by the environment, and
  - Unsafe work practices

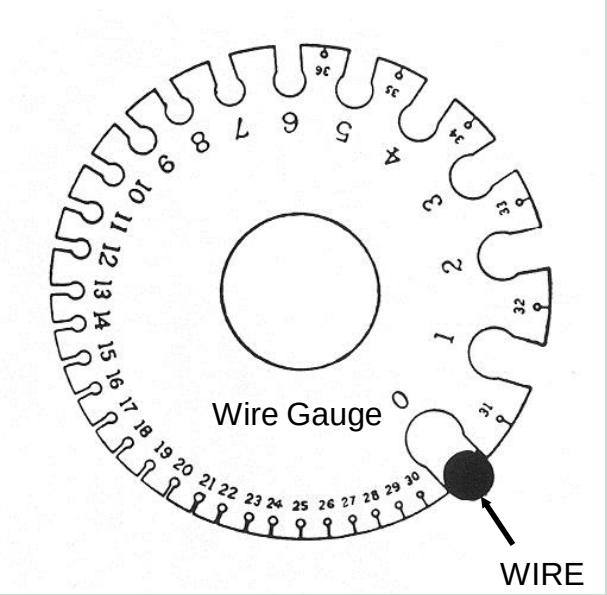


Clues that Electrical Hazards Exist

- Tripped circuit breakers or blown fuses
- Warm tools, wires, cords, connections, or junction boxes
- GFCI that shuts off a circuit
- Worn or frayed insulation around wire or connection

Inadequate Wiring Hazards

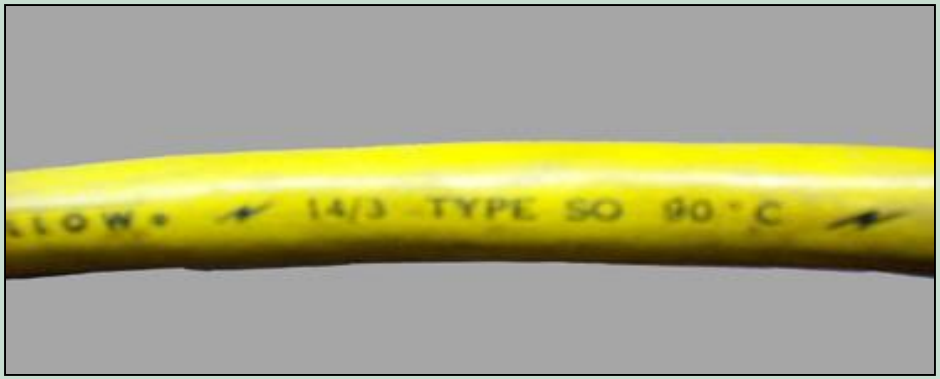
- A hazard exists when a conductor is too small to safely carry the current
- *Example:* using a portable tool with an extension cord that has a wire too small for the tool
  - The tool will draw more current than the cord can handle, causing overheating and a possible fire without tripping the circuit 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)

Control – Use the Correct Wire

- Wire used depends on operation, building materials, electrical load, and environmental factors
- Use fixed cords rather than flexible cords
- Use the correct extension cord



Must be 3-wire type and designed for hard or extra-hard use

Overload Hazards

- If too many devices are plugged into a circuit, the current will heat the wires to a very high temperature, which may cause a fire
- If the wire insulation melts, arcing may occur and cause a fire in the area where the overload exists, even inside a wall

Grounding Hazards

- Metal parts of an electrical wiring system that we touch (switch plates, ceiling light fixtures, conduit, etc.) should be at zero volts relative to ground
- Housings of motors, appliances or tools that are plugged into improperly grounded circuits may become energized
- If you come into contact with an improperly grounded electrical device, YOU WILL BE SHOCKED

Overhead Power Line Hazards

- Most people don’t realize that overhead power lines are usually not insulated
- Power line workers need special training and personal protective equipment (PPE) to work safely
- Beware of power lines when you work in the vicinity with ladders, erecting antennae, moving equipment, etc.

Preventing Electrical Hazards

- Ways of protecting workers and preventing electrical hazards are:
  - Insulation
  - Guarding
  - Grounding
  - Electrical protective devices
  - Safe work practices

Insulation

- Check insulation prior to using tools and equipment
- Remove from service any tools or equipment with damaged insulation

Guarding of Live Parts

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

29 CFR 1910.303(g)(2)(i)(A)

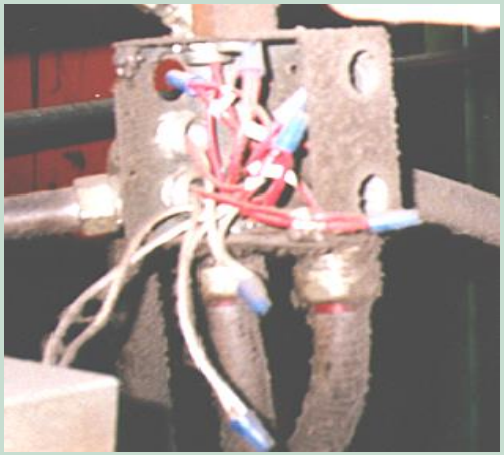
Guarding of Live Parts

- Must enclose or guard electric equipment in locations where it would be exposed to physical damage
  - Physical damage to conduit

29 CFR 1910.303(g)(2)(ii)

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)



29 CFR 1910.305(b)(1) and (2)

Grounding

- Grounding creates a low-resistance path from a tool to the earth to disperse unwanted current
- When a short or lightning occurs, energy flows to the ground, protecting you from electrical shock, injury and death

Improper Grounding

- Tools plugged into improperly grounded circuits may become energized
- Broken wire or plug on extension cord
- Some of the most frequently violated OSHA standards

Electrical Protective Devices

- These devices shut off electricity flow in the event of an overload or ground-fault in the circuit
- Include fuses, circuit breakers, and ground-fault circuit-interrupters (GFCIs)
- Fuses and circuit breakers are over-current devices
  - When there is too much current:
    - Fuses melt
    - Circuit breakers trip open

Ground-Fault Circuit Interrupter

- The GFCI detects a difference in current between the black and white circuit wires
  - This could happen when electrical equipment is not working correctly, causing current leakage known as a ground fault
- If a ground fault is detected, the GFCI can shut off electricity flow in as little as 1/40 of a second, protecting you from a dangerous shock

Safe Work Practices

- Never use plugs or receptacles that can alter polarity
- Properly plug all connecting plug-ins
- Install and use protective devices
- Stay away from all unguarded conductors
- Never overload a circuit or conductor

Safe Work Practices

- Know where the hazards are
- Properly maintain equipment
- No exposed parts or energized surfaces
- Use barriers and devices where appropriate
- No conductors to walk on or trip on
- No jewelry, or other metal objects around electricity

Planning

- Plan your work with others
- Plan to avoid falls
- Plan to lock-out and tag-out equipment
- Remove jewelry
- Avoid wet conditions and overhead power lines

Warn Others

- Use barricades to prevent or limit access to work areas with un-insulated energized conductors or circuit parts
- If signs and barricades do not provide sufficient warning and protection from electrical hazards, an attendant shall be stationed to warn and protect employees
- Use safety signs, safety symbols, or accident prevention tags to warn others about electrical hazards which may endanger them

Visually Inspect

- Portable cord and plug connected equipment and flexible cord sets (extension cords) shall be visually inspected before use on any shift for external defects:
  - Loose parts
  - Deformed or missing pins
  - Damage to outer jacket or insulation
  - Evidence of possible internal damage

Remove from Service

- If there is a defect or evidence of damage to any electrical tools or equipment
  - Immediately notify your supervisor
  - Remove the item from service
  - Tell your co-workers

Working on Energized Equipment

- Persons working on energized equipment must be familiar with the proper use of special precautionary techniques, PPE, insulating and shielding materials, and insulated tools

Working on Energized Equipment

- Isolate the area from all traffic
- Post signs and barricades
- Use an attendant if necessary
- Use insulated tools, mats and sheeting
- Use electrical rubber sheeting to cover nearby exposed circuits

Arc Flash Hazards

- **Electric arcs produce some of the highest temperatures known to occur on earth – up to 35,000 degrees Fahrenheit. This is four times the surface temperature of the sun.**
- **All known materials are vaporized at this temperature. When materials vaporize they expand in volume (Copper – 67,000 times, Water–1670 times). The air blast can spread molten metal to great distances with force.**
- **Rapidly expanding gases, extreme pressure and sound waves, molten metal and metal plasma.**

Arc Flash Hazards

- **Pressure: Blast pressure waves have thrown workers across rooms and knocked them off ladders. Pressure on the chest can be higher than 2000 lbs/ sq. ft. – blows clothing off body.**
- **Clothing can be ignited several feet away. Clothed areas can be burned more severely than exposed skin if clothing melts.**
- **Hearing loss from sound blast. The sound can have a magnitude as high as 140 dB at a distance of 2 feet from the arc.**

Electrical Arc Flash Burn

Electrical Arc Flash Accident

WARNING

Arc Flash and Shock Hazard
Appropriate PPE Required

3' - 4"	Flash Hazard Boundary
4.9	cal/cm2 Flash Hazard at 18 Inches
#2	PPE Level
	Cotton underwear plus FR shirt and FR pants
0.48	kV Shock Hazard when cover is removed
3' - 6"	Limited Approach
1' - 0"	Restricted Approach - Class 00 Voltage Gloves
0' - 1"	Prohibited Approach - Class 00 VoltageGloves

Equipment Name SWG-2A

IEEE 1584 Hazards; Project 1289A -- Safety Procedure #A6D24 --
EasyPower File: "Plant-A6.dez" -- Date: September 9, 2003

Arc Flash Causes

- Dust and impurities **- Dust and impurities on insulating surfaces can provide a path for current, allowing it to flashover and create arc discharge across the surface.**
- Corrosion **- Corrosion of equipment creates impurities on insulating surfaces. Corrosion also weakens the contact between conductor terminals, increasing the contact resistance through oxidation or other contamination. Heat is generated on the contacts; sparks may be produced; can lead to arcing faults closest ground source.**
- Condensation - **water vapor can drip causing tracking on the surface of insulating materials. Can create a flashover to ground.**
- Spark discharge – **Accidental contact; dropping tools**
- Overvoltage across narrow gaps
- Failure of insulating materials
- Improper work procedures

Arc Flash in Our Equipment

- **For a low voltage system (480/277 V), a 3 to 4-inch arc can become “stabilized” and persist for an extended period of time.**
- **Energy released is a function of system voltage, fault current magnitude and fault duration.**
- **Arcs in enclosures, such as a Motor Control Center (MCC) or panelboard, magnify blast and energy transmitted as the blast is forced to the open side of the enclosure and toward the worker (Arc-in-the-Box).**

Arc Flash in a Panelboard

Ionization cloud barely visible

Small arc – burn to hand

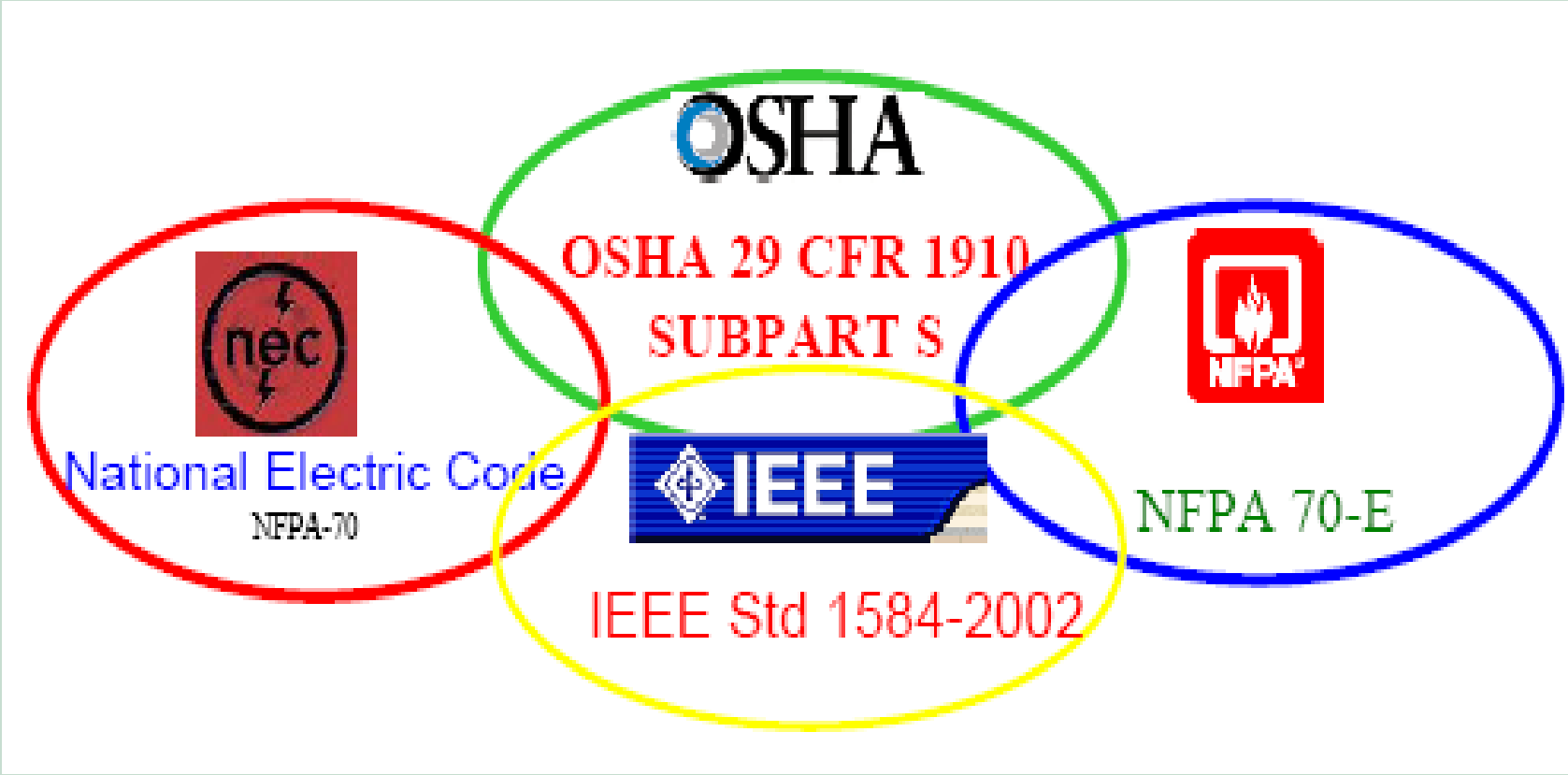
Clearly visible ionized gas

Medium arc – burn to hand, arm and chest

Exploding plasma of gases and vaporized metal

Severe arc – whole body burns

Standards Interaction



NFPA 70 E Standard

- National Consensus Standard
- 2004 Edition: *Electrical Safety in the Workplace*
- Can be cited by OSHA
- Provides guidance on electrical safety-related work
- practices and maintenance of electrical systems

Regulatory Requirement

- **Per OSHA Rule and NFPA 70E :**
  DO NOT WORK ON EQUIPMENT HOT

Equipment must be put in an electrically safe work condition prior to maintenance.

Working on Energized Equipment

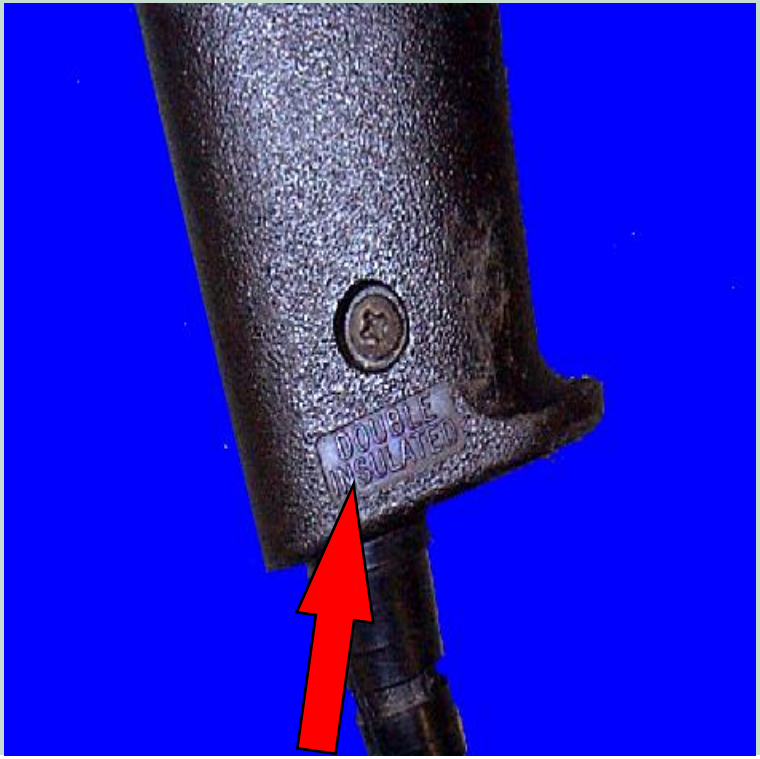
- You must be able to see what you are doing when working on energized equipment
- Don’t work on energized electrical parts:
  - Without adequate illumination
  - If there is an obstruction that prevents seeing your work area
  - If you must reach blindly into areas which may contain energized parts

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

Tools

- Inspect tools before use
- Use double insulated tools



Double Insulated Marking

Tools & Equipment

- Ground power supply systems, electrical circuits, and electrical equipment
- Frequently inspect electrical systems to insure path to ground is continuous
- Don’t remove ground prongs from tools or extension cords
- Ground exposed metal parts of equipment

PPE

- Persons working in areas where there are potential electrical hazards must use electrical protective equipment that is appropriate for the work to be performed
  - Proper foot protection (electrical rated)
  - Rubber insulating gloves, hoods, sleeves, matting, and blankets
  - Hard hat (insulated non-conductive)

PPE

- Use, store, and maintain your electrical PPE in a safe and reliable condition
- Wear non-conductive head protection wherever there is a danger of head injury from electric shock or burns due to contact with exposed energized parts
- 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

Conductive Work Locations

- Portable electric equipment & flexible cords used in highly conductive (wet) work locations where workers are likely to contact water or conductive liquids, must be rated for the wet environment

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

TRIUMVIRATE ENVIRONMENTAL

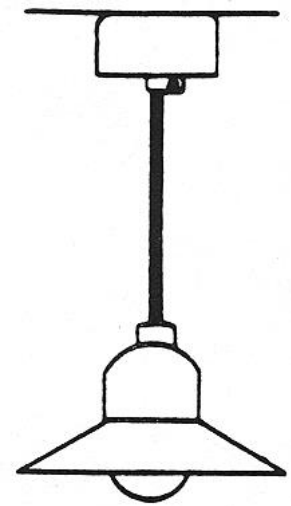
Working Safe with Cords

- Cords should be kept clean and free of kinks and insulation breaks
- Cords crossing vehicular or personnel passageways should be protected, a sign posted, and used temporarily or in an emergency only
- Cords should be of continuous length and without splices

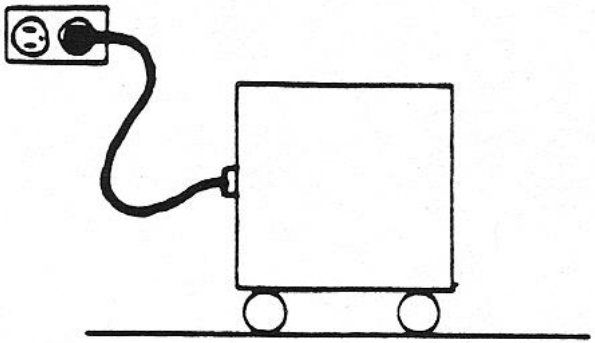
Working Safe with Cords

- Two conductor cords are illegal
- Damaged cords should never be used
- Ensure enough slack to prevent strain on plug or receptacle
- A plug-receptacle should have at least 8 ounces of contact tension

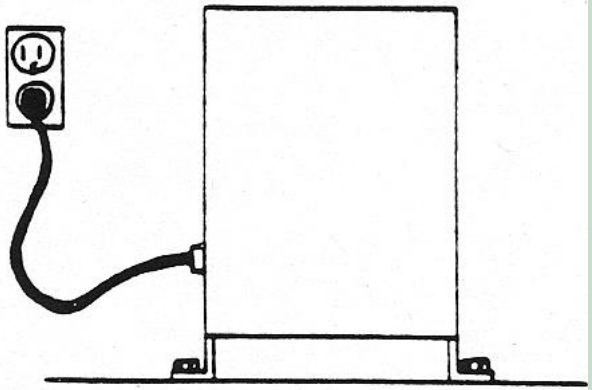
Permissible Uses of Flexible Cords
Examples



Pendant, or
Fixture Wiring



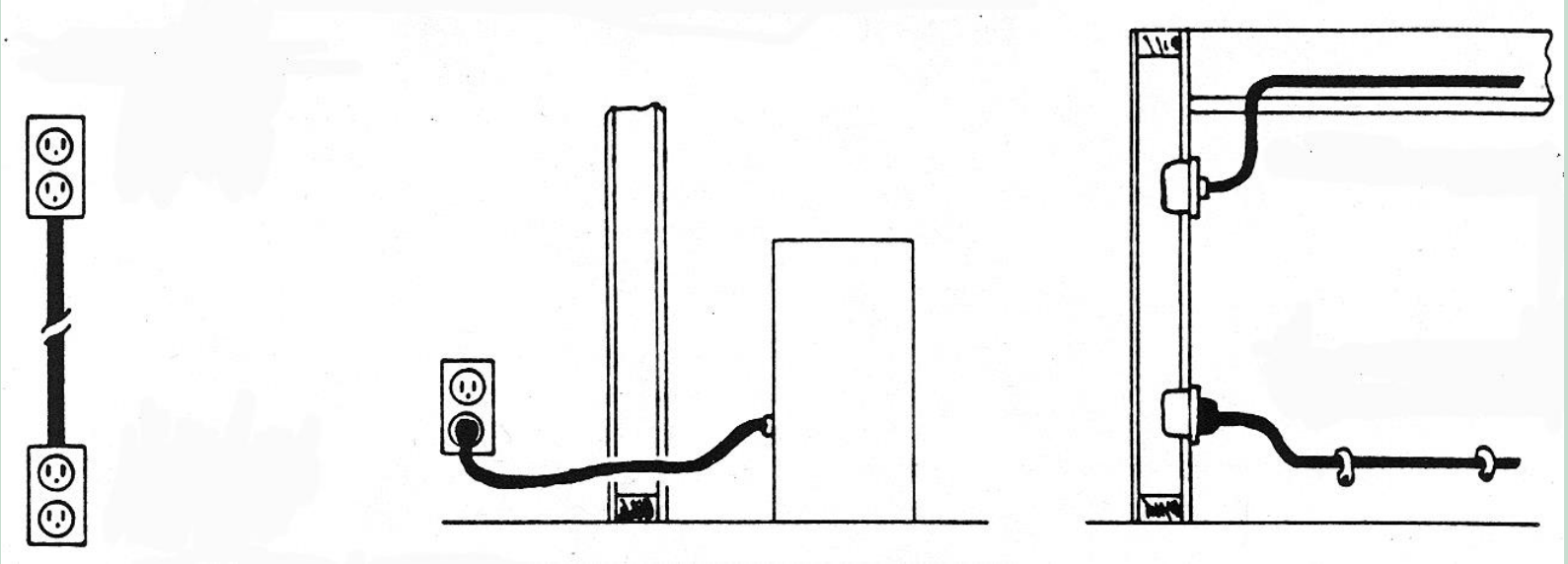
Portable lamps,
tools or appliances



Stationary equipment-
to facilitate interchange

1910.305(g)(1)(i)

Prohibited Uses of Flexible Cords Examples



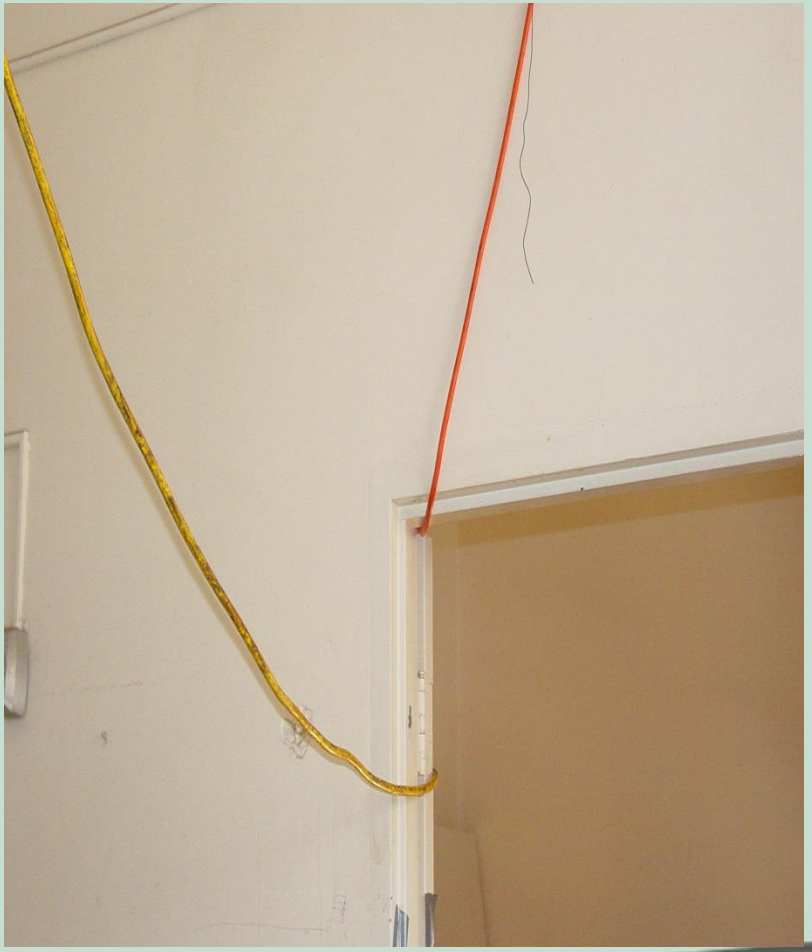
Substitute for fixed wiring

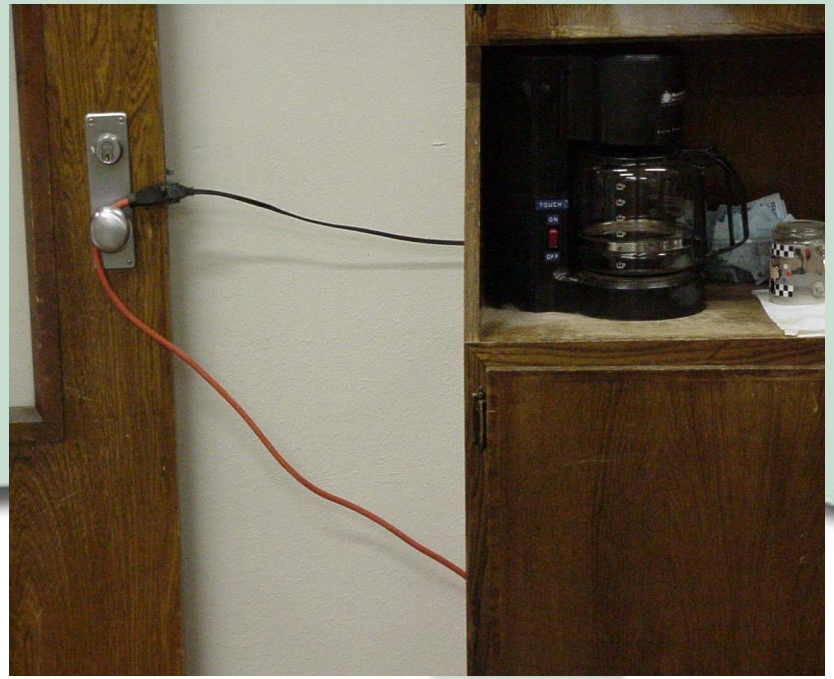
Run through walls, ceilings, floors, doors, or windows

Concealed behind or attached to building surfaces

1910.305(g)(1)(iii)

What's the hazard ?

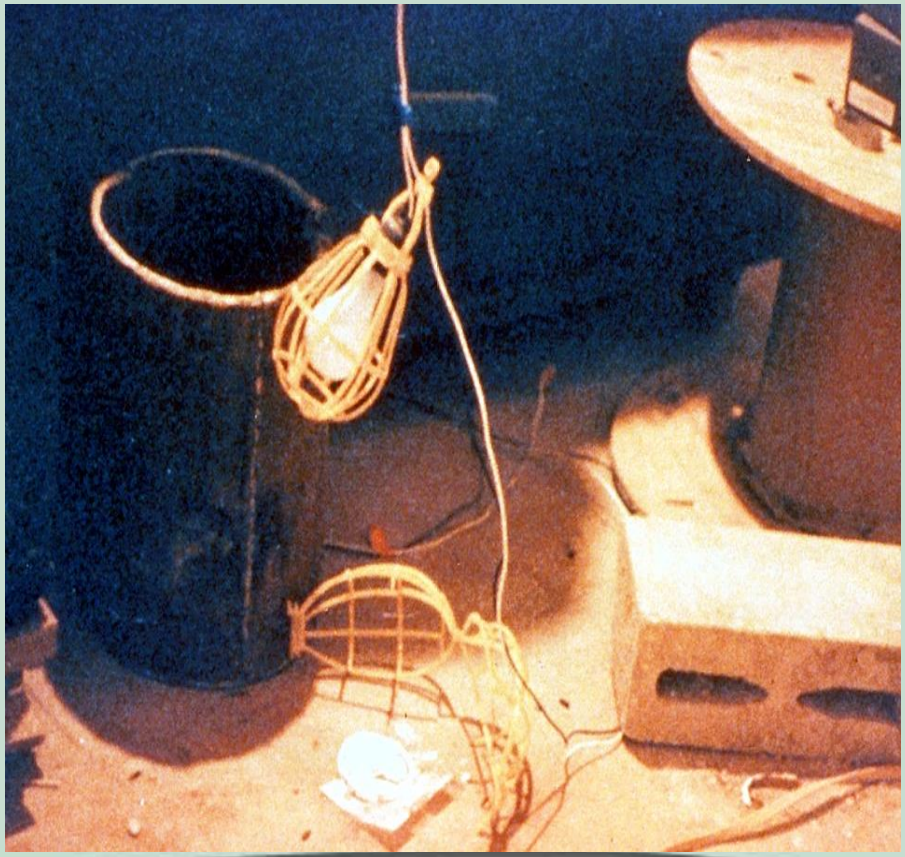




Temporary Lights

29 CFR 1926.405(a)(2)(ii)(F)

- Protect from contact and damage, and don’t suspend by the cord unless designed to do so



Bonding

- When filling metal containers use bonding wire and keep containers closed until after bonding
  - Attach the bonding cable to a shiny metal

Panel Boxes

- Panel boxes are used to house circuit breakers that block or isolate energy
  - Ensure panel boxes remain clear
  - Label all circuits for what they control
  - Label panel boxes for what they control
  - Replace circuit breakers with blanks when not in use

Test Instruments

- Test instruments, equipment and test leads, cables, power cords, probes, and connectors must be visually inspected for external defects and damage before the equipment is used
- Test instruments and equipment and accessories must be:
  - Rated for the circuits and equipment to which they will be connected
  - Designed for the environment in which they will be used

Suitability

- Suitability of electrical equipment for an identified purpose may be evidenced by listing or labeling by a nationally recognized testing laboratory which makes periodic inspections of equipment production and states that such equipment meets nationally recognized standards or tests to determine safe use in a specified manner

Control of Circuits

- Only switches and breakers designed to do so may be used to control current
- Only approved equipment may be used in wet or damp areas
- Use GFCIs when needed
- Never energize equipment when shields or guards have been removed
- Always honor lockout/tagout situations

Conductive Materials

- Conductive materials and equipment must be handled in a manner to prevent them from contacting exposed energized conductors or circuit parts

Training (29 CFR 1910.332)

- All qualified and unqualified (electrical) workers in jobs that face the risk of electric shock that is not reduced to a safe level by insulation requirements must receive classroom or on-the-job training in safety-related work practices that pertain to their respective job assignments
- Additional requirements for unqualified workers
  - Any electrically related safety practices that are necessary for their safety

Training (29 CFR 1910.332)

- Additional requirements for qualified workers (those permitted to work on or near exposed energized parts)
  - The skills and techniques necessary to:
    - Distinguish exposed live parts from other parts of electrical equipment
    - Determine the nominal voltage of exposed live parts
    - Determine the clearance distances and the corresponding voltages they will be exposed to

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 GFCIs
Using fuses and circuit breakers
Guarding live parts
Proper use of flexible cords
Training

References

- 29 CFR 1910 Subpart S
- 29 CFR 1926 Subpart K
- NFPA 70 National Electrical Code