Collaborative Bachelor's Degree Program of Fire Protection and Safety Engineering Technology between Southwest Jiaotong University and Oklahoma State University, U.S.A.

FPST 2023 Industrial and Occupation Safety

Electrical Safety – Part 2

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Collaborative Bachelor's Degree Program of Fire Protection and Safety Engineering Technology between Southwest Jiaotong University and Oklahoma State University, U.S.A.

Examples of OSHA Electrical Requirements

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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

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Grounding

- Two kinds of grounds are required by the standard:
  - Service or system ground. In this instance, one wire, called the neutral conductor or grounded conductor, is grounded. This type of ground is primarily designed to protect machines, tools, and insulation against damage.
  - For enhanced worker protection, an additional ground, called the equipment ground, must be furnished by providing another path from the tool or machine through which the current can flow to the ground. This additional ground safeguards the electric equipment operator if a malfunction causes the metal frame of the tool to become energized.

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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

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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

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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

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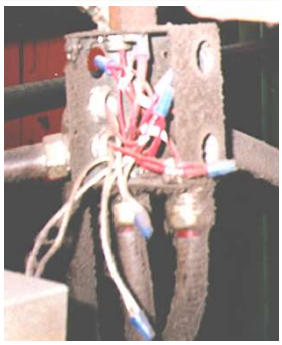
Cabinets, Boxes, and Fittings

- 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



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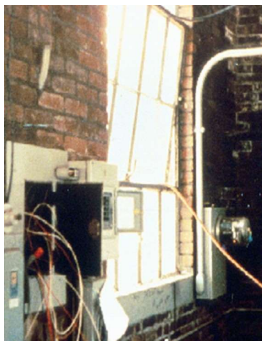
Use of Flexible Cords

- 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



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Permissible Uses of Flexible Cords - Examples

- Other examples:
  - Elevator cables
  - Wiring of cranes and hoists
  - Prevention of the transmission of noise or vibration
  - Appliances where the fastening means and mechanical connections are designed to permit removal for maintenance and repair
  - Data processing cables approved as part of the data processing system

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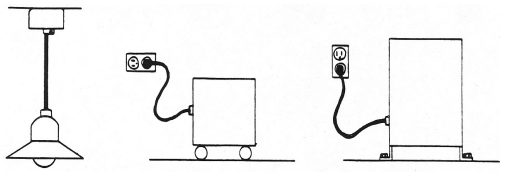
Permissible Uses of Flexible Cords - Examples



Pendant, or Fixture Wiring

Portable lamps, tools or appliances

Stationary equipment- to facilitate interchange

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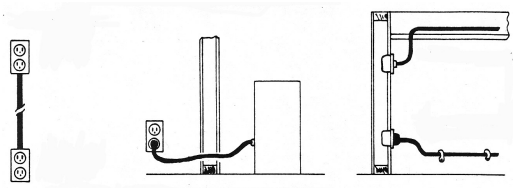
Prohibited Uses of Flexible Cords - Examples



Substitute for fixed wiring

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

Concealed behind or attached to building surfaces

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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

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ARC FLASH

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What is an Electric Arc?

- Simply put, an electric arc is a short circuit through the air.
- The amount of energy released depends, in part, on the amount of energy in the circuit. The more energy, the more powerful the arc.
- Electric arcs produce some of the highest temperatures known to occur on earth.

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What Causes Arc Flash?

- Dust, impurities, corrosion, condensation, animals
- Spark discharge from:
- Accidental touching
- Dropping tools
- Over-voltages across narrow gaps
- Failure of insulating materials
- Equipment failure

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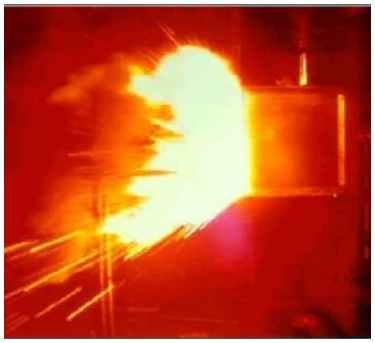
What is an Arc Flash Hazard?



- *". . . a dangerous condition associated with the release of energy caused by an electric arc."*
- Arc flash is the explosive release of energy when electrical current jumps the distance from one conductor to another, or when it jumps from a conductor to ground.
- That jump is called an "arc". "Flash" refers to the release of light and heat energy.

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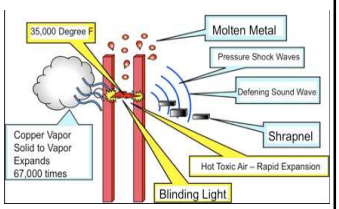
What is Arc Blast?

- The flash causes rapid explosive expansion of air and metal.
  - For example: When copper vaporizes it expands by a factor of 67,000.
- The blast produces dangerous:
  - Pressure waves
  - Sound waves
  - Molten steel and shrapnel.



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Electric arc → Arc flash → Arc blast

Compliments of Salisbury Electrical Safety L.L.C.

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Forms of Arc Flash Energy

- Noise
- Expansion
- Vaporization
- Thermal radiation

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Arc Flash Injuries

- Electric shock
- Severe burns
- Blindness
- Blast injuries
  - Shrapnel wounds
  - Lung blast injuries
  - Ruptured eardrums
  - Pressure wave injuries

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Severity Factors

- Power – amount of energy at the arc
- Distance – of the worker to the arc
- Time – duration of the arc exposure

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Electric Shock Injury – Burn

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Severe Burns from Arc Flash

- Arc flash
  - up to 35,000°F
- Sun surface
  - 10,000°F

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Blindness

- Flash of light is so intense it can damage vision.

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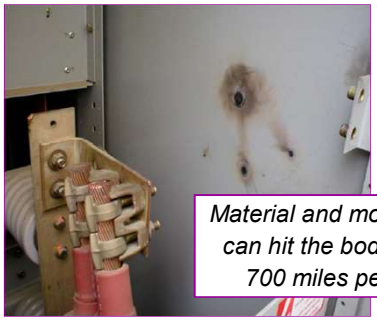
Shrapnel Wounds



Material and molten metal can hit the body at over 700 miles per hour.

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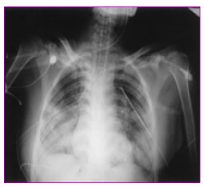
Blast Lung Injury (BLI)

- Arc blast can cause inhalation injuries.
  For example:
  - Inhaling high temperature copper vapor.
  - More than 100 toxic substances can be found in the fumes.



BLI + Burns = Greater chance of death

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Hearing Damage

Arc blast at 2 feet	145 decibels
Jet engine at 200 feet	132 decibels
Pain threshold	130 decibels

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Pressure Wave Injuries

- Arc blast can throw a worker:
  - Off a ladder
  - Into nearby walls or equipment.
- 2000 lbs/ft^2 pressure on the body can cause:
  - Concussion
  - Collapsed lungs
  - Other internal injuries

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Videos

- Watch Videos
  - Arc Flash 1
  - Arc Flash 2
  - Arc Flash 3
  - Arc Flash 4

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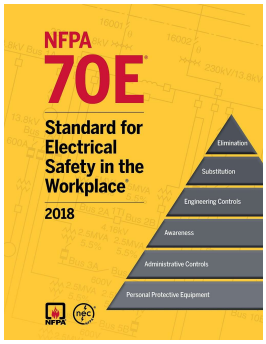
What is NFPA 70E?

- Created in 1979
- Evolved over the last 25 years to become the North American Standard for electrical safe work practices
- The 2009 edition was harmonized with the Canadian electrical safety Standard CSA Z462.



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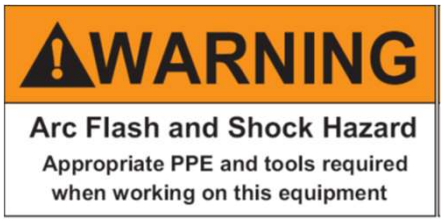
Required Warning Label



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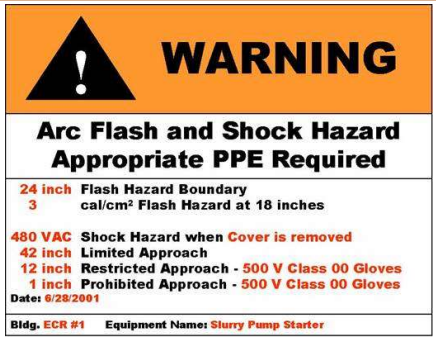
Optional Warning Label



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PROTECTIVE CLOTHING AND EQUIPMENT

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Flame-Resistant (FR) Clothing

- Protects a worker from receiving severe burns if the worker is exposed to a flame
- Is self-extinguishing when the source of the flame is removed
  - Treated
  - Inherent
- Thermal energy is measured in calories/cm².

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FR Rated Clothing

- Limit the 'Incident Energy' level of the arc flash to 1.2 cal/cm² against the worker's chest.
- Look for a label that states:
  - 1506 approval (ASTM F1506)
    Arc rating of the garment
- All materials in the garment should be FR Rated:
  - Thread
  - Buttons
  - Insulation
  - Zippers, etc.
- Watch video
  - Arc Flash Testing

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Arc Flash PPE Category 1

Arc-Rated Clothing, Minimum Arc Rating of 4 cal/cm² (16.75 J/cm²)[a]
Arc-rated long-sleeve shirt and pants or arc-rated coverall
Arc-rated face shield[b] or arc flash suit hood
Arc-rated jacket, parka, rainwear, or hard hat liner (AN)
Protective Equipment
Hard hat
Safety glasses or safety goggles (SR)
Hearing protection (ear canal inserts)[c]
Heavy-duty leather gloves[d]
Leather footwear (AN)

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Arc Flash PPE Category 2

Arc-Rated Clothing, Minimum Arc Rating of 8 cal/cm² (33.5 J/cm²)[a]
Arc-rated long-sleeve shirt and pants or arc-rated coverall
Arc-rated flash suit hood or arc-rated face shield[b] and arc-rated balaclava
Arc-rated jacket, parka, rainwear, or hard hat liner (AN)
Protective Equipment
Hard hat
Safety glasses or safety goggles (SR)
Hearing protection (ear canal inserts)[c]
Heavy-duty leather gloves[d]
Leather footwear

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Arc Flash PPE Category 3

Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 25 cal/cm² (104.7 J/cm²)[a]
Arc-rated long-sleeve shirt (AR)
Arc-rated pants (AR)
Arc-rated coverall (AR)
Arc-rated arc flash suit jacket (AR)
Arc-rated arc flash suit pants (AR)
Arc-rated arc flash suit hood
Arc-rated gloves[d]
Arc-rated jacket, parka, rainwear, or hard hat liner (AN)
Protective Equipment
Hard hat
Safety glasses or safety goggles (SR)
Hearing protection (ear canal inserts)[c]
Leather footwear

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Arc Flash PPE Category 4

Arc-Rated Clothing Selected so That the System Arc Rating Meets the Required Minimum Arc Rating of 40 cal/cm² (167.5 J/cm²)[a]
Arc-rated long-sleeve shirt (AR)
Arc-rated pants (AR)
Arc-rated coverall (AR)
Arc-rated arc flash suit jacket (AR)
Arc-rated arc flash suit pants (AR)
Arc-rated arc flash suit hood
Arc-rated gloves[c]
Arc-rated jacket, parka, rainwear, or hard hat liner (AN)
Protective Equipment
Hard hat
Safety glasses or safety goggles (SR)
Hearing protection (ear canal inserts)[c]

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Synthetic Clothing

- Synthetic clothing that melts ***shall not*** be worn, such as:
  - Acetate
  - Nylon
  - Polyester
  - Polypropylene
  - Spandex.

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Arc Flash Rated PPE

- Required minimum clothing:
  - Non-melting, flammable material,
  - Fabric weight of at least 4.5 oz/yd.
- PPE must also provide arc flash protection:
  - Face shield
  - Gloves, etc.

Photo compliments of
Salisbury Electrical Safety L.L.C.

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FR Clothing Can Be Layered

- Increases level of protection.
- May be lighter than a single heavy garment.
- Manufacturer must provide the new combined arc rating afforded by layering.
- Photo compliments of Salisbury Electrical Safety L.L.C.

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When Purchasing PPE

- Tell the supplier that you need ***arc flash rated*** PPE and clothing.
- PPE must have some resistance to:
  - Flame
  - Ignition
  - Melting
- Obtain PPE from a known and trusted supplier.

Photo compliments of Salisbury Electrical Safety L.L.C.

Not all FR clothing is tested to ASTM F1506

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Tasks with Potential for Arc Flash

- Operating a switch or circuit breaker
- Inserting or removing a circuit breaker
- Opening an enclosure door
- Removing a cover (bolted or hinged)
- Testing for voltage

In each task:
Worker is interacting with energized equipment.

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Arc Flash Hazard Analysis

If work must be done on or near energized electrical equipment, identify the potential for arc flash.

- Conduct a Flash Hazard Analysis to determine the
  - Flash Protection Boundary
  - Incident Energy exposure
  - Type and arc rating of PPE

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CONTROLLING ARC FLASH HAZARDS - At the Source

- Reduce the fault clearing time
  - Reduce the duration and magnitude of the heat released by the short circuit currents
- Reduce the short-circuit current
  - Current limiting fuses/breakers
  - Current limiting reactors
- Improve equipment maintenance
  - Maintain equipment maintenance records.
  - Conduct infrared scanning.
  - Identify and label equipment that poses flash hazard
  - Confirm single-line diagrams for accuracy and available fault current.

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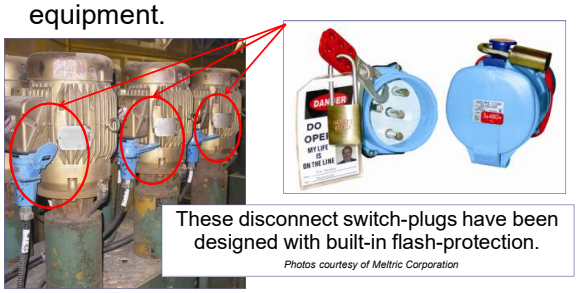
CONTROLLING ARC FLASH HAZARDS - At the Source

- Use flash-resistant equipment.



These disconnect switch-plugs have been designed with built-in flash-protection.

Photos courtesy of Meltric Corporation

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CONTROLLING ARC FLASH HAZARDS - Along the Path

- Increase the working distance
  - Use hot sticks to operate fuses and switches.
- Reduce the energy exposure
  - Arc resistant switchgear,
  - Arc shield when racking a circuit breaker
- Use hinged doors instead of bolted doors to eliminate the risk of bolts falling into the panel.
- Ideally…Work de-energized.

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CONTROLLING ARC FLASH HAZARDS - At the Worker

- Energized electrical work permit
- Barriers
- Training and skills
- Job briefings
- PPE
- Tools

Photo compliments of Salisbury Electrical Safety L.L.C.

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Prevention Summary

- Include Electrical Safety in your Occupational Health and Safety Management Program
- Use an electrical work permit system
- Conduct regular equipment maintenance and label equipment that poses a flash hazard
- Confirm single-line diagrams for accuracy and available fault current
- Maintain documentation process
- Provide training and job briefings
- Conduct periodic safety audits

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ARC FLASH PREVENTION

It is ALWAYS
preferable to work on
de-energized equipment