**ELECTRICAL SAFETY IN THE WORKPLACE**

**NFPA 70E 2018**

**Electric Hazards**

Electricity-related hazards include electric shock and burns, arc-flash burns, arc-blast impacts, and falls.

* **Electric shock and burns.** An electric shock occurs when an electric current passes through your body. This can happen when you touch an energized part. If the electric current passes across the chest or head, you can be killed. At high voltages, severe burns can result.
* **Arc-flash burns.** An electric arc flash can occur if a conductive object gets too close to a high­ amp current source or by equipment failure (for instance, while opening or closing disconnects). The arc can heat the air to temperatures as high as 35,000 F, and vaporize metal in the equipment. The arc flash can cause severe skin burns by direct heat exposure and by igniting clothing.
* **Arc-blast impacts.** The heating of the air and vaporization of metal creates a pressure wave that can damage hearing and cause memory loss (from a concussion) and other injuries. Flying metal parts are also a hazard.
* **Falls.** Electric shocks and arc blasts can cause falls, especially from ladders or unguarded scaffolding.

# Electric Safety Principles NFPA 70E Annex I

Plan every job.Decide on your approach and step-by-step procedures. Write down first-time procedures. Discuss hazards and procedures in a job briefing with your supervisor and other workers before starting a job. A district should already have or develop a permit system for working on live circuits if a circuit must be worked live.

* **Identify the hazards.** Due a job hazard analysis and identify steps that could create an electric shock or arc-flash hazards.
* **Minimize the hazards.** De-energize the equipment or insulate or isolate exposed live parts so

you cannot contact them. If this is impossible, get proper personal protective equipment (PPE) and tools.

* + Natural fiber clothing (long sleeve shirt and pants) is required. Further

Personal Protective Equipment (PPE) may be required in accordance with NFPA 7OE **Table 130.7 (C) (15) (c)**

* + Glove protectors may be omitted from Class O glove sets under limited-use conditions, where small equipment and parts manipulation require exceptional finger dexterity. Rubber insulating gloves that have been used without protectors shall not be used with protectors until the

rubber gloves have been returned to Electrical Safety and given an inspection and electrical test. Class 00 (600 volt) gloves may be used for better dexterity if required.

* Eye protection (safety glasses or goggles) shall be worn when performing testing.
* **Anticipate problems.** If it can go wrong, it might. Make sure you have the right PPE and tools for the worst-case scenario.
* **Get training.** Make sure you and everyone working with you is a qualified person with appropriate training for the job.

# To De-Energize or Not to De-Energize

One of the most important decisions in planning an electric task is whether to de-energize. Whenever possible, live parts to which you might be exposed should be put into an **electrically safe work condition,** unless your employer can demonstrate that de-energizing creates more or worse hazards, or is not practical because of equipment design or operational limitations.

You might need to work live to avoid deactivating emergency alarm systems, or shutting down ventilation equipment for hazardous locations, for instance. And de-energizing would not be practical during testing of live electric circuits or work on circuits that are part of a continuous process that cannot be completely shut down.

**De-Energizing**

**An Electrically Safe Work Condition**

The most important principle of electric safety is, **assume electric circuits are energized unless you make sure they are not.** Test ***every*** circuit and conductor every time you work on them. The National Fire Protection Association lists six steps to ensure conditions for electrically safe work.

* Identify all sources of power to the equipment.
* Interrupt the load current, then open the disconnecting devices for each power source.
* Where possible, visually verify that blades of disconnecting devices are fully open or that draw out-type circuit breakers are fully withdrawn.
* Apply lockout/tagout devices in accordance with a formal, written policy.
* Test each phase conductor or circuit part with an adequately rated voltage detector to verify that the equipment is de-energized. Check the voltage detector before and after each test to be sure it is working.
* Properly ground all possible sources of induced voltage and stored electric energy (such as capacitors) before touching. If conductors or circuit parts that are being de-energized could contact other exposed

conductors or circuit parts, apply ground-connecting devices rated for the available fault current.

**The process of de-energizing is "live" work and can result in an arc flash** due to equipment failure. When de-energizing, follow the procedures described below in "Working On or Near Live Circuits."

# Lockout/tag out Program NFPA 70E 120.1

Districts should establish a written lockout/tag out program and train employees in the program. The program should cover planning for locating and labeling energy sources, identifying employees at risk, how and by whom the equipment is de-energized, releasing of stored energy, verifying that the circuit is de-energized and can't be restarted, voltage testing, grounding requirements, shift changes, coordination with other jobs in progress, a procedure for keeping track of all involved personnel, applying and removing lockout/tagout devices, return to service, and temporary re-energizing for testing/positioning. Lockout/tagout procedures should be developed for each machine or piece of equipment that will require servicing.

**Lockout/tag out application.** Each person who could be exposed to electric energy must be involved in the lockout/tag out process.

* After de-energizing, each employee at risk should apply an individual lockout/tag out device to each source of electric energy. Pushbuttons or selector switches cannot be used as the only way to de-energize.
* A lockout device is a key or combination lock with a tag that can be attached to a disconnecting device to prevent the re-energizing of the equipment being worked on without removal of the lock. The lockout device should have a way of identifying whose lock it is. Individual lockout devices with your name and picture on them are preferred. You must be the only person who has the key or combination for a lockout device you install, and you should be the only person to remove the lock after all work has been completed.
* A tag out device is a tag and a way to attach it that can withstand at least 50 pounds of force. Tag out devices should be used alone only when it is not possible to install a lockout device.
* The tag used in conjunction with a lockout or tag out device must have a label prohibiting the unauthorized operation of the disconnecting means or unauthorized removal of the device.
* Before beginning work, you must verify through testing that all energy sources have been de­ energized.
* Electric lockout/tag out procedures should be coordinated with all

other site procedures for controlling exposure to electric energy and other types of energy sources.

**Individual qualified-employee control procedure.** For minor servicing, maintenance, inspection, and so on, on plug-connected equipment, work may be done without attaching lockout/tagout devices if the plug is next to where you are working and is always easy to see, and you do not ever leave the equipment alone.

**Complex lockout/tag out procedures.** Special procedures are needed when there is more than one energy source, crew, craft, location, employer, way to disconnect, or lockout/tagout procedure - or work that lasts beyond one shift. In any of these cases, one qualified person should be in charge of the lockout/tag out procedure with full responsibility for ensuring all energy sources are under lockout/tag out and to account for all people on the job. There should be a written plan addressing the specific details and naming the person in charge.

**Removal of lockout/tag out devices.** Lockout and tag out devices should be removed only by the person installing them. If work is not completed when the shift changes, workers arriving on shift should apply their locks before departing workers remove their locks.

**Return to service.** Once work is completed and lockout/tagout devices removed, tests and visual inspection must confirm that all tools, mechanical restraints, electric jumpers, shorts, and grounds have been removed. Only then is it safe to re-energize and return to service. Employees responsible for operating the equipment and needed to safely re-energize it should be out of the danger zone before equipment is re-energized.

**Temporary release.** If the job requiring lockout/tag out is interrupted for testing or positioning equipment, follow the same steps as in return to service (above).

# Working On or Near Live Circuits

Working on live circuits means actually touching energized parts. Working near live circuits means working close enough to energized parts to pose a risk even though you make be working on de­ energized parts. Common tasks where you need to work on or near live circuits include:

* Taking voltage measurements
* Opening and closing disconnects and breakers
* Racking breakers on and off the bus
* Removing panels and dead fronts
* Opening electric equipment doors for inspection.

There should be standard written procedures and training for these common tasks. For instance, when opening and closing disconnects, use the **left-hand rule** when possible (stand to the right side of the equipment and operate the disconnect with your left hand). For other situations where you might need to work on or near live circuits, a district should institute a written live work permit system, which must be authorized by a qualified supervisor.

# Live-Work Permit System

A live-work permit should, at a minimum, contain this information:

* A description of the circuit and equipment to be worked on and location
* The date and time covered by the permit
* Why live work will be done
* Results of shock hazard analysis and determination of shock protection boundaries
* Results of flash hazard analysis and determination of flash protection boundary
* PPE to be worn and description of safe work practices to be used
* Who will do the work and how unqualified persons will be kept away
* Evidence of completion of job briefing, including a description of job-specific hazards.

# Approach Distances to Exposed Live Parts

The National Fire Protection Association defines approach distances for shock hazards and one for arc flash. **Electric shock** (see Table 1 below).

* The **Limited Approach Boundary (NFPA 70E Article 130 (E)** is the closest distance an unqualified person can approach unless accompanied by a qualified person.
* The **Restricted Approach Boundary (NFPA 70E Article 130 (F)** is the closest distance to exposed live parts a qualified person can approach without proper PPE and tools. Inside this boundary, accidental movement can put a part of your body or conductive tools in contact with live parts or inside the prohibited approach boundary. To cross the restricted approach boundary, the qualified person must:
  + Have a documented plan that is approved by the manager responsible for the safety plan.
  + Use PPE suitable for working near exposed live parts and rated for the voltage and energy level involved.
  + Be certain that no part of the body enters the prohibited space.
  + Minimize the risk from unintended movement, by keeping as much of the body as possible out of the restricted space; body parts in the restricted space should be protected.

# Arc Flash

The **flash protection boundary** is the distance at which PPE is needed to prevent incurable burns (2nd degree or worse) if an arc flash occurs. (You still can get first or second-degree burns.) For systems of 600 volts and less, the flash protection boundary is four feet, based on an available bolted fault current of 50 kA (kilo amps) and a clearing time of 6 cycles (0.1 seconds) for the circuit breaker to act, or any combination of fault currents and clearing times not exceeding 300 kA cycles. For other fault currents and clearing times, *see* NFPA 70E.

Remember that when you have de-energized the parts you are going to work on, but are still inside the flash protection boundary for nearby live exposed parts: If the parts cannot be de-energized, you must use barriers such as insulated blankets to protect against accidental contact or you must wear proper PPE.

# Proper Personal Protective Equipment (PPE) NFPA 70E Article 130

When working on or around live circuits be sure to wear the right PPE to protect against electric shock and arc flash. Never wear clothing made from synthetic materials, such as acetate, nylon, polyester, or rayon - alone or combined with cotton. Such clothing is dangerous because it can burn and melt into your skin. The type of PPE worn depends on the type of electric work being done (See Table 2 below).

Once the hazard/risk category has been identified, check requirements for clothing and other PPE when working on or near energized equipment within the flash protection boundary. These PPE requirements protect against electric shock and incurable arc-flash burns. They do not protect against physical injuries from arc blasts.

The minimum PPE required would be an untreated natural fiber long-sleeve shirt and long pants with safety glasses with side shields (hazard/risk category 1).

**For more information** the National Institute for Occupational Safety and Health (1-800-35-NIOSH or [www.cdc.gov/niosh),](http://www.cdc.gov/niosh)) or OSHA (1-800-321-OSHA or <www.osha.gov>).

# Table 1. Approach boundaries to live parts for shock prevention NFPA 70E Table 130.4(D)(a)

|  |  |  |  |
| --- | --- | --- | --- |
| **Limited Approach Boundary** | | | |
| **Nominal System Voltage Range, Phase to Phase** | **Exposed Movable Conductor** | **Exposed Fixed-Circuit Part** | **Restricted Approach Boundary**  **(allowing for accidental movement)** |
| 0 to 50 volts | Not specified | Not specified | Not specified |
| 51 to 300 volts | 10 ft. 0 in. | 3 ft. 6 in. | Avoid contact |
| 301 to 750 volts | 10 ft. 0 in. | 3 ft. 6 in. | 1ft. 0 in. |
| 751 to 15,000 volts | 10 ft. 0 in. | 5 ft. 0 in. | 2 ft. 2 in. |

# NFPA 70E Table 130.5(C)

* For low-voltage tasks (600 volts and below), this table applies only when there is an available short-circuit capacity of 25 kA or less, and when the fault clearing time is 0.03 seconds (2 cycles) or less.
* For 600-volt-class motor control centers, and short-circuit current capacity of 65 kA or less and fault-clearing time of 0.33 seconds (20 cycles) is allowed.
* For 600-volt-class switchgear, you need and short-circuit current capacity of 65 kA or less and fault-clearing time of 1 second (60 cycles).
* For tasks not covered in this table and tasks involving equipment with larger short-circuit current capacities or longer fault-clearing times, a qualified person must conduct a flash hazard analysis NFPA 70E Article 100.

**NFPA 70E Article 130 Table 130.5 (C)**

|  |  |  |
| --- | --- | --- |
| **TASK** | **EQUIPMENT CONDITION** | **LIKELIHOOD OF OCCURRENCE** |
| * Reading a panel meter while operating a meter switch. * Performing infrared thermography and other non-contact inspections outside the restricted approach boundary. This activity does not include opening doors or covers. * Examination of insulated cable with no manipulation of the cable. * For dc systems, insertion or removal of individual cells or multi-cell units of a battery system in an open rack. * For dc systems, maintenance on a single cell of a battery system or multi-cell units in an open rack. | **Any** | **No** |
| * For ac systems, work on energized electrical conductors, and circuit parts including voltage testing. * For dc systems, working on energized electrical conductors and circuit parts of series-connected battery cells, including voltage testing. * Removal or installation of CBs or switches. * Opening hinged door(s) or cover (s) or removal of bolted covers (to expose bare energized electrical conductors and circuit parts). For dc systems, this includes bolted covers such as battery terminal covers. * Application of temporary protective grounding equipment after a voltage test. * Working on control circuits with exposed energized electrical conductors and circuit parts, greater than 120 volts. * Insertion or removal of individual starter buckets from the motor control center (MCC) * Insertion or removal (racking) of circuit breakers (CBs) or starters from cubicles, doors open or closed. * Insertion or removal of plugs-in devices into or from busways. * Examination of insulated cable with manipulation of cable. * Working on exposed energized electrical conductors and circuit parts of equipment directly supplied by a panelboard or motor control center. * Insertion or removal of revenue meters (kW-hour, at a primary voltage or current). * Removal of battery conductive intercell connector covers. * For dc systems, working on exposed energized electrical conductors and circuit parts of utilization equipment directly supplied by dc source. * Opening voltage transformer or control power transformer compartments. * Operation of outdoor disconnect switch (hook stick operated) at 1 kV through 15kV. * Operation of outdoor disconnect switch (gang-operated, from grade) at 1 kV through 15 kV. | **Any** | **Yes** |
| * Operation of a CB, switch, contactor, starter. * Voltage testing on individual battery cells or individual multi-cell units. * Removal or installation of covers for equipment such as wire-ways, junction boxes, and cable trays that do not expose bare, energized electrical conductors and circuit parts. * Opening a panel board hinged door or cover to access dead front overcurrent devices. * Remove of battery non-conductive inter-cell connector covers. | **Normal** | **No** |
| * Maintenance and testing on individual battery cells or individual multi-cell units in an open rack. * Insertion or removal of individual cells or multi-cell units of a battery system in an open rack. * Arc-resistant switchgear Type 1 or 2 (for clearing times of less than 0.5 sec with a prospective fault current not to exceed the arc-resistant rating of the equipment) and metal-enclosed interrupter switchgear, fused, or unfused of arc resistant type construction, 1 kV through 15 kV. * Insertion or removal (racking) of CBs from cubicles. * Insertion or removal (racking) of ground and test device. * Insertion or removal (racking) of voltage transformers on or off the bus. | **Abnormal** | **Yes** |

**NFPA 70E Table – 130.7 (C) (15) (c)**

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| --- | --- | --- | --- | --- |
| **Flame-Resistant Protective Clothing and Equipment** | **Protective Systems for Hazard/Risk Category (4 = most hazardous)** | | | |
| **Hazard/Risk Category Number** | **1** | **2** | **3** | **4** |
| **Flash suit jacket (2-layer)** |  |  |  | **X** |
| **Flash suit pants (2-layer)** |  |  |  | **X** |
| **Head protection** |  |  | **X** | **X** |
| **Hardhat** |  |  | **X** | **X** |
| **Flame-resistant hardhat liner** |  |  | **X** | **X** |
| **Eye protection (safety glasses plus side shields or safety goggles)** | **X** | **X** | **X** | **X** |
| **Face protection (double-layer switching hood)** | **X** | **X** | **X** | **X** |
| **Hearing protection (ear canal inserts)** |  |  | **X** | **X** |
| **Leather gloves or voltage-rated gloves with**  **leather protectors** | **X** | **X** | **X** | **X** |
| **Leatherwork shoes** | **X** | **X** | **X** | **X** |