

The Electrical Safety Risk Factor



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Objectives/Outline

- Identify overlapping components related to risk in NFPA standards:
 - Electrical installations,
 - Maintenance,
 - Personnel protection during PMs.
- Define normal operating conditions and how design and maintenance of electrical systems impact worker safety and risk.
- Implement risk assessment methods per NFPA 70E electrical safety standard.



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Don't judge a book by it's cover!



Risk?



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Risk?

Yes, No, Trick Question?



What is Risk?

- Combination of the **likelihood** of occurrence of injury and **severity** of injury that results from a hazard.
 - **Severity** relates to energy level (e.g.: 50 V, 1.2 cal/cm²).
 - **Likelihood** related to proximity, frequency, task.



Overlapping Components

- Code
 - Set of rules.
 - Not a law but can be adopted into law.
- Standard
 - Detailed elaboration.
 - The nuts and bolts of meeting code requirements.
 - **AHJ** Responsible for enforcing requirements of code/standard.



Overlapping Components

Q: An organization can have a(n) AHJ.

Yes No, Trick Question?

Authority Having Jurisdiction (AHJ)

An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Overlapping Components

Q: Is NFPA 70E a voluntary standard and not something OSHA enforces?

Yes, No, Trick Question?

A: From an enforcement perspective, OSHA does not enforce NFPA 70E, however, use NFPA 70E to support citations for violations relating to certain OSHA standards, such as general requirements for PPE in 29CFR1910.335/29CFR1926 subpart K.

Overlapping Components

Compliance may not = acceptable risk



Employees shall wear protective equipment for the eyes or face whenever there is danger of injury to the eyes or face from electric arcs.

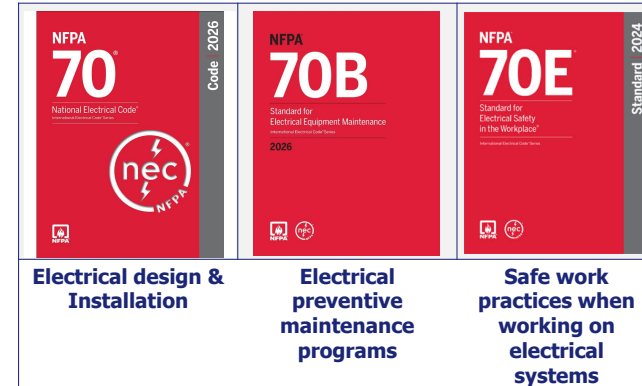


Face Protection. Face shield shall have an arc rating suitable for arc exposure.



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Overlapping Components



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Design & Maintenance

• Normal operating condition

- Discussed in several NFPA standards (70E & 70B)
- Refers to equipment or systems functioning as intended.
- Without abnormal conditions or hazards.
- Operation of equipment means interacting with it as intended, where the equipment meets specified criteria—no reason to **assume inherent safety risk**.
- Normal operation does not require a qualified person and is **considered low risk** if performed as designed.



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Design & Maintenance

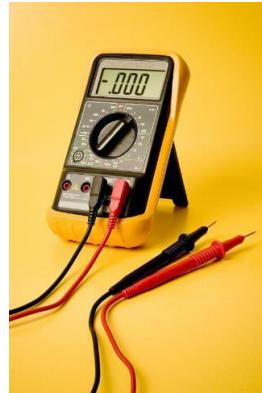
- Examples of interacting with electrical systems in a normal operating condition:
 - Most operations performed at control panel of equipment.
 - Most low voltage switching operations
 - Provided it is not being performed for the first time after installation or PM.
 - Equipment is properly installed & maintained.



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Design & Maintenance

- Normal operation of equipment involves interacting with it, but for most equipment, this does not meet the definition of **working on** as defined in NFPA 70E.
- Working On: Intentionally coming in contact with energized electrical conductors with tools, probes, or with test equipment.



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Design & Maintenance

• Normal operating condition (Summary)

- Equipment is properly installed.
- Equipment is properly maintained.
- Equipment is used in accordance with instructions included in listing and labeling.
- Equipment doors are closed and secure.
- Equipment covers are secure and in place.
- No evidence of failure.



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Design & Maintenance

Q: This operation here is a **normal operating condition**.

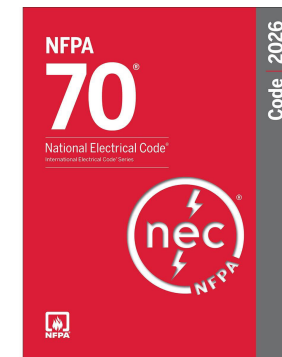
Yes, **No**, Trick Question?



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Design & Maintenance

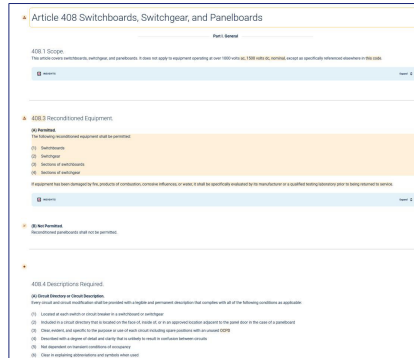
- Authoritative document addressing electrical installations.
- Revised every 3 years to stay in sync with industry practices, emerging trends, and introduction of technologies.
- Provide comprehensive rules for designers, installers, inspectors, engineers, electricians, and anyone else who works in the electrical industry.



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Design & Maintenance

- Example: Panelboards.
- NEC will give construction requirements.
- **Equipment properly installed.**



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Design & Maintenance

- Case Study:
 - A worker was injured from arc flash upon closing the main circuit breaker during commissioning operations on a 480 VAC Panelboard.
 - The root cause of the arc flash incident was attributed to improper installation of wiring on the panelboard.



Equipment not properly installed = Abnormal Operating Condition

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Design & Maintenance

Q: An effective electrical equipment maintenance program is essential in ensuring engineering controls properly protect the worker.

Yes No, Trick Question?

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Design & Maintenance

- Details preventive maintenance for electrical equipment.
- NFPA 70B helps users develop and carry out an effective Electrical Maintenance Program (EMP)
 - Prevent equipment failures and incidents.
 - Establish "*condition of maintenance*" for equipment that is required to be compliant when **assessing risk** in accordance with NFPA 70E®, *Standard for Electrical Safety in the Workplace*®.



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Design & Maintenance

Steps in establishing EMP

Equipment Inventory

| Equipment | Definition | NFPA 70B (2023) Reference Chapter | Equipment Present in facility? | Inventory? | Is it in place? |
|--------------------------------------|---|-----------------------------------|--------------------------------|------------|-----------------|
| GFCIs | A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a ground-fault current exceeds the values established for a Class A device. | 21 | | | |
| Lighting | Luminaires and lighting systems | 22 | | | |
| Motor control equipment | An assembly of one or more enclosed sections having a common power bus and principally containing motor control units. | 28 | | | |
| Panelboards | A single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic circuit breakers, and equipped with or without switches for the control of light, heat, or power circuits designed to be placed in a cabinet, enclosure, or control box placed in or against a wall, partition, or other support, and accessible only from the front. | 13 | | | |
| Switchboards | A large single panel, frame, or assembly of panels on which are mounted on the face, back, or both, busbars, overcurrent and other protective devices, buses, and auxiliary instruments. | 13 | | | |
| Photovoltaic systems | Solar photovoltaic (PV) systems and its associated equipment. | 30 | | | |
| Rotating equipment | Rotating equipment (machines) and their ancillary devices (e.g., fans). | 27 | | | |
| Stationary standby batteries | Stationary installations of storage stationary standby batteries comprised of lead-acid or nickel-cadmium (NiCd) cells. | 36 | | | |
| Substations | An assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings and inspection windows) and containing primary power or cut switching, interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors, removable covers, or both. | 12 | | | |
| Switchgear | An assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings and inspection windows) and containing primary power or cut switching, interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors, removable covers, or both. | 12 | | | |
| Uninterruptible power supplies (UPS) | Uninterruptible power supplies (UPS) rated 600 volts or less ac or dc. | 25 | | | |



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Design & Maintenance

Equipment Condition Assessment

Condition 1: Properly maintained.

Condition 2: Maintenance results deviate from past results.

Condition 3: Equipment has missed the last 2 maintenance cycles



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Design & Maintenance

Steps in establishing EMP

Plan of Service

| 70B Table 9.2.2 | 70E Article 120 (LOTO) Chapter 1 (Safety Related Work Practices) |
|------------------------|--|
| Visual inspection | May/may not be done energized. |
| Cleaning | Done de-energized. |
| Lubrication | Done de-energized. |
| Mechanical inspections | Energized or de-energized. |
| Electrical testing | Done Energized. |

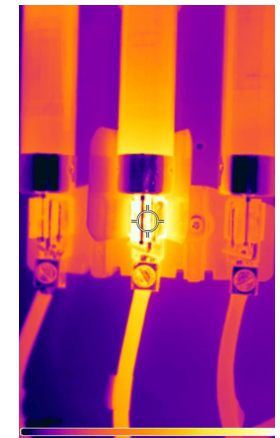


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Design & Maintenance

Q: What is going on here? Did we identify risk? Was there risk involved in identifying?

Yes No, Trick Question?



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Design & Maintenance

Steps in establishing EMP

Plan of Service

| ID Origin Header | | Table 9.2.2 Maintenance Intervals | | | Equipment Condition Assessment | | |
|------------------|-----------------------|-----------------------------------|-------------|-------------|--------------------------------|-------------|-------------|
| Product | Scope of Work | Condition 1 | Condition 2 | Condition 3 | Condition 1 | Condition 2 | Condition 3 |
| All equipment | Infrared thermography | 12 months | 12 months | 6 months | | | |



Table 9.2.2



Table 130.5(C)

IR Thermography

Done Energized.

Example: Panelboards



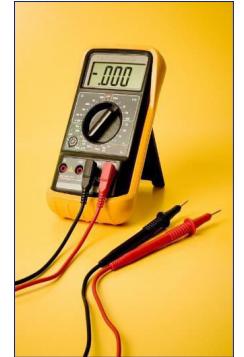
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Design & Maintenance

Table 13.3.5 Panelboard and Switchboard Electrical Testing

| No. | Task | Test Type* |
|-----|--|------------|
| 1. | Check Electrical Hardware Connections | NA |
| 2. | Measure insulation resistance of the main bus | 2 |
| 3. | Masure insulation resistance of control wiring | 2A |
| 4. | Test protective devices and systems | 2 |
| 5. | Perform system operational tests | 1 or 2 |

Some testing operations may need to be performed with equipment energized.



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Design & Maintenance

Steps in establishing EMP

Plan of Service

| Condition | Assessment Results | Maintenance Frequency |
|-----------|---|-----------------------|
| 1 | Maintained at required intervals. | 60 months |
| 2 | Previous maintenance cycle revealed issues requiring the repair or replacement of major equipment components. | 36 months |
| 3 | Equipment has missed the last two successive maintenance cycles. | 12 months |

Frequency of maintenance is based on condition of equipment (panelboard example).

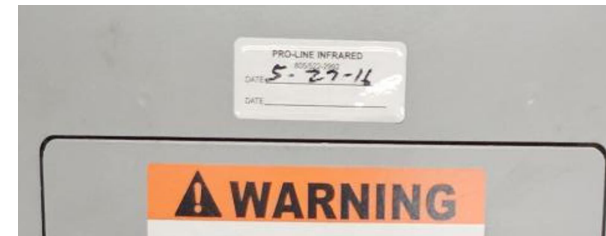


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Design & Maintenance

Q: This indicates a normal operating condition.

Yes, **No**, Trick Question?



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Design & Maintenance

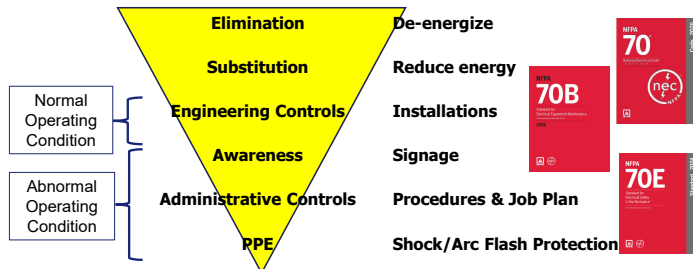
- Normal operating condition
 - Equipment is used in accordance with instructions included in listing and labeling.
 - Equipment doors are closed and secure.
 - Equipment covers are secure and in place.
 - No evidence of failure.



Risk Assessment

- Now that we have established Design & Maintenance criteria for **Normal Operating Condition**, we need to define safety criteria for maintenance of electrical systems.
- If maintenance requires system to be energized, we move to an **Abnormal Operating Condition**. Therefore, risk assessment and lower-level controls apply.
 - Testing
 - IR Thermography

Risk Assessment



Hierarchy of Controls

Risk Assessment

Essential in Risk Assessment Process

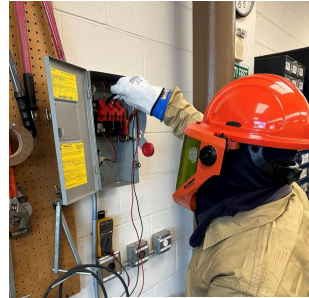
| | | | |
|---|-----------------------|---|---|
| | Article 6.3, 6.4, 6.7 | | Article 130.5(E)(1) Article 130.5(F) Article 130.5(G)/(H) |
| <ul style="list-style-type: none"> • Short-circuit studies • Coordination studies • Incident Energy Analyses | | Requires incident energy analysis be performed for administrative and PPE controls. | |
| Performed every 5-years | | | |

Risk Assessment

Example

A worker is going to perform Voltage Testing on (remember definition of risk).

- What some risk factors (definition of risk) associated with this task?
- What would you consider in assessing the risk?



| | |
|---------------------------------|---|
| WARNING | |
| Arc Flash and Shock Risk | |
| Appropriate PPE Required | |
| 58 in | Arc Flash Boundary |
| 7.76 cal/cm ² | Incident Energy at 18 in |
| PPE | Arc-rated shirt & pants + arc-rated coverall + arc-rated arc flash suit |
| 480 VAC | Shock Risk when cover is removed |
| 00 | Glove Class |
| 42 in | Limited Approach |
| 12 in | Restricted Approach |

Risk Assessment

Example (Potential Responses)

- **Consequences:** Shock & Arc Flash. Remember that consequences are the degree of hazard.
- **Likelihood:** What tasks are involved?
- You would need to consider energy levels involved:
 - Voltage
 - Amperage
 - Incident energy (cal/cm²)

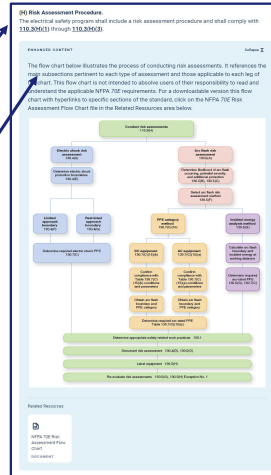


| | |
|---------------------------------|---|
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Risk Assessment

Risk Assessment Procedure is outlined in NFPA 70E (via NFPA LiNK®).

Flow chart in standard provides guidance in risk assessment procedure.

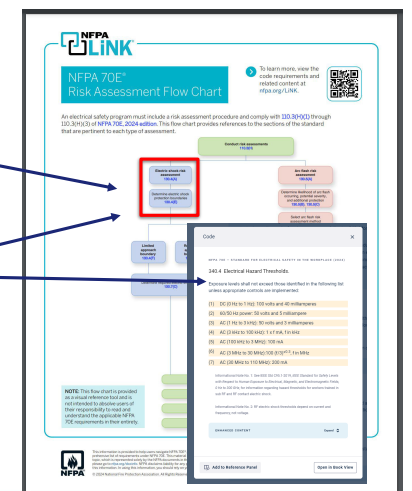


Risk Assessment

Left flowchart goes through steps of shock risk assessment.

Flowchart will give shock thresholds which necessitate further risk reduction.

(50 V)



Risk Assessment

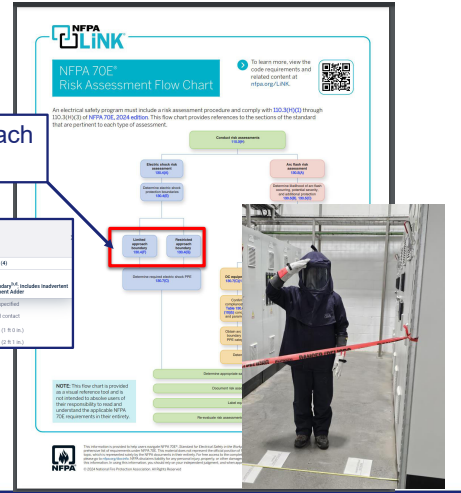
Q: In addressing shock thresholds, are we evaluating:
 a. Likelihood
 b. Consequence



Risk Assessment

Flowchart will give limited & restricted approach boundary requirements for shock hazard.

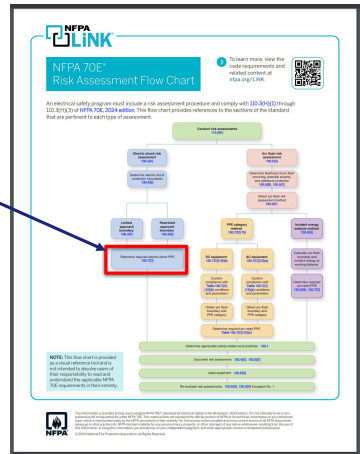
| Table 130.4(E)(4) Electric Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Energized Parts of Assembly-Corner Systems | | | |
|--|--|----------------------------|---|
| (1) | (2) | (3) | (4) |
| Nominal System Voltage Range, Phase to Phase ^a | Exposed Flexible Conductors ^b | Exposed Fixed Circuit Part | Restricted Approach Boundary ^c , Includes Insulated Personnel Safety |
| Less than 50 V | Not specified | Not specified | Not specified |
| 50 V-150 V ^d | 3.1 m (10 ft 0 in.) | 1.0 m (3 ft 0 in.) | Arrest contact |
| 151 V-250 V | 3.1 m (10 ft 0 in.) | 1.0 m (3 ft 0 in.) | 0.37 m (1 ft 0 in.) |
| 251 V-480 V | 3.1 m (10 ft 0 in.) | 1.0 m (3 ft 0 in.) | 0.46 m (1 ft 5 in.) |



Risk Assessment

Flowchart will detail PPE requirements.

(C) Personal Protective Equipment (PPE).
(1) General.
 When an employee is working within the restricted approach boundary, the worker shall wear PPE in accordance with 130.4. When an employee is working within the arc flash boundary he or she shall wear protective clothing and other PPE in accordance with 130.5. All parts of the body inside the arc flash boundary shall be protected.



Risk Assessment

Q: Assuming 480 VAC (and thresholds exceed those in Article 340.4) do consequences justify protective measures?
 • Yes
 • No

```

Code
340.4 Electrical Hazard Thresholds.
Exposure levels shall not exceed those identified in the following list unless appropriate controls are implemented.
(1) DC (0 Hz to 1 Hz): 100 volts and 40 milliamperes
(2) 60-50 Hz power: 50 volts and 5 milliamperes
(3) AC (1 Hz to 3 kHz): 50 volts and 3 milliamperes
(4) AC (3 kHz to 100 kHz): 1 x FmA, F in kHz
(5) AC (100 kHz to 3 MHz): 100 mA
(6) AC (3 MHz to 30 MHz): 100 (0.01) m2 T in MHz
(7) AC (30 MHz to 110 MHz): 200 mA
    
```

Risk Assessment

Assuming voltage testing requires contact work, and both shock boundaries will be crossed. Does *likelihood* justify protective measures?

- Yes
- No



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Risk Assessment

Since *likelihood* requires work inside of the limited & restricted approach boundary & *consequences* exceed energy thresholds, **are further risk reduction methods necessary?**

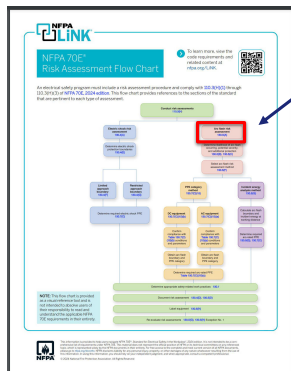
- Yes
- No

We have determined likelihood & consequences variables for shock!



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Risk Assessment/Arc Flash

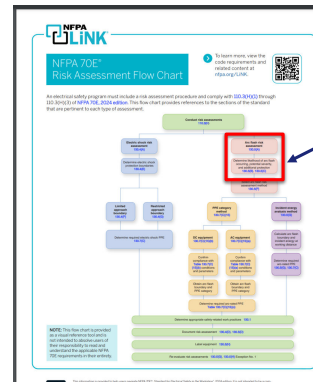


Left flowchart goes through steps of arc flash risk assessment.



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Risk Assessment/Arc Flash



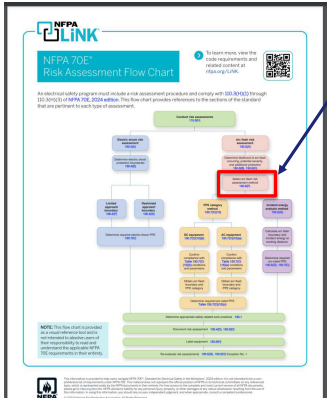
Flowchart will reference Table 130.5(C) in NFPA 70E for likelihood of arc flash based on task.

| TASK | Equipment Condition | Likelihood of Occurrence of arc flash |
|--|---------------------|---------------------------------------|
| Operation of a CB or switch the first time after installation or completion of maintenance | Any | Yes |
| Operation of a CB or switch | Normal | No |
| Work on energized electrical conductors, including voltage testing | Any | Yes |



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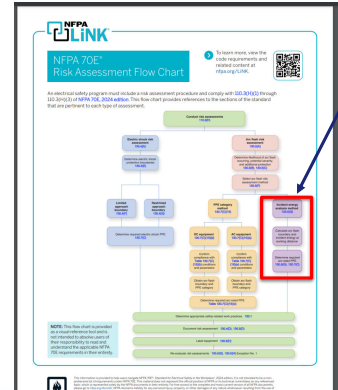
Risk Assessment/Arc Flash



Methods for incident energy analysis.

| | |
|---------------------------------|---|
| WARNING | |
| Arc Flash and Shock Risk | |
| Appropriate PPE Required | |
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| 00 | Glove Class |
| 42 in | Limited Approach |
| 12 in | Restricted Approach |

Risk Assessment/Arc Flash



Flowchart will detail PPE requirements. Standard requires arc rated PPE for exposure $\geq 1.2 \text{ cal/cm}^2$



Risk Assessment/Arc Flash

• Q: Assuming 7.76 cal/cm² at 18" working distance. Do *consequences* justify protective measures?

• Yes

• No

| | |
|---------------------------------|---|
| WARNING | |
| Arc Flash and Shock Risk | |
| Appropriate PPE Required | |
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Risk Assessment/Arc Flash

Assuming voltage testing task on system. Does *likelihood* justify protective measures?

• Yes

• No

Risk Assessment/Arc Flash

Since *likelihood* task indicates arc flash potential & *consequences* exceed energy thresholds, **are further risk reduction methods necessary?**

• Yes

We have determined likelihood & consequences variables for arc flash!

• No

Risk Assessment

| Likelihood of Occurrence of Harm | Severity (Consequence) of Harm | |
|----------------------------------|-----------------------------------|-----------------------------------|
| | <50 V <1.2 cal/cm ² | ≥50 V ≥1.2 cal/cm ² |
| No | Low | Low |
| Yes | Low | High |

Risk=High
Therefore, further risk reduction is required

Business Case for Safety

- An effective electrical safety program, along with an electrical maintenance program, will lead to
 - Higher reliability
 - Longer life of equipment
 - Lower cost than repair
 - Lower insurance costs

Summary

- Normal operating condition refers to equipment or systems functioning as intended and installed.
- To ensure proper functioning, equipment must be properly maintained.
- Equipment maintenance may require equipment to be placed in an abnormal operating condition, thus increasing risk and application of lower-level controls.

