ELECTRICAL SAFETY HAZARDS HANDBOOK

Littelfuse®




The World's Leading Provider of Circuit Protection Solutions

Littelfuse is the global leader in circuit protection

Companies around the world have come to rely on Littelfuse's commitment to providing the most advanced circuit protection solutions and technical expertise. It's this focus that has enabled Littelfuse to become the world's leading provider of circuit protection solutions.

For over 75 years, Littelfuse has maintained its focus on circuit protection. As we expand in global reach and technical sophistication, you can continue to count on us for solid circuit protection solutions, innovative technologies, and industry leading technical expertise. It is a commitment that only a world class leader with staying power can support.

A comprehensive approach to circuit protection

Littelfuse goes well beyond efficient and comprehensive product delivery. We offer an integrated approach to circuit protection that includes:

- A very broad, yet deep selection of products and technologies from a single source, so you benefit from a greater range of solutions and make fewer compromises.
- Products that comply with applicable industry and government standards, as well as our own uncompromising quality and reliability criteria.
- Forward thinking, application-specific solutions that provide the assurance your most demanding requirements will be met.
- Dedicated global, customer-focused and application-specific technical support services.

LITTELFUSE ELECTRICAL SAFETY HAZARDS HANDBOOK

Littelfuse is Committed to Safety

Littelfuse has a continuing commitment to improved electrical safety and system protection. As the leader in circuit protection, Littelfuse offers a variety of products and services designed to help you increase safety in your facility.

For assistance with Arc-Flash, products and services, or application information, call 1-800-TEC-FUSE (832-3873).

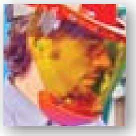
Electrical Safety is a Serious Issue

Electrical Safety in the workplace is the most important job of an electrical worker. No matter how much training one has received or how much employers try to safeguard their workers, Electrical Safety is ultimately the responsibility of the electrical worker. The human factor associated with electrical accidents can be immeasurable. No one can replace a worker or loved one that has died or suffered the irreparable consequences of an electrical accident.

Introduction

Electrical Safety Hazards Overview

97%
of all electricians have been shocked or injured on the job.



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Safety in the workplace is job number one for employer and employee alike. It is especially important for those who install and service electrical systems. Nothing can replace a worker or loved one that has died or suffered the irreparable consequences of an electrical accident. No matter how much an employer tries to safeguard its workers or how much safety training is provided; the ultimate responsibility lies with the worker. The human factor is part of every accident or injury.

The purpose of this handbook is to identify electrical safety hazards and present ways to minimize or avoid their consequences. It is a guide for improving electrical safety and contains information about governmental regulations, industry-accepted standards and work practices. It presents ways to meet the standards and reduce the hazards. While parts of the standards, regulations, and codes especially relating to electrical safety are quoted or summarized herein, it is the responsibility of the user to comply with all applicable standards in their entirety.

Why is Electrical Safety so Important?

Electrical hazards have always been recognized, yet serious injuries, deaths, and property damage occur daily. Organizations like the US Department of Labor and the National Safety Council compile statistics and facts on a regular basis. The following table demonstrates the importance of electrical safety.

FACTS...

- 97% of all electricians have been shocked or injured on the job.
- Approximately 30,000 workers receive electrical shocks yearly.
- Over 3600 disabling electrical contact injuries occur annually.
- Electrocutions are the 4th leading cause of traumatic occupational fatalities.
- Over 2000 workers are sent to burn centers each year with severe Arc-Flash burns.
- Estimates show that 10 Arc-Flash incidents occur every day in the US.
- 60% of workplace accident deaths are caused by burn injuries.
- Over 1000 electrical workers die each year from workplace accidents.
- Medical costs per person can exceed $4 million for severe electrical burns.
- Total costs per electrical incident can exceed $15 million.
- In the year 2002, work injuries cost Americans $14.6 billion.

Information derived from Industry Surveys, the NFPA, The National Safety Council, Bureau of Labor Statistics, and CapSchell, Inc.

The moral obligation to protect workers who may be exposed to electrical hazards is fundamental, but there are legal and other factors that require every facility to establish a comprehensive Electrical Safety Program. Meeting OSHA regulations, reducing insurance costs, and minimizing downtime and repair costs are additional benefits of Electrical Safety programs. When electrical faults occur, the electrical system is subjected to both thermal and magnetic forces. These forces can severely damage equipment and are accompanied by fires, explosions and severe arcing. Such violent damage often causes death or severe injury to personnel. Costs of repairs, equipment replacements, and medical treatment can run into millions of dollars. Loss of production and damaged goods are also important considerations. Other major factors include the cost of OSHA fines and litigation. Severe electrical faults may shut down a complete process or assembly plant, sending hundreds or thousands of workers home for weeks while repairs are being made. It is also possible that one tragic event could close a plant permanently.

Implementing and following a well designed Electrical Safety Program will protect employees and employers against:

- *Injury to personnel*
- *OSHA citations and fines*
- *Increased costs for insurance and workman compensation*
- *Lost or unusable materials*
- *Unplanned equipment repair or replacement costs*
- *Multi-million dollar lawsuits*
- *Possible bankruptcy*

Electrical Safety is not an option—it is absolutely necessary for workers and employers alike.

Littelfuse offers a variety of products and services designed to help you increase safety in your facility, such as:

- **Current-Limiting Fuses**
- **Fuse Holders and Accessories**
- **Training Seminars & Presentations**
- **Arc-Flash Calculators**
- **Electrical Safety Literature**
- **Electrical Safety Video**
- **Warning Labels**
- **Electrical Designers Reference (EDR) Software**
- **Technical Papers**
- **MRO*plus* Fuse Inventory Analysis**
- **Technical Support & Engineering Services**

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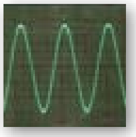
Electricity Basics

Ohm's Law:

The Current (I) in Amperes is equal to the electromotive force, or Voltage (V) divided by the Resistance (R) in "ohms."

$$\textit{Current (I)} = \frac{\textit{Voltage (V)}}{\textit{Resistance (R)}}$$

$$I = \frac{V}{R}$$



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Even the simplest electrical system can become dangerous. Unless proper procedures are instituted, personnel installing or servicing these systems are frequently exposed to the hazards of shock, arc flash and arc blast. Eliminating and/or reducing these hazards require a basic knowledge of electric circuits. The following is a brief overview.

Electricity can be defined as the flow of electrons through a conductor. This is similar to the flow of water through a pipe. Electromotive force, measured in volts, causes the current to flow similar to a pump moving water. The higher the water pressure and the larger the pipes, the greater the water flow. In electrical circuits the rate of current flow is measured in amperes, similar to gallons of water per second. Figure 1 illustrates a simple circuit.

Ohm's Law

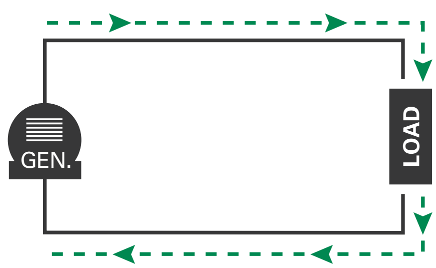
In 1827, George Simon Ohm discovered that the flow of electric current was directly proportional to the applied voltage and inversely proportional to the "resistance" of the wires or cables (conductors) and the load. This discovery became known as Ohm's Law.

Ohm's Law:
The Current in Amperes (I) is equal to the electromotive force, or Voltage (V) divided by the Resistance (R) in "ohms".

$$\textit{Current (I)} = \frac{\textit{Voltage (V)}}{\textit{Resistance (R)}}$$

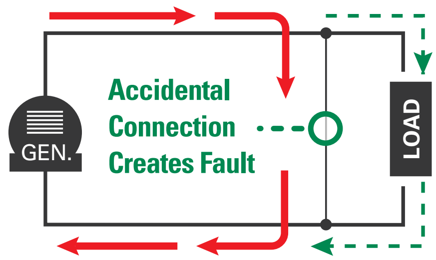
$$I = \frac{V}{R}$$

❶ CURRENT FLOW



System voltage and load resistance determine the flow of current.

❷ SHORT CIRCUIT



(red lines indicate increased current)

During a short circuit, only the resistance of the fault path limits current. Current may increase to many times the load current.

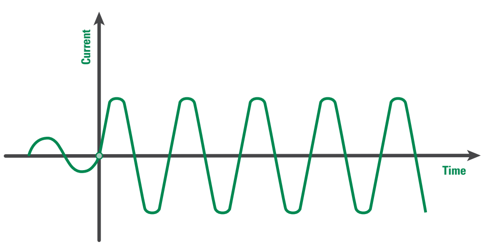
Figure 1

When two of the variables are known, the third can be easily determined using mathematical equations as shown above. Current seeks the path of least resistance; whether it is a conductor, the ground, or a human body. For example, at a given voltage, the higher the resistance is the lower the current will be. The lower the resistance is, the higher the current will be. Materials that have very low resistance such as metals like copper and aluminum are termed conductors, while non-metallic materials like rubber, plastics, or ceramics that have very high resistance are termed insulators. Conductors are usually insulated to confine current to its intended path and to help prevent electrical shock and fires. Conductor cross-section and material determine its resistance. Current produces heat as a function of current squared X resistance (I^2R). The NEC® publishes tables that show the rated current carrying capacity of various sizes and types of conductors (wire and cables). Currents that exceed the rating of the conductor increase temperature and decrease insulation life.

Types of Electrical Faults

Together, current and voltage supply the power we use every day. Any electric current that exceeds the rating of the circuit is an *Overcurrent*. When the current exceeds the rated current carrying capacity of the conductor, it generates excess heat that can damage insulation. If insulation becomes damaged, personnel may be severely injured and equipment or property compromised or destroyed. Overcurrents can be divided into two categories: *Overloads* and *Short Circuits*.

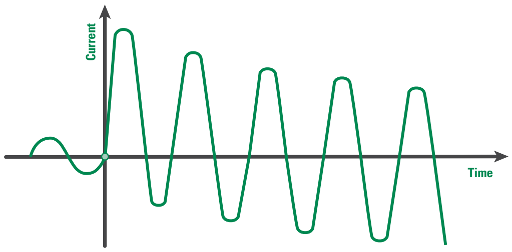
Overloads



Current flow during an overload condition. Figure 2

An *Overload* is defined as an overcurrent that is confined to the normal current path. Excessive connected loads, stalled motors, overloaded machine tools, etc. can overload a circuit. Most conductors can carry a moderate overload for a short duration without damage. In fact, transient moderate overloads are part of normal operation. Startup or temporary surge currents for motors, pumps, or transformers are common examples. Overcurrent protection must be selected that will carry these currents. However, if the overload persists for too long, excessive heat will be generated ultimately causing insulation failure. This may result in fires or lead to a short circuit.

Short Circuits



Current flow during a short circuit condition. Figure 3

A *Short Circuit* is any current not confined to the normal path. The term comes from the fact that such currents bypass the normal load (i.e., it finds a "short" path around the load). Usually, when a current is greater than 6 times (600%) the normal current, it should be removed as quickly as possible from the circuit. Short Circuits are usually caused by accidental contact or worn insulation and are more serious than overloads. Damage occurs almost instantly. Examples of Short Circuits include two or more conductors accidentally touching, someone touching or dropping tools across energized conductors or accidental connection between energized conductors and ground. Such ground faults may vary from a few amperes to the maximum available short circuit fault current.

Overcurrent Protective Devices

Overcurrent protective devices (fuses and circuit breakers) are used to protect circuits and equipment against overloads and

Types of Electrical Faults:

- **Overloads**
- **Short Circuits**

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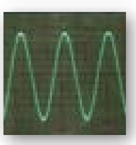
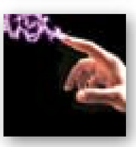
Always use overcurrent protective devices that have interrupting ratings greater than the maximum available fault current of your electrical system.

short circuits (faults). These devices vary in characteristic, design and function. Fuses and circuit breakers are designed to sense abnormal overloads and short circuits and open the circuit before catastrophic events occur. Each device, however, has different time characteristics and must be used and applied according to the appropriate standards and manufacturer's recommendations for the individual application.

Fuses and circuit breakers must be able to discern the difference between normal current variations that pose no threat to equipment, and dangerous overloads or short circuits that can cause extensive damage to equipment and compromise safety. Not all devices are designed to protect against both overloads and short circuits. Most motor starters provide only overload protection, while some circuit breakers provide only short-circuit protection. Overcurrent protective devices should be selected carefully to make sure they will open the circuit safely under any abnormal overcurrent condition. Interrupting ratings and opening times, especially under short-circuit conditions, must also be carefully observed. Failure to select the properly rated overcurrent protective device can result in fires, explosions, and death.





UL CLASS RK 1

Interrupting Rating

Interrupting Rating (sometimes called Interrupting Capacity) is the highest available symmetrical rms alternating current (for DC fuses the highest DC current) at which the protective device has been tested, and which it has interrupted safely under standardized test conditions. Fuses and circuit breakers often have very different interrupting ratings. Current-limiting fuses have interrupting ratings up to 300,000 Amperes. UL Class H fuses and most common molded case circuit breakers have interrupting ratings of only 10,000 Amperes. If an overcurrent protective device with 10,000 AIR (Amperes Interrupting Rating) is used in a circuit that is capable of delivering a short circuit over 10,000 amperes, a violent explosion or flash fire can occur. Always use overcurrent protective devices that have interrupting ratings greater than the maximum available fault current of your electrical system.

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Current Limitation with a Current-limiting Fuse

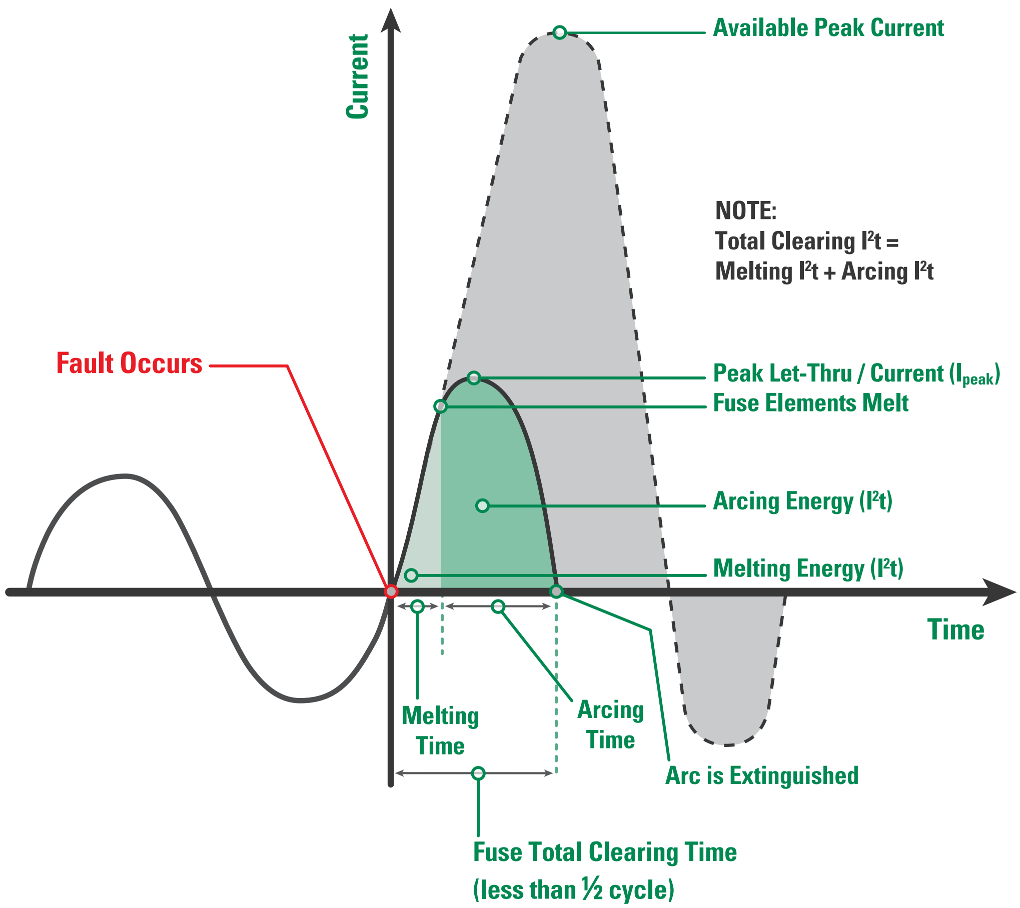

Figure 4

Current Limitation

What exactly is "Current Limitation" and why is it important? Article 240.2 of the National Electrical Code® (NEC®)[1] defines a Current-Limiting Overcurrent Protective Device as: "A device that, when interrupting currents in its interrupting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance." What this really means is that a current-limiting device is one that opens and clears a fault before the first current zero after the fault occurs, and limits the peak fault current. In most cases the current-limiting device will clear a fault in less than one half cycle of standard 60 Hz current (8.33 milliseconds). Figure 4 is a graphical representation of the effect of current limitation on a faulted circuit.

As seen above, the total clearing time "t" occurs before the first zero. The I^2t energy is the area under the curves. It is clear that I^2t through the fuse is much less than would otherwise occur. Heating is a direct function of current squared x time (I^2t). Reducing current in half reduces heat by 75%. Generally, the lower the peak instantaneous current is, the lower the I^2t energy will be. The square of peak current determines the amount of magnetic stress. For a given circuit, cutting the peak current in half reduces magnetic stress by 75%.

1. National Electrical Code® and NEC® are registered trademarks of the National Fire Protection Association, Quincy, MA.

Current Limitation:

A current-limiting device is one that opens and clears a fault within the first half cycle. One half cycle of standard 60 hz current is equivalent to .00833 seconds.

Article 240.2 of the National Electrical Code (NEC) further states that a current-limiting device will reduce the peak let-thru current to a value substantially less than the potential peak which would occur if the current-limiting device were not in the circuit.

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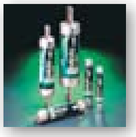
Low Voltage UL Fuse Classes:

- **Class R**
- **Class J**
- **Class CC**
- **Class CD**
- **Class L**
- **Class T**
- **Class G**
- **Class H**
- **Class K**
- **Plug**

Refer to UL 248 for more information.



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Fuses

A fuse is an intentional weak link in a circuit. It is a thermally responsive device designed to provide overcurrent protection. The main function of a fuse is to protect conductors and equipment from damaging overcurrents and quickly deenergize faulted circuits minimizing hazards to personnel.

Fuses may be classified as fast-acting or time-delay and as current-limiting or non-current-limiting. Fast-acting fuses are designed to respond quickly to overload currents, while time-delay fuses are required to carry an overload current for a predetermined amount of time. This permits time-delay fuses to carry starting current and other temporary overloads. Fuses that limit the maximum peak current (Ip) that could flow during a short circuit are classified as current-limiting fuses. Whether the fuse is classified as fast-acting or time-delay, current-limiting fuses will open quickly during short-circuit conditions.

Standard electrical fuses are available in current ratings from 1/10 to 6000 Amperes and for voltages up to 600 Volts. Underwriters Laboratories (UL) and CANENA (Council for the Harmonization of Electrotechnical Standards of the Americas) classify low voltage fuses (600VAC and less) into several main classes such as R, J, CC, CD, L, T, G, H, K and Plug, as well as Semiconductor or Supplemental fuses. Each class is defined by its performance characteristics, size, and function. Low voltage cartridge fuses are further classified as either current-limiting or non-current-limiting types. Cartridge fuses have ferrules, blades, or screw type methods of installation. They are generally intended for and suitable for branch circuit, feeder, and service entrance overcurrent protection in accordance with ANSI/NFPA 70, commonly known as the National Electrical Code®.

Inside a typical fuse, the current flows through the fuse elements, or "links". When enough heat is generated, the fuse element will melt and open (blow). Most power fuses incorporate a silica sand "filler" material that safely quenches the arc and stops the current flow.

Figure 5 illustrates the components of a Littelfuse LLSRK_ID current-limiting dual element time-delay fuse with blown fuse indication. It consists of two current sensing elements in series with each other. The first element is made with a very precise elastomeric silicone overload section that protects against sustained overloads. The second element opens quickly under short circuit conditions, limiting the damaging heat energy during short circuits and Arc-Flash events. Finally and perhaps just as important, the blown fuse indication makes trouble-shooting and replacement safe, fast, and easy.

A fuse is designed to safely open the circuit only once. Therefore, it must be carefully selected to keep the equipment operating unless there is danger of severe overheating or if a short circuit or arcing fault occurs. Selecting the right fuse for the application is critical to overall safety and reliability. At the same time, fuses are fail-safe. Unlike mechanical devices, nothing can happen to a fuse that will prevent it from opening or increase its opening time.

Circuit Breakers

Like fuses, circuit breakers are designed to protect circuits from overload and short circuit conditions when applied within their ratings. Most circuit breakers utilize a mechanical latching, spring assisted switching mechanism and a thermal, thermal-magnetic, hydraulic-magnetic, or electronic current sensing circuit that causes the switching mechanism to unlatch and open the circuit. Typical circuit breakers are not current-limiting. However, current-limiting circuit breakers are available in some ratings, but at a higher cost.

Standard circuit breakers are available with current ratings up to 6300A and voltage ratings up to 1000V. As current levels increase, the type of circuit breaker may vary from Molded

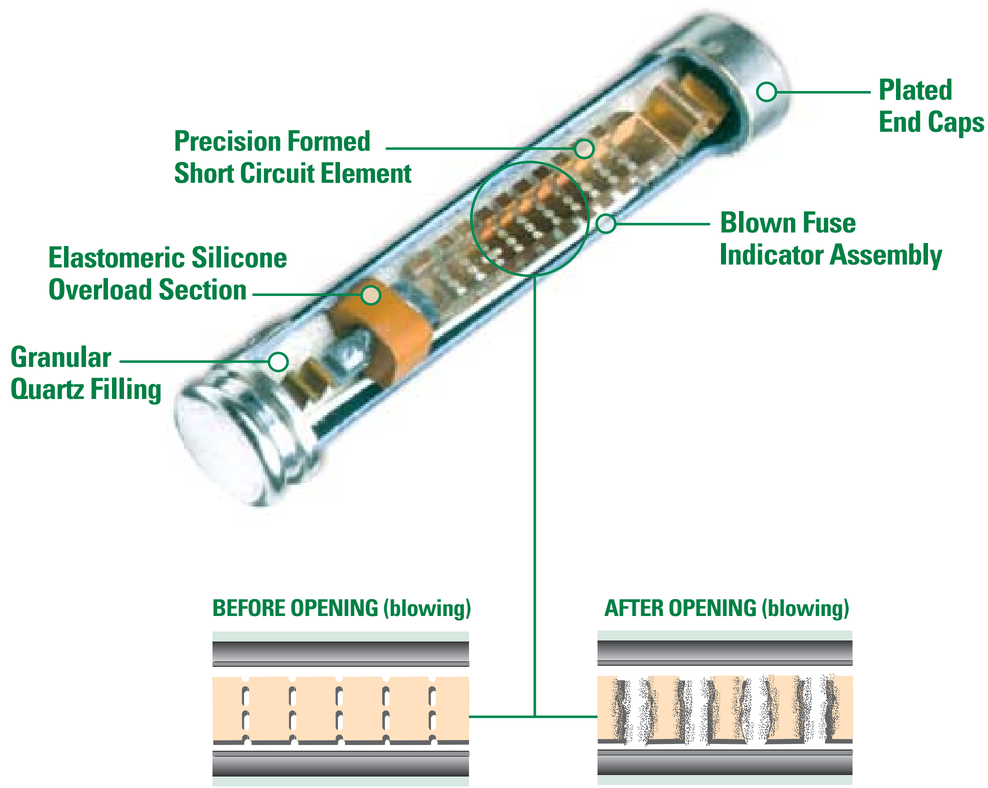


Figure 5

Case Circuit Breakers (MCCB) to Insulated-Case Circuit Breakers (ICCB) to Low-Voltage Power Circuit Breakers (LVPCB) types. Some circuit breakers have magnetic only trip units or electronic trip sensors that can be adjusted for long, short, or instantaneous delays.
In all cases, the sensing circuit causes the switching circuit within the circuit breaker to operate (open). Due to the mass of the contacts and mechanical switching components and other factors, opening times of non-current-limiting circuit breakers under short circuit conditions can vary from ¾ cycles (13 msec.) to 8 cycles (130 msec.) or more.

Common Molded Case Circuit Breakers (MCCB's) such as the one shown in Figure 6 usually have "Thermal-Magnetic" trip units. This means they have two sensing circuits in series with a spring assisted latching switch. The first sensing circuit uses a "thermal" sensing element that reacts to overloads. The second sensing circuit is a "magnetic" coil that reacts to short circuits. Either the thermal sensing circuit or the magnetic sensing circuit can cause the mechanically latched switching circuit to open the circuit. This provides time-current characteristics similar to dual-element fuses. However, most fuses have much higher interrupting ratings and react much faster to short circuits and Arc-Flash events, making them safer and more reliable to use than most circuit breakers.

Current-limiting fuses usually have much higher interrupting ratings and react much faster to short circuits and Arc-Flash events, making them safer and more reliable to use than most circuit breakers.

Failure to follow NFPA and all applicable standards and guidelines along with the the manu-facturers' recommen-dations can result in a catastrophy.

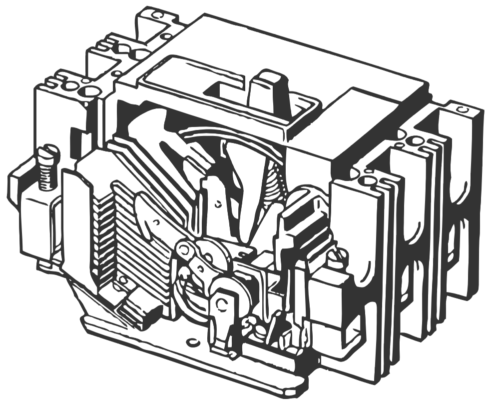
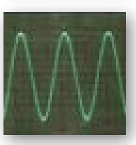
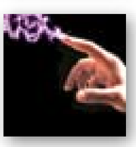


Figure 6
(Drawing courtesy of AVO Training Institute, Dallas, TX)

Circuit breaker manufacturers typically recommend that their circuit breakers be cycled ON and OFF at least once each year to keep the tripping mechanism from seizing under certain environmental conditions. Most manufacturers of industrial and commercial circuit breakers publish field-testing and maintenance instructions. This often includes annual testing and recalibration that requires special equipment and qualified personnel. Instructions for thermal-magnetic breakers require many of these tests to be performed at room temperature that can take breakers out of service for several hours. After a circuit breaker has opened, it is very important to examine the circuit to determine if the cause was a short circuit or an overload. Article 225.3 of NFPA 70E requires that if a circuit breaker interrupts a fault at or near its interrupting rating, it must be inspected by a trained technician and tested, repaired or replaced in accordance with the manufacturer's specifications.





Circuit breakers must be carefully selected according to the application and NEC® requirements. Current ratings that are too low will cause nuisance tripping and excessive downtime. Current ratings that are too high can cause excessive overheating or higher arc-flash hazards. Failure to follow NFPA standards and guidelines and the manufacturers' recommendations can result in catastrophic consequences.

Whether you use fuses or circuit breakers, both types of overcurrent protective devices must be tested and approved by a nationally recognized safety agency, such as Underwriters Laboratories. The device must also be applied in accordance with the National Electrical Code® or other codes and standards required by the Authority Having Jurisdiction over the facility. It is also important to remember that even if a fuse or circuit breaker is approved by a recognized safety agency like UL, it must be installed and used in accordance with any instructions included with its labeling or listing. There are differences, for example, in UL standards used to qualify fuses and circuit breakers such as UL 248, UL489, and UL1077. Always check the applicable standards and the manufacturer to determine if their devices meet the required interrupting ratings, voltage ratings, current limitation, etc. for each application. Failure to apply overcurrent protective devices within their ratings can result in fires, explosions, and deaths.

Short Circuit Current Rating (SCCR)

With all of the advances in engineering and safety, why is it that every day 1 maintenance person is either killed or injured in electricity related accidents? Is it possible the majority of effort that has gone into engineering and inspecting for safe electrical systems has ended when the electricity reaches the line side terminals of the equipment? The 2005 National Electrical Code addresses this situation with the advent of required labels on equipment that clearly state the equipment's Short Circuit Current Rating (SCCR). The NEC specifically addresses this for industrial control panels [Article 409], industrial machinery electrical panels [670], multiple motor HVAC equipment [440], meter disconnect switches [230] and multiple motor controllers [430].

The most dangerous and common misconception of SCCR by equipment manufacturers is that the interrupting capacity or rating of a circuit protection device is also the SCCR of the end use equipment in which it is installed. Meaning, the manufacturer

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that labels the equipment with a 22kA SCCR, solely because the main circuit breaker or fuse has an interrupting capacity of 22kA, is mislabeling its equipment and creating a potentially dangerous condition in your plant.

In order to build and label a safe piece of equipment, the manufacturer must determine the component in the primary electrical path with the lowest SCCR or withstand rating. The SCCR of the equipment then must match the rating of that component with the lowest SCCR. Just as every device within the electrical distribution system of your facility must be rated to handle a worst-case scenario in order to completely protect the people and equipment within your facility, every component within your equipment must be designed to handle a worst-case scenario for exactly the same reason.

The NEC® recognizes and specifically requires equipment to have accurate SCCR labels. These labels will allow you and inspectors to compare fault current studies to the SCCR and minimize potential hazards in your facilities.

Circuit Protection Checklist

Before a system is designed or when unexpected events may occur, circuit designers should ask themselves the following questions:

- ☑ **What is the normal or average current expected?**
- ☑ **What is the maximum continuous (three hours or more) current expected?**
- ☑ **What inrush or temporary surge currents can be expected?**
- ☑ **Are the overcurrent protective devices able to distinguish between expected inrush and surge currents and open under sustained overloads and fault conditions?**
- ☑ **What kind of environmental extremes are possible? Dust, humidity, temperature extremes and other factors need to be considered.**
- ☑ **What is the maximum available fault current the protective device may have to interrupt?**
- ☑ **Is the overcurrent protective device rated for the system voltage?**
- ☑ **Will the overcurrent protective device provide the safest and most reliable protection for the specific equipment?**
- ☑ **Under short-circuit conditions, will the overcurrent protective device minimize the possibility of a fire or explosion?**
- ☑ **Does the overcurrent protective device meet all the applicable safety standards and installation requirements?**

Answers to these questions and other criteria will help to determine the type of overcurrent protective device to use for optimum safety and reliability.

Unlike fuses, circuit breakers require annual maintenance to meet manufacturer's specifications.

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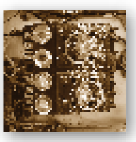
History of Electrical Safety

Thomas Edison is said to have developed the first "fuse" by using a wire between two terminals that would melt if too much current flowed through it.



Contrary to popular belief, Benjamin Franklin did not "discover" or "invent" electricity. The flow of electricity and its effects have been known for centuries, especially when traveling through air in the form of lightning. It wasn't until the late 18th and early 19th centuries, however, that scientists began to discover and analyze what electricity really is and how to harness it for man's benefit. Thus began the need to regulate electrical installations to protect people and equipment from its unintended effects.

With the advent of the electric light bulb and electric motors in the late 19th Century, it was soon discovered that electricity could also cause fires and kill people. Thomas Edison is said to have developed the first "fuse" by using a wire between two terminals that would melt if too much current flowed through it. In 1882, Edison opened the world's first central electric light power station in New York City. It produced enough DC current to power 7200 electric lamps. In 1887, Edison was issued the first fuse patent. Ever since, controlling electricity and protecting wires from fire has become more and more complex. In an effort to increase electrical safety, Thomas Edison and George Westinghouse confronted each other on the relative benefits and dangers of Direct Current (DC) vs. Alternating Current (AC). Concerned with electrical safety, Thomas Edison tried to establish DC current as the standard in the US. He argued that DC current was not as dangerous as AC, which George Westinghouse was promoting. In 1889, the state of New York commissioned the development of the electric chair for their capital punishment program. Even though Edison was not a proponent of capital punishment, he was asked to design the electric chair and assumed Westinghouse would be approached if he refused. Edison viewed this as an opportunity to prove that AC was more dangerous than DC and designed the "chair" using AC. In 1893, George Westinghouse received the contract to design the "Palace of Electricity" at the World's Columbian Exposition in Chicago. AC was used and shown to be safely applied. Obviously, Edison was proven wrong regarding the safe application of AC. Westinghouse also had a better plan for generating and distributing electrical energy over long distances at higher voltages and then transforming it to lower useable voltages. Thus began the need for increased electrical construction and safety standards.

1860s First fuses developed

1880s AC/DC Electrical systems were expanded

1889 Electric chair was developed

1890s Circuit breakers developed

1897 First NEC released

1897 UL is formed

1913 1st Edition Electrician's Handbook

1940s Current-limiting fuses were developed

1970 OSHA is formed

1979 NFPA 70E is Released

For more information:

800-TEC-FUSE

www.littelfuse.com

Because insurance companies were concerned about fire safety and electricity, the Underwriters Electrical Bureau (later to become UL) was established in 1894 to review various electrical safety standards and building codes that were quickly being developed. In the 1890's, the first crude circuit breakers were also developed. In 1896, the National Fire Protection Association was formed in New York City. Because electricity was viewed as a fire hazard, the National Board of Fire Underwriters unanimously approved the first "National Electrical Code" in June of 1897. Thus, the "NEC" was born.

Many electric generating plants and transmission lines were built and installed in the US in the early 20th Century. Construction and safety standards were quickly developed. In 1904 Underwriters Laboratories published the first fuse standard. In 1913, the first edition of the "American Electricians' Handbook" was issued. In the 1930's, the Wiggington Voltage Tester (a.k.a. the "Wiggie") was developed for testing the presence of voltage, etc. In June of 1940, UL published the first circuit breaker standard, UL489, entitled "Branch-Circuit and Service Circuit-Breakers." It was later in the 1940's when the first current-limiting fuses were developed.

Despite advances in technology and as hard as it may be to believe, the American Electricians Handbook of 1942 had the following to say about Electrical Safety:

"**158.** *Electricians often test for the presence of voltage by touching the conductors with the fingers. This method is safe where the voltage does not exceed 250 and is often convenient to locating a blown-out fuse or for ascertaining whether or not a circuit is alive. Some men can endure the electric shock that results without discomfort whereas others cannot. Therefore, the method is not feasible in some cases. Which are the outside wires and which is the neutral of a 115/230-volt, three-wire system can be determined in this way by noting the intensity of the shock that results by touching different pairs of wires with the fingers. Use the method with caution and be certain the voltage of the circuit does not exceed 250 before touching the conductors.*

159. *The presence of low voltages can be determined by tasting. The method is feasible only where the pressure is but a few volts and hence is used only in bell and signal work. Where the voltage is very low, the bared ends of the conductors constituting the circuit are held a short distance apart on the tongue. If voltage is present a peculiar mildly burning sensation results, which will never be forgotten after one has experienced it. The taste is due to the electrolytic decomposition of the liquids on the tongue, which produces a salt having a taste. With voltages of 4 or 5 volts, due to as many cells of a battery, it is best to test for the presence of voltages by holding one of the bared conductors in the hand and touching the other to the tongue. Where a terminal of a battery is grounded, often a taste can be detected by standing on moist ground and touching a conductor from the other battery terminal to the tongue. Care should be exercised to prevent the two*

1980 First burn centers opened

1982 Ralph Lee's Arc-Flash paper

1990 OSHA Subpart S updated

1995 NFPA 70E recognizes Arc-Flash

1995 Arc-Resistant switchgear introduced

2000 NFPA 70E expands on Arc-Flash

2002 NEC requires warning labels

2004 NFPA 70E is expanded and revised

2005 NEC is updated with new safety definitions

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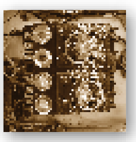
At OSHA's request, the National Fire Protection Association was asked to research and provide guidelines for electrical safety in the workplace.

As a result the NFPA 70E "Standard for Electrical Safety in the Workplace." was issued.



conductor ends from touching each other at the tongue, for if they do a spark can result that may burn." [1]

After World War II, the demand for electric power increased for new construction and advances in productivity created the need for circuit protection devices with higher current ratings and interrupting capacities. Electrical safety standards and practices needed to keep pace with the ever-increasing growth of electrical power use and generation.

In 1970, when the Williams-Steiger Act was signed into law, the Occupational Safety and Health Administration (OSHA) was created. It took OSHA several years before they issued comprehensive regulations that governed aspects of all workers safety. At OSHA's request, the National Fire Protection Association, which issues the National Electrical Code®, (NFPA 70), was asked to research and provide guidelines for electrical safety in the workplace. In 1979, the NFPA issued the first edition of NFPA 70E, entitled "Standard for Electrical Safety Requirements for Employee Workplaces" (since renamed the "Standard for Electrical Safety in the Workplace.") This was the first nationally accepted standard that addressed electrical safety requirements for employee workplaces.

In the 1970's, in addition to the known shock hazards associated with electricity, researchers began to address the phenomena of arcing faults that released large amounts of heat and light energy as well as pressure and sound energy. In 1980, Dr. Raphael Lee opened the first burn center in Chicago dedicated to the care and treatment of electrical burns. In 1982, Mr. Ralph Lee (no relation) wrote an IEEE technical paper entitled "The Other Electrical Hazard: Electric Arc Blast Burns." This paper introduced methods to determine and calculate the severity of electrical arc-flash hazards. It remains today as one of the most comprehensive dissertations on the causes and effects of Arc-Flash hazards. It was also the first notable publication that attempted to analyze and quantify the potential energy released during an Arc-Flash event.

In 1990, OSHA updated subpart S of the Code of Federal Regulations, CFR 29 Section 1910, which deals specifically with the practical safeguarding of electrical workers at their workplaces. In 1995, NFPA 70E was revised to include formulas to establish shock and flash protection boundaries. Also in the mid 1990's, equipment makers began to design their equipment to be more arc resistant. In the year 2000, NFPA 70E was again revised to include an expanded section on Arc-Flash hazards. In 2002, the National Electrical Code (NEC)® was updated to include the requirement of shock and Arc-Flash hazard warning labels on all equipment that is likely to be worked on while energized. Also in 2002, the IEEE (Institute of Electronic and Electrical Engineers) published IEEE 1584 "Guide for Performing Arc-Flash Hazard Calculation". The latest edition of NFPA 70E recognizes IEEE 1584 as a preferred method of calculating Arc-Flash hazards.

In addition to OSHA, NFPA, and the IEEE, there are several other safety organizations and standards such as American National Standards Institute (ANSI), American Society of Testing and Materials (ASTM) and the International Electrotechincal Commission (IEC) that have developed practices and have set standards for materials and the testing of products to protect workers from electrical hazards.

1. Croft, Terrell, American Electricians' Handbook, 5th edition, McGraw-Hill, New York, NY, 1942

For more information:

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Electrical Safety Organizations

Several organizations have developed and continue to revise standards to address the numerous concerns involving electrical power. Standards and safety organizations include:

- *OSHA*
  Occupational Safety & Health Administration
- *NFPA*
  National Fire Protection Association
- *IEEE*
  Institute of Electrical and Electronic Engineers
- *UL*
  Underwriters Laboratories
- *NEMA*
  National Electrical Manufacturers Association
- *ANSI*
  American National Standards Institute
- *ASTM*
  American Society for Testing and Materials
- *NECA*
  National Electrical Contractors Association

OSHA

The primary goal of the Occupational Safety and Health Administration (OSHA) is "to ensure safe and healthful conditions for every American worker." OSHA currently has thousands of rules and regulations that cover workplace safety. Federal and state OSHA programs enforce regulations through workplace inspections, voluntary assistance programs, and training activities. Citations and fines are also levied for violations found during inspections.

The General Duty Clause

Section 5(a)(1) of the Occupational Safety and Health Act of 1970 reads,

" 5. Duties

(a) **Each Employer**

(1) **Shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees;"**

The "General Duty Clause" is essentially the mission that OSHA strives to enforce. It is also often cited when OSHA investigates a workplace accident. Many OSHA regulations are prescriptive in nature like the "General Duty Clause". In other words, OSHA is the "shall" or the reason for addressing an issue. In some cases, OSHA will also provide detailed information on how to meet the requirements. In other instances, OSHA refers to national safety organizations such as NFPA to provide the required level of detail to meet the regulations. In either case, OSHA covers all employees and all employers.

OSHA Regulations

Published by the U.S. Federal Register, OSHA regulations can be found in the Code of Federal Regulations (CFR) under Title 29. More specifically, and legally enforced by OSHA, Subpart S (Parts 1910.301 to 1910.399) addresses "Electrical" safety standards and covers the practical safeguarding of electrical workers. Subpart S is divided into four major divisions:

- Design safety standards
- Safety-related work practices
- Safety-related maintenance requirements
- Safety requirements for special equipment

The primary goal of OSHA is "to ensure safe and healthful conditions for every American worker."

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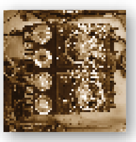
OSHA and NFPA have worked with each other to establish standards and codes that ensure employee safety in the workplace.



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Other OSHA standards outline some of the general requirements for electrical installations and general safe work practices:

> *29 CFR 1910.132*
> *Personal Protective Equipment General Requirements*
>
> ***29 CFR 1910.335***
> *Electrical Personal Protective Clothing*
>
> ***29 CFR 1910.147***
> *Control of Hazardous Energy (Lockout/tagout)*
>
> ***29 CFR 1910.269***
> *Power Generation, Transmission, & Distribution*

OSHA and NFPA have worked with each other to establish standards and codes that ensure employee safety in the workplace. One of their objectives is to minimize the hazards of electricity through standards that specify safe design characteristics and work practices for electrical equipment and systems. Many of the standards and codes are not only accepted in the United States, but throughout the world.

NFPA

The primary organization in the U.S. for fire and electrical safety standards is the NFPA. Their document, NFPA 70E, *Standard for Electrical Safety in the Workplace*, has been adopted by the American National Standards Institute (ANSI) as an American National Standard. This standard covers safety related work practices, defines qualified and unqualified workers and provides guidance to establish an electrical safety program. It also requires an electrical hazard analysis for shock and flash, discusses energized work permits, and proper Lockout/tagout procedures. NFPA 70E defines and establishes shock and Arc-Flash approach boundaries to energized equipment and addresses how to select appropriate PPE (personal protective equipment) and protective clothing.

In order to help meet the required OSHA regulations for electrical safety and training, OSHA refers to NFPA 70E as a national consensus standard for electrical safety in the workplace. NFPA also publishes NFPA 70, otherwise known as the National Electrical Code®, and other standards that address public safety and practices. Together, OSHA and the NFPA continue to work to improve workplace safety. To ensure the safety of your plant and personnel, OSHA and NFPA standards should always be followed.

IEEE

The Institute of Electrical and Electronic Engineers, Inc. (IEEE) is an association of electrical and electronic engineers established to advance the theory and application of electro-technology and allied sciences. The Industry Application Society (IAS) of the IEEE is the group that addresses power distribution in industrial and similar facilities. There are numerous sub-committees that meet regularly to research, publish, and update standards and guidelines for the testing, evaluation, and application of their particular industry or specialty. In 2002, the Petroleum and Chemical Industry Committee IAS published IEEE1584, entitled, *IEEE Guide for Performing Arc-Flash Hazard Calculations*. Although there are other methods of determining Arc-Flash hazards, IEEE 1584 has quickly become the de facto standard for determining the extent of potential Arc-Flash Hazards.

NATIONALLY RECOGNIZED TESTING LABORATORIES (NRTL)

The best-known NRTL is Underwriters Laboratories, Inc. (UL). UL is an independent, not-for-profit product safety testing and certification organization that lists and labels products for conformance to accepted standards. Working with industry associations, manufacturers, experts, insurance companies, and government agencies, UL publishes various standards and minimum test requirements for all types of electrical equipment. Manufacturers submit their products to be evaluated for conformance to one or more of these standards. If the product meets or exceeds the standards, UL lists the product in their guides and permits manufacturers to display the UL label on the product. Protective devices such as fuses and circuit breakers must meet rigid standards such as UL248, UL489, or UL1077. There are other Nationally Recognized Testing Laboratories such as Canadian Standards Association (CSA), Electrical Testing Laboratories (ETL) that test and evaluate products to UL or other industry standards. Equipment that has been modified may require new evaluation and manufacturers routinely submit their products to UL for re-evaluation to maintain their listing.

NEMA

The National Electrical Manufacturers Association (NEMA) has over 400 member companies including large, medium, and small businesses that manufacture products used in the generation, transmission and distribution, control, and end-use of electricity. NEMA has developed and published hundreds of standards jointly developed by its member companies. The standards have been established in the best interests of the industry and users of its products. NEMA works closely with the American National Standards Institute (ANSI) and the International Electrotechnical Commission (IEC) to be an advocacy group to UL and governmental agencies. Many NEMA publications have been adopted by ANSI as American National Standards. Some address the use and application of overcurrent protective devices including AB3-2001 *Molded Case Circuit Breakers and their Application*; AB4-2003 *Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications*; and FU1-2002 *Low-voltage Cartridge Fuses*, while others address safety issues such as safety signs, tags, and barricades.

ANSI

The American National Standards Institute (ANSI) is a private, non-profit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment system. Working in conjunction with organizations such as NFPA, IEEE, NEMA, ASME (American Society of Mechanical Engineers), ASCE (American Society of Civil Engineers), AIMME (American Institute of Mining and Metallurgical Engineers), and ASTM (American Society of Testing and Materials), ANSI coordinates and adopts these various industry consensus standards and publishes standards to promote US and Global conformity. ANSI has adopted many NFPA, NEMA, and ASTM standards for procedures, materials, and personal protective equipment used by electrical workers.

ASTM

ASTM International, formerly known as the American Society for Testing and Materials, is a voluntary standards development organization primarily involved with establishing standards for the testing and analysis of materials. The ASTM has published several standards accepted by ANSI and other organizations that govern the manufacturing, testing methods, and ratings of personal protective equipment used by electrical and other workers.

NECA

NECA, the National Electrical Contractors Association, is in the process of developing installation standards for electrical construction work. They have also developed electrical safety standards with emphasis on their members. In many cases, these standards are being adopted by ANSI.

OSHA commonly is referred to as the "Shall" and NFPA 70E as the "How to" with regards to electrical safety.

Electrical Safety Codes and Standards

20,000+

standards have been developed to reduce the risk of electrical hazards.

Over 20,000 standards have been developed to reduce the risk of electrical hazards. Except for OSHA regulations most standards do not automatically become law. However, they are often adopted by governmental bodies and become law; enforced by the Authority Having Jurisdiction (AHJ). Other standards are written into manufacturing and construction specifications. Whether law or not, applicable standards should be followed to improve safety and reduce potential hazards.

Working on deenergized equipment

OSHA 29 Part 1910.333 covers selection and use of (electrical) work practices. It defines and regulates such things as working on or near energized or deenergized parts, Lockout/tagout procedures, who is or is not considered qualified to work on live circuits, approach distances, use of personal protective equipment, and other requirements. Paragraph 1910.333 (a)(1) reads:

> *"Deenergized parts.*
> *Live parts to which an employee may be exposed shall be deenergized before the employee works on or near them, unless the employer can demonstrate that deenergizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Live parts that operate at less than 50 volts to ground need not be deenergized if there will be no increased exposure to electrical burns or to explosion due to electric arcs."*

To demonstrate the close relationship between OSHA and NFPA 70E, here is what NFPA 70E Article 130.1 has to say regarding the need for equipment to be deenergized:

> *"Justification for Work.*
> *Live parts to which an employee might be exposed shall be put into an electrically safe work condition before an employee works on or near them, unless the employer can demonstrate that deenergizating introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Energized parts that operate at less than 50 volts to ground shall not be required to be deenergized if there will be no increased exposure to electrical burns or to explosion due to electric arcs…"* [1]

When electrical equipment has been deenergized, OSHA Part 1910.147 (c) and 1910.333 (b)(2) requires Lockout/tagout procedures be followed. Failure to follow Lockout/tagout procedures is also consistently listed as one of the top ten OSHA violations.

How to establish an electrically safe work condition

Equipment that has been deenergized and verified as such is said to be in an electrically safe work condition. Article 120.1 of NFPA 70E outlines 6 steps that must be followed to insure that employees are working in an electrically safe work condition. They are:

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1. *“Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.*

2. *After properly interrupting the load current, open the disconnecting device(s) for each source.*

3. *Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that drawout-type circuit breakers are withdrawn to the fully disconnected position.*

4. *Apply Lockout/tagout devices in accordance with a documented and established policy.*

5. *Use an adequately rated voltage detector to test each phase conductor or circuit part to verify they are deenergized. Test each phase conductor or circuit part both phase-to-phase and phase-to-ground. Before and after each test, determine that the voltage detector is operating satisfactorily.*

6. *Where the possibility of induced voltages or stored electrical energy exists, ground the phase conductors or circuit parts before touching them. Where it could be reasonably anticipated that the conductors or circuit parts being deenergized could contact other exposed energized or circuit parts, apply ground connecting devices rated for the available fault duty.”* [1]

It is important to note that a safe work condition does not exist until all 6 steps are complete. During the process of creating the electrically safe work condition, the appropriate PPE must also be utilized.

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Working on energized equipment

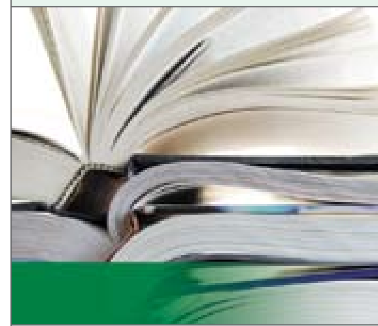
Although the best practice is to always work on deenergized equipment, OSHA and NFPA do recognize that in some circumstances it may create an additional hazard or be infeasible to deenergize. OSHA 29 CFR 1910.333 (a)(2) states:

> *“Energized parts.*
> *If the exposed live parts are not deenergized (i.e., for reasons of increased or additional hazards or infeasibility), other safety-related work practices shall be used to protect employees who may be exposed to the electrical hazards involved. Such work practices shall protect employees against contact with energized circuit parts directly with any part of their body or indirectly through some other conductive object....”*

Electrical tasks such as troubleshooting and testing for the presence of voltage, current, etc., can only be done while equipment is energized. In these instances, work on energized equipment is allowed, but workers must follow safe work practices and use the appropriate PPE. Other exceptions that allow work on energized equipment include:

- **Life-support equipment**
- **Emergency alarm systems**
- **Hazardous area ventilation equipment**

Deenergizing these types of equipment could increase or create additional hazards. A mistake often made is confusing infeasibility with inconvenience. For example, meeting a manufacturing production schedule does not qualify as infeasible. It may be very inconvenient but it still does not authorize working on energized equipment. OSHA 29 CFR 1910.331-335 outlines the conditions for working on energized circuits in much greater detail. When work is to be performed on energized equipment, extra care must be used and all applicable OSHA and NFPA



Establish a “safe work condition” and work on system components *deenergized* when possible.

As a worker, you may be qualified for some tasks and unqualified for other.

Knowing the difference between the two can save your life.

codes and standards followed. Electrical workers must also be trained and specially "qualified" to work on energized equipment, and the specific equipment to be serviced.

Who is Qualified?

The definition of a "Qualified" person continues to change and evolve. As a worker, you may be qualified for some tasks and unqualified for others. Knowing the difference may even save your life. It is no longer sufficient for those who will install and/or maintain electrical systems and equipment to be just "familiar" with the hazards involved. Training is the key in determining who is considered a qualified worker. All personnel who may be exposed to electrical hazards MUST receive documented training in order to become qualified. OSHA 29 CFR 1910.333 (c)(2) states;

> ***"Work on energized equipment.***
> *Only qualified persons may work on electric circuit parts or equipment that have not been deenergized under the procedures of paragraph (b) of this section. Such persons shall be capable of working safely on energized circuits and shall be familiar with the proper use of special precautionary techniques, personal protective equipment, insulating and shielding materials, and insulated tools."*

Article 100 of the National Electrical Code® and NFPA 70E also defines a Qualified Person as:

> ***"Qualified Person***
> *One who has skills and knowledge related to the construction and operation of the electrical equipment and installations and has received safety training on the hazards involved."* [1]

NFPA 70E Article 110.6 (D) Employee Training covers the requirements for "Qualified" persons in more detail. In addition to being trained and knowledgeable, qualified persons must also be familiar with emergency procedures, special precautionary techniques, personal protective equipment, Arc-Flash, insulating materials and tools, and testing equipment. In some instances, employees receiving on-the-job training may be considered "Qualified" for specific duties under supervision.

Ultimately, a person can be considered qualified with respect to certain equipment and methods but still be considered unqualified for others. Unqualified persons must also be trained in the risks they are exposed to and the procedures that are necessary to ensure their safety, however, they may not be considered "qualified" to work on specific equipment. It is vital that Unqualified workers have an understanding of what tasks can only be performed by Qualified workers.

Energized Electrical Work Permit

Before work is performed on energized equipment, NFPA 70E states:

> ***Article 130 (A)(1)***
> *"If live parts are not placed in an electrically safe work condition (i.e., for the reasons of increased or additional hazards or infeasibility per 130.1), work to be performed shall be considered energized electrical work and shall be performed by written permit only."* [2]

The intent of an Energized Electrical Work Permit is to discourage the practice of working on energized equipment. The objective is to get the supervisor or manager to recognize

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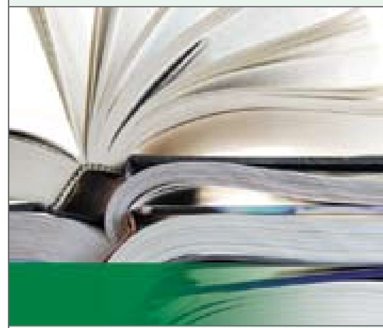
and fully understand the additional risks involved so they will be less likely to approve work on energized components. In essence, this shifts the decision to work on energized equipment from the worker to management.

According to the NFPA 70E Handbook, work permits can also be written to cover a certain length of time for routine tasks provided the worker is trained and qualified. Other tasks that are not routine should generate a work permit as needed to insure the worker is trained and qualified for the task. Exceptions to the written work permit include testing, troubleshooting, and voltage measuring by qualified workers.

NFPA 70E does not require a specific format for an Energized Electrical Work Permit. However, it should contain the following 11 elements:

1. *The location and description of equipment to be serviced*
2. *Justification why circuit cannot be deenergized*
3. *Description of safe work practices employed*
4. *Results of the shock hazard analysis*
5. *Determination of the shock protection boundaries*
6. *Results of the flash hazard analysis*
7. *The Flash Protection Boundary*
8. *Description of PPE to be used*
9. *Description of barriers used to restrict access*
10. *Evidence of job briefing*
11. *Signature of responsible management*



XYZ COMPANY ENERGIZED ELECTRICAL WORK PERMIT

Section 1 - Work Request
(To be completed by person requesting the permit)

WORK ORDER NO: ______

LOCATION: ______ EQUIPMENT: ______

START DATE: ______ TIME: ______ TIME REQUIRED: ______ TIME REQUIRED: ______

DESCRIPTION OF TASK: ______

DESCRIPTION OF EQUIPMENT: ______

SYSTEM VOLTAGE: ______

AVAILABLE FAULT CURRENT: ______

Section 2 - Justification of Work
(To be completed by Qualified Person performing the work)

WHY IS TASK BEING PERFORMED IN ENERGIZED CONDITION? ______

WHAT WORK PRACTICES WILL BE UTILIZED TO INSURE SAFETY? ______

WHAT WERE THE RESULTS OF THE SHOCK ANALYSIS? ______

LIMITED: ______ RESTRICTED: ______ PROHIBITED: ______

WHAT WERE THE RESULTS OF THE FLASH HAZARD ANALYSIS? ______

HAZARD RISK CATEGORY: ______ INCIDENT ENERGY: ______ FLASH PROTECTION BOUNDARY: ______

WHAT IS THE REQUIRED PERSONNEL PROTECTIVE EQUIPMENT (PPE) FOR THIS TASK ?

☐ HARD HAT ☐ EAR PROTECTION ☐ VOLTAGE RATED GLOVES ☐ FR PANTS
☐ SAFETY GLASSES ☐ T-SHIRT ☐ LEATHER GLOVES ☐ FR COVERALL
☐ SAFETY GOGGLES ☐ LONG SLEEVE SHIRT ☐ COTTON UNDERWEAR ☐ FLASH SUIT
☐ FACE SHIELD ☐ FR SHIRT ☐ LONG PANTS ☐ LEATHER SHOES
☐ FLASH HOOD

SAMPLE

HOW WILL ACCESS TO THE WORK AREA BE RESTRICTED FROM UNQUALIFIED PERSONNEL? ______

HAS A JOB BRIEFING BEEN COMPLETED? ______

WHAT EVIDENCE IS AVAILABLE? ______

WERE THERE ANY JOB SPECIFIC HAZARDS? ______

IN YOUR OPINION, CAN THIS JOB BE COMPLETED SAFELY? ☐YES ☐NO

Signature of Qualified Person ______ Date ______

Signature of Qualified Person ______ Date ______

Section 3 - Approval to Perform Work on Energized Equipment
(To be completed by Management)

IS WORK ON ENERGIZED EQUIPMENT APPROVED? ______

Signature of Manufacturing Manager ______ Date ______

Signature of Plant Manager ______ Date ______

Signature of Safety Manager ______ Date ______

Signature of Electrical Maintenance Manager ______ Date ______

Signature of Qualified Person ______ Date ______

SAMPLE

See Appendix C for Sample Work Permit

Figure 7
Energized Electrical Work Permit

The intent of an Energized Electrical Work Permit is to discourage the practice of working on energized equipment.

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Safety is the responsibility of both the employer and employee. Together they must develop and implement safe work practices and procedures and an Electrical Safety Program.

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The implementation and proper use of Energized Work Permits has forced employers and employees to perform hazard risk assessments and justify working on potentially hazardous energized equipment. At this time, OSHA does not specifically require the written Energized Electrical Work Permit. However, it is implied within current OSHA regulations and will most likely be enforced in future OSHA revisions. For an example of an Energized Electrical Work Permit refer to Annex C of this handbook or Annex J of NFPA 70E.

Employer and Employee Responsibilities

According to OSHA and NFPA 70E, if work is planned or performed on energized equipment, employers must:

- *Justify why work must be performed on energized equipment.*
- *Perform an electrical hazard assessment.*
- *Inform and train employees of the potential hazards and how to avoid them.*
- *Test and verify that employees are "qualified" to work on specific equipment.*
- *Select and provide proper personal protective equipment for employees.*
- *Train employees how to use and care for PPE.*
- *Provide their employees with a job briefing and written Energized Work Permit signed by management.*

Employees are expected to:

- *Be trained and "qualified"*
- *Use the PPE provided by their employer*
- *Inform their employers of the need to repair or replace PPE*

At the end of the day, safety is the responsibility of both the employer and employee. Together they must develop and implement safe work practices and procedures and an Electrical Safety Program.

Arc-Flash and Other Electrical Safety Hazards

Electrical Safety Hazards

When electrical systems break down what are the primary hazards and what are the consequences to personnel?

- *Electric shock*
- *Exposure to Arc-Flash*
- *Exposure to Arc-Blast*
- *Exposure to excessive light and sound energies*

Secondary hazards may include burns, the release of toxic gases, molten metal, airborne debris and shrapnel. Unexpected events can cause startled workers to lose their balance and fall from ladders or jerk their muscles possibly causing whiplash or other injuries.

Electric Shock

When personnel come in contact with energized conductors they receive a shock with current flowing through their skin, muscles and vital organs. The severity of the shock depends on the current's path through the body, the current intensity, and the duration of the contact. They may only experience a mild tingling sensation or it could result in serious injury or death. As voltage levels increase, the effects of electric shock escalate. Current may also cause an erratic heartbeat known as ventricular fibrillation. If fibrillation occurs even briefly and goes untreated, the effects are usually fatal.

A clear understanding of how electric current travels through the body can help minimize injury if such contact occurs. The table below outlines the effects that various values of electrical current have on the human body.

CONDITION	EFFECTS
1-3mA of current	Mild sensation
10mA of current	Muscles contract, releasing grip may be difficult
30mA of current	Breathing difficult, possible loss of consciousness
30-75mA of current	Respiratory paralysis
100-200mA of current	Ventricular fibrillation
50-300mA of current	Shock (potentially fatal)
Over 1500mA of current	Tissue and organ burn
150˚ F	Cell destruction
200˚ F	Skin experiences "third degree" burns

When personnel come in contact with energized conductors they receive a shock with current flowing through their skin, muscles and vital organs.

The shock may result in a serious and sometimes fatal injury.

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As little as 50 mA
of current can be fatal.

There are three basic pathways electric current travels through the body;

1) **Touch Potential (hand/hand path)**

2) **Step Potential (foot/foot path)**

3) **Touch/Step Potential (hand/foot path)**

Figure 8 illustrates these groups and the path of current through the body.

1) In a touch potential contact, current travels from one hand through the heart and out through the other hand. Because the heart and lungs are in the path of current, ventricular fibrillation, difficulty in breathing, unconsciousness, or death may occur.

2) In a step potential contact, current travels from one foot through the legs, and out of the other foot. The heart is not in the direct path of current but the leg muscles may contract, causing the victim to collapse or be momentarily paralyzed.

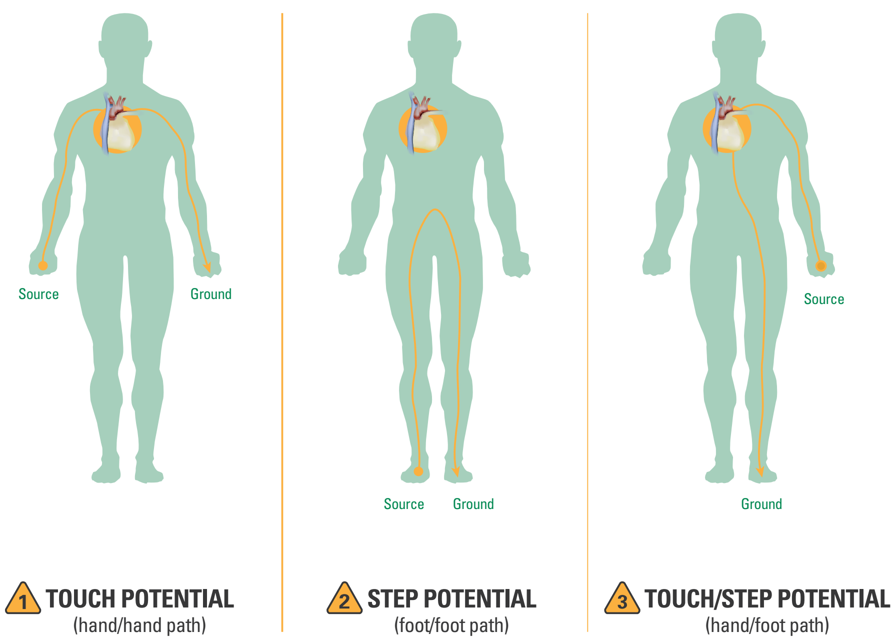
3) In a touch/step potential contact, current travels from one hand, through the heart, down the leg, and out of the foot. The heart and lungs are in the direct path of current so ventricular fibrillation, difficulty in breathing, collapse, unconsciousness, or death may occur.

Even though there may be no external signs from the electrical shock, internal tissue or organ damage may have occurred. Signs of internal damage may not surface immediately; and when it does, it may be too late. Any person experiencing any kind of electrical shock should seek immediate medical attention. Using the correct personal protective equipment (PPE) and following safe work practices will minimize risk of electrical shock hazards.

Arc-Flash and Arc Blasts

An Arc-Flash is an unexpected sudden release of heat and light energy produced by electricity traveling through air, usually caused by accidental contact between live conductors. Temperatures at the arc terminals can reach or exceed 35,000 degrees Fahrenheit (F), or four

Figure 8



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times the temperature of the sun's surface. The air and gases surrounding the arc are instantly heated and the conductors are vaporized causing a pressure wave called an Arc Blast.

Personnel directly exposed to an Arc-Flash and Arc-Blast events are subject to third degree burns, possible blindness, shock, blast effects and hearing loss. Even relatively small arcs can cause severe injury. The secondary effect of arcs includes toxic gases, airborne debris, and potential damage to electrical equipment, enclosures and raceways. The high temperatures of the arc and the molten and vaporized metals quickly ignite any flammable materials. While these fires may cause extensive property damage and loss of production, the hazards to personnel are even greater.

Any energized electrical conductor that makes accidental contact with another conductor or with ground will produce an Arc-Flash. The arcing current will continue to flow until the overcurrent protective device used upstream opens the circuit or until something else causes the current to stop flowing. The arc current can vary up to the maximum available bolted fault current.

Arc-Flash Metrics

In order to determine the potential effects of an Arc-Flash, we need to understand some basic terms. An Arc-Flash produces intense heat at the point of the arc. Heat energy is measured in units such as BTU's, joules, and calories. The following data provides a basis for measuring heat energy:

A Calorie is the amount of heat energy needed to raise the temperature of one gram of water by one degree Celsius.

ARC-FLASH METRICS

Energy (E)	=	*Power (P) × Time (t)*
Power (P)	=	*Volts (V) × Amps (I)*
Calories (E)	=	*Volts (V) × Amps (I) × Time (t)*
1 Calorie	=	*4.1868 watt-seconds*
1 Joule	=	*1 watt-second*

Since energy equals power multiplied by time, and power (wattage) is volts X amps, we can see that calories are directly related to amperes, voltage, and time. The higher the current, voltage and time, the more calories produced.

To define the magnitude of an Arc-Flash and the associated hazards, some basic terms have been established: The amount of instantaneous heat energy released by an Arc-Flash is generally called incident energy. It is usually expressed in calories per square centimeter (cal/cm^2) and defined as the heat energy impressed on an area measuring one square centimeter (cm^2). However, some calculation methods express the heat energy in Joules/cm^2 and can be converted to calories/cm^2 by dividing by 4.1868.

If we place instruments that measure incident energy at varying distances from a controlled Arc-Flash, we would learn that the amount of incident energy varies with the distance from the arc. It decreases approximately as the square of the distance in feet. Just like walking into a room with a fireplace, the closer we are, the greater the heat energy. Tests have indicated that an incident energy of only 1.2 cal/cm^2 will cause a second-degree burn to unprotected skin. A second-degree burn can be defined as "just" curable.

For the purpose of understanding the potential effects of an Arc-Flash, you must determine the working distance from an exposed "live" part. Most measurements or calculations are made at a working distance of 18 inches. This distance is used because it is the approximate distance a worker's face or upper body torso may be away from an arc, should one occur. Some parts of a worker may be less than 18 inches away, but other work may be performed at greater distances. The working distance is used to determine the degree of risk and the type of personal protection equipment necessary to protect against the hazard.

NFPA 70E, *Standard for Electrical Safety in the Workplace* categorizes Arc-Flash Hazards into five Hazard Risk Categories (HRC 0 through 4)

Incident energy is the instantaneous energy released by an Arc-Flash and is usually expressed in calories per square centimeter (cal/cm^2).

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The amount of incident energy a worker may be exposed to during an Arc-Flash is directly proportional to the clearing time of the overcurrent protective device.

In general, a current-limiting fuse will clear a fault much quicker than a standard circuit breaker.

INCIDENT ENERGY (cal/cm^2)	RESULTS/EXAMPLE
0.0033	Amount of energy the sun produces in 0.1sec. on the ground's surface at the equator.
1	Equivalent to a finger tip exposed to a cigarette lighter flame for one second
1.2	Amount of energy that will instantly cause 2nd degree burns to bare skin
4	Amount of energy that will instantly ignite a cotton shirt
8	Amount of energy that will instantly cause incurable 3rd degree burns to bare skin

based on the amount of energy that can be released at a certain working distance during an Arc-Flash event. They are:

INCIDENT ENERGY (cal/cm^2)	HAZARD RISK CATEGORY
0 to 1.2	0
1.21 to 4	1
4 .1 to 8	2
8.1 to 25	3
25.1 to 40	4

Studies show that many industrial Arc-Flash events produce 8 cal/cm^2 (HRC 2) or less, but other accidents can produce 100 cal/cm^2 or more (exceeding all HRC). It is important to remember that it only takes 1.2 cal/cm^2 (HRC 0) to cause a second degree burn to unprotected skin.

What determines the severity of an Arc Flash?

Several groups and organizations have developed formulas to determine the incident energy available at various working distances from an Arc-Flash. In all cases, the severity of the Arc-Flash depends on one or more of the following criteria:

- *Available short circuit current*
- *System voltage*
- *Arc gap*
- *Distance from the arc*
- *Opening time of overcurrent protective device (OCPD)*

When a severe enough Arc-Flash occurs, the overcurrent protective device (fuse or circuit breaker) upstream of the fault interrupts the current. The amount of incident energy a worker may be exposed to during an Arc-Flash is directly proportional to the total clearing ampere-squared seconds (I^2t) of the overcurrent protective device during the fault. High current and longer exposure time produces greater incident energy. The only variable that can be positively and effectively controlled is the time it takes for the overcurrent protective device to extinguish the arc. A practical and significant way to reduce the duration of an Arc-Flash and thereby the incident energy is to use the most current-limiting OCPD's throughout the electrical system.

Current-limiting devices such as Littelfuse type LLSRK_ID or JTD_ID fuses will open in ½ AC cycle (8.33 milliseconds) or less under short circuit conditions. Studies have shown that many existing molded case circuit breakers take up to 6 AC cycles (100 milliseconds) or longer to open under short circuit conditions. Refer to the table on page 31 showing the typical opening times for various overcurrent protective devices.

Arc Blast Effect

During an Arc-Flash, the rapidly expanding gases and heated air may cause blasts, pressure waves, or explosions rivaling that of TNT. The gases expelled from the blast also carry the products of the arc with them including droplets of molten metal similar to buckshot. For example, the high temperatures will vaporize copper, which expands at the rate of 67,000 times its mass when it changes from solid to vapor. Even large objects such as switchboard doors, bus bars, or other components can be propelled several feet at extremely high velocities. In some cases, bus bars have been expelled from switchboard enclosures entirely through walls. Blast pressures may exceed 2000 pounds per square foot, knocking workers off ladders or collapsing workers' lungs. These events occur very rapidly with speeds exceeding 700 miles per hour making it impossible for a worker to get out of the way.

Light and Sound Effects

The intense light generated by the Arc-Flash emits dangerous ultraviolet frequencies, which may cause temporary or permanent blindness unless proper protection is provided. The sound energy from blasts and pressure waves can reach 160 dB, exceeding the sound of an airplane taking off, easily rupturing eardrums and causing permanent hearing loss. For comparison, OSHA states that decibel levels exceeding 85 dB require hearing protection.

Common Causes

The most common cause of Arc-Flash and other electrical accidents is carelessness. No matter how well a person may be trained, distractions, weariness, pressure to restore power, or over-confidence can cause an electrical worker to bypass safety procedures, work unprotected, drop a tool or make contact between energized conductors. Faulty electrical equipment can also produce a hazard while being operated. Electrical safety hazards such as exposure to shock and Arc-Flash can also be caused by:

- *Worn or broken conductor insulation*
- *Exposed live parts*
- *Loose wire connections*
- *Improperly maintained switches and circuit breakers*
- *Obstructed disconnect panels*
- *Water or liquid near electrical equipment*
- *High voltage cables*
- *Static electricity*
- *Damaged tools and equipment*

The severity and causes of electrical hazards are varied, but the best protection is to deenergize equipment before working on it. No one has ever been killed or injured from an Arc-Flash while working on deenergized equipment. If equipment cannot be deenergized, electrical workers must be "qualified", trained, wear appropriate personal protective equipment (PPE), and follow all applicable OSHA and NFPA standards. It is important to remember that proper selection and application of overcurrent protective devices (OCPD) will also substantially reduce the hazards.

OVERCURRENT PROTECTIVE DEVICE	TYP. OPENING TIME AT 8 × RATING	TYPICAL OPENING TIME AT 20 × RATING
Current-limiting fuses or current-limiting circuit breakers	0.1 to 1 second	< ½ cycle = 8.3 milliseconds
Molded case circuit breakers without adj. trip	5 to 8 seconds	1.5 cycles = 25 milliseconds
Molded case circuit breakers with adj. trip	1 to 20 seconds	1.5 cycles = 25 milliseconds
Large air power breakers with electronic trip	5 to 20 seconds	3 cycles = 50 milliseconds
Medium voltage breakers with electronic trip	5 to 20 seconds	5 to 6 cycles = 100 milliseconds

Circuit breakers can take up to 12 times longer to open under short circuit conditions than current-limiting fuses.

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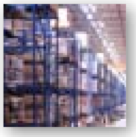
Electrical Hazard Analysis

Electric Hazard Analysis is required for all areas of the electrical system that operate at 50 volts or higher.



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Both OSHA and NFPA 70E require an Electrical Hazard Analysis prior to beginning work on or near electrical conductors that are or may become energized. The analysis must include all electrical hazards: shock, Arc-Flash, Arc-Blast, and burns. NFPA 70E Article 110.8(B)(1) specifically requires Electrical Hazard Analysis within all areas of the electrical system that operate at 50 volts or greater. The results of the Electrical Hazard Analysis will determine the work practices, protection boundaries, personal protective equipment, and other procedures required to protect employees from Arc-Flash or contact with energized conductors.

Shock Hazard Analysis

NFPA 70E Articles 110.8(B)(1) and 130.2(A) require a Shock Hazard Analysis. The Shock Hazard Analysis determines the system voltage to which personnel can be exposed, the protection boundary requirements as established in NFPA 70E Table 130.2(C), and identifies personal protective equipment (PPE) required to minimize shock hazards.

Approach Boundaries

NFPA 70E has established three shock protection boundaries:

1) *Limited Approach Boundary*

2) *Restricted Approach Boundary*

3) *Prohibited Approach Boundary*

Limited Approach Boundary

The Limited Approach Boundary is an approach boundary to protect personnel from shock. A boundary distance is established from an energized part based on system voltage. To enter this boundary, unqualified persons must be accompanied by a qualified person and use PPE.

Restricted Approach Boundary

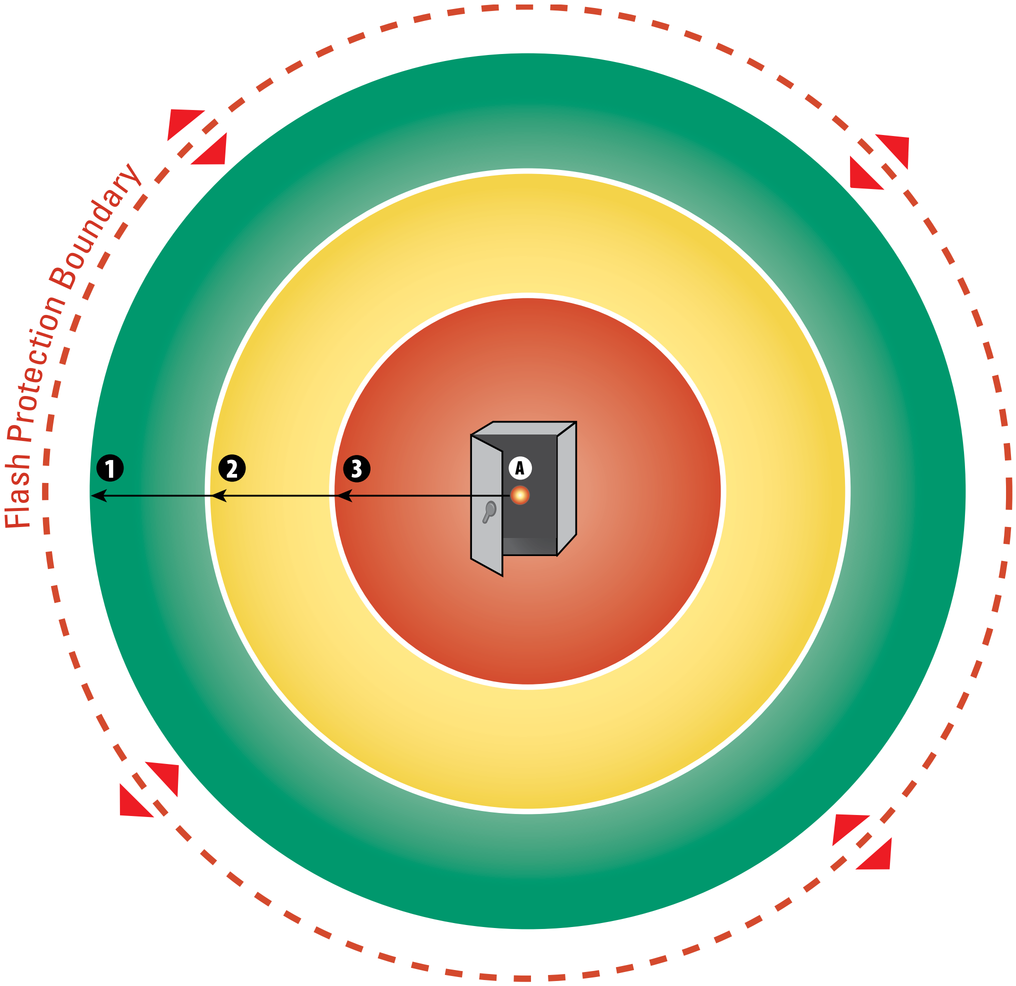
The Restricted Approach Boundary is an approach boundary to protect personnel from shock. A boundary distance is established from an energized part based on system voltage. Only qualified persons are allowed in this boundary and they must use PPE.

Prohibited Approach Boundary

The Prohibited Approach Boundary is an approach boundary to protect personnel from shock. Work in this boundary is considered the same as making direct contact with an energized part. Only qualified persons are allowed to enter this boundary and they must use PPE.

Shock protection boundaries are based on system voltage and whether the exposed energized components are fixed or movable. NFPA 70E Table 130.2(C) defines these boundary distances for nominal phase-to-phase system voltages from 50 Volts to 800kV. Approach Boundary distances may range from an inch to several feet. Please refer to NFPA 70E Table 130.2(C) for more information.

In summary, a Shock Hazard Analysis is performed to reduce the potential for direct shock. It will establish shock protection boundaries and determine PPE required for protecting workers against shock hazards.



❶ **Limited Approach Boundary**

❷ **Restricted Approach Boundary**

❸ **Prohibited Approach Boundary**

Ⓐ **Energized Part**

Figure 9
Shock Protection Boundaries

Completing a shock hazard analysis establishes the system voltage, shock protection boundaries and type of personal protection equipment required to protect workers against shock hazards.

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In part, Arc-Flash hazard calculations are based on the available fault current and the opening time of overcurrent protective devices.

Flash Hazard Analysis

A complete electrical hazard analysis must also contain a Flash Hazard Analysis. NFPA 70E Article 130.3 requires this analysis to be performed:

> ***"A Flash Hazard Analysis***
> *shall be done in order to protect personnel from the possibility of being injured by an Arc-Flash. The analysis shall determine the Flash Protection Boundary and the personal protective equipment that people within the Flash Protection Boundary shall use."* [1]

The analysis requires the available fault current to be calculated and documented at every point in the electrical system. This includes all components contained in the electrical system. The end result of this research will be an accurate, documented one-line diagram, which will provide the data for a short circuit analysis, and the other calculations that determine the Flash Protection Boundary and required level of PPE. In part, Arc-Flash hazard calculations are based on the available fault current and the opening time of overcurrent protective devices. NFPA 70E has also assigned Hazard Risk Categories based on the estimated incident energy (typically expressed in cal/cm^2), from an Arc-Flash.

> ***The Flash Protection Boundary (FPB)***
> *The Flash Protection Boundary is the distance in feet (D_C) from a given arc source that will produce a second-degree burn on exposed bare skin.*

Unlike the Shock Hazard Protection Boundaries that are based solely on system voltage, the Flash Protection Boundary is not fixed. In order to determine the potential Arc-Flash hazard, Flash Protection Boundaries must be calculated at every point where service on energized equipment, devices, or conductors may be required. The discussion and examples that follow are intended to introduce readers to the required data and some of the methods for performing an electrical flash hazard analysis at 600 volts and below. Readers are cautioned that calculations for systems with different voltages, equipment, devices, and a wider range of fault currents require the more complete methods contained in NFPA 70E Article 130 and Annex D.

According to NFPA 70E, the default Flash Protection Boundary is four feet (48") based on an OCPD clearing time of 6 cycles (0.1 sec) and an available fault current of 50 kA or other combinations not exceeding 5,000-ampere seconds. For other conditions or under engineering supervision, calculations are permitted to determine the Flash Protection Boundary. Complete formulas for varying conditions are given in NFPA 70E Article 130 and NFPA 70E Annex D.

The following data is required to complete the Flash Hazards Analysis:

- **Up-to-date one-line circuit diagram of the electrical distribution system**
- **Available fault current from the utility or generator**
- **Maximum available bolted fault currents at each location**
- **Minimum self-sustaining arcing current at each location**
- **Clearing times of all overcurrent protective devices**

As power is distributed throughout your facility, it is important to remember that although voltage levels may be higher at the service entrance, secondary power distribution transformers can produce much higher current levels and Arc-Flash energy levels. Power utilities should be consulted regularly to establish the maximum available fault current at the service entrance location of your building. Hand calculations or

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commercial software can be used to estimate the maximum available short circuit current at every access point in your electrical system.

Arc-Flash Calculations

If the maximum available fault current at a particular location is known, then an analysis of the upstream overcurrent protective device (OCPD) will determine how fast the device will clear the circuit at the fault current. If these two factors are known, the amount of incident energy and the Flash Protection Boundary can be calculated.

The Flash Protection Boundary (D_c) measured in feet is based on the bolted fault mega volt-amperes (MVA_{bf}) and the clearing time (t) of the OCPD. If the bolted fault current (I_{sc}) is not known, it can be calculated based on the MVA rating and impedance of the source transformer. An alternate method of determining the Flash Protection Boundary based on the MVA rating of a source transformer with an impedance of 5% and the clearing time (t) of the OCPD is supplied in NFPA 70E. Table A provides a basic formula for calculating the Flash Protection Boundary.

Multiple methods are also provided in NFPA 70E Annex D for estimating incident energy under varying conditions. The results can vary drastically depending on the specific system parameters. An arcing fault will also produce very different incident energy levels depending on if the arc is in open air or confined in a cubic box. The formula in Table B estimates the incident energy for a fault occurring in a 20 inch cubic box with one side open. This estimate simulates the potential effect of an arc-flash while working in equipment and switchgear enclosures.

During arcing faults the arc impedance (resistance) reduces arc current. Because the opening times of OCPD increase as the short-circuit current (I_{sc}) decreases, lower arc fault currents may greatly increase the total arc energy. Studies have shown that the minimum self-sustainable arc in 480 volt systems is 38% of the available bolted fault current. Because of the increased time at this reduced fault level, the incident energy may be higher than under bolted fault conditions. Each point in the system needs to be evaluated for both maximum and minimum fault currents.

Table A

$D_c = [2.65 \times MVA_{bf} \times t]^{1/2}$ **OR** $D_c = [53 \times MVA \times t]^{1/2}$	
D_c	= *FPB distance in ft. from the Arc*
MVA_{bf}	= *Available bolted fault MVA in mega volt-amps at point of fault*
MVA	= *Transformer capacity in mega volt-amps*
t	= *Clearing time of overcurrent protective device in seconds*

Table B

$E_{MB} = 1038.7\, D_B^{-1.4738}\, t_A\, [0.0093F^2 - 0.3453F + 5.9675]\ \text{cal/cm}^2$	
E_{MB}	= *Maximum 20 in. cubic box incident energy*
D_B	= *Distance from arc electrodes, (usually 18 in.)*
t_A	= *Arc duration, seconds*
F	= *Bolted fault current in kA*

Note: *The formula in Table B only applies to systems where the available short circuit current is in the range of 16kA to 50kA.*

NFPA 70E refers to three methods to determine the incident energy or Hazard Risk Category.

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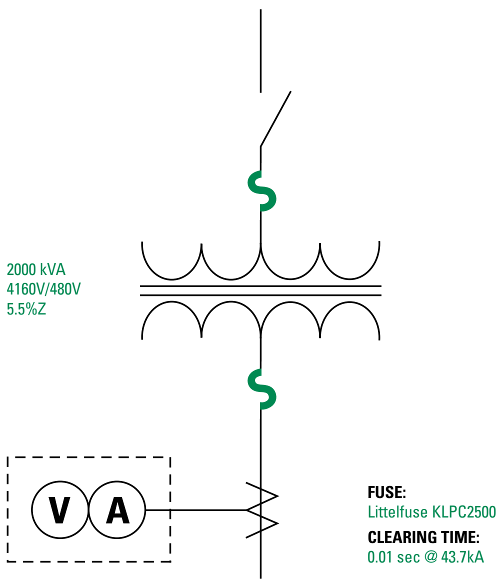
The following example illustrates the difference in incident energy between a current-limiting fuse and a circuit breaker.

Arc-Flash Hazard Calculation Examples

The following examples break down the calculations and compare the Hazard Risk Category (HRC), Incident Energy (cal/cm²), Flash Protection Boundary (FPB) and PPE (Personal Protective Equipment) required to work on an energized 480V system protected by either 2500 Amp Class L fuses or a 2500 Amp low voltage power circuit breaker.

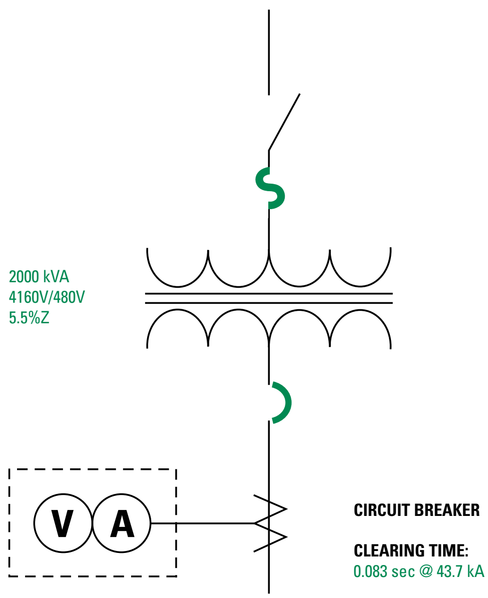
Example 1

Calculation for energized work in the transformer metering section of a 2000 kVA substation. Transformer secondary protected with current-limiting fuses.



Example 2

Calculation for energized work in the transformer metering section of a 2000 kVA substation. Transformer secondary protected with a circuit breaker.



Refer to Annex D for Step by step instructions of this example.

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Example 1 (continued)

NFPA 70E Article 130.3 (A)
Flash Protection Boundary Distance

Calculate MVA_{bf} :

Note: 2000 kVA = 2 MVA

$$MVA_{bf} = \frac{100}{\%Z} \times MVA = \frac{100}{5.5} \times 2$$

MVA_{bf} = 36.4 MVA

Calculate D_C:

t = 0.01 sec

$$D_C = \sqrt{(2.65 \times MVA_{bf} \times t)}$$

$$D_C = \sqrt{(2.65 \times 36.4 \times 0.01)} = 0.98 \text{ ft} \cong 12 \text{ inches}$$

NFPA 70E Annex D.6.2(a)
Incident Energy Exposure

Calculate I_{sc}:

$$I_{sc} = \frac{MVA \times 10^6}{\sqrt{3} \times V_{AC}} \times \frac{100}{\%Z}$$

$$I_{sc} = \frac{2 \times 10^6}{\sqrt{3} \times 480} \times \frac{100}{5.5} = 43{,}738 \text{ Amps}$$

Calculate F:

$$F = \frac{Isc}{1000} = \frac{43{,}738 \text{ A}}{1000} = 43.7 \text{ kA}$$

Calculate E_{MB}:

For this calculation, D_B = 18 inches

$$E_{MB} = 1038.7 \times D_B^{-1.4738} \times t_a \times (0.0093\, F^2 - 0.3453\, F + 5.9675)$$

$$E_{MB} = 1038.7 \times (18)^{-1.4738} \times (.01) \times [0.0093\,(43.7)^2 - 0.3453\,(43.7) + 5.9675]$$

E_{MB} = 1.27 cal/cm²

Example 2 (continued)

NFPA 70E Article 130.3 (A)
Flash Protection Boundary Distance

Calculate MVA_{bf} :

Note: 2000 kVA = 2 MVA

$$MVA_{bf} = \frac{100}{\%Z} \times MVA = \frac{100}{5.5} \times 2$$

MVA_{bf} = 36.4 MVA

Calculate D_C:

t = 0.083 sec

$$D_C = \sqrt{(2.65 \times MVA_{bf} \times t)}$$

$$D_C = \sqrt{(2.65 \times 36.4 \times 0.083)} = 2.83 \text{ ft} \cong 34 \text{ inches}$$

NFPA 70E Annex D.6.2(a)
Incident Energy Exposure

Calculate I_{sc}:

$$I_{sc} = \frac{MVA \times 10^6}{\sqrt{3} \times V_{AC}} \times \frac{100}{\%Z}$$

$$I_{sc} = \frac{2 \times 10^6}{\sqrt{3} \times 480} \times \frac{100}{5.5} = 43{,}738 \text{ Amps}$$

Calculate F:

$$F = \frac{Isc}{1000} = \frac{43{,}738 \text{ A}}{1000} = 43.7 \text{ kA}$$

Calculate E_{MB}:

For this calculation, D_B = 18 inches

$$E_{MB} = 1038.7 \times D_B^{-1.4738} \times t_a \times (0.0093\, F^2 - 0.3453\, F + 5.9675)$$

$$E_{MB} = 1038.7 \times (18)^{-1.4738} \times (.083) \times [0.0093\,(43.7)^2 - 0.3453\,(43.7) + 5.9675]$$

E_{MB} = 10.54 cal/cm²

In this example the incident energy is much less when a current-limiting fuse is used to provide protection.

In this example, the incident energy for a current-limiting fuse is *eight times lower* than the incident energy for a circuit breaker.

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According to the previous example the required level of PPE needed while working on the equipment protected by the circuit breaker would be much greater than the level of PPE needed while working on the equipment protected by the fuse.

DATA	EX. 1 - FUSE	EX. 2 - CIRCUIT BREAKER
Fault Current (I_{SC})	43.7 kA	43.7 kA
Flash Protection Boundary (D_C)	12 inches	34 inches
Incident Energy (E_{MB})	1.27 cal/cm^2	10.54 cal/cm^2
Hazard Risk Category	1	3

Example Results Comparison

As the examples show, the Flash Protection Boundary, Incident Energy, and Hazard Risk Category can vary greatly depending on the overcurrent protective device being used. In this particular comparison, the required level of PPE would also be quite different between the fuse and circuit breaker. The above calculations can also be performed using commercially available software programs. Refer to Annex D of this handbook for more details on the steps required to complete the hand calculations.

IEEE 1584 Arc-Flash Hazard Calculation

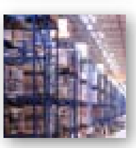
The Institute of Electrical and Electronic Engineers (IEEE) publishes the IEEE 1584 "Guide for Performing Arc-Flash Hazard Calculations." It contains detailed methods and data that can be used to calculate Arc-Flash Hazards for the simplest to the most complex systems. The Petroleum and Chemical Industry committee of the IEEE spent many years developing these methods. They are based on empirical testing of Class RK1 and Class L fuses, Low Voltage Molded Case Circuit Breakers, Insulated Case Circuit Breakers and Low Voltage Power Circuit Breakers as well as theoretical modeling. Included in 1584 are spreadsheet programs that simplify the calculation of incident energy and flash-protection boundaries.

IEEE 1584 does not address the Safety-related Work Pratices in the same manner as NFPA 70E. IEEE 1584 concerns itself primarily with performing the calculations that may be necessary to determine safe practices. The calculation methods in Annex D of NFPA 70E are based on IEEE 1584 but do not contain all the data or descriptions of how these methods were developed. IEEE 1584 outlines 9 steps necessary to properly perform an Arc-Flash hazard calculation.

Step 1

Collect the system and installation data

Depending on whether you are doing a complete site analysis or looking at one individual portion, this step can take a few minutes or several weeks to perform. Begin by reviewing the latest up-to-date single line diagram(s) of the equipment or system you are analyzing. If single line diagrams are not available, you must create them. The utility can provide you with the available fault MVA and X/R ratio at the entrance to your facility. If you generate your own electricity, or if you have emergency or standby generators and large motors, a more detailed analysis must be performed. In order to calculate the bolted fault current available at the point of your application, you must record on your one line diagram all transformers and their ratings, circuit breakers or fusible distribution circuits and their ratings, MCC's, and all other equipment between the power source and the area you are concerned with. Next, you must record the size, type, length, and number of cables or busbars, etc. used between the utility and the distribution and control equipment being analyzed. The type of conduit or raceway must also be recorded. All transformer data must be recorded including MVA ratings and impedance, and all overcurrent protective devices must be identified with their specific characteristics or trip ratings recorded.



Step 2

Determine the system modes of operation

Most installations have only one mode of operation with one utility connection. However, larger industrial or commercial buildings or manufacturing plants may have two or more utility feeders with tie switching of two or more transformers, or co-generators running in parallel. Each mode can be very complex and require a detailed hazard analysis.

Step 3

Determine the bolted fault currents

You can perform hand calculations or use commercially available software programs such as the Littelfuse EDR software to calculate the bolted fault currents at all points between the utility and the distribution or control equipment you are analyzing. It will be necessary to plug in all of the data you have recorded about the transformers, cable sizes and lengths, and type of conduit, etc. used in each installation to determine the bolted fault currents.

Step 4

Determine the arc fault currents

After determining the bolted fault currents, IEEE 1584 provides a formula to calculate the predicted arc fault current due to typical arc impedance and other factors. The predicted arc fault current for system voltages under 1kV depends on the bolted fault current, system voltage, arc gap, and whether the arc would most likely occur in the open air or in an enclosed box configuration.

Step 5

Find the protective device characteristics and the duration of the arcs

From the data collected in Step 1 and the predicted arc fault current determined in Step 4, the next step is to establish the total clearing time of the overcurrent protective device immediately on the LINE side of the equipment you are analyzing. If the fuse manufacturer or circuit breaker manufacturer publishes maximum and minimum clearing times, it is important to use the maximum clearing time possible for the predicted arc fault current.

NOTE: This step can be omitted if the overcurrent protective devices are those already tested and listed in the IEEE 1584 document. See Section 4.6 of IEEE 1584.

Step 6

Document the system voltages and classes of equipment

Make sure you document the system voltages and class of equipment such as 15kV switchgear, 5kV switchgear, low-voltage switchgear, low-voltage MCCs and panelboards, or cable runs.

Step 7

Select the working distances

IEEE 1584 has established three typical working distances for different classes of equipment. As previously discussed, incident energy calculations and Hazard Risk Categories will depend on the working distances selected.

Step 8

Determine the incident energy for all equipment

You can use formulas included in the IEEE 1584 document or commercially available software to calculate the incident energy possible in cal/cm^2 at the working distance selected.

Step 9

Determine the flash protection boundary for all equipment

The formulas given within IEEE 1584 can

IEEE 1584 is one method of determining incident energy and Flash Protection Boundaries (FPB). Another method will be to use NFPA 70E equations and calculations.

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The Table Method may be used in lieu of a complete Flash Hazard Analysis. However, a complete analysis will provide more accurate results.

be used to determine the distance from the arc at which the onset of a second-degree burn will occur to unprotected skin. This distance must be established and will vary based on system parameters. Software programs automatically calculate the distance based on the arc fault current, system voltage, arc gap, and arc duration.

If the overcurrent protective devices (OCPD) are something other than those covered by IEEE 1584, or if the voltage levels and short circuit currents exceed the IEEE 1584 limitations, then the opening times of the overcurrent protective devices must be analyzed and the corresponding Flash Protection Boundary and incident energy must be calculated by another method.

NFPA 70E Table Method

Although NFPA 70E (Article 130.3) requires a Flash Hazard Analysis, it also provides an alternate method for determining Hazard Risk Categories and required PPE. This is commonly called the “Table Method” and is based on various tasks to be performed on energized equipment (see NFPA 70E Table 130.(C)(9)(a)). The Table Method may be used in lieu of a complete Flash Hazard Analysis in some cases. However, a complete analysis provides more accurate results.

Caution is advised when using the Table Method. All footnotes listed at the end of NFPA 70E Table 130.7(C)(9)(a) and in any applicable Tentative Interim Amendments must be observed and all prescribed conditions verified. If a task is not listed in NFPA 70E Table 130.7(C)(9)(a) or cannot be verified, then NFPA 70E leaves no other alternative but to do a complete hazard risk assessment using one of the other calculation methods.

Steps Required to Use the NFPA 70E Table Method

Step 1

Once the equipment is identified where work is to be performed, review the up-to-date one line drawing for information about the available short circuit current and other details about the location of the equipment. If the one line drawing is not up to date or the available short circuit is not known, it must be determined.

Step 2

Consult NFPA 70E Table 130.7(C)(9)(a) and find the task to be performed. If the desired task to be performed is not listed, the Table Method cannot be used and a complete Flash Hazard Analysis is required.

Step 3

Once you find your task in the table, identify the Hazard Risk Category and determine if voltage rated gloves or tools are required.

Step 4

Verify that the conditions stated in the footnotes for NFPA 70E Table 130.7(C)(9)(a), and any Tentative Interim Amendments such as those stated in NFPA 70E, are applicable to the task.

Step 5

Using NFPA 70E Tables 130.7(C)(10-11) and the corresponding notes in Table 130.7(C)(9)(a), identify the required PPE for the task.

Step 6

The NFPA 70E Table Method does not provide the Flash Protection Boundary, but it must be determined. For systems 600V and below, NFPA 70E defines the FPB as 4 feet. See NFPA 70E for more information on calculating the FPB.

Whether calculations are made or NFPA 70E Table 130.7(C)(9)(a) is used, the results of an Electrical Hazard Analysis (Shock and Flash Hazard Analysis) will determine the following:

- *The Limited Approach Boundary*
- *The Restricted Approach Boundary*
- *The Prohibited Approach Boundary*
- *Incident Energy possible at each location*
- *Flash Protection Boundary*
- *Hazard Risk Category*
- *PPE required to work on energized equipment*

OSHA regulations must be followed to perform a hazard assessment, and to determine the PPE required for properly protecting electrical workers.

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Minimizing Arc-Flash and Other Electrical Hazards

Estimates show that ***10 Arc-Flash incidents*** **occur every day in the U.S.**

NFPA 70E guidelines and practices are generally considered the "How to" of conforming to the OSHA regulations when performing a hazard assessment, and determining the required PPE. There are many practices that will help reduce Arc-Flash and other electrical hazards while conforming to OSHA and NFPA 70E regulations and guidelines. Circuit designers and electrical maintenance engineers should carefully consider each of the following recommendations:

1. Design a safer system.

2. Use and upgrade to current-limiting overcurrent protective devices.

3. Implement an Electrical Safety Program.

4. Observe safe work practices.

5. Use Personal Protective Equipment (PPE).

6. Use Warning Labels.

7. Use an Energized Electrical Work Permit.

8. Avoid hazards of improperly selected or maintained overcurrent protective devices.

9. Achieve or Increase Selective Coordination.

1. Design a safer system.

Goals

When designing a safer system the following goals and factors should be considered:

- *Provide maximum protection to personnel, equipment, and property.*
- *Meet all applicable code requirements (OSHA, NFPA, Building and Insurance codes, etc.)*
- *Utilize current-limiting overcurrent protective devices to minimize Arc-Flash hazards.*
- *Utilize "touch-safe" components to minimize exposure to energized components*
- *Utilize fuses with blown fuse indication to minimize exposure to energized components while trouble-shooting the circuit.*
- *Provide selective coordination (only the area where the fault occurs is shut-off)*
- *Provide a system that is safe to service and maintain.*

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System Requirements

Once the goals for your system are established, the selection of the overcurrent protective devices that best meet those goals can be determined. What is the best choice for your application; fuses or circuit breakers? Fuses offer many safety and performance advantages over circuit breakers. Factors to consider include:

- **System voltage**
  Voltage ratings for fuses are standardized at 250, 300, and 600 volts. In comparison, some circuit breakers are rated for dual voltages and are often mis-applied.

- **Interrupting rating**
  Most fuses have standard ratings of 200kA at full rated voltage. Circuit breaker interrupting ratings may range from 10kA to 100kA, but the interrupting ratings of many breakers vary with system voltage and type of trip unit.

- **System changes resulting in increased available fault current**
  If your facility grows or the utility makes changes, fault currents have been known to more than double. Interrupting ratings of overcurrent protective devices must be regularly reviewed to insure the device will still protect the system.

- **Load current characteristics**
  Inductive loads such as motors and transformers and even large incandescent lamps have large inrush currents that require circuit breakers to be oversized so that overload protection is sacrificed. Properly selected time-delay fuses can be sized close to load currents and will offer better overload protection.

- **Current-limitation**
  Current-limiting OCPDs reduce damage from major faults. Often devices or equipment can be easily repaired rather than face time-consuming and costly replacement.

- **Are your sensitive control devices such as motor starters truly protected?**
  After a fault, will the units be usable or will they require replacement? Only current-limiting fuses can provide Type 2 Protection. That means you are up and running once the cause of the fault is removed.

2. Use and upgrade to current-limiting overcurrent protective devices.

The incident energy from an Arc-Flash depends on the magnitude of the current and the time it is allowed to flow. Within their current-limiting range, current-limiting devices reduce the peak fault current. Current-limiting fuses have much faster clearing times when operating within their current-limiting range than standard circuit breakers. The faster the overcurrent protective device clears the fault, the lower the I^2t and incident energy will be. If current-limiting fuses are used, the incident energy and the Hazard Risk Category may be reduced significantly.

Upgrade to Class RK1 or Class J current-limiting fuses

One of the quickest and easiest ways to reduce potential incident energy, lower the Hazard Risk Categories and reduce the required PPE, is to replace UL Class H, K5 or Class RK5 fuses with current-limiting UL Class RK1 or Class J fuses. Upgrading to time-delay Class J fuses affords the best solution by providing the best current limitation while assuring non-interchangeability with non-current-limiting fuses. If an equipment manufacturer

Upgrading to Class RK1 or Class J current- limiting fuses is the easiest way to:

- **Reduce potential Arc-Flash hazards**
- **Reduce Hazard Risk Categories**
- **Reduce the amount of required PPE**

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Current-limiting fuses that also offer blown fuse indication such as the Littelfuse Class RK1 LLSRK_ID series can help:

- **reduce exposure to electrical hazards**
- **decrease downtime**
- **maximize safety**

has specified a non-time delay fuse, standard Class J fuses are available. If your equipment already has UL Class H fuse clips, it is very easy to replace the Class H or K5 fuses being used with Class RK1 fuses. For a given current and voltage rating, UL Class H, K5, RK5, and RK1 fuses are the same physical size, therefore, it is easy and strongly recommended to upgrade to better fuse protection. To assure that only current-limiting fuses are used, consider changing to Class J clips or to rejection type clips that will accept only Class R fuses.

Current-limiting fuses that also offer blown fuse indication such as the Littelfuse Class J JTD_ID and Class RK1 LLSRK_ID can help reduce exposure to electrical hazards. The unique blown fuse indicator decreases downtime by immediately indicating the opened circuit and maximizes safety by minimizing exposure to energized components when trouble-shooting. Replacing non-current-limiting fuses with Littelfuse current-limiting Indicator® fuses can significantly reduce the:

- *Incident energy from an Arc-Flash*
- *The Hazard Risk Category*
- *The level and type of PPE necessary*
- *Trouble-shooting and downtime.*

Use the table below to consolidate your fuse inventory and eliminate unsafe or unnecessary fuses.

You Should Use This Fuse....			If You Have This Fuse....			
Class L		**KLPC**	KLPC KLLU	KRPC KLU KTU	A4BQ A4BY A4BT	LCL LCU
Class RK1 (600 Volts)		**LLSRK_ID**	FLSR FLSR_ID NLS* RLS* LLSRK KLSR*	FRSR NOS* RES* LPSRK KTSR*	TRS OTS* RFS* A6DR A6KR*	GF6B ECSR LESRK KOS* ERS*
Class RK1 (250 Volts)		**LLNRK**	FLNR NLN* RLN* KLNR*	FRNR NON* REN* LPNRK KTNR*	TR OT* RF* A2DR A2KR*	GF6A ECNR LENRK* KON* ERN*
Class J		**JTD_ID**	JTD JLS*	LPJ JHC JKS*	AJT A4J*	JDL JFL*
Class CC		**CCMR**	FLM FLQ KLDR KLK BLS BLF BLN KLKR	LPCC FNM FNQ FNQR KTKR KTK BBS BAF BAN	ATDR TRM ATQ ATQR ATMR SBS OTM ATM	EDCC MEN MEQ HCTR HCLR MCL EBS MOL

* Consult Article 430 of the NEC® when substituting for loads with motors, or call 800-TEC-FUSE

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3. Implement an Electrical Safety Program.

Electrical Safety Programs protect both employees and employers and provide goals, procedures and work practices to insure safety. NFPA 70E Article 110.7 requires employers to establish an Electrical Safety Program that must be documented and include the minimum following components:

- *Scope of the Program*
- *Company Philosophy*
- *Responsibilities*
- *Establishment of a Safety Team or Committee*
- *Written Procedures*
- *Work Instructions*
- *Identification of Industry Codes & Standards to be adhered to*
- *Establishment of a Documented Training Program*
- *Establishment of Assessment and Audit Requirements*
- *Company Policies and Enforcement*

Increased safety will be possible with the implementation and vigorous enforcement of a well-designed and documented Electrical Safety Program. These programs should be in accordance with all OSHA regulations and nationally recognized safety standards such as NFPA 70E and NEC®. For more information on establishing an Electrical Safety Program, refer to NFPA 70E Annex E or NFPA's Electrical Safety Program Book.

4. Observe safe work practices

Maintenance

Safe maintenance practices and procedures include properly training employees in the knowledge of the equipment and tools necessary for maintenance and repair. NFPA 70E states that employees "shall be trained in and familiar with the specific maintenance procedures and tests required." Test equipment as well as hand tools are often overlooked and must be insulated and rated for the voltage of the circuits where they will be used. All tools and equipment used for maintenance must also be periodically inspected to ensure they are not damaged (i.e. torn insulation) and are still in good working condition.

Disconnect Operation

Operating a damaged disconnect switch, whether it's a fusible switch or circuit breaker, can be dangerous. Serious injury could occur if someone is standing in front of a faulty switch or circuit breaker while opening or closing the device. If the handle is on the right hand side of the device, stand to the right, use your left hand to grasp the handle, turn your face away and then operate it. If the handle is on the left side, reverse the procedure. Use special caution while operating circuit breakers. If closed into a fault, circuit breakers will trip, drawing an internal arc. The gases from the arc are very hot, and vent through openings in the breaker. These hot gases often vent around the handle and can cause burns unless proper protective equipment is used.

Proper Service or Repair of All Equipment or Devices

a) Locate the equipment where work is to be performed. If equipment is running, follow manufacturer's shutdown procedures being sure that all unit switches are off. Do not open any enclosures. Determine if there is adequate working space and that it is clear of obstructions.

b) Locate all disconnecting means providing power to the equipment, including all sources of emergency, alternate, and control power. This must include discharging capacitors and other sources of stored energy. Turn all disconnecting devices to the OFF position and apply lockout/tagout devices as required by OSHA and the company's Electrical Safety Program.

c) While wearing proper personal protective equipment, open the enclosure door or access panels. Test the voltage meter to be

The implementation and enforcement of a well-designed Electrical Safety Program in accordance with OSHA and NFPA 70E will increase safety in your facility.

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It is estimated that Lockout/Tagout prevents about *120* fatalities and *50,000* workday injuries annually.

Source:
Occupational Safety and Health Administration

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used on a known energized source to be sure it is working properly. Test all exposed wires, contacts and other components likely to be energized insuring that the equipment is in an electrically safe work condition.

Equipment containing fuses

d) If it is suspected there is one or more opened fuses, remove fuses from the circuit using the proper size fuse puller.
Note: *The use of Littelfuse Indicator® Fuses will minimize time required to locate opened fuses, and help avoid mixing them with good fuses.*

e) Place fuses on a non-conductive surface and measure fuse resistance across the ends (endcaps/blades) of the fuse with a meter. If the fuses have knife blades be sure to test from blade to blade since some types of fuses have insulated end caps and will give a false reading. High resistance indicates that the fuse may be open.

f) Investigate the circuit to identify the cause of any blown fuses. Look for loose connections or signs of overheating. Correct the problem.

g) Verify the proper fuse class, voltage, ampere, and interrupting ratings before installing replacement fuses. (Caution: because fuse characteristics may vary between manufacturers and fuse classes, fuses should be of the same manufacturer and class for each application.)

h) Examine fuse clips or mountings for signs of corrosion, overheating, or loss of tension. Service if necessary. Install the replacement fuse with the proper size fuse puller.

Equipment containing circuit breakers

i) After following steps 1 through 3 above, look for circuit breakers and examine to see if any are tripped. Examine the circuit breaker(s) to see if the case or surrounding area shows signs of severe venting indicating a serious fault.

j) Investigate the circuit for the causes of circuit breaker tripping. Correct the problem. If breaker is protecting motor starters, especially IEC or single-purpose type, test the motor starters to be sure they are still functional. If the motor starters have heaters (resistance coils) in the overloads, test the resistance across the heaters to insure they are still functional.

k) Test resistance across the poles of the open circuit breaker to be sure all poles are open and there are no shorts between poles. Close the circuit breaker and measure resistance across the closed poles to insure resistances are within tolerances and are equal from pole to pole.

Placing equipment in service

l) Following manufacturer's instructions, close all internal switches and circuit breakers and other procedures necessary for start-up.

m) Close enclosure door(s) and access panels and check the area for other personnel. Remove lockout/tagout devices following OSHA and safety program procedures.

n) Restore power standing to the side of the switch enclosures.

o) Restart equipment following manufacturer's instructions and exercising caution until satisfactory operation is insured.

Lockout/tagout Procedures

OSHA requires that energy sources to machines or equipment must be turned off and disconnected isolating them from the energy source. The isolating or disconnecting means must be either locked or tagged with a warning label. While lockout is the more reliable and preferred method, OSHA accepts tagout to be a suitable replacement in limited situations. It is estimated that Lockout/tagout prevents about 120 fatalities and 50,000 workday injuries annually. Approximately 39 million workers are protected by Lockout/tagout practices. Failure to comply with Lockout/tagout safety regulations is frequently one of the top five OSHA violations. In 2004 alone, there were over 4,300 violations cited by OSHA. NFPA 70E Article 120 contains detailed instructions for lockout/tagout and placing equipment in an Electrically Safe Work Condition.

Application of Lockout/tagout Devices

a) Make necessary preparations for shutdown

b) Shut down the machine or equipment

c) Turn OFF (open) the energy-isolating device (fuse/circuit breaker)

d) Apply the lockout or tagout device

e) Render safe all stored or residual energy

f) Verify the isolation and deenergization of the machine or equipment

Removal of Lockout/tagout Devices

a) Inspect the work area to ensure that non-essential items have been removed and that machine or equipment components are intact and capable of operating properly. Especially look for tools or pieces of conductors that may not have been removed.

b) Check the area around the machine or equipment to ensure that all employees have been safely positioned or removed.

c) Make sure that only the employees who attached the locks or tags are the ones that are removing them.

d) After removing locks or tags, notify affected employees before starting equipment or machines.

5. Use Personal Protective Equipment (PPE)

The proper selection and use of Personal Protective Equipment will significantly reduce the risk of Arc-Flash and other electrical hazards to personnel working on energized equipment. OSHA Part 1910.335 (a) states:

> *"...Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed."*

A variety of PPE is available from numerous manufacturers. The most common types of protective gear include:

- *Nonconductive flame-resistant head, face, and chin protection (hard hats, full face shields, switching hoods, etc.)*
- *Eye protection (face shields, safety glasses, goggles)*
- *Body protection resistant to flash flame (shirts, pants, jackets, coveralls)*
- *Hand and arms protection (insulating gloves and sleeves with leather protectors)*
- *Foot and leg protection (insulated leg and footwear)*
- *Insulating blankets or mats*

The proper selection and use of PPE will greatly reduce the risk of Arc-Flash and other electrical hazards.

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PPE that is selected should be rated for, or greater than, the minimum Arc-Flash rating required for each Hazard Risk Category.

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Selection of PPE is dependant on the task to be performed. NFPA 70E Tables 130.7(C)(9), (10), and (11) provide guidance for the selection of personal protective equipment to be used for specific tasks and hazard levels. The Table of PPE requirements below provides typical clothing requirements for Hazard Risk Categories from 0 through 4. Note: Hazard Risk Category 0 still requires some level of protective clothing or equipment. Manufacturers have also developed tables and selection guides based on NFPA 70E recommendations. It is important to note that the level of PPE recommended by NFPA 70E is: "intended to protect a person from arc-flash and shock hazards". Even with PPE, some arc-flash conditions may result in burns to the skin or include arc blast pressures, toxic vapors, and propelled particles and materials. PPE that is selected should be rated for, or greater than, the minimum Arc-Flash rating required for each Hazard Risk Category.

Common Personal Protective Equipment Terms and Definitions

Arc Thermal Performance Exposure Value (ATPV)

The incident energy level (in cal/cm²) that can cause the onset of a second-degree burn as defined in ASTM F 1959 Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing. Personal Protective Equipment will be labeled with a calorie rating (Example: 11 cal/cm²).

V-rated

Tools and gloves rated and tested for the line-to-line voltage at the area where the work is to be performed.

Flame Resistant (FR)

"The property of a material whereby combustion is prevented, terminated, or inhibited following the application of a flaming or non-flaming source of ignition, with or without susequent removal of the ignition source."[1]

Breakopen Threshold Energy (E_{BT})

The incident energy level which does not cause flame resistant (FR) fabric breakopen and does not exceed second-degree burn criteria, as defined in ASTM F 1959.

Standards such as OSHA 1910.137 also specify that protective gear must be maintained and periodically inspected to ensure that it remains in a safe and reliable condition. NFPA also supports this in NFPA 70E Articles 130.7(B), 130.7(C)(8) and 130.7(F). NFPA requirements state that PPE should be inspected before and after each use, and be repaired, cleaned or laundered according to the manufacturer's instructions prior to use. It is also extremely important to avoid contamination of PPE material. Contact with grease, solvents, and flammable liquids may destroy the protection.

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PPE REQUIREMENTS

Hazard Risk Category	Required Minimum Arc Rating of PPE (cal/cm²)	Typical Protective Clothing Systems Clothing Description	Minimum Flash Protection Boundary (in.)
0	N/A	1 layer of non-melting, flammable fabric with weight of at least 4.5 oz/yd²	6
1	4	1 layer of a FR shirt and FR pants or FR coverall	15
2	8	1 or 2 layers of FR shirt and FR pants with conventional cotton underwear	45
3	25	2 or 3 layers of FR shirt, FR pants plus FR coverall cotton underwear	60
4	40	3 or more layers of FR shirt, FR pants plus multi-layer flash suit	~120

Derived from NFPA 70E Table 130.7(C)(11)

6. Use Warning Labels.

The National Electrical Code® recently recognized Arc-Flash hazards and developed a warning label requirement. NEC® Article 110.16 states:

> *"110.16 Flash Protection:*
> *Switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential electric Arc-Flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment."* [1]

While the overall requirement is very comprehensive, the required label format can be very generic. However, if a complete electrical hazard analysis is performed, the preferred approach would be to include the Hazard Risk Category, Flash Protection Boundary, Incident Energy available, level of PPE required, system voltage, and shock protection boundaries on labels. See Figures 10 and 11 for examples of typical warning labels:

Minimum Label Requirements

Figure 10

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Preferred Label Approach

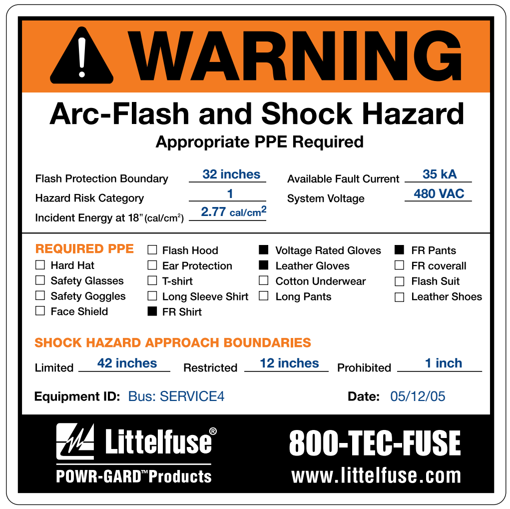

Figure 11

The use of detailed warning labels not only increases safety, but also minimizes the time required to identify minimum levels of PPE. Other types of warning labels should also be used to include information about proper fuse replacements, location of disconnects and other sources of power, etc. Warning labels can be applied directly to pieces of equipment or on enclosure doors. Computer programs and adhesive blank labels make it easy to create labels for almost every purpose.

7. Use an Energized Electrical Work Permit.

NFPA 70E requires that a detailed written Energized Electrical Work Permit must be used and signed by responsible management whenever work is performed on live energized equipment.

See Annex C of this handbook for an example of an Energized Electrical Work Permit. For additional information on Energized Electrical Work Permits, refer to NFPA 70E Article 130.1(A).

The use of detailed warning labels will increase safety as well as minimize the time required to identify minimum levels of PPE.

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Circuit breakers tripping mechanisms could seize up and not operate properly if not maintained to manufacturer's specifications.

8. Avoid Hazards of Improperly Selected or Maintained Overcurrent Protective Devices.

Whether in the design or maintenance of an electrical system, hazards exist if the proper overcurrent device is not selected and applied. Circuit breakers and other electrical equipment must be maintained and serviced regularly to ensure that they will operate properly when needed. Unfortunately, in many industries and especially during economic turndowns, the tendency is to limit or eliminate regularly scheduled maintenance on circuit breakers and other electrical equipment. However, the potential costs associated with OSHA violations, liability lawsuits, workers compensation, equipment replacement, and lost production far exceeds the costs of regular testing and maintenance of circuit breakers and other electrical equipment.

OSHA 29 CFR 1910.334(b)(2)

"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 reenergized. 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."

In this section of the regulations, OSHA recognizes the importance of knowing why the overcurrent protective device has opened. If the fuse or circuit breaker opened due to an overload, no examination of the circuit or connected equipment is necessary. However, if the overcurrent protective device opened due to a short circuit fault, catastrophic results can occur if the fuse or circuit breaker is replaced or closed on the short circuit before it is corrected. This is especially important for circuit breakers and switches because short circuit currents can permanently damage the equipment to the point that it will not operate safely when reenergized.

Circuit Breakers

Circuit breakers, like fuses, are rated to safely interrupt their maximum interrupting current only once. Molded Case Circuit Breakers (commonly referred to as MCCB's) must meet the requirements of UL489, "Standard for Safety," Molded-Case Circuit Breakers, Molded Case Switches and Circuit Breaker Enclosures. This standard allows manufacturers to list their circuit breakers at varying degrees of available fault currents, current-limiting ability and other characteristics. They must be applied within the maximum limitations of their ratings.

Circuit breaker manufacturers typically recommend that their circuit breakers be cycled ON and OFF at least once each year to keep the tripping mechanism from seizing under certain environmental conditions. Cycling circuit breakers ON and OFF manually may help keep the switching mechanism from seizing, but may not guarantee that the tripping mechanism will operate properly. Some manufacturers also recommend that their circuit breakers be periodically tested and recalibrated under carefully controlled conditions. When testing time-current characteristics, recommendations state the circuit breaker being tested must be at room temperature. This practice would increase equipment downtime while the circuit breaker to be tested cools down after it is removed from service.

The National Electrical Manufacturers Association (NEMA) has published standard AB 4-2003 entitled, "Guidelines for Inspection and Preventive Maintenance of Molded Case Circuit Breakers Used in Commercial and Industrial Applications." It deals exclusively with the maintenance and care of Molded Case Circuit Breakers to provide reliable protection. The expected lifetime of a circuit breaker, however, depends on circuit conditions and its' environment. Standard AB 4-2003 emphasizes that safe work practices

include regular periodic maintenance, and investigating what caused the circuit breakers to operate prior to reenergizing the circuit—similar to OSHA 29 CFR 1910.334(b)(2). There are other published industry standards for maintenance of large Air Power Circuit Breakers. Preventive maintenance of these circuit breakers should be performed at least annually, and after interruption of a fault some 20 or more steps are required before placing the circuit breaker back in service.

The Institute of Electrical and Electronic Engineers (IEEE) has also published Standard 493-1997, otherwise known as the "Gold Book," entitled, *Recommended Practice For the Design Of Reliable Industrial And Commercial Power Systems*. The IEEE studied failure statistics of typical industrial and commercial electrical distribution systems and components over several years prior to 1974 and more recently in 1996. The results of the 1996 study concluded nearly 1/3 of all circuit breakers that failed while in service could have been avoided if proper maintenance and testing was performed.

Article 225.3 of NFPA 70E
requires that if a circuit breaker interrupts a fault at or near its interrupting rating, it must be inspected by a trained technician and tested, repaired or replaced in accordance with the manufacturer's specifications.

If proper maintenance and repair is neglected, circuit breakers may fail to open or open more slowly than when first calibrated. The IEEE study noted that circuit breaker failures caused excessive equipment damage, blackouts, unexpected repair and replacement costs, lost production, scrap production, and most importantly, severe blast and burn injuries to personnel. Proper care and maintenance of circuit breakers must be part of any Electrical Safety Program.

Other common safety hazards involve using overcurrent protective devices with improper interrupting ratings. Standard circuit breakers have relatively low interrupting ratings (typically 10,000 to 100,000 AIC) when compared to fuses (200,000 AIR). The circuit breaker's low interrupting rating may not be an initial hazard, but as available fault currents rise from the utility, a dangerous situation is created. During service upgrades, circuit breakers with low interrupting capacities may have to be replaced by higher rated devices or protected by fuses in order to lower fault currents.

Non-current-limiting fuses

Another potential electrical hazard is the use of non-current-limiting fuses including "renewable" fuses. Although fuse standards and fuse technology have changed greatly, many older machines and equipment may contain Class H (one-time or renewable) or K5 one-time fuses. The continued use of these fuses especially where available fault currents exceed their interrupting ratings can be catastrophic. In addition to being non-current-limiting, Class H and K5 fuses have lower interrupting ratings than the Class R or J fuses. Just like non-current-limiting circuit breakers, the Class H and K5 fuses may permit much higher current to flow for a much longer time, increasing risk to workers and the equipment. The incident energy of an Arc-Flash could be deadly to an unsuspecting worker who is not properly protected.

9. Achieve or Increase Selective Coordination.

When an overcurrent occurs in a system only the overcurrent protective device immediately on the line side of the overcurrent should open. This reduces unnecessary shutdown of other equipment and simplifies locating the problem. Such systems are defined as "selectively coordinated." Refer to Figure 12.

If a system is **not** selectively coordinated, a fault at point A can cause the fuses or circuit breakers at points B, C, and D to open, needlessly shutting off power to two or more unaffected areas. In a selectively coordinated system, a fault at point A will cause **only** the fuse or circuit breaker immediately before the fault to open, keeping power supplied to the rest of the feeder and branch circuits throughout the facility.

Achieving a selectively coordinated system not only reduces downtime and the risk of Arc-Flash exposure, but the National Electrical Code® requires it.

Feeder circuit breakers or fuses are typically rated at least twice that of the downstream devices. An Arc-Flash that opens the upstream devices means that the total I^2t heat energy and consequently, incident energy, is determined by the largest upstream device. In this situation, the electrical system is not selectively coordinated, and the incident energy increases as a result of the time elapsed before the upstream overcurrent protective device clears the fault.

Achieving a selectively coordinated system not only reduces downtime and the risk of Arc-Flash exposure, but Articles 240.12, 700.27, 701.18 and 620.62 of the National Electrical Code require it. These code specifications refer to emergency circuits or potential life saving circuits such as alarm circuits, emergency lighting, and elevator circuits. For example, during an emergency or in a building with an elevator, an overcurrent on one elevator motor must not cause the feeder circuit to open all other elevator circuits, or alarm systems.

It is also unsafe to replace blown fuses with slightly higher ampere ratings in order to compensate for nuisance openings. Doing so will defeat selective coordination and can dramatically increase the amount of risk to workers if an Arc-Flash occurs. In order to decrease downtime and reduce the risk of Arc-Flash exposure to unsuspecting workers, it is best to replace non-current-limiting fuses and circuit breakers with more accurately rated time-delay current-limiting fuses such as the Littelfuse Class RK1 LLSRK_ID series.

Electrical safety is important for everyone. Employees working on electrical systems are at risk every day, but with the properly designed overcurrent protection system, the implementation of safe work practices and the utilization of the appropriate PPE, risk can be minimized.

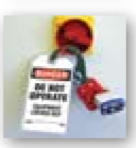
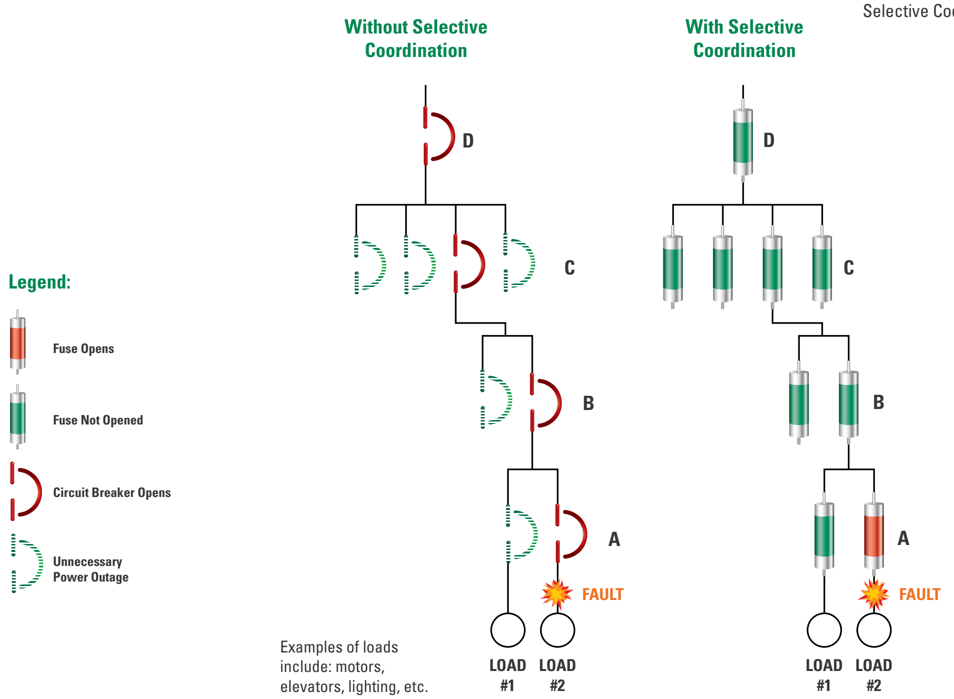


Figure 12
Selective Coordination



For more information:

800-TEC-FUSE
www.littelfuse.com

Electrical Safety Summary

Here is a brief review of some basic electrical safety concepts.

1) **Unless there is a compelling safety issue such as life-support equipment, alarm systems, hazardous location ventilation, or lighting required for safety, OSHA requires that circuits be deenergized and the system be placed in an Electrically Safe Work Condition before any work is performed.**

2) **When placing equipment in an Electrically Safe Work Condition, always follow proper Lockout/tagout procedures.**

3) **An Electrical Hazard Analysis must be performed on all circuits 50 volts and higher that may be worked on while energized.**

4) **The Hazards must be identified and warning labels must be applied to all equipment that may be worked on while energized.**

5) **Workers must be trained on the equipment, hazards and safety precautions, and be certified as "qualified" to work on energized equipment. Training and certification must be documented.**

6) **All work performed on energized equipment must be preceded by a job briefing and a signed Energized Electrical Work Permit.**

7) **When working on or approaching energized circuits, proper protective clothing must be worn. The minimum flame retardant clothing, safety glasses, and protective gloves and equipment must meet OSHA and NFPA 70E guidelines. Protective insulating blankets and mats are also used to minimize exposure.**

8) **Be certain there is adequate lighting for the tasks to be performed. Portable lighting must be fully insulated so that it will not accidentally cause short circuits when used near energized components.**

9) **Use barricades or barriers to warn unqualified individuals from entering the area.**

10) **Be prepared for the unexpected. Make sure emergency communications and trained medical personnel are available if something goes wrong.**

11) **Use current-limiting overcurrent protective devices wherever possible to reduce the potential electrical hazards.**

Electrical Safety in the workplace can only be attained when workers and employers diligently follow OSHA and industry accepted standards and regulations. It is our sincere hope and desire that this handbook has been helpful in informing the reader of the importance of Electrical Safety while providing methods and information on how to effectively and safely reduce electrical hazards.

Employees working on electrical systems are at risk every day, but with the properly designed overcurrent protection system, the implementation of safe work practices and the utilization of the appropriate PPE, risk can be minimized.

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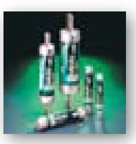
Annex A

Electrical Safety Terms and Definitions



A.I.C. or A.I.R.:
See Interrupting Capacity.

Ambient Temperature:
The air temperature surrounding a device. For fuses or circuit breakers in an enclosure, the air temperature within the enclosure.

Ampacity:
The current in amperes that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. It is sometimes informally applied to switches or other devices. These are more properly referred to by their ampere rating.

Ampere Rating:
The current rating, in amperes, that is marked on fuses, circuit breakers, or other equipment. It is not to be inferred that equipment or devices can continuously carry rated amperes. Various derating factors may apply. Refer to NEC® for further information.

Ampere-Squared-Seconds (I^2t):
The heat energy passed by a fuse or circuit breaker from the instant the fuse links melt or circuit breaker contacts part (arcing time). It is equal to the rms arcing current squared multiplied by the arcing time.

Approach Boundaries:
Protection boundaries established to protect personnel from shock.

Arcing I^2t:
The heat energy passed by a fuse during its arcing time. It is equal to the rms arcing current squared multiplied by the arcing time.

Arcing Current (See Figure 13):
The current that flows through the fuse after the fuse link has melted and until the circuit is interrupted.

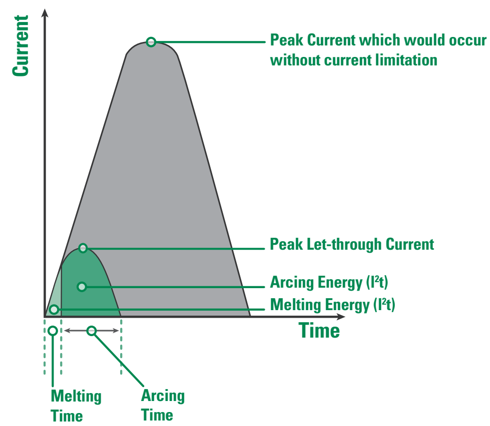


Figure 13
Current Limitation

Arcing-fault:
A short circuit that arcs at the point of fault. The arc impedance (resistance) tends to reduce the short-circuit current. Arcing faults may turn into bolted faults by welding of the faulted components. Arcing faults may be phase-to phase or phase-to-ground.

Arc-Blast:
A pressure wave created by the heating, melting, vaporization, and expansion of conducting material and surrounding gases or air.

Arc-Flash:
The sudden release of heat energy and intense light at the point of an arc. Can be considered a short circuit through the air, usually created by accidental contact between live conductors.

Arc Gap:

The distance between energized conductors or between energized conductors and ground. Shorter arc gaps result in less energy being expended in the arc, while longer gaps reduce arc current. For 600 volts and below, arc gaps of 1.25 inches (32 mm) typically produce the maximum incident energy.

Arc Rating:

A rating assigned to material(s) that relates to the maximum incident energy the material can resist before breakopen of the material or onset of a second-degree burn. The arc rating is typically shown in cal/cm².

Arcing Time:

(See Figure 13): The time between the melting of a fuse link or parting of circuit breaker contacts, until the overcurrent is interrupted.

Arc Voltage:

A transient voltage that occurs across an overcurrent protection device during the arcing time. It is usually expressed as peak instantaneous voltage (Vpeak or Epeak), but sometimes as rms voltage.

Asymmetrical Current:

AC current that is not symmetrical around the zero axis. Usually caused by a fault in circuits with low power factors. (See Power Factor and Symmetrical Current).

Available Short Circuit Current:

(also Available or Prospective Fault Current): The maximum rms Symmetrical Current that would flow at a given point in a system under bolted-fault conditions. Short-circuit current is maximum during the first half-cycle after the fault occurs. (See definitions of Bolted Fault and Symmetrical Current.)

Bolted Fault:

A short circuit that has no electrical resistance at the point of the fault. It results from a firm mechanical connection between two conductors, or a conductor and ground. Bolted faults are characterized by a lack of arcing. Examples of bolted faults are a heavy wrench lying across two bare bus bars, or a crossed-phase condition due to incorrect wiring.

Boundaries of Approach:

Protection boundaries established to protect personnel from shock and Arc-Flash hazards.

Calorie:

The amount of heat needed to raise the temperature of one gram of water by one degree Celsius. 1 cal/ cm² is equivalent to the exposure on the tip of a finger by a cigarette lighter for one second.

Clearing I²t (Also Total Clearing I²t):

The ampere-squared seconds (I²t) through an overcurrent device from the inception of the overcurrent until the current is completely interrupted. Clearing I²t is the sum of the Melting I²t and the Arcing I²t.

Coordination or Coordinated System:

See Selective Coordination.

Current-Limiting Fuse (Figure 14):

A fuse which, when interrupting currents within its current-limiting range, reduces the current in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device was replaced with a solid conductor having comparable impedance. To be labeled "current-limiting," a fuse must mate with a fuse block or fuse holder that has either a rejection feature or dimensions that will reject non-current-limiting fuses.

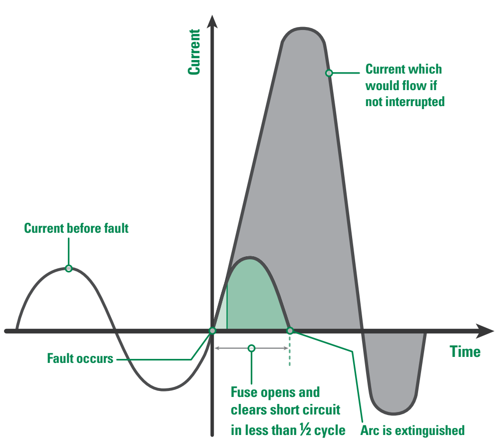


Figure 14
Current Limiting Fuse

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Current-Limiting Range:
For an individual overcurrent protective device, the current-limiting range begins at the lowest value of rms symmetrical current at which the device becomes current-limiting (the Threshold Current) and extends to the maximum interrupting capacity of the device.

Current Rating:
See Ampere Rating.

Deenergized:
Equipment or components that have had all energy sources removed.

Device Rating:
Refers to the standard ampere rating of a device as defined by NEC® Article 240.6. Standard ampere ratings ranges from 1 to 6000 amperes.

Distance to Arc:
Refers to the distance from the receiving surface to the arc center. The value used for most calculations is typically 18 inches.

Electrical Hazard:
A dangerous condition caused by equipment failure or contact with an energized conductor. Hazards include shock, Arc-Flash, burns and arc blasts.

Electrical Hazard Analysis:
A study to identify the potential electrical hazards that may be exposed to personnel. The analysis should address both shock and Arc-Flash hazards.

Electrically Safe Work Condition:
Condition where the equipment and or circuit components have been disconnected from electrical energy sources, locked/tagged out, and tested to verify all sources of power are removed.

Energized:
Refers to components within a system being connected to a "live" voltage source.

Fault:
Same as Short-Circuit and used interchangeably.

Fault Current:
Same as Short-Circuit Current.

Flash Hazard Analysis:
A study that analyzes potential exposure to Arc-Flash hazards. The outcome of the study establishes Incident Energy levels, Hazard Risk Categories, Flash Protection Boundaries, and required PPE. It also helps define safe work practices.

Flash Protection Boundary:
A protection boundary established to protect personnel from Arc-Flash hazards. The Flash Protection Boundary is the distance at which an unprotected worker can receive a second-degree burn to bare skin.

Fuse:
An overcurrent protective device consisting of one or more current-carrying elements enclosed in a body fitted with contacts so that the fuse may be readily inserted into or removed from an electrical circuit. The elements are heated by the current passing through them, thus interrupting current flow by melting during specified overcurrent conditions.

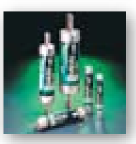
Ground-fault:
A short circuit caused by insulation breakdown between a phase conductor and a grounded object or conductor.

Hazard Risk Category:
A classification of risks (from 0 to 4) defined by NFPA 70E. Each category requires PPE and is related to incident energy levels.

Incident Energy:
The amount of thermal energy impressed on a surface generated during an electrical arc at a certain distance from the arc. Typically measured in cal/cm^2.

I^2t:
Symbol for Ampere-Squared-Seconds. A means of describing the thermal energy generated by current flow. When a fuse or current-limiting circuit breaker are interrupting currents within their current-limiting range, the term is expressed as melting, arcing, or total clearing I^2t. (See Melting I^2t, Arcing I^2t, and Clearing I^2t)





Instantaneous Peak Current (I_p or I_{peak}):

The maximum instantaneous current value developed during the first half-cycle (180 electrical degrees) after fault inception. The peak current determines magnetic stress within the circuit.

Interrupting Capacity (AIC):

The highest available symmetrical rms alternating current (for DC the highest direct current) at which the protective device has been tested, and which it has interrupted safely under standardized test conditions. The device must interrupt all available overcurrents up to its interrupting capacity. Also commonly called Interrupting Rating.

Interrupting Rating (IR, I.R., AIR or A.I.R.):

The highest rms symmetrical current, at specified test conditions, which the device is rated to interrupt. The difference between Interrupting Capacity and Interrupting Rating is in the test circuits used to establish the ratings.

Limited Approach Boundary:

An approach boundary to protect personnel from shock. A boundary distance is established from an energized part based on system voltage. To enter this boundary, unqualified persons must be accompanied with a qualified person and use PPE.

Melting I^2t:

The heat energy created by an overcurrent required to melt the fuse link(s). It equals the rms current (or DC current) squared, multiplied by the melting time in seconds. For times less than 0.004 seconds, melting I^2t approaches a constant value for a given fuse.

Overcurrent:

Any current larger than the equipment, conductor, or devices are rated to carry under specified conditions.

Overload:

An overcurrent that is confined to the normal current path (e.g., not a short circuit), which, if allowed to persist, will cause damage to equipment and/or wiring.

Peak Let-through Current (See Figure 15):

The maximum instantaneous current that passes through an overcurrent protective device during its total clearing time when the available current is within its current-limiting range.

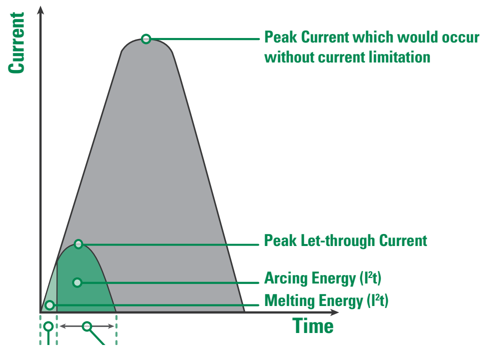


Figure 15
Peak let-through

Power Factor (X/R):

As used in overcurrent protection, power factor is the relationship between the inductive reactance (X) and the resistance (R) in the system during a fault. Under normal conditions a system may be operating at a 0.85 power factor (85%). When a fault occurs, much of the system resistance is shorted out and the power factor may drop to 25% or less. This may cause the current to become asymmetrical. See definition of Symmetrical Current.

PPE:

An acronym for Personnel Protective Equipment. It can include clothing, tools, and equipment.

Prohibited Approach Boundary:

An approach boundary to protect personnel from shock. Work in this boundary is considered the same as making direct contact with an energized part. Only qualified persons are allowed to enter this boundary and they must use PPE.

Protection Boundaries:

Boundaries established to protect personnel from electrical hazards.

Qualified Person:

A person who is trained and knowledgeable *on the construction and operation of the equipment and can recognize and avoid electrical hazards that may be encountered.*

Rating:

A designated limit of operating characteristics based on definite conditions, such as current rating, voltage rating and interrupting rating.

Renewable Fuse:

A fuse that may be readily restored to service by replacing the renewable element after operation.

Restricted Approach Boundary:

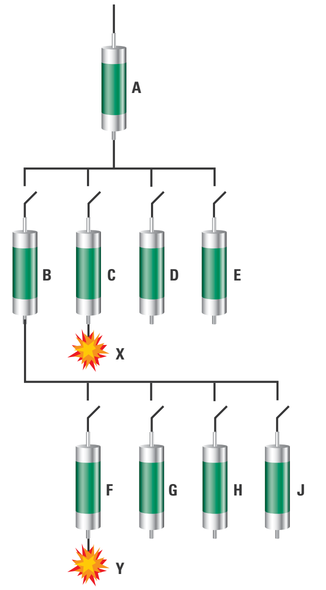
An approach boundary to protect personnel from shock. A boundary distance is established from an energized part based on system voltage. Only qualified persons are allowed in the boundary and they must use PPE.

Selective Coordination (See Figure 16):

In a selectively coordinated system, only the protective device immediately on the line side of an overcurrent opens. Upstream protective devices remain closed. All other equipment remains in service, which simplifies the identification and location of overloaded equipment or short circuits.

Shock:

A trauma subjected to the body by electrical current. When personnel come in contact with energized conductors, it can result in current flowing through their body often causing serious injury or death.



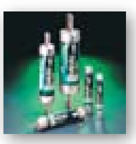
In a selective system:

For a fault at "X" only fuse "C" will open.
For a fault at "Y" only fuse "F" will open.

Figure 16

Short Circuit (See Figure 17):

A current flowing outside its normal path. It is caused by a breakdown of insulation or by faulty equipment connections. In a short circuit, current bypasses the normal load. The amount of current is determined by the system impedance (AC resistance) rather than the load impedance. Short-circuit currents may vary from fractions of an ampere to 200,000 amperes or more.



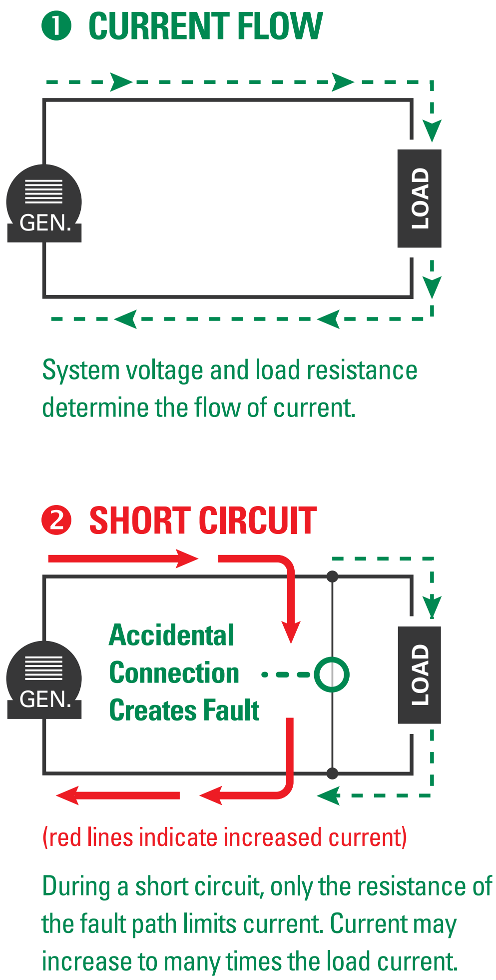


Figure 17

Short-Circuit Rating:

The maximum rms symmetrical short-circuit current (for DC equipment DC current) at which a given piece of equipment has been tested under specified conditions, and which at the end of the test, is in essentially the same condition as prior to the test. Short-circuit ratings (also called withstand ratings) apply to equipment that will be subjected to fault currents, but which are not required to interrupt them. This includes switches, busway (bus duct), switchgear and switchboard structures, motor control centers and transformers. Most short-circuit ratings are based on tests which last three complete electrical cycles (0.05 seconds). Some equipment may have reduced short-circuit rating for times longer than 3 cycles. Refer to manufacturers literature. If the equipment is protected during the test by fuses or by a circuit breaker with instantaneous trips, the test duration is the time required for the overcurrent protective device to open the circuit.

When so protected during testing, the equipment instructions and labels must indicate that the equipment shall be protected by a given fuse class and rating, or by a specific make, type, and rating of circuit breaker. Certain circuit breakers equipped with short-delay trip elements instead of instantaneous trip elements may have withstand (short-circuit) ratings in addition to their interrupting rating. The withstand rating is the fault current the breaker must be able to withstand for a specified time or if it is protected by a fuse or another circuit breaker in series with it. They may also have reduced interrupting ratings.

Symmetrical Current:

The terms "Symmetrical Current" and "Asymmetrical Current" describe an AC wave's symmetry around the zero axis. The current is symmetrical when the peak currents above and below the zero axis are equal in value, as shown in Figure 18. If the peak currents are not equal, as shown in Figure 19, the current

Symmertrical Current

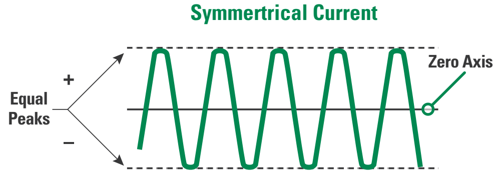


Figure 18

Asymmertrical Current

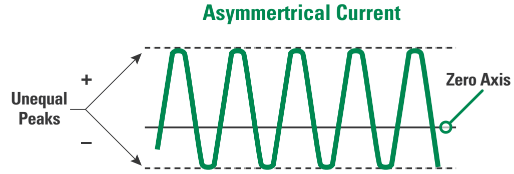


Figure 19

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is asymmetrical. The degree of asymmetry during a fault is determined by the change in power factor (X/R) and the point in the voltage wave when the fault occurs.

System Voltage:

The phase-to-phase or three-phase voltage(s) at the point being evaluated.

Threshold Current:

The minimum current for a given fuse size and type at which the fuse becomes current-limiting. It is the lowest value of available rms symmetrical current that will cause the device to begin opening within the first 1/4 cycle (90 electrical degrees) and completely clear the circuit within 1/2 cycle (180 electrical degrees). The approximate threshold current can be determined from the fuse's peak let-through charts. See Figure 20.

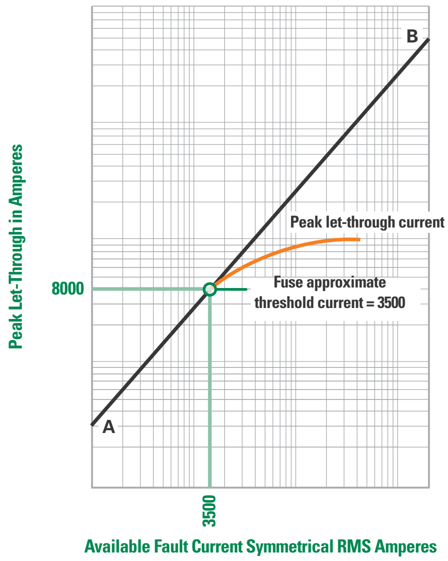


Figure 20

Threshold Ratio:

The threshold current divided by the ampere rating of a specific type or class of overcurrent device. A fuse with a threshold ratio of 15 becomes current-limiting at 15 times its current rating.

Unqualified Person:

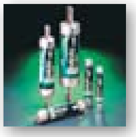
A person that does not possess all the skills and knowledge or has not been trained for a particular task.

Voltage Rating:

The maximum rms AC voltage and/or the maximum DC voltage at which the device is designed to operate. For example, fuses rated 600 volts may be applied at any system voltage less than or equal to their rating. [There are no specific rules for applying AC fuses in DC circuits.] Fuses used on DC circuits must have proper DC voltage ratings. Circuit breaker ratings are more complex since some breakers may have dual voltage ratings.

Withstand Rating:

See Short-Circuit Rating.



Annex B

Electrical Safety Codes and Standards

National Electrical Code® (NEC®)

In 1896 members of the industry met in New York City to develop a single electrical installation code from the five then in use. After review by over 1200 individuals, it was published in 1897 and has become known as the National Electrical Code. In 1911 the NFPA became the sponsor of the NEC and continues the tradition of wide spread consensus. The purpose of the National Electrical Code "is the practical safeguarding of persons and property from hazards arising from the use of electricity. The NEC contains provisions considered necessary for safety." The NEC is updated and revised every three years. The NEC, also known as NFPA 70, is the nationally accepted standard for safe electrical installation methods and practices. Although the NEC is regarded as the "Bible" for electrical construction practices, it does not provide comprehensive details for workplace safety when servicing electrical systems.

While the NEC is not a design manual, following its provisions help ensure that electrical systems are reasonably safe. Some of the NEC provisions specifically addressing application of overcurrent protective devices are listed herein, however users are cautioned the NEC must be considered in its entirety.

NEC Articles

The following NEC paragraphs are important when designing and servicing electrical systems:

> ***"110.4 Voltages.***
> *Throughout this Code, the voltage considered shall be that at which the circuit operates. The voltage rating of the electrical equipment shall not be less than the nominal voltage of the circuit to which it is connected."* [1]

> ***"110.9 Interrupting Rating:***
> *Equipment intended to interrupt current at fault levels shall have an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment. Equipment intended to interrupt current at other than fault levels shall have an interrupting rating at nominal circuit voltage sufficient for the current that must be interrupted."* [2]

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"110.10 Circuit Impedance and Other Characteristics:

The overcurrent protective devices, the total impedance, the component short-circuit current ratings, and other characteristics of the circuit to be protected shall be selected and coordinated to permit the circuit-protective devices used to clear a fault to do so without extensive damage to the electrical components of the circuit. This fault shall be assumed to be either between two or more of the circuit conductors or between any circuit conductor and the grounding conductor or enclosing metal raceway. Listed products applied in accordance with their listing shall be considered to meet the requirements of this section." [1]

"110.16

Flash Protection: Switchboards, panelboards, industrial control panels, meter socket enclosures, and motor control centers that are in other than dwelling occupancies and are likely to require examination, adjustment, servicing, or maintenance while energized shall be field marked to warn qualified persons of potential electric Arc-Flash hazards. The marking shall be located so as to be clearly visible to qualified persons before examination, adjustment, servicing, or maintenance of the equipment." [2]

"240.2 Definition: Current-Limiting Overcurrent Protective Device:

A device that when interrupting currents in its current-limiting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance." [3]

"240.12 Electrical System Coordination:

Where an orderly shutdown is required to minimize the hazard(s) to personnel and equipment, a system of coordination based on the following two conditions shall be permitted:

1. *Coordinated short-circuit protection*
2. *Overload indication based on monitoring systems or devices.*

FPN:

The monitoring system may cause the conditions to go to alarm, allowing corrective action or an orderly shutdown, thereby minimizing personnel hazard and equipment damage." [4]

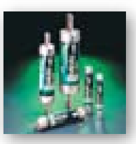
Other related articles:

430.32 Continuous-Duty Motors and 430.52 Rating Or Setting for Individual Motor Circuit.

These code articles outline sizing requirements for overcurrent devices when used for the protection of motor circuits. For more information, consult NFPA 70: The National Electrical Code.

620.62, 700.12, and 701.18

Refer to selective coordination of systems that provide emergency power, signaling systems or elevator circuits. For more information, consult NFPA 70: National Electrical Code (NEC).



For more information:

800-TEC-FUSE
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Annex C

Energized Electrical Work Permit

XYZ COMPANY ENERGIZED ELECTRICAL WORK PERMIT

Section 1 - Work Request

(To be completed by person requesting the permit)

WORK ORDER NO: ______________________

LOCATION: ____________ EQUIPMENT: ____________

START DATE: ______ TIME: ______ TIME REQUIRED: ______ TIME REQUIRED: ______

DESCRIPTION OF TASK:

DESCRIPTION OF EQUIPMENT:

SYSTEM VOLTAGE:

AVAILABLE FAULT CURRENT:

Section 2 - Justification of Work

(To be completed by Qualified Person performing the work)

WHY IS TASK BEING PERFORMED IN ENERGIZED CONDITION?

WHAT WORK PRACTICES WILL BE UTILIZED TO INSURE SAFETY?

WHAT WERE THE RESULTS OF THE SHOCK ANALYSIS?

LIMITED: ________ RESTRICTED: ________ PROHIBITED: ________

WHAT WERE THE RESULTS OF THE FLASH HAZARD ANALYSIS?

HAZARD RISK CATEGORY: ________ INCIDENT ENERGY: ________ FLASH PROTECTION BOUNDARY: ________

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WHAT IS THE REQUIRED PERSONNEL PROTECTIVE EQUIPMENT (PPE) FOR THIS TASK ?

☐ HARD HAT	☐ EAR PROTECTION	☐ VOLTAGE RATED GLOVES	☐ FR PANTS
☐ SAFETY GLASSES	☐ T-SHIRT	☐ LEATHER GLOVES	☐ FR COVERALL
☐ SAFETY GOGGLES	☐ LONG SLEEVE SHIRT	☐ COTTON UNDERWEAR	☐ FLASH SUIT
☐ FACE SHIELD	☐ FR SHIRT	☐ LONG PANTS	☐ LEATHER SHOES
☐ FLASH HOOD			

HOW WILL ACCESS TO THE WORK AREA BE RESTRICTED FROM UNQUALIFIED PERSONNEL?

____

HAS A JOB BRIEFING BEEN COMPLETED?

____

WHAT EVIDENCE IS AVAILABLE?

____

WERE THERE ANY JOB SPECIFIC HAZARDS?

____

IN YOUR OPINION, CAN THIS JOB BE COMPLETED SAFELY? ☐ YES ☐ NO

____

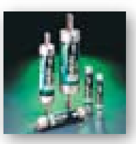
Signature of Qualified Person	Date
Signature of Qualified Person	Date

Section 3 - Approval to Perform Work on Energized Equipment
(To be completed by Management)

IS WORK ON ENERGIZED EQUIPMENT APPROVED?

____

Signature of Manufacturing Manager	Date
Signature of Plant Manager	Date
Signature of Safety Manager	Date
Signature of Electrical Maintenance Manager	Date
Signature of Qualified Person	Date



Annex D

Arc-Flash Calculation Steps For Example on Page 36

Arc-Flash Hazard Calculations:

Example 1
With Littelfuse Class L 2500 Amp fuses

Step 1:

Review the up-to-date one line drawing for information about the available short circuit current and other details about the location of the equipment.

Step 2:

The one line drawing states that the 2000 kVA transformer has a 4160V primary and 480V secondary with 5.5% impedance.

Step 3:

Determine the MVA_{bf} of the transformer. Since 2000kVA is 2 MVA, the MVA_{bf} = MVA x 100/%Z = = 2 x 100/5.5 = 36.4 MVA.

Step 4:

Determine the clearing time of the 2500 Amp Class L fuse at the fault current. The maximum three phase bolted fault current at the transformer secondary is given by the formula, $I_{sc} = (MVA \times 10^6 \times 100) / \sqrt{3} \times 480 \times 5.5$ = 43,738 Amps = 43.7 kA. Referring to the time current curve for the Littelfuse 2500 Amp Class L fuse, the clearing time at 43,738 Amps is 0.01 second = t_a.

Step 5:

Determine the Flash Protection Boundary (FPB) using the formula in NFPA 70E Article 130.3(A).
Since MVA_{bf} = 36.4 and t = 0.01 sec.,
$D_c = [2.65 \times MVA_{bf} \times t]^{1/2}$
$D_c = [2.65 \times 36.4 \times 0.01]^{1/2} = 0.98$ ft. (~12 inches)

Step 6:

Calculate the Incident Energy at 18 inches working distance using the NFPA 70E formula for "Arc-in-a-box" [ref. NFPA 70E Annex D 6.2(a)], where D_B =18; t_a = 0.01; and F = 43.7

$$E_{MB} = 1038.7\ D_B^{-1.4738}\ t_a [0.0093F^2 - 0.3453F + 5.9675]$$

$$E_{MB} = 1038.7 \times (18)^{-1.4738} \times (.01) \times [0.0093(43.7)^2 - - 0.3453(43.7) + 5.9675]$$

$$\mathbf{E_{MB} = 1.27\ cal/cm^2}$$

Step 7:

*Determine the Hazard Risk Category with Littelfuse 2500 Amp Class L fuse. Since the Incident Energy is 1.27 cal/cm^2 at 18 inches, NFPA 70E Table 130.7(C)(11) defines the minimum Arc Rating of PPE up to 4 cal/cm^2 as **Hazard Risk Category 1.***

Example 2
With 2500 Amp Low Voltage Power Circuit Breaker

Step 1:

Determine the clearing time of the circuit breaker at the fault level. Since the I_{sc} = 43,738 Amps, consulting the time current curve for the Circuit Breaker shows the clearing time "t" is 5 cycles = 0.083 second.

Step 2:

Determine the Flash Protection Boundary (FPB) using the formula in NFPA 70E Article 130.3(A).
Since MVA_{bf} = 36.4 and t = 0.083 sec.,
$D_c = [2.65 \times MVA_{bf} \times t]^{1/2}$
$D_c = [2.65 \times 36.4 \times .083]^{1/2} = 2.83$ ft. (34 inches)

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Step 3:

Determine the Incident Energy at 18 inches working distance with the Circuit Breaker.

Since $t_a = 0.083$ *and* $I_{sc} = 43{,}738 = 43.7\ kA = F$,

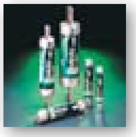
$$E_{MB} = 1038.7\ D_B^{-1.4738}\ t_a[0.0093F^2 - 0.3453F + 5.9675]$$

$$E_{MB} = 1038.7 \times (18)^{-1.4738} \times (0.083) \times [0.0093(43.7)^2 - 0.3453(43.7) + 5.9675]$$

$$\mathbf{E_{MB} = 10.54\ cal/cm^2}$$

Step 4:

Determine the Hazard Risk Category. Since the Incident Energy is 10.54 cal/cm^2 *at 18 inches and NFPA Table 130.7(C)(11) defines the minimum Arc Rating of PPE up to 25 cal/cm*^{2} *as* ***Hazard Risk Category 3****.*



Annex E

Arc Flash Calculator Tables

The following Arc-Flash Calculator tables are based on published data in IEEE 1584 "Guide for Performing Arc-Flash Hazard Calculations". It is meant to serve as a guide only for determining the incident energy level at specific points of an electrical system. The purpose of a Flash Hazard Analysis is to determine a worker's potential exposure to Arc-Flash energy in order to minimize injury and determine safe work practices and appropriate levels of PPE. Prior to using these tables, users must know and understand the steps required to perform a Flash Hazard Analysis.

The Arc-Flash Calculator tables may be used for systems rated 600 volts and below. The incident energy calculations are based on data and equations in IEEE 1584 for 600V Class RK1 and Class L fuses and 600V circuit breakers. Incident energy for 600V Class J, Class T, and Class CC fuses may also be determined by using these tables.

How to use the Arc-Flash Calculator Tables:

1) Calculate the available 3-phase bolted fault current available at every point in the electrical system where workers may be exposed to energized components.

2) Determine the ampere rating of the overcurrent protective device (fuse or circuit breaker) to be used to protect the equipment where work is to be performed. If ratings are not shown in calculator tables, select the next largest rating.

3) Consult the table and determine the Incident Energy, Hazard Risk Category, and Flash Protection Boundary.

4) Select the appropriate PPE outlined in NFPA 70E that meets the determined Hazard Risk Category and Incident Energy.

Arc-Flash Calculator Table Notes

- Even when the Hazard Risk Category is zero, workers should wear FR clothing to protect against unrecognized hazards. NFPA 70E Annex H provides a simplified approach to everyday clothing for workers in diverse environments.
- PPE may have higher ratings than required for the Hazard Risk Category.
- The standards and regulations establish minimum requirements for improving safety. The incident energy levels used in these tables were determined under specified test conditions used in IEEE 1584. The recommended level of PPE is the minimum recommended to reduce injury from burns that could occur from an arcing fault. These minimums may not be adequate, and it may be necessary to use PPE with higher ratings than calculated.
- Refer to NFPA 70E Table 130.7 (C)(10) Protective Clothing and PPE Matrix to determine specific PPE requirements.
- For more information on performing a Flash Hazard Analysis, refer to NFPA 70E or IEEE 1584.

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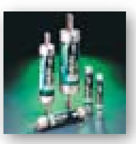
Fuse Rating Amperes

(Calories/cm² at 18″ and Hazard Risk Category)



Fault Current kA	Amperes	1-100 Fuse	101-200 Fuse	201-400 Fuse	401-600 Fuse	601-800 Fuse	801-1200 Fuse	1201-1600 Fuse	1601-2000 Fuse
1	I.E.	2.39	>100	>100	>100	>100	>100	>100	>100
	FPB	30	>120	>120	>120	>120	>120	>120	>120
	HRC	1	X	X	X	X	X	X	X
2	I.E.	0.25	5.19	>100	>100	>100	>100	>100	>100
	FPB	6	54	>120	>120	>120	>120	>120	>120
	HRC	0	2	X	X	X	X	X	X
4	I.E.	0.25	0.25	20.59	>100	>100	>100	>100	>100
	FPB	6	6	>120	>120	>120	>120	>120	>120
	HRC	0	0	3	X	X	X	X	X
6	I.E.	0.25	0.25	0.75	>100	>100	>100	>100	>100
	FPB	6	6	18	>120	>120	>120	>120	>120
	HRC	0	0	0	X	X	X	X	X
8	I.E.	0.25	0.25	0.69	36.84	>100	>100	>100	>100
	FPB	6	6	12	>120	>120	>120	>120	>120
	HRC	0	0	0	4	X	X	X	X
10	I.E.	0.25	0.25	0.63	12.81	75.42	>100	>100	>100
	FPB	6	6	12	96	>120	>120	>120	>120
	HRC	0	0	0	3	X	X	X	X
12	I.E.	0.25	0.25	0.57	6.71	49.64	73.57	>100	>100
	FPB	6	6	12	60	>120	>120	>120	>120
	HRC	0	0	0	2	X	X	X	X
14	I.E.	0.25	0.25	0.51	0.60	23.85	39.84	>100	>100
	FPB	6	6	12	12	>120	>120	>120	>120
	HRC	0	0	0	0	3	4	X	X
16	I.E.	0.25	0.25	0.45	0.58	1.94	11.14	24.95	>100
	FPB	6	6	12	12	30	84	>120	>120
	HRC	0	0	0	0	1	3	3	X
18	I.E.	0.25	0.25	0.39	0.48	1.82	10.75	24.56	>100
	FPB	6	6	12	12	24	84	>120	>120
	HRC	0	0	0	0	1	3	3	X
20	I.E.	0.25	0.25	0.33	0.38	1.70	10.36	24.19	>100
	FPB	6	6	12	12	24	78	>120	>120
	HRC	0	0	0	0	1	3	3	X
22	I.E.	0.25	0.25	0.27	0.28	1.58	9.98	23.82	>100
	FPB	6	6	6	6	24	78	>120	>120
	HRC	0	0	0	0	1	3	3	X
24	I.E.	0.25	0.25	0.25	0.25	1.46	8.87	23.44	29.17
	FPB	6	6	6	6	24	72	>120	>120
	HRC	0	0	0	0	1	3	3	4
26	I.E.	0.25	0.25	0.25	0.25	1.34	7.52	23.07	28.91
	FPB	6	6	6	6	24	60	>120	>120
	HRC	0	0	0	0	1	2	3	4
28	I.E.	0.25	0.25	0.25	0.25	1.22	6.28	22.70	28.65
	FPB	6	6	6	6	18	60	>120	>120
	HRC	0	0	0	0	1	2	3	4
30	I.E.	0.25	0.25	0.25	0.25	1.01	5.16	22.33	28.40
	FPB	6	6	6	6	18	54	>120	>120
	HRC	0	0	0	0	0	2	3	4
35	I.E.	0.25	0.25	0.25	0.25	0.80	2.84	17.03	27.75
	FPB	6	6	6	6	18	36	114	>120
	HRC	0	0	0	0	0	1	3	4
40	I.E.	0.25	0.25	0.25	0.25	0.49	1.25	9.28	27.11
	FPB	6	6	6	6	12	18	78	>120
	HRC	0	0	0	0	0	1	3	4
45	I.E.	0.25	0.25	0.25	0.25	0.25	0.39	2.94	26.47
	FPB	6	6	6	6	6	12	36	>120
	HRC	0	0	0	0	0	0	1	4
50	I.E.	0.25	0.25	0.25	0.25	0.25	0.39	2.94	25.83
	FPB	6	6	6	6	6	12	36	>120
	HRC	0	0	0	0	0	0	1	4
55	I.E.	0.25	0.25	0.25	0.25	0.25	0.39	2.94	25.19
	FPB	6	6	6	6	6	12	36	>120
	HRC	0	0	0	0	0	0	1	4
60	I.E.	0.25	0.25	0.25	0.25	0.25	0.39	2.94	24.55
	FPB	6	6	6	6	6	12	36	>120
	HRC	0	0	0	0	0	0	1	3
65	I.E.	0.25	0.25	0.25	0.25	0.25	0.39	2.94	23.90
	FPB	6	6	6	6	6	12	36	>120
	HRC	0	0	0	0	0	0	1	3
70	I.E.	0.25	0.25	0.25	0.25	0.25	0.39	2.67	21.67
	FPB	6	6	6	6	6	12	36	>120
	HRC	0	0	0	0	0	0	1	3

I.E. = Incident Energy (cal/cm²)
HRC = Hazard Risk Category
FPB = Flash Protection Boundary (in.)
X = Exceeds NFPA 70E

For more information:

800-TEC-FUSE

www.littelfuse.com

Fault Current kA	Amperes	1-100 CB	101-200 CB	201-400 CB	401-600 CB	601-800 CB	801-1200 CB	1201-1600 CB	1601-2000 CB
1	I.E.	>100	>100	>100	>100	>100	>100	>100	>100
	FPB	>120	>120	>120	>120	>120	>120	>120	>120
	HRC	X	X	X	X	X	X	X	X
2	I.E.	0.17	>100	>100	>100	>100	>100	>100	>100
	FPB	6	>120	>120	>120	>120	>120	>120	>120
	HRC	0	X	X	X	X	X	X	X
4	I.E.	0.33	0.33	>100	>100	>100	>100	>100	>100
	FPB	6	6	>120	>120	>120	>120	>120	>120
	HRC	0	0	X	X	X	X	X	X
6	I.E.	0.50	0.50	0.50	>100	>100	>100	>100	>100
	FPB	12	12	12	>120	>120	>120	>120	>120
	HRC	0	0	0	X	X	X	X	X
8	I.E.	0.66	0.66	0.66	>100	>100	>100	>100	>100
	FPB	12	12	12	>120	>120	>120	>120	>120
	HRC	0	0	0	X	X	X	X	X
10	I.E.	0.82	0.82	0.82	>100	20.01	>100	>100	>100
	FPB	18	18	18	>120	>120	>120	>120	>120
	HRC	0	0	0	X	3	X	X	X
12	I.E.	0.97	0.97	0.97	1.67	24.00	>100	>100	>100
	FPB	18	18	18	24	>120	>120	>120	>120
	HRC	0	0	0	1	3	X	X	X
14	I.E.	1.13	1.13	1.13	1.94	27.45	>100	>100	>100
	FPB	18	18	18	30	>120	>120	>120	>120
	HRC	0	0	0	1	4	X	X	X
16	I.E.	1.29	1.29	1.29	2.21	31.62	31.62	>100	>100
	FPB	24	24	24	30	>120	>120	>120	>120
	HRC	1	1	1	1	4	4	X	X
18	I.E.	1.45	1.45	1.45	2.48	35.46	35.46	>100	>100
	FPB	24	24	24	30	>120	>120	>120	>120
	HRC	1	1	1	1	4	4	X	X
20	I.E.	1.60	1.60	1.60	2.74	39.29	39.29	39.29	>100
	FPB	24	24	24	36	>120	>120	>120	>120
	HRC	1	1	1	1	4	4	4	X
22	I.E.	1.76	1.76	1.76	3.01	43.10	43.10	43.10	>100
	FPB	24	24	24	36	>120	>120	>120	>120
	HRC	1	1	1	1	X	X	X	X
24	I.E.	1.91	1.91	1.91	3.28	46.91	46.91	46.91	>100
	FPB	30	30	30	36	>120	>120	>120	>120
	HRC	1	1	1	1	X	X	X	X
26	I.E.	2.07	2.07	2.07	3.54	50.71	50.71	50.71	50.71
	FPB	30	30	30	42	>120	>120	>120	>120
	HRC	1	1	1	1	X	X	X	X
28	I.E.	2.22	2.22	2.22	3.81	54.50	54.50	54.50	54.50
	FPB	30	30	30	42	>120	>120	>120	>120
	HRC	1	1	1	1	X	X	X	X
30	I.E.	2.38	2.38	2.38	4.07	58.28	58.28	58.29	58.29
	FPB	30	30	30	42	18	54	>120	>120
	HRC	1	1	1	2	X	X	X	X
35	I.E.	2.76	2.76	2.76	4.73	67.72	67.72	67.72	67.72
	FPB	36	36	36	48	>120	>120	>120	>120
	HRC	1	1	1	1	X	X	X	X
40	I.E.	3.14	3.14	3.14	5.39	77.11	77.11	77.11	77.11
	FPB	36	36	36	54	>120	>120	>120	>120
	HRC	1	1	1	2	X	X	X	X
45	I.E.	3.53	3.53	3.53	6.04	86.47	86.47	86.47	86.47
	FPB	42	42	42	54	>120	>120	>1 20	>120
	HRC	1	1	1	2	X	X	X	X
50	I.E.	3.91	3.91	3.91	6.69	95.81	95.81	95.81	95.81
	FPB	42	42	42	60	>120	>120	>120	>120
	HRC	1	1	1	2	X	X	X	X
55	I.E.	4.29	4.29	4.29	7.34	>100	>100	>100	>100
	FPB	48	48	48	60	>120	>120	>120	>120
	HRC	1	1	1	2	X	X	X	X
60	I.E.	4.66	4.66	4.66	7.99	>100	>100	>100	>100
	FPB	48	48	48	66	>120	>120	>120	>120
	HRC	1	1	1	2	X	X	X	X
65	I.E.	5.04	5.04	5.04	8.64	>100	>100	>100	>100
	FPB	48	48	48	72	>120	>120	>120	>120
	HRC	2	2	2	3	X	X	X	X
70	I.E.	5.42	5.42	5.42	9.28	>100	>100	>100	>100
	FPB	54	54	54	78	>120	>120	>120	>120
	HRC	2	2	2	3	X	X	X	X

I.E. = Incident Energy (cal/cm²)

FPB = Flash Protection Boundary (in.)

HRC = Hazard Risk Category

X = Exceeds NFPA 70E

Circuit Breaker Rating Amperes

(Calories/cm² at 18″ and Hazard Risk Category)

Arc-Flash Calculator Table Example

Example #1:
Determine the Incident Energy (I.E.), Flash Protection Boundary (FPB), and Hazard Risk Category (HRC) for equipment supplied by a 600V 400A fusible safety switch.

Step 1:
Review the up-to-date one line drawing for information about the available short circuit current and other details about the safety switch location.

Step 2:
Assume the one line diagram shows that 26 kA is available at the terminals of the switch and the switch has 400A Class RK1 fuses installed.

Step 3:
Using the Fuse Calculator Table from a preceding page, determine the incident energy of 0.25 cal/cm², Flash Protection Boundary of 6 inches, and a Hazard Risk Category of 0 for a 400A Class RK1 current-limiting fuse when 26kA is available.

Step 4:
Using NFPA 70E Tables 130.7(C)(10-11), determine the required level of PPE needed for work in Hazard Risk Category 0.

Example #2:
Determine the Incident Energy (I.E.), Flash Protection Boundary (FPB), and Hazard Risk Category (HRC) for equipment supplied by a 600V 400A main circuit breaker panelboard.

Step 1:
Review the up-to-date one line drawing for information about the available short circuit current and other details about the panelboard location.

Step 2:
The one line diagram shows that 26 kA is available at the terminals of the panelboard and it has a 400 A main molded case circuit breaker.

Step 3:
Using the Circuit Breaker Calculator Table from a preceding page, determine the incident energy of 2.07 cal/cm², Flash Protection Boundary of 30 inches, and a Hazard Risk Category of 1 for a 400A circuit breaker when 26kA is available.

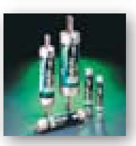
Step 4:
Using NFPA 70E Tables 130.7(C)(10-11), determine the required level of PPE needed for work in Hazard Risk Category 1.

Example Comparison

The table below illustrates the difference between the fuse and circuit breaker for this example:

DATA COMPARISON	CLASS RK1 FUSE	CIRCUIT BREAKER
Incident Energy (cal/cm²)	0.25	2.07
Flash Protection Boundary	6″	30″
Hazard Risk Category	0	1





Annex F

Resources for Electrical Safety

OSHA

Occupational Safety and Health Administration
U.S. Department of Labor
Washington D.C. 20210
www.osha.gov

The federal OSHA program is operated under a multi-million dollar budget with a staff of over 2200 people. Inspectors, which comprise more than 50 percent of OSHA's workforce, conduct several thousand inspections every year. Fines are often levied for violations found during inspections. In addition to the federal program, twenty-five states operate their own OSHA programs that are supported by a staff of 2600 people including over 1200 inspectors.

NFPA

National Fire Protection Association
1 Batterymarch Park, PO Box 9101
Quincy, MA 02269-9101
Ph. 800-344-3555
www.nfpa.org

Founded in 1896, the National Fire Protection Association (NFPA) was originally formed to standardize the installation of fire sprinklers. This nonprofit organization also operates on a multi-million dollar budget and is supported by a staff of several hundred people. Although the NFPA has no power to enforce its standards and codes, many governmental agencies on the local and national level have adopted the NFPA's standards and codes and in essence, have made them into law.

IEEE

Institute of Electrical and Electronics Engineers
445 Hoes Lane
PO Box 1331
Piscataway, NJ 08855-1331
Ph. 800-678-IEEE
www.ieee.org

The Institute of Electrical and Electronic Engineers, Inc. (IEEE) was officially named in 1963, but its predecessors, the AIEE (American Institute of Electrical Engineers) and the IRE (Institute of Radio Engineers), date back to 1884. Just as its name indicates, the IEEE is an association of electrical and electronic engineers organized to advance the theory and application of electro-technology and allied sciences.

UL

Underwriters Laboratories
333 Pfingsten Road
Northbrook, IL 60062
Ph. 847-272-8400
www.ul.com

Underwriters Laboratories (formerly the Underwriters Electrical Bureau) originally was founded in 1894. Underwriters Laboratories Inc. (UL) is an independent, not-for-profit product-safety testing and certification organization that tests and certifies products for public safety.

NEMA

National Electrical Manufacturers Association
15 Inverness Way East
Englewood, CO 80112-5776
Ph. 800-854-7179
www.nema.org

The National Electrical Manufacturers Association (NEMA) was formed in 1926. NEMA works closely with ANSI (American National Standards Institute) and IEC (International Electrotechnical Committee) and is an advocacy group to UL and governmental agencies.

ANSI

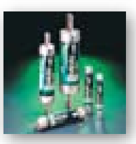
American National Standards Institute
11 W. 42nd Street
New York, NY 10036
Ph. 212-642-8908
www.ansi.org

The American National Standards Institute (ANSI) was founded in 1918. ANSI is a private, non-profit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment system.

ASTM

ASTM International
100 Barr Harbor Drive
Conshohocken, PA 19428-2959
Ph. 610-832-9585
www.ASTM.org

ASTM International, formerly known as the American Society for Testing and Materials (ASTM) is a voluntary standards development organization that was founded in 1898. ASTM International is primarily involved with establishing standards for materials used in manufacturing and methods of testing and analysis.



NIOSH

National Institute for Occupational Safety and Health
Hubert H. Humphrey Bldg.
200 Independence Ave., SW
Room 715H
Washington, DC 20201
Ph. 202-401-6997
www.cdc.gov/niosh

The Occupational Safety and Health Act of 1970 created NIOSH along with OSHA. NIOSH is part of the U.S. Department of Health and Human Services Agency and provides research, education, training, and information to insure safe and healthful workplaces.

NSC

National Safety Council
1121 Spring Lake Drive
Itasca, IL 60143
Ph. 800-845-4NSC
www.nsc.org

The National Safety Council (NSC) was founded in 1913. Their mission is essentially to educate and influence people to adopt safety policies and practices. It is a nonprofit, nongovernmental organization.

Annex G

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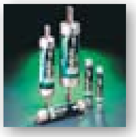
Annex H

Electrical Safety Quiz

1.	OSHA requires employers to perform hazard assessments of their plants and facilities.	T	F
2.	Unless it is justifiable, you should always deenergize equipment before working on it.	T	F
3.	You must apply lockout/tagout devices in accordance with a documented and established policy in order to establish an electrically safe work condition.	T	F
4.	According to NFPA 70E, all circuits must be analyzed for safety.	T	F
5.	Only qualified electricians are allowed to work on energized circuits.	T	F
6.	1.2 cal/cm^2 will cause 2nd degree burns to bare skin.	T	F
7.	Only qualified workers are allowed within the Limited Approach Boundary.	T	F
8.	Unqualified workers are never allowed within the Restricted Approach Boundary.	T	F
9.	Decreasing the opening time of the overcurrent protective device will decrease Arc-Flash hazards.	T	F
10.	An Energized Electrical Work Permit is always required when working on any energized equipment.	T	F
11.	The NEC® requires Arc-Flash warning labels on all equipment that may be worked on while energized.	T	F
12.	NFPA 70E is often thought of as the ‘How-to’ Source for OSHA compliance.	T	F
13.	Qualified and unqualified workers can work on or near exposed energized electrical components.	T	F
14.	Failure to perform regular maintenance on circuit breakers may result in increased Incident Energy.	T	F
15.	The use of Current-Limiting fuses can reduce Arc-Flash hazards.	T	F

For Quiz Answers see page 75.



Electrical Safety Quiz Answers
(from pg 74):

1-T; 2-T; 3-T; 4-F; 5-F; 6-T; 7-F; 8-T; 9-T; 10-F; 11-T; 12-T; 13-F; 14-T; 15-T

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- Warning Labels
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- Electrical Safety Literature
- Electrical Safety Video
- Training Seminars & Presentations
- Electrical Designers Reference (EDR) Software
- MRO*plus* Fuse Inventory Analysis
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