Introduction

There is a great deal of activity in the electrical industry concerning electrical safety. The present focus is on two of the greatest electrical hazards to workers: shock and arc flash. In recent years, significant knowledge has been gained through testing and analysis concerning arc flash hazards and how to contend with this type of hazard. Note: a third electrical hazard is arc blast and work is ongoing to learn more about how to deal with this electrical hazard.

NFPA 70E "Standard for Electrical Safety in the Workplace," 2012 Edition, is the foremost consensus standard on electrical safety. References to NFPA 70E in this section are to the 2012 NFPA 70E.

Why is there an NFPA 70E?

In 1976 a new electrical standards development committee was formed to assist the Occupational Safety and Health Administration (OSHA) in preparing electrical safety standards. This committee on Electrical Safety Requirements for Employee Workplaces, NFPA 70E, was needed for a number of reasons, including:

1. The NEC® is an installation standard while OSHA addresses employee safety in the workplace.
2. Most sections in the NEC® do not relate to worker safety.
3. Safety related work and maintenance practices are generally not covered, or not adequately covered, in the NEC® and
4. A national consensus standard on electrical safety for workers did not exist, but was needed – an easy to understand document that addresses worker electrical safety.

The first edition of NFPA 70E was published in 1979. In most cases, OSHA regulations can be viewed as the Why and NFPA 70E as the How. Although OSHA and NFPA 70E may use slightly different language, in essence, NFPA 70E does not require anything that is not already an OSHA regulation. In most cases, OSHA is performance language and NFPA 70E is prescriptive language.

If an arc fault occurs, the tremendous energy released in a fraction of a second can result in serious injury or death. NFPA 70E, Article 100, defines an arc flash hazard as:

- A dangerous condition associated with the possible release of energy caused by an electric arc.

The first informational note to this definition indicates that an arc flash hazard may exist when electrical conductors or circuit parts, which are not in an electrically safe work condition, are exposed or may exist if a person interacts with parts that are not exposed but an increased arc flash hazard exists, unless justified in accordance with NFPA 70E Article 100. NFPA 70E, Article 100, defines an electrically safe work condition as:

- A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.

NFPA 70E 100.3(A)(2) requires work on electrical conductors or circuit parts not in an electrically safe work condition to be performed by only qualified persons. In some situations, an arc flash hazard may exist beyond the Limited Approach Boundary. It is advisable to use the greater distance of either the Limited Approach Boundary or the arc flash Protection Boundary in complying with NFPA 70E 100.3(A)(2).

When energized work is justified per NFPA 70E 100.3(A)(1) or (A)(2), NFPA 70E 100.3(B)(1) requires an electrical hazard analysis (shock hazard analysis in accordance with NFPA 70E 100.4(A) and an arc flash hazard analysis in accordance with NFPA 70E 100.5). A written energized electrical work permit may also be required per NFPA 70E 100.2(B)(1). When an energized electrical work permit is required, it must include items as shown in NFPA 70E 100.2(B)(2). Some key items of the energized electrical work permit include determination of the shock protection boundaries in accordance with NFPA 70E 100.3(B)(1), the arc flash Protection Boundary in accordance with NFPA 70E 100.5, and the necessary protective clothing and other Personal Protective Equipment (PPE) in accordance with NFPA 70E 100.5. Similarly, OSHA 1910.132(d)(2) requires the employer to verify that the required workplace hazard assessment has been performed through a written certification that identifies the workplace evaluated; the person certifying that the evaluation has been performed; the date(s) of the hazard assessment; and, identifies the document as a certification of hazard assessment.

Note: deenergized electrical parts are considered as energized until all steps of the lockout/tagout procedure are successfully completed per OSHA 1910.333(b)(1). Similarly, all electrical conductors and circuit parts must be considered to be in an electrically safe work condition until all the requirements of Article 120 have been met per NFPA 70E 120.2(A).

Verifying that the circuit elements and equipment parts are deenergized by a qualified person is a required step while completing the lockout/tagout procedure per OSHA 1910.333(b)(2)(iv)(B). Conductors and parts of electric equipment that have been deenergized but have not been locked out or tagged and proven to be deenergized are required to be treated as energized parts per 1910.333(b)(1). Similarly NFPA 70E 120.2(A) requires that all electrical conductors and circuit parts are not considered to be in an electrically safe work condition - until the entire process of establishing the electrically safe work condition is met.

Therefore, adequate PPE is always required during the tests to verify the absence of voltage during the lockout/tagout procedure or when putting equipment in an electrically safe work condition. Adequate PPE may also be required during load interruption and during visual inspection that verifies all disconnecting devices are open.

Only Work On Equipment That Is In An Electrically Safe Work Condition

The rule for the industry and the law is “don’t work it hot,” OSHA 1910.333(a)(1) requires live parts to be deenergized before an employee works on or near them except for two demonstrable reasons by the employer:

1. Deenergizing introduces additional or increased hazards (such as cutting ventilation to a hazardous location) or
2. Infeasible due to equipment design or operational limitations (such as when voltage testing is required for diagnostics).

Similarly, NFPA 70E 100.2 requires energized electrical conductors and circuit parts to be put in an electrically safe work condition before an employee works within the Limited Approach Boundary of those conductors or parts of the employee interacts with parts that are not exposed but an increased arc flash hazard exists, unless justified in accordance with NFPA 70E 100.2(A). NFPA 70E, Article 100, defines an electrically safe work condition as:

- A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to ensure the absence of voltage, and grounded if determined necessary.
Shock Hazard Analysis

No matter how well a worker follows safe work practices, there will always be a risk associated with interacting with electrical equipment – even when putting equipment in an electrically safe work condition. And there are those occasions where it is necessary to work on energized equipment such as when a problem can not be uncovered by troubleshooting the equipment in a deenergized state.

What Can Be Done To Lessen the Risk?

There are numerous things that can be implemented to increase electrical safety, from design aspects and upgrading systems, to training, implementing safe work practices and utilizing PPE. Not all of these topics can be covered in this section. The focus of this section will mainly concern some overcurrent protection aspects related to electrical safety.

Shock Hazard Analysis

The Shock Hazard Analysis per NFPA 70E 130.4(A) requires the determination of the voltage exposure as well as the boundary requirements and the PPE necessary to minimize the possibility of electric shock. There are three shock approach boundaries required to be observed in NFPA 70E Table 130.4(C)(a); these shock approach boundaries are dependent upon the system voltage. The significance of these boundaries for workers and their actions while within the boundaries can be found in NFPA 70E. See Figure 2 for a graphic depiction of the three shock approach boundaries with the arc flash protection boundary (following the section on arc flash Hazard Assessment). For electrical hazard analysis and worker protection, it is important to observe the shock approach boundaries together with the arc flash protection boundary (which is covered in paragraphs ahead).

Although most electrical workers and others are aware of the hazard due to electrical shock, it still is a prevalent cause of injury and death. One method to help minimize the electrical shock hazard is to utilize finger-safe products and non-conductive covers or barriers. Finger-safe products and covers reduce the chance that a shock or arcing fault can occur. If all the electrical components are finger-safe or covered, a worker has a much lower chance of coming in contact with a live conductor (shock hazard), and the risk of a conductive part falling across bare, live conductive parts creating an arcing fault is greatly reduced (arc flash hazard). Shown below are the new CUBE Fuses that are IP20 finger-safe, in addition, they are very current-limiting protective devices. Also shown are SAMI™ fuse covers for covering fuses, Safety J™ fuse holders for LPJ fuses, CH fuse holders, new fuseblocks with integral covers, available for a variety of Cooper Bussmann fuses and disconnect switches, with fuse and terminal shrouds. All these devices can reduce the chance that a worker, tool or other conductive item will come in contact with a live part.
Arc Fault Basics
An electrician that is working in an energized panelboard or just putting equipment into an electrically safe work condition is potentially in a very unsafe place. A falling knockout, a dislodged skinned wire scrap inadvertently left previously in the panelboard or a slip of a screwdriver can cause an arcing fault. The temperature of the arc can reach approximately 35,000°F, or about four times as hot as the surface of the sun. These temperatures easily can cause serious or fatal burns and/or ignite flammable clothing.

Figure 1 is a model of an arc fault and the physical consequences that can occur. The unique aspect of an arcing fault is that the fault current flows through the air between conductors or a conductor(s) and a grounded part. The arc has an associated arc voltage because there is arc impedance. The product of the fault current and arc voltage concentrated at one point results in tremendous energy released in several forms. The high arc temperature vaporizes the conductors in an explosive change in state from solid to vapor (copper vapor expands to 67,000 times the volume of solid copper). Because of the expansive vaporization of conductive metal, a line-to-line or line-to-ground arcing fault can escalate into a three-phase arcing fault in less than a thousandth of a second. The speed of the event can be so rapid that the human system can not react quickly enough for a worker to take corrective measures. If an arcing fault occurs while a worker is in close proximity, the survivability of the worker is mostly dependent upon (1) system design aspects, such as characteristics of the overcurrent protective devices and (2) precautions the worker has taken prior to the event, such as wearing PPE, appropriate for the hazard.

These two characteristics are 1) the time it takes the overcurrent protective device to open and 2) the amount of fault current the overcurrent protective device lets-through. For instance, the faster the fault is cleared by the overcurrent protective device, the lower the energy released. If the overcurrent protective device can also limit the current, thereby reducing the actual fault current magnitude that flows through the arc, the lower the energy released. Overcurrent protective devices that are current-limiting can have a great affect on reducing the energy released. The lower the energy released the better for both worker safety and equipment protection.

The photos and recording sensor readings from actual arcing fault tests (next page) illustrate this point very well. An ad hoc electrical safety working group, within the IEEE Petroleum and Chemical Industry Committee, conducted these tests to investigate arc fault hazards. These tests and others are detailed in Staged Tests Increase Awareness of Arc-Fault Hazards in Electrical Equipment, IEEE Petroleum and Chemical Industry Conference Record, September, 1997, pp. 313-322. This paper can be found at www.cooperbussmann.com. One finding of this IEEE paper is that current-limiting overcurrent protective devices reduce damage and arc-fault energy (provided the fault current is within the current-limiting range). To better assess the benefit of limiting the current of an arcing fault, it is important to note some key thresholds of injury for humans.

Results of these tests were recorded by sensors on mannequins and can be compared to these parameters:

- Just Curable Burn Threshold: 80°C / 175°F (0.1 sec)
- Incurable Burn Threshold: 96°C / 205°F (0.1 sec)
- Eardrum Rupture Threshold: 720 lbs/ft²
- Lung Damage Threshold: 1728 - 2160 lbs/ft²
- OSHA Required Ear Protection Threshold: 85db (for sustained time period)

(Note: an increase of 3 db is equivalent to doubling the sound level.)

Arc Flash Tests
All three of these tests were conducted on the same electrical circuit set-up with an available bolted three-phase, short-circuit current of 22,600 symmetrical RMS amps at 480V. In each case, an arcing fault was initiated in a size 1 combination motor controller enclosure with the door open, as if an electrician were working on the unit “live” or before it was placed in an electrically safe work condition.

Test 4 and Test 3 were identical except for the overcurrent protective device protecting the circuit. In Test 4, a 640 amp circuit breaker with short time-delay is protecting the circuit; the circuit was cleared in 6 cycles. In Test 3, KRP-C-601SP, 601 amp, current-limiting fuses (Class L) are protecting the circuit; they opened the fault current in less than ½ cycle and limited the current. The arcing fault was initiated on the lineside of the motor branch circuit device in both Test 4 and Test 3. This means the fault is on the feeder circuit but within the controller enclosure.

In Test 1, the arcing fault is initiated on the loadside of the branch circuit overcurrent protective devices, which are LPS-RK-30SP, 30 amp, current-limiting fuses (Class RK1). These fuses limited this fault current to a much lower value and cleared this circuit in approximately ¾ cycle or less.

Following are the results recorded from the various sensors on the mannequin closest to the arcing fault. T1 and T2 recorded the temperature on the bare hand and neck respectively. The hand with T1 sensor was very close to the arcing fault. T3 recorded the temperature on the chest under the cotton shirt. P1 recorded the pressure on the chest. And the sound level was measured at the ear. Some results “peged the meter.” That is, the specific measurements were unable to be recorded in some cases because the actual level exceeded the range of the sensor/recorder setting. These values are shown as “>”, which indicates that the actual value exceeded the value given but it is unknown how high of a level the actual value attained.

The Role of Overcurrent Protective Devices In Electrical Safety
The selection and performance of overcurrent protective devices play a significant role in electrical safety. Extensive tests and analysis by industry has shown that the energy released during an arcing fault is related to two characteristics of the overcurrent protective device protecting the affected circuit.
Test 4:

Staged test protected by circuit breaker with short time-delay (not a current-limiting overcurrent protective device). Short time-delay intentionally delayed opening for six cycles (0.1 second). Note: Unexpectedly, there was an additional fault in the wireway and the blast caused the cover to hit the mannequin in the head. Analysis results in incident energy of 5.8 cal/cm² and arc flash boundary of 47 inches per 2002 IEEE 1584 (basic equations).

Test 3:

Staged test protected by KRP-C-601SP Low-Peak® current-limiting fuses (Class L). These fuses were in their current-limiting range and cleared in less than a ¼ cycle (0.008 second). Analysis results in incident energy of 1.58 cal/cm² and arc flash boundary of 21 inches per 2002 IEEE 1584 (simplified fuse equations).

Test 1:

Staged test protected by LPS-RK-30SP Low-Peak current-limiting fuses (Class RK1). These fuses were in current-limiting range and cleared in approximately ¼ cycle (0.004 second). Analysis results in incident energy of less than 0.25 cal/cm² and arc flash boundary of less than 6 inches per 2002 IEEE 1584 (simplified fuse equations).
**Arc Flash Protection**

A couple of conclusions can be drawn from this testing.

1. Arcing faults can release tremendous amounts of energy in many forms in a very short period of time. Look at all the measured values compared to key thresholds of injury for humans given in a previous paragraph. Test 4 was protected by a 640 A, non current-limiting device that opened in 6 cycles or 0.1 second.

2. The overcurrent protective devices’ characteristic can have a significant impact on the outcome. A 601 amp, current-limiting overcurrent protective device, protects the circuit in Test 3. The current that flowed was reduced (limited) and the clearing time was 1/8 cycle or less. This was a significant reduction compared to Test 4. Compare the Test 3 measured values to the key thresholds of injury for humans and the Test 4 results. The measured results of Test 1 are significantly less than those in Test 4 and even those in Test 3. The reason is that Test 1 utilized a much smaller (30 amp), current-limiting device. Test 3 and Test 1 both show that there are benefits of using current-limiting overcurrent protective devices. Test 1 just proves the point that the greater the current-limitation, the more the arcing fault energy may be reduced. Both Test 3 and Test 1 utilized very current-limiting fuses, but the lower amp rated fuses limit the current more than the larger amp rated fuses. It is important to note that the fault current must be in the current-limiting range of the overcurrent protective device in order to receive the benefit of the lower current let-through. See the diagram below that depicts the oscillographs of Test 4, Test 3 and Test 1.

(3) The cotton shirt did not ignite and reduced the thermal energy exposure on the chest (T3 measured temperature under the cotton shirt). This illustrates the benefit of workers wearing protective garments.

Note: Per NFPA 70E 130.7(C)(6): Arc-Rated (AR) clothing is required wherever there is a possible exposure to an electric arc flash above the threshold incident energy level for a second-degree (just curable) burn (1.2 cal/cm²).

**Arc Flash Hazard Analysis**

As discussed, arc flash currents can release tremendous amounts of energy. NFPA 70E 130.3(B)(1) requires an arc flash hazard analysis be performed per 130.5 “before any person is exposed to the electrical hazards involved.”

The incident energy (see definition in NFPA 70E) is a measure of thermal energy at a specific distance from an arc fault; the unit of measure is typically in calories per centimeter squared (cal/cm²). The distance from the fault in determining the incident energy depends on the worker’s body position to the live parts. After determining the incident energy in cal/cm², the value can be used to select the appropriate PPE. There are various types of PPE with distinct values (arc ratings or AR) of thermal protection capabilities termed “Arc Thermal Performance Exposure Values” (ATPV) rated in cal/cm². Note: for 600V and less a very common working distance for which incident energy is determined is 18 inches. If it is necessary to determine incident energy at a different distance, NFPA 70E (Annex D) and 2002 IEEE 1584 have equations that can be used in many situations (for greater or less than 18 inches).

130.5 arc flash hazard analysis has several elements for compliance. The first paragraph of 130.5 requires determining the arc flash boundary (AFB), incident energy at a specified working distance, and the PPE that must be worn within the AFB. However, 130.5 permits two methods to determine the necessary information: (1) calculating the AFB and incident energy method or (2) the hazard/risk categories (HRC) “Tables” method.

The AFB, determined by NFPA 70E is the distance from the energized parts at which a worker could sustain a just curable burn (bare skin) as a result of an arcing fault. A worker entering the AFB must be qualified and must be wearing appropriate PPE (proper items and sufficient AR) in accordance with NFPA 70E 130.5(B). Figure 2 depicts the AFB and the three shock approach boundaries discussed previously that must be observed per NFPA 70E. In an actual situation, before a worker is permitted to approach equipment with exposed, energized parts or where there is an arc flash hazard and/or shock hazard, these boundaries must be determined. In addition, the worker must be wearing the required PPE and follow safe work practices.

![Figure 2](image-url)

**Prior to Doing Analysis**

Important: the 3rd paragraph of 130.5 requires the arc flash hazard analysis to “take into consideration the design of the overcurrent protective device and its opening time, including the “condition of maintenance.” If the condition of maintenance of the OCPD used for the arc flash hazard analysis is not known to be good, it is advisable to use the characteristics of an OCPD further upstream toward the source that is known to be in good maintenance condition. See the Maintenance Considerations section immediately following.

**Incident Energy Method**

Calculate the AFB per 130.5(A) and the incident energy at a working distance per 130.5(B)(1). The related PPE required by 130.7(C) must have the appropriate arc rating equal to or greater than the incident energy, where applicable. For systems 50V or greater, 130.5(A) requires determining the AFB, the distance where the incident energy equals 1.2 cal/cm². NFPA 70E Annex D provides information on methods to calculate both the AFB and incident energy.

2002 IEEE 1584 is the foremost industry consensus standard for these calculations. This guide has the basic method of calculations, simplified fuse method, and simplified circuit breaker method.
Maintenance Considerations

The available short-circuit current is necessary input information for these methods. This guide has equations for calculating arcing current for specific circuit conditions. The basic method requires the calculation of the arcing current which then requires determining the OCPD clearing time for the arcing current. Then the AFB and incident energy can be calculated.

It is important to note that current-limiting overcurrent protective devices (when in their current-limiting range) can reduce the required AFB and the required PPE AR as compared to non-current-limiting overcurrent protective devices.

There are various resources and tools available in the industry to aid in performing the 2002 IEEE 1584 calculations. Later in this section is a table method derived using the 2002 IEEE 1584 simplified methods for fuses and circuit breakers. The incident energy calculation method with examples is covered in greater detail later in this section.

HRC Method

130.5 Exception and 130.5(B)(2) permits using the hazard/risk categories method if the requirements of 130.7(C)(15) and 130.7(C)(16) are met.

Important: the HRC method can be used for many situations but cannot be used for all situations. 130.7(C)(15) provides the conditions of use as to when Tables 130.7(C)(15)(a) and 130.7(C)(15)(b) are permitted to be used. If all the conditions of use are not satisfied, the tables cannot be used and an incident energy method must be used.

Table 130.7(C)(15)(a) Conditions of Use:
(All must be satisfied)

• Limited to equipment types and voltage ratings listed in table
• Limited to tasks listed in table
• Parameters under the specific equipment type being evaluated
  – Maximum available bolted short-circuit current at installation of equipment cannot exceed the value in the table
  – The clearing time for the type of OCPD at the given value of maximum available bolted short-circuit current in the table cannot exceed the maximum fault clearing time value the in table
  – The working distance cannot be less than the value in the table

If all conditions are met, then the AFB and the HRC number can be used in conjunction with Table 130.7(C)(16) to select PPE. The hazard/risk categories are 0, 1, 2, 3, and 4. Other PPE may be required per 130. Per 130.1 all pertinent requirements of Article 130 are applicable even when using the HRC method.

Table 130.7(C)(15)(a) has Notes at the end of the table. Notes 5 and 6 provide the basis of how the AFB was determined for each equipment type in the table. Note 4 permits reducing the HRC number by one for specific equipment type/task if the overcurrent protective device is a current-limiting fuse and that fuse is in its current-limiting range for the arcing current.

Table 130.7(C)(15)(a) Note 4:

When equipment protected by upstream current-limiting fuses with arcing fault current in their current-limiting range (1/2 cycle fault clearing time or less), the hazard/risk category required may be reduced by one number. For instance, when a specific task to be performed has a hazard/risk category 2, if the equipment is protected by current-limiting fuses (with arcing current within their current-limiting range), the hazard/risk category can be reduced to a HRC 1.

In addition, NFPA 70E 130.5 requires the arc flash hazard analysis to be updated when there is an electrical system change that affects the arc flash hazard level such as when a major modification or renovation takes place. The arc flash hazard analysis must be periodically reviewed, not to exceed five years to account for changes in the electrical distribution system that could affect the results of the arc flash hazard analysis.

Arc Flash Analysis Equipment Labeling

NEC 110.16 Arc Flash Hazard Warning does not require NFPA 70E arc flash hazard analysis information to be on the label. It is merely a label to warn people that there is an arc flash hazard but does not provide specific information on the level of arc flash hazard.

Label complying to NEC 110.16

NFPA 70E 130.5(C) requires specific information on the level of arc flash hazard to be marked on the equipment when an arc flash hazard analysis has been performed. At a minimum the label must include these three items:
1. At least one of following
   • Incident energy at the working distance
   • Minimum arc rating of clothing
   • Level of PPE required
   • Required level of PPE (this may be to a specific company PPE safety program)
   • Highest HRC for the equipment type
2. System voltage
3. Arc flash boundary

Additional information is often included on the label, such as the values determined by the shock approach boundaries.

Label required by NFPA 70E 130.5(C) must provide specific values determined by an arc flash hazard analysis.

The last paragraph of 130.5 requires that the calculation method and data to support this information shall be documented. For instance, in both the incident energy method and HRC method the available short-circuit current must be determined in the process of the analysis. The method of calculating the short-circuit current and the results must be documented and retained. This information may be required for a future OSHA inspection/investigation. As well, if future system changes occur, this documentation will assist in determining whether the arc flash hazard results changed.
Maintenance Considerations

The reliability of overcurrent protection devices can directly impact arc flash hazards. Poorly maintained overcurrent protective devices (OCPDs) may result in higher arc flash hazards. NFPA 70E 130.5 reads in part:

“The arc flash hazard analysis shall take into consideration the design of the overcurrent protective device and its opening time, including its condition of maintenance.

130.5 has two Informational Notes (IN) concerning the importance of overcurrent protective device maintenance:

IN No.1: Improper or inadequate maintenance can result in increased opening time of the overcurrent protective device, thus increasing the incident energy.

IN No.2: For additional direction for performing maintenance on overcurrent protective devices see Chapter 2, Safety-Related Maintenance Requirements.

The 130.5 requirement to take into consideration the condition of maintenance of OCPDs is very relevant to arc flash hazards. The reliability of OCPDs can directly impact the incident energy. Poorly maintained OCPDs may take longer to clear, or not clear at all resulting in higher arc flash incident energies. Figure 3 illustrates the dangerous arc flash consequences due to poorly maintained OCPDs.

Figure 3 Arc flash hazard is affected by OCPD condition of maintenance.

3A. Arc flash hazard analysis calculation assuming the overcurrent protective device has been maintained and operates as specified by manufacturer’s performance data.

3B. The actual arc flash event can be significantly higher if the overcurrent protective device clearing time is greater than specified performance due to improper or lack of maintenance. Calculations are per IEEE 1584.

NFPA 70E has other OCPD maintenance requirements including:

205.4: requires OCPDs to be maintained per manufacturers’ instructions or industry consensus standards. Very important: “Maintenance, tests, and inspections shall be documented.”

210.5: requires OCPDs to be maintained to safely withstand or be able to interrupt the available fault current. Informational Note makes mention that improper or lack of maintenance can increase arc flash hazard incident energy.

225.1: requires fuse body and fuse mounting means to be maintained. Mountings for current-limiting fuses cannot be altered to allow for insertion of non-current-limiting fuses.

225.2: requires molded cases circuit breaker cases and handles to be maintained properly.

225.3: shown below is especially important since many workers are unaware of this requirement and do not follow this in their safe work practices.

225.3 Circuit Breaker Testing After Electrical Fault.

Circuit breakers that interrupt faults approaching their interrupting rating shall be inspected and tested in accordance with the manufacturer’s instructions.

NFPA 70E 225.3 complements an OSHA regulation which states:

OSHA 1910.334(b)(2) Use of Equipment.

Reclosing circuits after protective device operation. After a circuit is deenergized by a circuit protective device, the circuit may not be manually reenergized until it has been determined that the equipment and circuit can be safely energized. The repetitive manual reclosing of circuit breakers or reenergizing circuits through replaced fuses is prohibited.

NOTE: When it can be determined from the design of the circuit and the overcurrent devices involved that the automatic operation of a device was caused by an overload rather than a fault condition, no examination of the circuit or connected equipment is needed before the circuit is reenergized.
Maintenance Considerations

A key phrase in the regulation is “circuit can be safely energized.” When complying with NFPA 70E 225.3 it is impractical if not impossible to determine the level of fault interrupted by a circuit breaker.

Sources for guidance in setting up maintenance programs, determining the frequency of maintenance and providing prescriptive procedures include:

1. Equipment manufacturer’s maintenance manuals
2. NFPA 70B Recommended Practice for Electrical Equipment Maintenance
3. ANSI/NETA MTS-2011, Standard for Maintenance Testing Specifications for Electrical Distribution Equipment and Systems. This standard includes guidelines for the frequency of maintenance required for electrical system power equipment in Appendix B, Frequency of Maintenance Test as well as prescriptive inspections and tests in the standard.

The internal parts of current-limiting fuses do not require maintenance for arc flash protective considerations. However, it is important to periodically check fuse bodies and fuse mountings.

Circuit breakers are mechanical devices and require periodic maintenance to help retain proper operation. Preventive maintenance for circuit breakers should include exercising the mechanism by opening and closing circuit breakers periodically and using the Push-to-Test feature if so equipped, periodic visual and mechanical inspections, periodic microhm contact tests, and periodic calibration tests. A time travel analysis is becoming more popular on medium voltage circuit breakers and in some cases low voltage circuit breakers.

In addition, for both fuse and circuit breaker systems, periodically check conductor terminations for signs of overheating, poor connections and/or insufficient conductor ampacity. Infrared thermographic scans are one method that can be used to monitor these conditions. Records on maintenance tests and conditions should be retained and trended.

For more indepth discussion see OCPD Maintenance section in this handbook.
**Arc Flash Hazard Analysis**

**Simple Method for Arc Flash Hazard Analysis**

In this section there are two examples of determining the arc flash hazard per 130.5(A) for the arc flash boundary and 130.5(B)(1) by the incident energy analysis method.

Various information about the system may be needed to complete this analysis but the two pieces that are absolutely necessary are:

1. The available 3Ø bolted fault current.
2. The fuse or circuit breaker type and amp rating.

Consider the following one-line diagram and then follow the examples that take the steps needed to conduct an arc flash hazard analysis.

The following information utilizes the simplified fuse formulas based upon IEEE 1584-2002 Guide for arc flash Hazard Analysis and shown in NFPA 70E Annex D.7.6.

Steps necessary to conduct an arc flash hazard analysis when using Low-Peak fuses or circuit breakers and Table 1 and 1a: arc flash Incident Energy Calculator.

1. Determine the available bolted fault current on the lineside terminals of the equipment that will be worked upon.
2. Identify the amperage of the Low-Peak fuse or circuit breaker upstream that is protecting the panel where work is to be performed.
3. Consult the Low-Peak Fuse Incident Energy Calculator, Table 1 and 1a, next pages, to determine the Incident Energy Exposure (I.E.) available.
4. Determine the AFB that will require PPE based upon the incident energy. This can also be simplified by using the column for AFB in Table 1 and 1a.
5. Identify the minimum requirements for PPE when work is to be performed inside of the AFB by consulting the requirements found in NFPA 70E 130.7(C)(1) to (C)(16).

**Example 1: Arc Flash Hazard Analysis using Cooper Bussmann Current-Limiting Fuses**

The following is a simple method when using certain Cooper Bussmann fuses; this method is based on actual data from arcing fault tests (and resulting simplified formulas shown in NFPA 70E Annex D.7.6 and 2002 IEEE 1584) with Cooper Bussmann current-limiting fuses. Using this simple method, the first thing that must be done is to determine the incident energy exposure. Cooper Bussmann has simplified this process when using LPS-RK_SP, LPJ_SP, TCF, LP-CC_ or KRP-C_SP Low-Peak fuses or JJS_ T-Tron fuses and FCF fuses. In some cases the results are conservative; see Note 6.

In this example, the line side OCPD in Figure 4 is a LPS-RK-600SP, Low-Peak current-limiting fuse. Simply take the available 3Ø bolted short-circuit current at the panel, in this case 42,000 amps, and locate it on the vertical column in the arc flash Incident Energy Calculator Table 1 on the following page. Then proceed directly to the right to the 401-600A fuse column and identify the I.E. (incident energy) and AFB (arc flash Boundary).

With 42,000 amps of 3Ø bolted short-circuit current available, the table shows that when relying on the LPS-RK-600SP Low-Peak fuse to interrupt an arcing fault, the incident energy is 0.25 cal/cm². Notice the variables required are the available 3Ø bolted fault current and the ampacity of the Low-Peak current-limiting fuse. See Notes 7 and 8.

The next step in this simplified arc flash hazard analysis is to determine the AFB. With an incident energy of 0.25 cal/cm² and using the same table, the AFB is approximately 6 inches, which is found next to the incident energy value previously located. See Note 6. This AFB distance means that anytime work is to be performed inside of this distance, including voltage testing to verify that the panel is deenergized, the worker must be equipped with the appropriate PPE.

The last step in the arc flash hazard analysis is to determine the appropriate PPE for the task. To select the proper PPE, utilize the incident energy exposure values and the requirements from NFPA 70E. NFPA 70E 130.7(C)(1) through (C)(16) that has requirements for the PPE based upon the incident energy. When selecting PPE for a given application or task, keep in mind that these requirements from NFPA 70E are minimum requirements. Having additional PPE, above what is required, can further assist in minimizing the effects of an arc flash incident. Another thing to keep in mind is that PPE available on the market today does not protect a person from the pressures, shrapnel and toxic gases that can result from an arc-blast, which are referred to as “physical trauma” in NFPA 70E. Existing PPE is only tested to minimize the potential for burns from the arc flash. See Notes 1 and 2.
## Arc Flash Incident Energy Calculator

Cooper Bussmann Low-Peak LPS-RK_SP fuses and molded case circuit breakers (MCCB)

Incident Energy (I.E.) values expressed in cal/cm², arc flash Boundary (AFB) expressed in inches.

<table>
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<th>Bolted Fault</th>
<th>1-100A</th>
<th>101-200A</th>
<th>201-400A</th>
<th>401-600A</th>
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<tr>
<td>Current (kA)</td>
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<td>MCCB</td>
<td>Fuse</td>
<td>MCCB</td>
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</table>

Read notes on the page following these tables. Fuse results based on actual test data and simplified fuse formulas in NFPA 70E Annex D.7.6 and 2002 IEEE 1584 2002. Circuit breaker results are based on simplified circuit breaker formulas in NFPA 70E Annex D.7.7 and 2002 IEEE 1584 calculations. If circuit breakers are not properly maintained, values can be considerably greater.

Arc Flash Hazard Analysis Tools on [www.cooperbussmann.com/ArcFlashCalculator](http://www.cooperbussmann.com/ArcFlashCalculator)

Cooper Bussmann continues to study this topic and develop more complete data and application tools.

Visit [www.cooperbussmann.com](http://www.cooperbussmann.com) for interactive arc flash calculators and the most current data.
## Arc Flash Incident Energy Calculator

Cooper Bussmann Low-Peak KRP-C, SP fuses; low voltage power circuit breakers (LV PCB) with short time-delay (STD) Incident Energy (I.E.) values expressed in cal/cm², arc flash Boundary (AFB) expressed in inches.

### Current (kA) Fuse LV PCB Fuse LV PCB Fuse LV PCB Fuse LV PCB

**Bolted Fault**

<table>
<thead>
<tr>
<th>Current (kA)</th>
<th>Fuse LV PCB</th>
<th>Fuse LV PCB</th>
<th>Fuse LV PCB</th>
<th>Fuse LV PCB</th>
</tr>
</thead>
<tbody>
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<td>&gt;100</td>
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<tr>
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<td>&gt;120</td>
<td>&gt;100</td>
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<td>&gt;100</td>
</tr>
</tbody>
</table>

**Table 1a: 601 - 2000A**

Incident Energy (I.E.) values expressed in cal/cm², arc flash Boundary (AFB) expressed in inches.

Based on simplified circuit breaker formulas in NFPA 70E Annex D.7.6 and 2002 IEEE 1584 calculations. If circuit breakers are not properly maintained, values can be considerably greater.

### Read notes on the page following these tables. Fuse results based on actual test data and simplified fuse formulas in NFPA 70E Annex D.7.6 and 2002 IEEE 1584 calculations. If circuit breakers are not properly maintained, values can be considerably greater.

### Arc Flash Hazard Analysis Tools on [www.cooperbussmann.com/ArcFlashCalculator](http://www.cooperbussmann.com/ArcFlashCalculator)

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Arc Flash Incident Energy Calculator

Notes for Arc Flash Hazard Analysis Table 1 and 1a

Steps necessary to conduct a Flash Hazard Analysis.

1. Determine the available bolted fault current on the line side terminals of the equipment that will be worked upon.

2. Identify the amperage of the upstream Low-Peak fuse or circuit breaker that is protecting the equipment where work is to be performed.

3. Consult the table to determine the incident energy exposure and the arc flash Boundary (AFB).

4. Identify the minimum requirements for PPE when work is to be performed inside of the AFB by consulting the requirements found in NFPA 70E.

General Notes for fuses and circuit breakers:

Note 1: First and foremost, this information is not to be used as a recommendation to work on energized equipment. This information is to help assist in determining the PPE to help safeguard a worker from the burns that can be sustained from an arc flash incident. This information does not take into account the effects of pressure, shrapnel, molten metal spray or the toxic vapor resulting from an arc-fault. This information does not address the maintenance conditions of the overcurrent protective device.

Note 2: This data is based upon the simplified fuse and circuit breaker formulas in NFPA 70E Annex D.7.6 and 2002 IEEE 1584 Guide for arc flash Hazard Analysis. These methods were created so that the PPE selected from the calculated incident energy would be adequate for 98% of arc flash incidents. In up to 2% of incidents, second-degree burns to the body and torso could result. This was based upon PPE with standard arc ratings of 1.2, 8, 25, 40 and 100 cal/cm². PPE with intermediate ATPV values can be utilized, but at the next lower standard ATPV rating. NFPA 70E Annex D.7 does not recognize 100 cal/cm², instead a fine print note is added to recommend greater emphasis than normal to de-energize equipment when the incident energy exceeds 40 cal/cm².

Note 3: PPE must be utilized any time work is to be performed on equipment that is not placed in an electrically safe work condition. Voltage testing, while completing the lockout/tagout procedure (putting the equipment in an electrically safe work condition), is considered as working on energized parts per OSHA 1910.333(b).

Note 4: The data is based on 32mm (1 1/4”) electrode spacing, 600V 3Ø ungrounded system, and 20” x 20” x 20” box. The incident energy is based on a working distance of 18 inches, and the AFB is based on 1.2 cal/cm² (threshold for a second-degree “just curable” burn).

Note 5: The data is based upon tests that were conducted at various fault currents for each Cooper Bussmann Low-Peak KRP-C.SP and LPS-RK.SP fuse indicated in the charts. These tests were used to develop the formulas as shown in NFPA 70E Annex D.7.6 and 2002 IEEE 1584 2002. Actual results from incidents could be different for a number of reasons, including different (1) system voltage, (2) short-circuit power factor, (3) distance from the arc, (4) arc gap, (5) enclosure size, (6) fuse manufacturer, (7) fuse class, (8) orientation of the worker and (9) grounding scheme. 100A LPS-RK.SP fuses were the smallest fuses tested. Data for the fuses smaller than that is based upon the 100A data, arcing flash values for actual 30 and 60A fuses would be considerably less than 100A fuses. However, it does not matter since the values for the 100A fuses are already so low.

Note 6: The fuse incident energy values were chosen not to go below 0.25cal/cm² even though many actual values were below 0.23cal/cm². This was chosen to keep from encouraging work on energized equipment without PPE because of a low AFB.

Note 7: This arc flash Incident Energy Calculator Table can also be used for LPJ.SP, TCF, FCF, JJS, and LP-CC fuses to determine the incident energy available and AFB.

Note 8: These values from fuse tests and calculations for circuit breakers take into account the translation from available 3-phase bolted fault current to the arcing fault current.

Note 9: To determine the AFB and incident energy for applications with other fuses, use the basic equations in 2002 IEEE 1584 or NFPA 70E Annex D.7.

Note 10: The circuit breaker information comes from the simplified circuit breaker equations in 2002 IEEE 1584 and NFPA 70E Annex D.7.7 that are based upon how circuit breakers operate.

Note 11: Where the arcing current is less than the instantaneous trip setting of the circuit breaker or current-limiting range of the fuse when calculated per NFPA 70E Annex D.7.6 or D.7.7 and 2002 IEEE 1584 2002. The value for incident energy is given as >100cal/cm².

Note 12: The data for circuit breakers up to 400A is based on Molded Case Circuit Breakers (MCCB) with instantaneous trip, for 401-600A it is based on MCCBs with electronic trip units, and the data for circuit breakers from 601 up to 2000A is based on Low Voltage Power Circuit Breakers (LVPCB) with short time-delay (STD). Per the simplified circuit breaker formulas in NFPA 70E Annex D.7.7 and 2002 IEEE 1584 the STD setting is assumed to be set at maximum.

Note 13: The data for circuit breakers is based upon devices being properly maintained in accordance with manufacturer’s instructions and industry standards. Devices that are not properly tested and maintained may have longer clearing times resulting in higher incident energies.
Arc Flash Hazard Analysis


**WARNING** If a Circuit Breaker has not been exercised, tested, and maintained per manufacturer's instructions or industry standards (NFPA 70B or ANSI/ANSI MTS-11), then a longer clearing time may occur, resulting in a higher incident energy calculation. Consult www.cooperbussmann.com or www.netaworld.org for more information or technical papers on testing and maintenance and/or consequences to potential arc flash hazard.

The following is a simplified method using Table 1 as done in Example 1. Instead of using LPS-RK-600SP, 600A, current-limiting fuse, we will use a 600A Molded Case Circuit Breaker.

With the same 3Ø available short-circuit current as in example 1, 42,000 amps, locate this on the vertical column (Bolted Fault Current kA) of Table 1. Then proceed directly to the right over to the 401-600 MCCB Column. Then record the I.E. (Incident Energy) which should be 5.62 cal/cm². Also, record the value for the AFB (Arc Flash Boundary) which is 51 inches.

The last step in the arc flash hazard analysis is to determine the appropriate PPE for the task.

If the circuit breaker in question is a Low Voltage Power Circuit Breaker (LVPCB) with short time-delay feature (no instantaneous trip), the incident energy calculation will increase. For example, with a short time-delay feature set at 30 cycles the incident energy at this available fault current could be as high as 80.97 (see value in Table 1a with a bolted fault current of 42kA for 601-800A LVPCB) cal/cm² at 18 inches from the arc fault source.

The following staged arc flash test resulted in an incident energy of 5.8 cal/cm² and an AFB of 47 inches using 2002 2002 IEEE 1584 calculation method.

**AFPB: 47 Inches**

**I.E.: 5.8 cal/cm²**

The test parameters were:

* Available fault current = 22,600A at 480Vac.
* OCPD clearing time of six cycles or 0.1 second.
* The PPE for this would have to be equal to or greater than 5.8cal/cm².

Use of PPE

Employees must wear and be trained in the use of appropriate protective equipment for the possible electrical hazards with which they may face. Examples of equipment could include (much of this has to be arc related) a hard hat, face shield, neck protection, ear protectors, Arc Rated (AR) clothing, arc flash suit, insulated rubber gloves with leather protectors, and insulated leather footwear. All protective equipment must meet the requirements as shown in Table 130.7(C)(14) of NFPA 70E. The selection of the required arc rated PPE depends on the incident energy level at the point of work.

As stated previously, the common distance used for most of the low voltage incident energy measurement research and testing is at 18 inches from the arcing fault source. So what energy does a body part experience that is closer to the arcing fault than 18 inches? The closer to the arcing fault the higher the incident energy and arc blast energy. This means that when the arc flash hazard analysis results in relatively high incident energies at 18 inches from the arcing fault source, the incident energy and arc blast energy at the point of the arcing fault can be considerably greater. Said in another way, even if the body has sufficient PPE for an 18” working distance, severe injury can result for any part of the body closer than 18” to the source of the arc.

**Exposure Time**

As the previous sections have illustrated, the clearing time of overcurrent protective devices is a major factor in the severity of an arc flash incident. Following is a table for some general minimum overcurrent protective device clearing times that can be used for the AFP and incident energy calculations if this data is not available from the manufacturer. "STD Setting" refers to the short time-delay setting if a circuit breaker has this feature; typical STD settings could be 6, 12, 18, 24, or 30 cycles. If an arc flash hazard analysis is being done for a circuit breaker with adjustable settings, then the maximum settings should be used for the analysis. If the lowest settings are used for the analysis, yet a maintenance person has inadvertently increased the setting to the maximum, then the analysis could yield results that are incorrect and lower than required for proper personnel protection.

<table>
<thead>
<tr>
<th>Type of Device</th>
<th>Clearing Time (Seconds)*</th>
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<tr>
<td>Current-limiting fuse</td>
<td>0.004-0.008</td>
</tr>
<tr>
<td>Circuit Breaker (5kV &amp; 15kV)</td>
<td>0.08</td>
</tr>
<tr>
<td>Standard molded case circuit breakers (600V &amp; below) without short time-delay (STD)</td>
<td>0.025</td>
</tr>
<tr>
<td>with short time-delay (STD) STD Setting</td>
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</tr>
<tr>
<td>Insulated case circuit breakers (600V &amp; below) without short time-delay</td>
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</tr>
<tr>
<td>with short time-delay STD Setting</td>
<td></td>
</tr>
<tr>
<td>Low voltage power (air frame) circuit breakers (600V &amp; below) without short time-delay</td>
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</tr>
<tr>
<td>with short time-delay STD Setting</td>
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</tr>
<tr>
<td>Current-limiting molded case circuit breaker (600V &amp; below)</td>
<td>0.008 or less</td>
</tr>
</tbody>
</table>

* These are approximate clearing times for short-circuit currents within the current-limiting range of a fuse or within the instantaneous region of circuit breakers. The clearing times for circuit breakers are based upon Table 1 in 2002 IEEE 1584 2002. The clearing time for current-limiting fuses and circuit breakers is based on published manufacturer data and tests. Lower current values may cause the overcurrent device to operate more slowly; arc flash energy may actually be highest at lower levels of available short-circuit current. This requires that arc flash energy calculations be completed for the range of sustainable arcing currents. This is also noted in NFPA 70E 130.5 IN No. 2.
Arc Flash Hazard Analysis

Expect the Worst Case
If planning to work on a piece of equipment, it is necessary to do the arc flash hazard analysis for the worst-case situation if an incident occurred. For instance, in the diagram below, if the combination controller door were to be opened, the worst-case arc flash hazard in the enclosure would be on the lineside of the branch circuit circuit breaker. If an arcing fault occurred in the enclosure, on the lineside of the of the branch circuit circuit breaker, the 400 amp feeder circuit breaker is the protective device intended to interrupt. So the arc flash hazard analysis for this combination motor controller enclosure must be determined using the characteristic of the 400 amp feeder circuit breaker.

When performing an arc flash hazard analysis, it is important to consider the effect of improper equipment maintenance of overcurrent devices on the incident energy. Because of this, in some cases, it may be necessary to increase the protective clothing and PPE where equipment is not properly maintained. What if the ability of an overcurrent protective device to function properly is questioned? Often times, as part of the hazard/risk analysis, assuming that the OCPD will not function properly is safer. In determining the arc flash hazard, then the next overcurrent protective device upstream that is deemed reliable has to be considered as the protective device that will operate and should be used to assess the arc flash hazard. It is probable that, due to the increase in operating time, the incident energy will be substantially higher.

Other Arc Fault Hazards
An arcing fault may create such enormous explosive forces that there is a huge arc blast wave and shrapnel expelled toward the worker. Neither NFPA 70E nor 2002 2002 IEEE 1584 account for the pressures and shrapnel that can result due to an arcing fault. There is little or no information on protecting a worker for these risks.

On a somewhat positive note, because the arc pressure blows the worker away, it tends to reduce the time that the person is exposed to the extreme heat of the arc. The greater the fault current let-through, the greater the explosive forces. It is important to know that product standards do not evaluate a product for a worker’s exposure to arc flash and arc blast hazards with the door(s) open. Equipment listed to a Nationally Recognized Testing Laboratory product standard is not evaluated for arc flash or arc blast protection (with the door(s) open) because the equipment is tested with the doors closed. Once a worker opens the doors, the parameters under the evaluation testing and listing do not apply.

Summary About the Risks From Arc Faults
Arc faults can be an ominous risk for workers. And an uneducated eye can not identify whether the risk is low, medium or high just by looking at the equipment. Current-limiting overcurrent protection may reduce the risk. In other words, if an incident does occur, current-limiting overcurrent protective devices may reduce the probability of a severe arc flash. In many cases, using current-limiting protective devices greatly reduces the arc flash energy that might occur for the range of arc fault currents that are likely. However, current-limiting overcurrent protective devices do not mitigate the potential hazard in all situations, such as when the overcurrent protective devices become larger than 1200 amp and the available short circuit current is low or very low, however, all things being equal, systems with protective devices that have a high degree of current-limitation generally lower the risks. Regardless it is still necessary to follow all the requirements of NFPA 70E and other safe work practices.

A General Recommendations For Electrical Safety Relative to Overcurrent Protection
(1) Finger-safe products and terminal covers: utilize finger-safe overcurrent protective devices such as the CUBEFuse or insulating covers over the overcurrent protective devices, disconnect terminals and all terminations.

(2) Proper interrupting rating: be absolutely sure to use overcurrent protective devices that have adequate interrupting ratings at their point of application. An overcurrent protective device that attempts to interrupt a fault current beyond its interrupting rating can violently rupture. Consideration for interrupting rating should be for the life of the system. All too often, transformers are replaced or systems are upgraded and the available short-circuit currents increase. Modern fuses have interrupting ratings of 200,000 and 300,000 amps, which virtually eliminates this hazard contributor.

(3) Current-limiting overcurrent protection: use the most current-limiting overcurrent protective devices possible. There are a variety of choices in the market for overcurrent protective devices. Many are not marked as current-limiting and therefore can not be considered current-limiting. And then for those that are marked current-limiting, there are different degrees of current-limitation to consider. For Cooper Bussmann, the brand to use for 600V and less, electrical distribution applications and general equipment circuit protection is Low-Peak fuses. The Low-Peak family of fuses is the most current-limiting type fuse family for general protection and motor circuit protection.

(4) Upgrade existing fuse systems: if the electrical system is an existing fusible system, consider replacing the existing fuses with the Low-Peak family of fuses. If the existing fuses in the clips are not the most current-limiting type fuses, upgrading to the Low-Peak family of fuses can reduce the hazards associated with arc flash. Visit www.cooperbussmann.com/lowpeak to review the Low-Peak Fuse Upgrade Program.

(5) Install current-limiting overcurrent protection for actual loads: if the actual maximum full load current on an existing main, feeder or branch circuit is significantly below its designed circuit ampacity, replace the existing fuses with lower amp rated Low-Peak fuses. Or, if the OCPD is a circuit breaker, put a fused disconnect with Low-Peak fuses in series with the circuit breaker. For instance, an industrial found that many of their 800 amp feeders to their MCCs were lightly loaded; so for better arc flash protection they installed 400 and 600 amp current-limiting fuses and switches in the feeders.

(6) Reliable overcurrent protection: use overcurrent protective devices that are reliable and do not require maintenance to assure performance per the original specifications. Modern fuses are reliable and retain their ability to react quickly under fault conditions. When a fuse is replaced, a new factory calibrated fuse is put into service – the circuit has reliable protection with performance equal to the original specifications. If mechanical overcurrent protective devices are utilized, be sure to perform the manufacturers’ recommended periodic exercise.
Arc Flash Protection Marking

maintenance, testing and possible replacement. When an arc fault or overcurrent occurs, the overcurrent protective device must be able to operate as intended. Thus, for mechanical overcurrent protective devices, this may require testing, maintenance, and possible replacement before resetting the device after a fault interruption.

(7) Reduce feeder size in design phase: Reducing the size of large feeders can greatly reduce incident energy, especially for feeders 1600A and larger.

(8) Within sight motor disconnects: install HP rated disconnects (with permanently installed lockout provision) within sight and within 50 feet of every motor or driven machine. This measure fosters safer work practices and can be used for an emergency disconnect if there is an incident.

(9) Where “power” or “air frame” circuit breakers are utilized without an instantaneous trip, 240.87 requires some means to reduce the arc flash hazard. Potential solutions include, but are not limited to: (1) arc flash reducing maintenance switches, differential relaying, and zone selective interlocking. See Low Voltage Power Circuit Breakers (LVPCB) with short time-delay in the section on Selective Coordination – Circuit Breakers.