Table of Contents

Bussmann®

Safety BASICs™

Handbook for Electrical Safety

COOPER Bussmann

Table of Contents

Safety BASICs™

(Bussmann Awareness of Safety Issues Campaign)

A special thanks goes to Ray A. Jones PE with Electrical Safety Consulting Services, Inc., (ESCS, Inc.) who provided consultation services for the Safety BASICs program material.

Ray is a professional engineer with more than 35 years of experience in developing and operating electrical safety systems and processes in industrial units. Ray retired from the DuPont Company in 1998 where he held the position of Principal Consultant, concentrating on electrical safety systems and processes as well as codes and standards. Ray is active in multiple technical committees for NFPA, including NFPA 70E, which covers electrical safety requirements for employee workplaces. He is a senior member of the Institute of Electrical and Electronic Engineers (IEEE).

Ray has authored or co-authored ten technical papers covering safety systems and processes, five of which have been published in IEEE Transactions on Industry Applications, and five of which earned awards from IEEE. He is a frequent lecturer and contributor at the IEEE-IAS Petroleum and Chemical Industry Committee Electrical Safety Workshop and other IEEE tutorials.

To learn more about services offered by ESCS, Inc., contact Ray Jones at 919-557-7711, rayjones@ieee.org or jandrjones@worldnet.att.net.

Safety BASICs™ - Bussmann Awareness of Safety Issues Campaign

Printed in the U.S.A

Table of Contents

I. Introduction

An increasing number of organizations are actively promoting electrical safety for employees. For example, the National Fire Protection Association NFPA 70E "Standard for Electrical Safety Requirements for Employee Workplaces" has been completely updated. The Institute of Electrical and Electronics Engineers (IEEE) just published a new "Yellow Book," the "IEEE Guide for Operation, Maintenance and Safety of Industrial & Commercial Power Systems." The University of Chicago Trauma Center has a new unit specializing in electrical burns and related injuries. Its interests are not only on improving treatment methods, but also providing more insight of electrical injuries and awareness on how to avoid electrical hazards. Major manufacturers and entire industries are seeing benefits of becoming more involved in promoting employee safety awareness programs.

The purpose of this Safety BASICs handbook is to:

- provide increased awareness of safety issues faced by individuals who work on or near electrical equipment, as well as system operators and equipment designers/specifiers
- and to provide safety principles to be used for protecting individuals from potential injuries and even death caused by electrical hazards.

This material is designed to provide the reader with an overview of hazards associated with exposure to electrical energy. It will highlight standards and standard organizations, and offer guidance on safety procedures and a number of key principles that will help to minimize exposure to electrical hazards. Knowing how to minimize the exposure to electrical hazards will help to reduce future injuries and even deaths.

The Safety BASICs program is for the supervisor, manager, electrician, engineer, and the designer/specifier of equipment used in the electrical system. The IEEE makes it very clear that, "Engineers engaged in the design and operation of electrical systems protection should familiarize themselves with the most recent OSHA regulations and all other applicable regulations related to human safety." To the IEEE, providing adequate safety means going beyond the minimum requirements from consensus standards.

Perhaps a statement in the IEEE "Buff Book" says it best - "**Safety has priority** over service continuity, equipment damage or economics."

II. Consensus Standards

Consensus standards are seen as the generally accepted engineering practices and can be used for litigation purposes when entered as evidence in a legal proceeding. In case of an accident, where litigation is involved, the design and safety practices used will be compared with these standards. In some cases this type of enforcement is more critical than if the government were the enforcing agent.

In the United States, consensus standards are normally written by volunteers and published by standards developing organizations (SDOs). The content of consensus standards is the result of a blue-ribbon panel of experts and defines the industry's best generally available knowledge. Consensus standards fall into several different classes. Some consensus standards are product oriented; others define testing requirements, cover installation or design issues, or are people oriented. Many become legally mandated by governmental organizations.

Whether a national consensus standard is mandated and enforced by governmental action or not, the judicial system tends to use these standards as generally recognized and accepted engineering practices for litigation purposes. In order to understand the significance of this point, consider the text used in the OSHA Act: "the (Labor) Secretary shall...by rule promulgate as an occupational safety or health standard any national consensus standard...." The legal profession will use relevant national consensus standards in a court case where the standard is entered into evidence.

Each SDO and standard has a principle objective. In order to correctly apply any individual consensus standard, both the SDO objective and the standard objective should be clearly understood. The standard then should be applied with this understanding in mind. For instance, the National Fire Protection Association (NFPA) is primarily concerned with fire protection and personal safety. Therefore, NFPA standards should be embraced when these objectives are considered important. Some NFPA standards are product oriented; others are installation oriented. These standards should be applied as discussed in the scope of the document.

The NFPA publishes two critical standards. One is the NFPA 70, otherwise known as the National Electrical Code® (NEC®) and the other is Electrical Safety Requirements for Employee Workplaces (NFPA 70E). The NFPA has many other standards, but these are two of the most important electrical standards. The premier standards publishing organization in the U.S. is the American National Standards Institute (ANSI). ANSI is authorized by the U.S. government as the organization that has the authority to identify American National Standards (ANS). No standard is written by ANSI; instead, ANSI identifies requirements for both the SDO and the standard. Among these is a requirement that each standard be produced by people knowledgeable in the area being addressed. Each ANSI standard then is ensured to have had broad, knowledgeable input as well as a "consensus" by the community covered by the standard.

Most consensus standards define minimum requirements necessary to accomplish the prime objective under normal operating or functioning conditions. Of course, in most cases, a standard tends to define some protective measures. However, defined protective measures are intended to protect the equipment from destruction in case of a failure. Generally, consideration for the "people factor" is missing from the standards puzzle, even though actions of people account for more than 75 percent of all accident incidents that result in injury.

A. Types of Standards

There exists, today, more than 22,000 national consensus standards in the United States. Standards Developing Organizations (SDOs) addressing electrical safety include the American National Standards Institute (ANSI), National Fire Protection Association (NFPA), Institute of Electrical and Electronic Engineers (IEEE), Underwriters Laboratories (UL), the U.S. Occupational Safety and Health Administration (OSHA), and the National Electrical Manufacturers Association (NEMA). Note that these SDOs are mostly U.S. based and have primarily a U.S. focus.

Each of these SDOs writes and publishes standards that address various electrical safety issues. As stated earlier, some standards are intended for adoption by governmental organizations. However, national SDO developed consensus standards not adopted by governmental organizations can still be used in a court of law.

B. NFPA 70 (National Electrical Code - NEC)

NFPA 70 is commonly called the National Electrical Code® or the NEC®. The NEC is currently adopted by more than 1,800 different governmental organizations in the U.S, and by several Latin American countries. These organizations include city, county or state governments. Some adopt the NEC as it is published by NFPA; others add or subtract requirements.

The NEC is the document related to installation of "premises" wiring. Premise wiring involves interior and exterior wiring, including power, lighting, control and signal circuits along with all associated hardware. This extends from the service point from the utility or separately derived system to the outlet(s).

The focus of the NEC is to identify requirements used to control the probability of electrical fires and provide safe installation when the system or equipment is operating normally. By itself, the NEC is a standard with advisory information offered for use in law and for regulatory purposes. The NEC is reviewed and revised on a three-year cycle.

Keep in mind however that the NEC is offered as a "minimum" standard, and therefore its requirements sometimes have to be exceeded to meet functional necessities, sound engineering judgment, and improved safety.

C. OSHA Standards

The U.S. Occupational Safety and Health Administration was authorized in the Williams-Steiger act of 1970. The OSHA Act passed both Houses of Congress. Signed into public law, it became known as "The Act". The Act provides for several very important elements:

- Establishes OSHA as an arm of the U.S. Department of Labor
- Mandates that an employer provide a safe workplace for employees
- Defines national consensus standards as the starting point for a safe workplace
- Provides for an inspection and enforcement process
- Provides for a due process
- Provides for specific standards related to personal safety requirements
- Provides for public input to the process

OSHA standards are published in the U.S. Federal Register and made available to the general public on the World Wide Web at www.osha.gov and in hard copy from the U.S. Government Printing Office.

The United States Department of Labor has written the OSHA regulations under Title 29 of the Code of Federal Regulations (CFR) establishing them as requirements for electrical installations and electrically safe practices. In the Standard 29 CFR, Part 1910 covers general industry, while Part 1926 covers the construction industry (See Table I). Each Part is subdivided into Subparts. Each Subpart is further subdivided into Paragraphs.

Table I. OSHA Standards for Electrical Work

OSHA Standard	Title	Addresses
1910.7	Nationally Recognized Testing Laboratories	NRTLs
1910.137	Electrical Personal Protective Equipment	Voltage Rated Protective Products
1910.147	Control of Hazardous Energy	Lockout/Tagout
1910.269	Power Generation, Transmission and Distribution	Overhead and Underground Distribution
1910.300-399	Electrical Safety Requirements	General Industry
1926.400-449	Electrical Safety Requirements	Construction

General industry tasks (for electrical energy) are covered in 29 CFR 1910.7, 1910.137, 1910.147, 1910.269, and 1910.300-399. Construction tasks are located in section 1926.400-449. OSHA standards (rules) and requirements also contain definitions. These definitions are generally related to tasks rather than employers or even industries. Employers should therefore pay close attention to the type of tasks being performed.

It is important to note that OSHA enforcement of the law includes fines. While many fines may be small, it is not unusual for fines of $70,000 per instance, per exposed employee to be assessed. OSHA fines can easily escalate to more than a million dollars. In addition to fines, OSHA violations can result in criminal indictment. It is also becoming more common for an employer to be held personally accountable. In some situations the employer, or even the plant manager, can be held criminally liable and sent to jail.

D. NFPA 70E

The NFPA 70E is the “Standard for Electrical Safety Requirements for Employee Workplaces.” This standard focuses on protecting people and identifies requirements that are considered necessary to provide a workplace that is generally free from electrical hazards. NFPA 70E is intended to address conditions that exist, may exist, and in abnormal conditions where people can become involved.

The NFPA 70E suggests that:

- electrical hazards include shock, arc flash and arc blast
- the best way to avoid injury or incident is to establish an electrically safe work condition prior to beginning the work
- procedures and training are extremely important if injury is to be avoided

When OSHA’s electrical standards were first developed, they were based on the National Electrical Code. As OSHA focused more on all aspects of electrical safety, the need was created for a consensus document in preparing electrical safety requirements for protecting individuals working on, or near, electrical equipment.

The first edition of the NFPA 70E was published in 1979. Although, to date, the NFPA 70E may not have the same extensive recognition as the NEC, it does provide the latest thinking on the subject of electrical safety, particularly in the area of safe work practices. Many parts of the current OSHA regulations 29 CFR 1910 Subpart S were derived from NFPA 70E.

NFPA 70E identifies the requirements for enhanced personal safety. It is an extremely important national consensus standard and must be considered to define the requirements for an overall electrical safety program. Also consider National consensus standards, like the NFPA 70E, may be entered into evidence in a court of law.

E. Other Standards and Resources

The ***National Electrical Safety Code*** (NESC) is an ANSI standard that is written and published by the IEEE. This standard is intended to identify requirements that apply to outdoor electrical transmission, distribution, and communication systems, equipment, and associated work practices, as opposed to premises wiring, addressed in the NEC. The NESC is the base standard providing the starting point for OSHA when 29 CFR 1910.269 was being written.

The ***NFPA 70B***, “Recommended Practices for Electrical Equipment Maintenance”, is a document whose purpose is to reduce hazards to life and property that can result from failure or malfunction of industrial and commercial electrical systems and equipment. Along with its maintenance guidance, it also addresses electrical safety.

The ***National Electrical Manufacturers Association*** (NEMA) has many standards on electrical products and systems. NEMA standards have often served as a basis for Underwriter Laboratories’ (UL) safety standards. Both NEMA and UL standards are designed as consensus standards and are considered as minimal requirements.

The Color Book Series by the ***Institute of Electrical and Electronic Engineers*** (IEEE) provides recommended practices and guidelines that go beyond the minimum requirements of the NEC, NEMA and UL standards. When designing electrical power systems for industrial and commercial facilities, consideration should be given to the design and safety requirements of the following IEEE color books:

- “Red Book” -IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants
- “Green Book” -IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems
- “Gray Book” -IEEE Recommended Practice for Electrical Power Systems in Commercial Buildings
- “Brown Book” -IEEE Recommended Practice for Power System Analysis
- “Buff Book” -IEEE Recommended Practice Protection and Coordination of Industrial and Commercial Power Systems
- “Orange Book” -IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications
- “Gold Book” -IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power
- “White Book” -IEEE Recommended Practice for Electrical Systems in Health Care Facilities
- “Bronze Book” -IEEE Recommended Practice for Electrical Conservation and Cost-Effective Planning in Industrial Plants
- “Emerald Book” -IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment
- “Yellow Book” -IEEE Guide to Operation, Maintenance and Safety of Industrial & Commercial Power Systems
- “Blue Book” -IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems

The need for unified international standards was identified many years ago. The U.S. standards system is essentially voluntary. In some parts of the world, governments essentially mandate adherence to the standards system that is in place. The ***International Electrotechnical Commission*** (IEC) standards are an attempt within international communities to reach a consensus on standard requirements. Significant progress is being achieved with this objective. Many of the European governments have mandated standards systems. The European Union (EU) encourages further consensus among affected nations.

In many instances, protection schemes embraced in the IEC differ from those in the U.S. For example, in the U.S., nationally recognized testing laboratories are used to perform standardized "third party" product testing. Products meeting the testing standard are marked, identifying the testing laboratory. Many products meeting international safety requirements for installation in Europe require certification to testing standards and must bear a CE mark. The CE mark applies to certain "Directives" within European Union countries. The intent is to provide a "safe" product that is acceptable to all of the EU countries.

In regard to personnel safety, the IEC standards address protection from electrical shock more directly than U.S. standards. For instance, IEC standards generally recognize that degrees of exposure vary. This will be discussed further in the section on IP Ratings (see Page 38).

III. Electrical Hazards

Electricity has become such an integral part of our society that it is often taken for granted. Yet, electricity remains a very dangerous hazard for people working on or near it.

Hazards can include poor work conditions, equipment or practices. It may also include careless, inadvertent actions made on the part of individuals. Avoiding hazards requires that as many reasonable precautions be taken as possible to provide a safe work environment. This starts at the design of the facility and electric system. It includes the design and specification of the electrical components and equipment, through the installation, start-up, operations and during equipment maintenance.

First, we must recognize the three common electrical hazards that cause injury and even death, while working on or near electrical equipment and systems:

- electrical shock
- arc-flash burns from contact (current) and flash (radiant)
- and arc-blast impact from expanding air and vaporized materials

Many electrical circuits do not directly pose serious shock or burn hazards by themselves. However, many of these circuits are found adjacent to circuits with potentially lethal levels of energy. Even a minor shock can cause a worker to rebound into a lethal circuit or cause the worker to drop a tool into the circuit. Involuntary reaction to a shock may also result in bruises, bone fractures, and even death from collisions or falls.

A. Electrical Shock

It is estimated that more than 30,000 non-fatal electrical shock accidents occur each year. The National Safety Council estimates that between 600 and 1,000 people die every year from electrocution. Of those killed with voltages below 600 volts, nearly half were working on “hot” energized equipment at the time the fatal injury occurred. Electrocution continues to rank as the fourth highest cause of industrial fatalities (behind traffic, violence/homicide, and construction accidents).

Most personnel are aware that there is a danger of electrical shock, even electrocution. It’s the one electrical hazard that most electrical safety standards have been built around. However, few really understand just how little current is required to cause injury, even death. Actually, the current drawn by a 7 1/2 watt, 120 v lamp, passing across the chest, from hand to hand or foot, is enough to cause fatal electrocution.

The effects of electric current on the human body depend on:

- circuit characteristics (current, resistance, frequency and voltage)
- contact and internal resistance of the body
- the current’s pathway through the body, determined by contact location and internal body chemistry
- duration of contact
- environmental conditions affecting the body’s contact resistance

To understand the currents possible in the human body, it is important to understand the contact resistance of skin (see Table II). The skin’s resistance can change as a function of the moisture present in its external and internal layers, with changes due to ambient temperatures, humidity, fright, anxiety, etc.

Table II. Human Resistance Values for Various Skin-contact Conditions

Condition	Resistance, (ohms)	
	Dry	Wet
Finger Touch	40,000 to 1,000,000	4,000 to 15,000
Hand Holding Wire	15,000 to 50,000	3,000 to 6,000
Finger-Thumb Grasp	10,000 to 30,000	2,000 to 5,000
Hand Holding Pliers	5,000 to 10,000	1,000 to 3,000
Palm Touch	3,000 to 8,000	1,000 to 2,000
Hand Around 1 1/2 Pipe	1,000 to 3,000	500 to 1,500
Two Hands Around 1 1/2 Pipe	500 to 1,500	250 to 750
Hand Immersed		200 to 500
Foot Immersed		100 to 300
Human Body, Internal, Excluding Skin	200 to 1,000	

This table was compiled from data developed by Kouwenhoven and Milnor.

Body tissue, vital organs, blood vessels and nerve (non-fat) tissue in the human body contain water and electrolytes and are highly conductive with limited resistance to alternating electrical current. As the resistance of the skin is broken down by electrical current, resistance drops and current levels increase.

Consider the human body as a resistor with a resistance R (hand to hand) of just 1,000 ohms. The voltage V will determine the amount of current passing through the body:

While 1,000 ohms may appear to be rather low, even lower levels can be approached by someone having sweat-soaked cloth gloves on both hands, and a full hand grasp of a large energized conductor and a grounded pipe or conduit. Moreover, cuts, abrasions or blisters on hands can negate skin resistance, leaving only internal body resistance to oppose current flow. A circuit in the range of 50 volts could be dangerous in this instance.

Ohm's Law: I (Amperes) = V (Volts) / R (Ohms)

Example 1: I = 480 / 1000 = 480 mA (or 0.480 amps)

Product standards consider 4 to 6 mA to be the safe upper limit for children and adults (hence the reason a 5 milliamp rated GFCI circuit). *[Note: GFCIs do not protect against a line-to-neutral or a line-to-line shock.]* (see Page 38)

Electrical currents can cause muscles to lock up. This results in an inability to release the hand's grasp from the current source. This is known as the "let go" threshold current. This current level will vary with the frequency (see Table III). DC currents usually cause a single twitch and are considered less dangerous at lower voltage levels. Alternating currents in the frequency range of skeletal muscles (40-150 Hz) are more serious (i.e. 60 Hz).

Table III. The Effects of Electrical Current on the Body

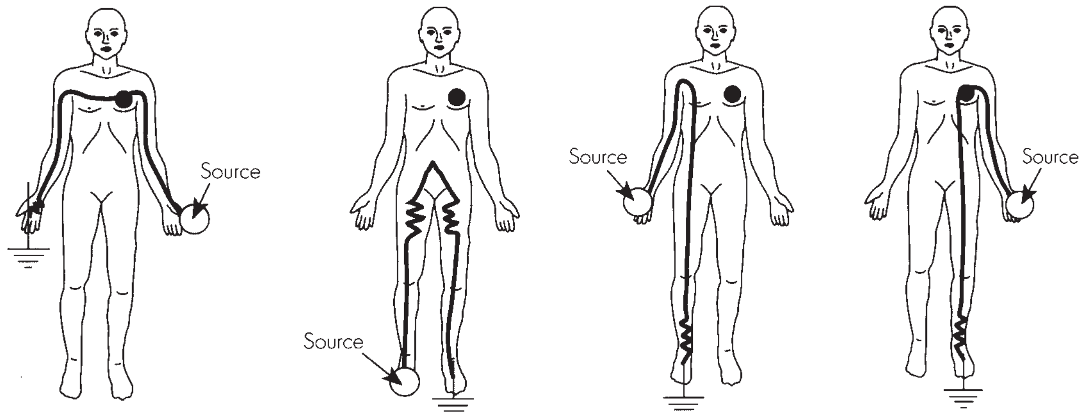
Effects	Current, mA					
	Direct Current		Alternating Current			
			60 Hz		10 kHz	
	Men	Women	Men	Women	Men	Women
Slight sensation on hand	1	0.6	0.4	0.3	7	5
Perception "let go" threshold, median	6.2	3.5	1.1	0.7	12	8
Shock - not painful and no loss of muscular control	9	6	1.8	1.2	17	11
Painful shock - muscular control lost by 1/2%	62	41	9	6	55	37
Painful shock - "let-go" threshold, median	76	51	16	10.5	75	50
Painful and severe shock - breathing difficult, muscular control lost	90	60	23	15	94	63

Deleterious Effects of Electric Shock, Charles F. Dalziel

At 60 Hz., most females have a "let go" limit of about 6 milliamps, with an average of 10.5 milliamps. Most males have a "let go" limit above 9 milliamps, with an average of 15.5 milliamps.

Sensitivity, and potential injury, also increases with time. A victim who can not "let-go" of a current source is much more likely to be electrocuted than someone whose reaction removes them from the circuit more quickly. The victim who is exposed for only a fraction of a second is less likely to sustain an injury.

The most damaging path for electrical current is through the chest cavity (See A and D in Figure 1) and head. In short, any prolonged exposure to 60 Hz current of 10ma or more may be fatal. Fatal ventricular fibrillation of the heart (stopping of rhythmic pumping action) can be initiated by a current flow of as little as several milliampers (mA). These injuries can cause fatalities resulting from either direct paralysis of the respiratory system, failure of the rhythmic heart pumping action, or immediate heart stoppage.



(A) Touch Potential (B) Step Potential (C and D) Touch/Step Potential

Figure 1. Current Pathways Through the Body

During fibrillation, the victim may become unconscious. On the other hand, he may be conscious, deny needing help, walk a few feet and then collapse. Death may occur within a few minutes or take hours. Prompt medical attention is needed for anyone receiving electrical shock. Many of these people can be saved provided they receive proper medical treatment including cardiopulmonary resuscitation (CPR) quickly.

Table IV. Effects of Electrical Shock (60 Hz AC)

Response*	60 Hz. AC Current
Tingling Sensation	0.5 - 3 mA
Muscle Contraction and Pain	3 - 10 mA
"Let Go" Threshold	10 - 40 mA
Respiratory Paralysis	30 - 75 mA
Heart Fibrillation and May Clamp Tight	100 - 200 mA
Tissue and Organs Burn	Over 1,500 mA

* Note the degree of injury also depends on the duration and frequency of the current

Think of electrical shock injuries as "icebergs" where most of the injury is unseen below the surface. Entrance and exit wounds are usually coagulated areas, and may have some charring, or these areas may be missing, having "exploded" away from the body due to the level of energy present. The smaller the area of contact, the greater the heat produced. For a given current, damage in the limbs may be the greatest, due to the higher current flux per unit of cross-sectional area.

Within the body, the current can burn internal body parts in its path. This type of injury may be difficult to diagnose, as the only initial sign of injury is the entry and exit wounds. Damage to the internal tissues, while not apparent immediately, may cause delayed internal tissue swelling and irritation. Prompt medical attention will minimize possible loss of blood circulation and the potential for amputation of the affected extremity as well as avoid death.

Most electrocutions are preventable. A significant part of the OSHA code is dedicated to electrical safety. It would be an oversimplification to state that everyone should comply with the code. However, OSHA code compliance is considered a minimum requirement and seen as a very good place to start for improving the safety of the workplace.

Any time an electrocution occurs there is the potential for both a civil lawsuit and an OSHA citation. It is always a good proactive measure to review internal safety procedures when investigating industrial accidents. Make sure that you have an accurate set of facts to work with. Accidents are always costly - most can be avoided!

Several standards offer guidance regarding safe approach distances to minimize the possibility of shock from exposed electrical conductors of different voltage levels. The most recent and probably the most authoritative guidance is presented in NFPA 70E. Safe approach distances to exposed energized electrical conductors are discussed in Section VI of this handbook. (see Page 20)

B. Arc Flash

Nearly everyone is aware that an electrical shock is a hazard that can ultimately lead to death. In fact, while many people have experienced minor shocks, few have found any real consequences making them somewhat complacent. Few appreciate the extreme nature of electrical arc flash and the potential of severe burns, but this is starting to change.

In recent years, awareness of arc-flash hazards has been increasing. Recent studies of reported electrical injuries have indicated that as many as 80% of documented injury cases were burns resulting from exposure to radiant energy from electrical arcs. In addition, each year more than 2,000 people are admitted to burn centers with severe electrical burns. Standards organizations are now taking a more active role in addressing the problem.

Electrical burns are considered extremely hazardous for a number of reasons. One important reason is that contact with the circuit is not necessary to incur a serious, even deadly, burn.

Fire

A fierce conductive-plasma fireball can develop when fault currents occur where poor electrical contacts or insulation failure allow an arc flash to develop. Serious or fatal burns can occur at distances of more than 10 ft. from the source of a flash.

In addition to burns from the flash, flammable clothing can ignite. Failure to remove or extinguish the clothing quickly enough can cause serious burns over much of the body.

Electrical workers are frequently required to work on or near energized electrical equipment. Safety standards and procedures are being developed that recognize the fact that arcs cause serious injuries at significant distances from energized sources. Spectators should stay away from electrical equipment. Although they think they are far enough away, they generally do not have an understanding of what is a safe approach distance. (see section on Approach Boundaries page 20)

Radiant Heat

An electrical arc flash is the passage of electric current between two conducting metals through an ionized gas or vapor, usually air. It is initiated by a flashover, or from the introduction of some conductive material (ex. screwdriver). Arc temperatures can exceed 35,000 °F at the arc terminals. Compare this to the surface of the sun where the temperature is about 9,000 °F. No material on earth can withstand this temperature. In fact, not only do all materials melt at this temperature but they vaporize.

A misconception is that the magnitude of an arc is solely due to magnitude of the voltage. The amount of arc energy generated is actually dependent more upon the short circuit current available and the time taken by the circuit breaker of fuse to clear the fault.

Burns suffered in electrical accidents are of three basic types:

- **Electrical burns** — tissue damage (whether skin deep or deeper) occurs because the body is unable to dissipate the heat from the current flow. Typically, electrical burns are slow to heal.
- **Arc burns** — caused by electric arcs and are similar to heat burns from high temperature sources. Temperatures generated by electric arcs can melt nearby material, vaporize metal in close vicinity, and burn flesh and ignite clothing at distances of 10 ft or more.
- **Thermal contact burns** — normally experienced from skin contact with the hot surfaces of overheated electric conductors or clothing once ignited.

The human body survives in a relatively narrow temperature range around 97.7 °F. Studies show that when the skin temperature is as low as 110 °F, the body's temperature equilibrium begins to break down in about 6 hours. At 158 °F, only one-second duration is sufficient to cause total cell destruction. Exposure of the skin to temperatures of 200 °F for more than one tenth (1/10th) of a second will cause incurable "third degree" burns. (see Table V)

Table V. Skin Temperature Tolerance Relationship

Skin Temperature	Time of Skin Temp.	Damage Caused
110 °F	6 Hours	Cell breakdown starts
158 °F	1 sec.	Total cell destruction
176 °F	0.1 sec	Curable burn
200 °F	0.1 sec	Incurable burn

C. Arc Blast

High-energy arcing faults generate a tremendous amount of heat. This heat causes melting, vaporization and expansion of conducting material as well as expansion of air creating a pressure wave. This pressure wave ("blast") is a serious electrical hazard that is often not recognized. While it has been known to save many lives by rapidly hurling victims away from the arc heat source, more often it causes serious falls and other injuries.

Physical injuries include:

- impact with objects
- hearing damage
- concussion

Flying shrapnel from damaged electrical and mechanical components, as well as molten conductive metals, may cause injuries. Individuals in close proximity to these severe pressures are also likely to suffer short-time loss of memory or may not remember the intense explosion of the arc itself.

The main sources of this pressure wave coming from an electrical arc include:

- Heating of the air passage of the arc through it (much like lightning)
- Expansion from melting, boiling and vaporizing of the conducting metal

Copper expands by a factor of 67,000 times as it vaporizes, in the same way that water expands about 1,670 times when it becomes steam. This accounts for the expulsion of near-vaporized droplets of molten metal from an arc. It also generates plasma (ionized vapor) that moves outward from the arc for distances proportional to the arc energy. As discussed earlier, this heat with the addition of molten metal droplets emanating from the arc can cause serious burns to nearby personnel.

Another consequence of arcs is damage to equipment and nearby structures. One study found that the pressure from a 100 kA, 10 kV arc reached a pressure level of about 400 lb/ft^2 at a distance of just over three feet. This force could easily destroy a conventional wall at a distance up to 40 feet away. A smaller 25 kA arc blast could destroy a wall or equipment at a distance of nearly 10 feet.

This same 25 kA arc can create as much as 160 lb/ft^2 of pressure on an individual two feet from the arc source. This would place 480 lbs. of force upon an average person's body. It is certainly enough energy to knock a person from a ladder or throw them across the room. This level of pressure has also been found to cause ear damage. Hearing protection even in low noise level locations should be considered.

Electrical equipment must sometimes be maintained while energized. This means that workers could be exposed to energized circuits during a fault. The risk of a fault occurring while people are in close proximity to equipment must be taken into account. As in shock and arc flash, the ideal method to avoid this hazard is to stay away from exposed energized electrical systems. Unfortunately, this is not always possible.

IV. Attending to Electrical Accident Victims

Preparedness

Site personnel need to be trained in CPR and first-aid techniques to prepare for possible electrical accidents. CPR training and periodic retraining of site personnel must be carefully planned and documented.

First-aid supplies approved by the consulting physician should be easily accessible when required. The first-aid kit should consist of materials approved by the consulting physician, in a weatherproof container with individually sealed packages for each type of item. The contents of the first-aid kit should be checked weekly to ensure that all supplies are present and in good order.

Plans must be in place for transporting accident victims to a physician or hospital. Recovery of electrical accident victims can be greatly enhanced if they can be transported as quickly as possible to a burn center or other medical facility that specializes in electrical trauma. Employers should evaluate medical facilities in their area and determine in advance where such victims should be taken and how they will be transported. Emergency telephone numbers and specific instructions should be conspicuously posted.

Locations of eyewash stations and safety showers must be posted so that they are easily found to cool and flush the burn victim after an accident.

Effects of Electrical Accidents

Electrical accidents and the complexities of the trauma they cause to the human body have historically been surrounded by mystery and lack of understanding. As more knowledge is gained about electrical trauma, strategies for effectively handling the emergency and ways to improve hospital treatment of victims become more apparent. In addition, research suggests ways in which workplace supervisors and responders can help an accident victim's caregivers provide appropriate medical attention.

In the case of an electrical accident, the extent of injury to the victim often is not immediately apparent. Some symptoms may be masked by the more readily apparent thermal effects of the injury (burns). Caregivers must be aware of additional possible biological effects of electric shock.

In an arc-flash or arc-blast energy accident , the victim's skin, ears, eyes, lungs, internal organs, and nervous, muscular, and skeletal systems can be affected not only by the direct effects of electrical current, but also by the following:

- Radiant heat from an electrical arc that produces extremely high temperatures
- Disturbance of the heart's electrical conduction, causing changes in the heart rhythm or possible cardiac arrest
- Barotrauma from the acoustic and vibratory forces around arc blast
- Inhaled or deposited vapors released through an arc explosion

Accident victims are also subject to the following types of injury related to contact with electricity:

- Low-voltage contact wounds
- High-voltage contact wounds of entry and exit of electrical current
- Burns
- Respiratory difficulties (The tongue may swell and obstruct the airway, or vaporized metal or heated air may have been inhaled.)
- Infectious complications
- Injury to bone through falls, heat necrosis (death of tissue), and muscle contraction (Shoulder joint injuries and fracture of bones in the neck are common injuries caused by muscle contraction.)
- Injury to the heart such as ventricular fibrillation, cardiac arrest or stoppage
- Internal and organ injuries
- Neurological (nerve) injury
- Injury to the eyes (Cataracts from electrical injury have been reported up to three years after an accident.)

Enhancement of Chances for Recovery

In most electrical accidents, the inability to diagnose the extent of injury at the time of admission to the hospital can delay the patient's treatment. Recovery can be enhanced by more detailed information about the accident, including the system voltage, amount of available current, length of contact with current, and possibility of arc flash. Recovery can be maximized by transporting the victim as quickly as possible to a burn center or other facility that specializes in treatment of electrical trauma.

A. Procedures

In response to an electrical accident, the following procedures should be followed immediately:

- **Remove the immediate hazard; turn off the power**. If you are a witness to an electrical accident, exercise great caution that you do not sustain injury as well. Always assume that the source of electricity is still energized unless you or another qualified person determines that the power has been turned off. Unless you are using insulated equipment (e.g., voltage-rated gloves, hot sticks, a rubber blanket, etc.) to dislodge a victim, you must delay the rescue effort until the circuit can be interrupted.
  Note: Sites must establish a training policy and plan to cover electrical rescue methods, approved rescue devices, and CPR training.
- **Speed is essential.** The victim's potential for injury increases with contact time. The resistance of the body is mostly in the skin. If the skin breaks down electrically, only the low internal body resistance remains to impede current.
- **Call for help.** Delegate someone else to get help, if possible. Make sure that an ambulance or emergency medical service is on the way.
- **Begin CPR.** If the victim's pulse or breathing has stopped, cardiopulmonary resuscitation (CPR) is essential to avoid brain damage, which usually begins in four to six minutes. If CPR is needed, make sure assistance is on the way but do not wait for help to arrive.

  Make sure you and the victim are in a *safe zone* (not in contact with any electrical source and out of reach of any downed or broken wires). If the person is unconscious, begin the CPR sequence.
- **Apply first aid to the victim.**
  - If the person's clothing is on fire, remind him/her to drop and roll, or tackle him/her, if necessary, to smother the flames.
  - Cool the burn with water or saline for a few minutes or until the skin returns to normal temperature. (For flash burn victims, safety showers may be the best method due to the possibility of wide-spread surface burns on the body.) Do not attempt to remove clothing that is stuck to a burn.
  - Remove constricting items such as shoes, belts, jewelry, and tight collars from the victim.
  - Elevate burned limbs to reduce swelling.
  - Handle the victim with care, being aware that he or she might have broken bones or spinal injuries.
  - Treat for shock: maintain body temperature, do not give anything by mouth; administer high concentrations of oxygen, if available.

– Keep the victim warm and as comfortable as possible while awaiting transport to the medical facility. Cover him or her with clean, dry sheets or blankets. Cover burn wound(s) with sterile dressings or clean sheets.

B. Additional Information

After the victim's immediate needs are met, note as many details of the accident as possible. The details can help an accident victim's caregivers provide appropriate medical attention.

It is especially important that hospital personnel know the cause of the victim's injuries. They need to know if the victim had contact with electricity or if arc flash caused the injuries.

While the victim of electrical contact may suffer some surface burns where the current entered the body, he or she often suffers additional, less visible (internal) damage because of the path of the current through the body.

The flash burn victim is more likely to have greater evident burn damage on the surface of the body, due to the extremely high temperatures from arc flash. He or she is likely to suffer first, second, and third-degree burns, especially on the face, wrists, ears, back of the head, neck, and ankles. Any skin surface that is not adequately covered by protective clothing or equipment is at risk.

In addition to burns to the skin, the flash burn victim may also have inhaled metal vapor (such as copper) into the lungs or suffered adverse effects (such as damage to the eardrum) due to the pressure wave caused by arc blast.

C. Advance Help for Accident Victims

Prepare a checklist in advance to provide detailed information about an accident (see the sample checklist in the Appendix). This list should be a part of a site's emergency response plan for electrical injuries. Make this checklist readily available on site and communicate its existence to all employees. A completed copy should accompany the victim to the hospital or treatment center if at all possible.

The information will help to ensure the best possible evaluation and treatment by initial medical caregivers.

V. Who's Responsible for Safety?

In most instances, three distinctly different entities are associated with a project or site: the employer, the employee, and the owner. When discussing responsibility, it is important to understand the existence of these different roles.

- The ***"Employer"*** can be thought of in terms of a person who represents ***"the Company."*** The employer, then, can be the owner of the company or any member of the line management of the organization.
- On the other hand, the ***"Employee"*** is the electrician or other worker. A first or second-line supervisor, then, has two roles. He or she may be a representative of the company, operating as an employer, in addition to being an employee.
- The term ***"Owner"*** has still a different twist. Rather than a person, the owner is the entity that owns the equipment or facility. The owner has a role and responsibility that is somewhat different from either employer or employee.

In The Act, OSHA is chartered to establish requirements for ***"Employers"***. It has no jurisdiction to assign responsibilities to employees. Therefore, meeting requirements defined by OSHA is the responsibility of the employer (management of the company). It is the employer who must provide for a safe workplace. It is the employer who must establish and implement a safety program. It is the employer who must establish an enforcement policy to ensure that employees follow established practices.

In the case where a ***"Contractor"*** is performing work on a site or facility owned by someone else, some inherent responsibilities must be assumed by the ***"Owner"***. Perhaps the most important of those responsibilities is to make sure that the contractor is fully apprised of all hazards existing that might impact the work.

National consensus standards are not similarly constrained. As a result, NFPA 70E also assigns responsibility. Responsibility assigned to the employer is the same as in 29 CFR 1910 Subpart S. The employer's responsibilities include the development and implementation of an electrical safety program, and the development of safety procedures and guidelines for an employee safety training program on proper implementation of those procedures.

NFPA 70E suggests that employees are responsible for implementing the program and procedures provided by the employer. The standard goes on to suggest that although responsibility of employer and employee are distinct and clear, the most effective process is to establish a close working relationship between employer and employee in which each has value for the other as they work together.

VI. Electrical Accident and Hazard Prevention

Before working on electrical equipment it is important to provide an **"Electrically Safe Work Condition".** This is defined by the NFPA 70E as a state in which the conductor or circuit component to be worked on, or near, has been:

- disconnected from energized parts (verified by checking S/L drawings) *NOTE*: Current drawings are very important to make sure that alternate supplies are known
- locked out/tagged out in accordance with established standards
- tested to ensure the absence of voltage
- grounded if determined necessary

Before approaching the equipment disconnect it is important to wear the appropriate Personal Protective Equipment. This is to provide proper protection form potential electrical hazards. Once this process is complete the individual may start to work on the equipment. At this point Personnel Protection Equipment may be reevaluated and some equipment removed to match the potential hazards. It is always a good idea to be overly cautious, aware, alert, yet efficient.

Because workers may need to work on or near equipment not in an electrically safe work condition, additional safety measures must be taken. Because it is possible for electrical arcs to seriously burn employees, the NFPA 70E has adopted procedures to provide safe working distances from a hazardous arc. One formula used for these calculations is based upon the work and a technical paper by Ralph H. Lee, "The Other Electrical Hazard: Electrical Arc Blast Burns," IEEE Transactions on Industrial Applications, Volume IA-18. No.3, May/June 1982. Another formula is taken from a paper by R.L. Doughty, T.E. Neal, and H.L. Floyd II, "Predicting Incident Energy to Better Manage the Electric Arc Hazard on 600V Power Distribution Systems," Record of Conference Papers IEEE IAS 45th Annual Petroleum and Chemical Industry Conference, September 28-30, 1998.

A. Approach Boundaries

Table VI (based on Table 2-1.3.4 in the NFPA 70E) provides approach distances to exposed energized electrical conductors. The Table identifies boundaries for limited approach, restricted approach and prohibited approach. The table establishes satisfactory distances between a qualified and unqualified person and conductors that have not been placed in an electrically safe work condition.

The ***Limited Approach Boundary*** (columns 2 and 3) is the limit of approach distance for unqualified persons to a live part. In concept, unqualified people are less capable of recognizing a shock and flash hazard. Therefore, these persons should remain at a safer distance from open, energized conductors. When there is a need for an unqualified person to cross the limited approach boundary to perform a minor task, or look at equipment, a qualified person shall advise him/her of the possible hazards and ensure the unqualified person is safeguarded. Under no circumstances shall an unqualified person be permitted to cross the restricted approach boundary.

The ***Exposed Movable Conductor*** (column 2) is intended to mean that either the conductor might move (as in an overhead line) or the person might move (as in an articulating support platform). A fixed circuit part (column 3) refers to a task where the conductor is not expected to move, such as within a unit substation.

The ***Restricted Approach Boundary*** (column 4) is the closest distance for an "unqualified person". Under no circumstances shall an unqualified person be permitted to cross the restricted approach boundary. To cross this boundary, a person must:

- Be a "qualified person",
- Have an approved plan,
- Use personal protective equipment approved for the conditions, and
- Position his or her body in a way that minimizes risk of inadvertent contact.

In some instances, work outside the restricted approach boundary but within the person's reach may be classified as restricted work if, in the judgment of the personnel involved, conductive objects or ungrounded body parts could make unintentional contact or cross the prohibited approach boundary.

The ***Prohibited Approach Boundary*** (column 5) is the minimum approach distance to an exposed energized conductor or circuit part and is the closest point to prevent flashover. To cross this boundary and enter the prohibited space shall be considered the same as making contact with exposed energized conductors or circuit parts.

To do so, the qualified person must:

(1) Have specified training to work on energized conductors or circuit parts,
(2) Have a documented plan justifying the need to work inside the prohibited approach boundary,
(3) Do a risk analysis,
(4) Have (2) and (3) above approved by the site manager, and
(5) Use Personal Protective Equipment appropriate for working on exposed energized conductors or circuit parts and rated for the voltage and energy level involved.

Table VI. Approach Boundaries to Live Parts for Shock Protection. (NFPA 70E-2000, Table 2-1.3.4) (All dimensions are distance from live part to employee.)

(1)	(2)	(3)	(4)	(5)
	Limited approach Boundary[1]		Restricted Approach Boundary[2] Includes	
Nominal System Voltage Range Phase-to-Phase	Exposed Movable Conductor[4]	Exposed Fixed Circuit Part[4]	Inadvertent Movement Adder[4]	Prohibited Approach Boundary[3]
0 to 50	Not Specified	Not Specified	Not Specified	Not Specified
51 to 300	10 ft. 0 in.	3 ft. 6 in.	Avoid contact	Avoid contact
301 to 750	10 ft. 0 in.	3 ft. 6 in.	1 ft. 0 in.	0 ft. 1 in.
751 to 15 kV	10 ft. 0 in.	5 ft. 0 in.	2 ft. 2 in.	0 ft. 7 in.
15.1 kV to 36 kV	10 ft. 0 in	6 ft. 0 in.	2 ft. 7 in.	0 ft. 10 in.
36.1 kV to 46 kV	10 ft. 0 in.	8 ft. 0 in.	2 ft. 9 in.	1 ft. 5 in.
46.1 kV to 72.5 kV	10 ft. 0 in	8 ft. 0 in.	3 ft. 3 in.	2 ft. 1 in.
72.6 kV to 121 kV	10 ft. 8 in.	8 ft. 0 in	3 ft. 2 in.	2 ft. 8 in.
138 kV to 145 kV	11 ft. 0 in.	10 ft. 0 in.	3 ft. 7 in.	3 ft. 1 in.
161 kV to 169 kV	11 ft. 8 in.	11 ft. 8 in.	4 ft. 0 in.	3 ft. 6 in.
230 kV to 242 kV	13 ft. 0 in.	13 ft. 0 in.	5 ft. 3 in.	4 ft. 9 in.
345 kV to 362 kV	15 ft. 4 in.	15 ft. 4 in.	8 ft. 6 in.	8 ft. 0 in.
500 kV to 550 kV	19 ft. 0 in.	19 ft. 0 in.	11 ft. 3 in.	10 ft. 9 in.
765 kV to 800 kV	23 ft. 9 in.	23 ft. 9 in.	14 ft. 11 in.	14 ft. 5 in.

Notes:
For SI Units: 1 in. = 25.4 mm; 1 ft. = 0.3048 m.
For flash protection boundary, see 2-1.3.3.2.

Column No. 1: The voltage ranges have been selected to group voltages that require similar approach distances based on the sum of the electrical withstand distance and an inadvertent movement factor. The value of the upper limit for a range is the maximum voltage for highest nominal voltage in the range based on ANSI C84.1-1995, Electric Power systems and equipment—Voltage Ratings (60 Hertz). For single-phase systems, select the range that is equal to the system's maximum phase-to-ground voltage times 1.732.

Column No. 2: The distances in this column are based upon OSHA's rule for unqualified persons to maintain a 10 ft (3.05m) clearance for all voltages up to 50 kV (voltage-to-ground), plus 0.4 in (102 mm) for each 1 kV over 50 kV.

Column No. 3: The distances are based on the following:

750 V and lower, use NEC Table 110.26 (a) Working Clearances, Condition 2 for 151-600 V range.

For voltages over 750 V, but not over 145 kV, use NEC Table 110.34 (a) Working Space, Condition 2.

For over 145 kV, use OSHA's 10 ft (3.05 m) rules as used in Column No. 2.

Column No. 4: The distances are based on adding to the flashover dimensions shown above the following inadvertent movement distance:

300 V and less, avoid contact, based upon experience and precautions for household 120/240 systems.

Over 300 V and not over 750 V, add 1 ft 0 in. inadvertent movement. These values have been found to be adequate over years of use in ANSI C2, National Electrical Safety Code, in the approach distances for communication workers.

Over 72.5 kV, add 1 ft. 0 in. inadvertent movement.

These distances have been found to be adequate over years of use in the NESC in the approach distances for supply workers.

Column No. 5: The distances are based on the following:

300 and less, avoid contact.

Over 300 but less that 750 V, use Clearances from NEC table 230.51(C).

Between open conductors and surfaces, 600 V not exposed to weather.

Over 750 V but not over 2.0 kV, value selected that fits in with adjacent values.

Over 2 kV but not over 72.5 kV, use NEC Table 490.24, Minimum Clearance of Live Parts, outdoor phase-to-ground values.

Over 72.5 kV, add 0 ft 6 in. inadvertent movement.

These values have been found to be adequate over years of use where there has been a hazard/risk analysis, either formal or informal, of a special work procedure that allows closer approach that that permitted by the restricted approach boundary distance.

B. Insulation Flashover Distances

The following table identifies voltage ranges and minimum air insulation distances. These distances must not be abridged. The voltage ranges align with those contained in the NESC. The basic minimum air insulation distance for voltages 72.5 kV and under are based upon ANSI/IEEE 4-1995, Appendix 2B; and for voltages over 72.5 kV, are based upon ANSI/IEEE 516-1995. The minimum air insulation distances required to avoid flashover are as follows:

Table VII. Air Insulation Flashover Distances

Voltage Flashover	Distance
300 V and less	0 ft. 0.03 in.
Over 300 V, not over 750V	0 ft. 0.07 in.
Over 750 V, not over 2 kV	0 ft. 0.19 in.
Over 2 kV, not over 15 kV	0 ft. 1.5 in.
Over 15 kV, not over 36 kV	0 ft. 6.3 in.
Over 36 kV, not over 48.3 kV	0 ft. 10 in.
Over 48.3 kV, not over 72.5 kV	1 ft. 3 in.
Over 72.5 kV, not over 121 kV	2 ft. 1.2 in.
Over 138 kV, not over 145 kV	2 ft. 6.6 in.
Over 161 kV, not over 169 kV	3 ft. 0.0 in.
Over 230 kV, not over 242 kV	4 ft. 2.4 in.
Over 345 kV, not over 362 kV	7 ft. 5.8 in.
Over 500 kV, not over 550 kV	10 ft. 2.5 in.
Over 765 kV, not over 800 kV	13 ft 10.3 in.

C. Flash Hazard Analysis

In order to perform a flash hazard analysis, it is imperative that the arc flash boundary distance be known. This is the linear distance between the body part that is exposed (such as hand or face) and the potential arc flash source. It is expected that the potential arc flash source is the closest uninsulated electrical conductor. The arc flash boundary may be generated by one of two methods. One is to simply assume 4.0 ft., based upon a clearing time of 6 cycles and an available bolted fault current of 50kA or any combination where the product of the two does not exceed 300 kA cycles or 5000 ampere seconds. (Typically, the 4' length can be considered conservative, but not for all applications). Where available fault currents are high, (above 50 kA) or where the overcurrent devices have a built-in "short-time delay", the arc flash boundary must be calculated.

The other method allows for calculating the actual arc flash boundary. Either of the following formulas may be used for this calculation.

$$D_c = [2.65 \times MVA_{bf} \times t]^{1/2} \text{ (ft)}$$

or

$$D_c = [53 \times MVA \times t]^{1/2} \text{ (ft)}$$

Where:

D_c = Arc flash boundary (Distance of a person (in feet) from an arc source for a just curable burn)

MVA_{bf} = Bolted 3-phase fault MVA at point involved

= 1.73 x voltage L-L x available short-circuit current x 10^{-6}

MVA = MVA rating of transformer (For transformers with an MVA rating below 0.75 MVA, multiply the transformer MVA rating by 1.25.)

t = Time of arc exposure in seconds

The first formula is more accurate since it accounts for conductor impedance in the circuit. The second is simpler, yet it still provides satisfactory results. Note that there are two essential variables: MVA and time of arc exposure. MVA is a function of the amount of energy the supply point is capable of delivering on a continuous basis. The critical variable is time. Energy released in an electrical arc escalates rapidly. An overcurrent device should be selected that will limit the duration of any arc to as short a time as possible. Within their current limiting range, current-limiting fuses will generally limit the arc flash exposure. Avoiding the existence of an arc flash boundary is not possible, but the exposure can be limited significantly.

Using the above formula is the accepted method for performing this analysis using system parameters. The idea is to consider the following elements and then identify a safe working distance to avoid an arc flash injury:

- Current that is "let-through" by the overcurrent protection device
- Length of time the fault current is permitted to flow
- Skin temperature at which a second-degree burn occurs
- Energy absorption of the skin surface
- Rate of energy transfer from the arc to the skin surface

If the skin's surface is covered with clothing, the analysis objective changes. In this situation the objective is to avoid ignition of the clothing material. Should the apparel be ignited, the exposure time to a very high temperature is much greater. In 29 CFR 1910.269, OSHA suggests that clothing must not add to the degree of the injury.

It is also critical that the overcurrent device selected be capable of safely interrupting every fault that might occur. If the system is capable of delivering 65kA of fault current, the circuit protective device, or series rated combination of protective devices, must be capable of interrupting this current. If the overcurrent device is exposed to a fault level exceeding the circuit protective device's ability to interrupt, an unrestrained release of energy will likely occur. In this situation, should this occur, the "over-stressed" overcurrent device may rupture or explode, causing an additional "event" in the load center, panel board or switchboard.

The following example will provide some insight into a typical situation:

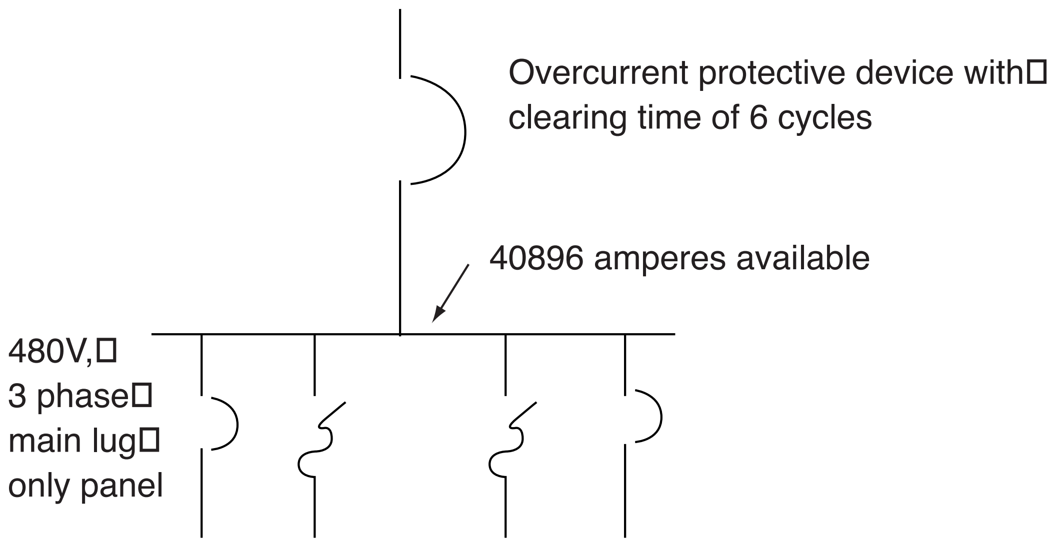


Figure 2: Circuit using Non-current Limiting Circuit Breakers

Example 1: Assume a circuit with 40896 amperes of 3-phase fault current available on a 480 volt system. The clearing time of the non-current limiting overcurrent protection device is 6 cycles (0.1 seconds). Find the distance in feet for the arc-flash boundary (just-curable burn).

$$D_c = [2.65 \times MVA_{bf} \times t]^{1/2} \text{ (ft)}$$

$$D_c = (2.65 \times 1.732 \times 480 \times 40896 \times 10^{-6} \times 0.1)^{1/2} \text{ (ft)}$$

$$D_c = (9.00)^{1/2} \text{ (ft)}$$

$$D_c = 3 \text{ ft.}$$

This means that any exposed skin closer than 3 feet to this available fault, for 0.1 seconds or longer, may not be curable should an arcing fault occur. If the employee must work on this equipment where parts of his/her body would be closer that 3 feet from the possible arc, suitable Personal Protective Equipment must be utilized so that the potential employee injury is minimized.

Example 2: Assume a circuit with the same 40896 amperes of 3-phase fault current available. In this example a 200 Amp Class J current-limiting fuse is utilized as the lineside overcurrent protection device. The approximate opening time of the fuse is 1/4 cycle (0.004 seconds) with an equivalent RMS let-through current of only 6,000 amperes [based on the use of Bussmann LPJ-200SP LOW-PEAK® fuses].

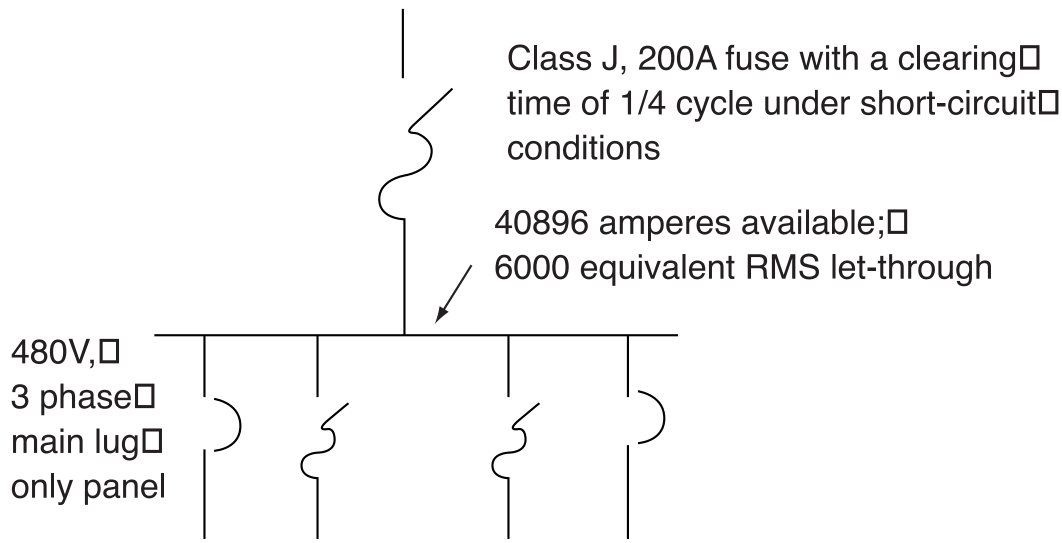


Figure 3: Circuit using Current-Limiting Fuses

Now find the distance in feet for the arc-flash boundary.

D_c = $[2.65 \times MVA_{bf} \times t]^{1/2}$ (ft)

D_c = $(2.65 \times 1.732 \times 480 \times 6{,}000 \times 10^{-6} \times 0.004)^{1/2}$ (ft)

D_c = $(0.528)^{1/2}$ (ft)

D_c = 0.229 ft. (or 2.75 inches)

CONCLUSION: For this value of flash energy, the flash protection boundary was decreased 92%, from 3 feet (Example 1) to 2.75 inches (Example 2). This is because the current limiting fuse was able to limit the short circuit current from 40,896 to 6,000 amperes and open more quickly, reducing the exposure time from 6 cycles to 1/4 cycle.

Workers must also consider examining the flash protection boundary for low levels of arcing faults. Low level faults, below the current limiting threshold of a fuse or the instantaneous trip circuit breaker, will often produce a greater flash protection boundary than higher level faults. Consideration should also be given for how long a worker could be exposed to an arc, based upon the location of the worker.

For example, is the worker standing in front of the switchboard or is he or she kneeling or lying down in front of the gear? Is the worker on the ground or up in a bucket working on a bus duct? Can the worker easily escape the room or could he or she become trapped in the vault?

Most electrical systems have a main overcurrent device and disconnecting means. If it is possible to create a fault on the line side of the main, the opening time and let-through characteristics of the overcurrent device which feeds the main device should be considered. (see Example 3)

Example 3: A 10HP motor starter uses an instantaneous trip circuit breaker for its main overcurrent device and disconnecting means. Even though this breaker has an opening time of approximately 1/2 cycle (.0083 sec), it cannot be used for the flash distance calculation. This is because it may be possible for a fault to be created on the line side of the device.

If this starter is fed from a 400 ampere air frame circuit breaker with short time delay set at 12 cycles (.2 sec.), the time which must be used in the flash distance calculation would be .2 seconds. That's the time it would take for the 400 ampere device on the line side to clear a fault if the fault occurred on the line side of the instantaneous trip breaker. The full available fault current, at the line side of the instantaneous trip breaker, would be used in the formula because the 400 amp breaker takes too long to operate and would not be current limiting. The NFPA 70E suggests clearing times for current limiting fuses of 1/4 cycle and for 5KV and 15KV circuit breakers of 6 cycles. Industry accepted values for other devices are as follows:

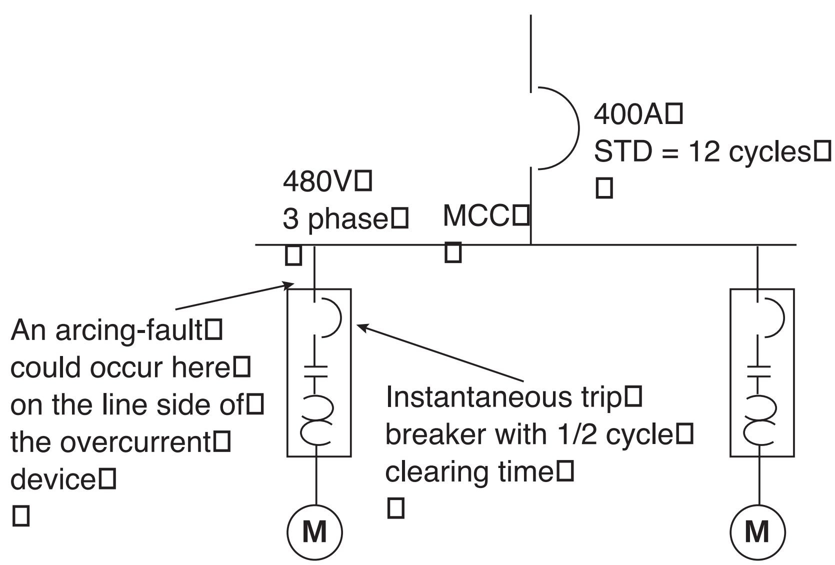


Figure 4: Fault on the Line Side of the Motor Controller

Where equivalent RMS let-through data is available, it can be used in the flash distance formula. Where data is unavailable, the full available short circuit should be used.

Table VIII. Industry Accepted Minimum Opening Times

TYPE OF DEVICE	TIME (Seconds)
Standard molded case circuit breakers (600 volt & below) • without short time-delay (STD) • with short time-delay (STD)	 .0083-.0167 STD Setting
Insulated case circuit breakers (600 volt & below) • without short time-delay • with short time-delay	 .033 STD Setting
Low voltage power (air frame) circuit breakers (600 volt & below) • without short time-delay • with short time delay	 .05 STD Setting
Current limiting molded case circuit breaker (600V & below)	.004

D. Personal Protective Equipment

OSHA recognizes that on occasion, electrical work must be performed while the equipment or circuit is energized. Effective procedures, Personal Protective Equipment (PPE), and personnel training are key elements for executing live work without injury. Consider these issues when designing electrical systems. In addition to PPE, specification of electrical system components that offer "Finger-Safe" IP2X terminals, covers and shrouds will help to provide additional protection to avoid injury or incident.

Flash Protection - Arc flash events are unpredictable. The only effective method for preventing an arc flash event is to de-energize the circuit. While it is not always possible to de-energize the circuit, it is best to first reduce the arc-flash energy exposure with the use of current-limiting devices. Consensus standards require that any body part within the arc flash boundary area be protected using appropriate PPE. OSHA standards outlining PPE are provided in Table X. NFPA 70E identifies PPE that should be worn in Part II, Chapter 3.

The following table (see Table IX) rates various Protective Clothing Systems. The Hazard Risk Category, can be matched up with 5 pages within NFPA 70E (Tables 3-3.9.1 & 3-3.9.2) which provide a risk category for common tasks and corresponding clothing systems. The values in cal/cm^2 can be compared to the results of calculations mentioned previously from the Doughty, Neal and Floyd PCIC paper. The following, from that paper, applies to arcs in a cubic box.
$E_{MB}=1038.7D_B^{-1.4738}t_A[0.0093F^2-0.3453F+5.9675]$ where E_{MB}=incident energy, cal/cm^2 D_B=distance, inches (for distances ≥ 18 inches) t_A=arc doration, seconds F=bolted fault short circuit current, kA (16-50kA)

Bussmann Safety BASICs

Table IX. Protective Clothing Characteristics (NFPA70E-2000, Table 3-3.9.3)

	Typical Protective Clothing Systems		
Hazard Risk Category	Clothing Description (Number of clothing layers is given in parentheses)	Total Weight oz/yd^2	Minimum Arc Thermal Performance Exposure Value (ATPV)* or Breakopen Threshold Energy (E_{BT})* Rating of PPE cal/cm^2
0	Untreated cotton (1)	4.5 - 7	N /A
1	FR shirt and FR pants (1)	4.5 - 8	5
2	Cotton underwear plus FR shirt and FR pants (2)	9 -12	8
3	Cotton underwear plus FR shirt and FR pants plus FR coverall (3)	16 - 20	25
4	Cotton underwear plus FR shirt and FR pants plus double layer switching coat and pants (4)	24 - 30	40

*ATPV is defined in the ASTM P S58 standard arc test method for flame resistant (FR) fabrics as the incident energy that would just cause the onset of a second degree burn (1.2 cal/cm2). EBT is reported according to ASTM P S58 and is defined as the highest incident energy which did not cause FR fabric breakopen and did not exceed the second-degree burn criteria. EBT is reported when ATPV cannot be measured due to FR fabric breakopen.

Table X. Listing of OSHA Standards for Protective Equipment

- OSHA 1910.38 - Employee Emergency Plans and Fire Prevention Plans
- OSHA 1910.95 - Hearing Protection
- OSHA 1910.132 - Personal Protection Equipment - General Requirements
- OSHA 1910.133 - Eye and Face Protection
- OSHA 1910.134 - Respiratory Protection
- OSHA 1910.135 - Head Protection
- OSHA 1910.136 - Foot Protection
- OSHA 1910.138 - Hand Protection
- OSHA 1910.146 - Permit Required Confined Spaces
- OSHA 1910.147 - Lockout/Tagout
- OSHA 1910.151 - Medical Services and First Aid
- OSHA 1910.212 - Machine Guarding
- OSHA 1910.331-335 - Electrical Protection
    - OSHA 1910.331 - Scope
    - OSHA 1910.332 - Training
    - OSHA 1910.333 - Selection and Use of Work Practices
    - OSHA 1910.334 - Use of Equipment
    - OSHA 1910.335 - Safeguards for Personnel Protection

Table XI. Standards on Protective Equipment (Table 3-3.6 in NFPA 70E)

Subject	Number and Title
Head Protection	ANSI Z89.1, *Requirements for Protective Headwear for Industrial Workers*, 1997
Eye and Face Protection	ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, 1989
Gloves	ASTM D120, *Standard Specification for Rubber Insulating Gloves,* 1995
Sleeves	ASTM D1051, *Standard Specification for Rubber Insulating Sleeves*, 1995
Gloves and Sleeves	ASTM F496, *Standard Specification for In-Service Care of Insulating Gloves and Sleeves,* 1997
Leather Protectors	ASTM F696, *Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens*, 1997
Footwear	ASTM F1117, *Standard Specification for Dielectric Overshoe Footwear*, 1993 ASTM Z41, *Standard for Personnel Protection, Protective Footwear*, 1991
Visual Inspection	ASTM F1236, *Standard Guide for Visual Inspection of Electrical Protective Rubber Products*, 1996
Apparel	ASTM F1506, *Standard Specification for Protective Wearing Apparel for Use by Electrical Workers When Exposed to Momentary Electric Arc and Related Thermal Hazards*, 1998

ANSI-American National Standards Institute
ASTM-American Society for Testing and Materials

Any body part extended within the appropriate risk boundary must be protected from the hazard(s) existing within that boundary. If a hand is within the arc flash boundary, then the hand must be protected by PPE. If a person's head is within the arc flash boundary, the head must be protected. Unless the electrical equipment is placed into an "Electrically Safe Work Condition", locked out, tagged, and tested for voltage per proper procedures, the system must be considered unsafe, requiring proper protective equipment to be used.

NFPA 70E also makes it clear (section 2-3.5 and 2-3.6) that conductive materials, tools and equipment that are in contact with any part of an employee's body be handled in a manner that will prevent accidental contact with exposed energized conductors or circuit parts. This includes articles of jewelry such as rings, conductive watchbands and metal frame glasses. In most instances, wearing flame-resistant clothing continuously is an effective safety measure for personnel who are frequently exposed or potentially exposed to arc flash.

Note: OSHA 1910.335 (a) (1) (I)
Employees working in areas where there are potential electrical hazards shall be protected 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.

Table XII. Standards on Other Protective Equipment
(Table 3-4.11 in NFPA 70E)

Subject	Number and Title
Ladders	ANSI A14.1, *Safety Requirements for Portable Wood Ladders*, 1994 ANSI A14.3, *Safety Requirements for Fixed Ladders*, 1984 ANSI A14.4, *Safety Requirements for Job-Made Ladders,* 1992 ANSI A14.5, *Safety Requirements for Portable Reinforced Plastic Ladders*, 1992
Safety Signs and Tags	ANSI Z535, *Series of Standards for Safety Signs and Tags*, 1998
Blankets	ASTM D1048, *Standard Specification for Rubber Insulation Blankets*, 1998
Covers	ASTM D1049, *Standard Specification for Rubber Covers,* 1998
Line Hoses	ASTM D1050, *Standard Specification for Rubber Insulating Line Hoses, 1990*
Line Hoses and Covers	ASTM F478, *Standard Specification for In-Service Care of Insulating Line Hose and Covers*, 1992
Blankets	ASTM F479, *Standard Specification for In-Service Care of Insulating Blankets,* 1995
Fiberglass Tools/ Ladders	ASTM F711, *Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Use in Line Tools*,1989 (R 1997)
Plastic Guards	ASTM F712, *Test Methods for Electrically Insulating Plastic Guard Equipment for Protection of Workers*, 1988 (R 1995)
Temporary Grounding	ASTM F855, *Standard Specification for Temporary Protective Grounds to Be Used on Deenergized Electric Power Lines and Equipment*, 1997
Insulated Hand Tools	ASTM F1505, *Specification for Insulated Hand Tools*, 1994

ANSI-American National Standards Institute
ASTM-American Society for Testing and Materials

PPE should be maintained in accordance with requirements contained in the above table. It should be noted that the standards contained in this Table XII are the base standards used by OSHA to generate 29 CFR 1910.137 - Personal Protective Equipment. The same information served as the basis for 29 CFR 1910.269 (generation, transmission, and distribution).

In addition to the PPE contained in 1910.137, 1910.269 suggests that in event of exposure to arc flash, clothing must be worn that does not increase the degree of injury. Without directly saying it, these words effectively mandate flame-resistant clothing be worn on any body part within the arc flash boundary.

E. Hazard/Risk Analysis

Every electrical safety program must include a procedure for analyzing the risks and hazards associated with each job. This analysis must include an evaluation of hazards, work procedures involved, special precautions, energy source controls and PPE requirements. A more extensive analysis shall be conducted if the work is complicated, particularly hazardous or the employer can not be expected to recognize and avoid the hazard involved.

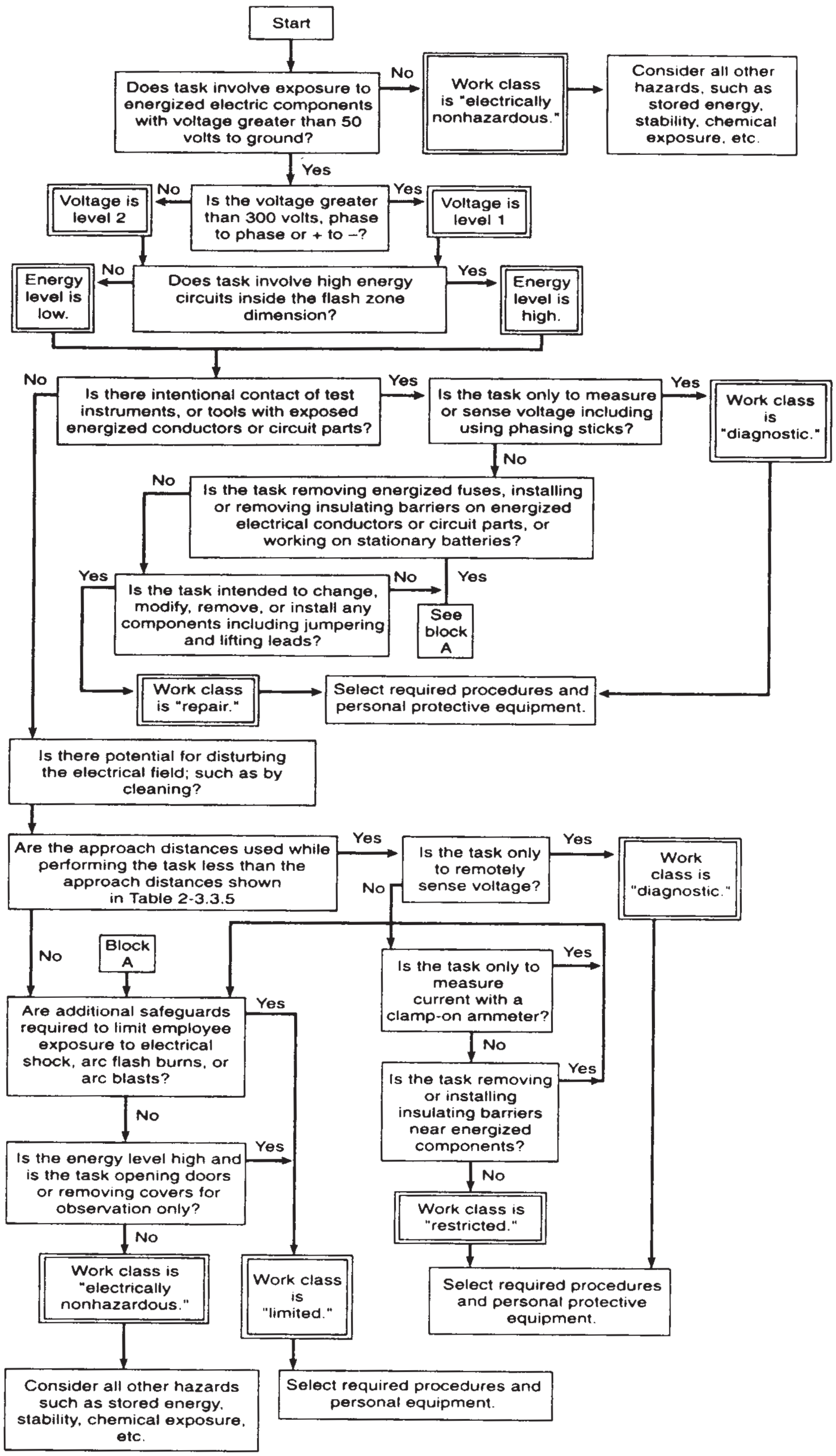
The hazard/risk analysis can only be performed after the task planning process is complete. In concept, each step of a task should be analyzed in accordance with a defined protocol. Each step of the protocol should take a step closer to understanding if a risk is associated with the task. In performing a hazard/risk analysis, analyzing the exposure to electrical hazards must be the main focus.

Identifying the necessary PPE is also important to protect the person should there be an accidental release of energy. For instance, the first step should be to determine if the equipment or service must remain energized while the task is executed. When the questions are answered, the task will be defined in terms of the amount of voltage and energy available in the system while the work is executed.

The analysis should identify a work class. PPE should then be selected based upon that information. Using the information contained in NFPA 70E, appropriate PPE must be selected and worn during the time the work is executed. It should be noted that the preferred work practice is to establish an electrically safe work condition prior to executing the task. It should also be noted that PPE might be necessary until the electrically safe work condition is established.

The following sample risk/hazard analysis flow diagram is offered as a beginning point (see Figure 5).

Figure 5. Risk/Hazard Analysis (Figure D-2 Part II, Appendix D - NFPA 70E)



Bussmann Safety BASICs

F. Lockout/Tagout

Procedure OSHA 1910.147 for applying the Lock/Tag

The Lockout/Tagout Standard has been in effect since 1989. It was created to help reduce the death and injury rate caused by the unexpected energization or start-up of machines, or the release of stored energy. Normal production operations, cords and plugs under exclusive control, and hot tap operations are not covered. This standard applies to energy sources such as electrical, mechanical, hydraulic, chemical, nuclear, and thermal.

Lockout is the placement of a key or combination lock on an energy isolation device (disconnect switch, circuit breaker, etc.) to ensure that the energy isolating device and equipment being controlled cannot be operated until the lockout device is removed. Lockout devices hold an energy isolating device in a safe position and prevent the energization of a machine or equipment. The lockout device must be substantial enough to prevent removal without use of excessive force or unusual techniques.

Tagout is the placement of a tag or other prominent warning device and a means of attachment on an energy isolation device to indicate that the energy isolating device and the equipment being controlled may not be operated until the tagout device is removed. Tagout devices shall be non-reusable, attached by hand, self-locking, and non-releasing with a minimum unlocking strength of no less than 50 pounds and must be at least equivalent to an all-environment tolerant nylon cable tie.

Lockout devices must be used unless the employer can demonstrate that the utilization of a tagout system will provide full employee protection.

Applying the Lock/Tag

Step 1 - *Before the Shutdown:* Before an authorized or affected employee turns off machinery or equipment, they should have knowledge of the type and magnitude of energy, the hazards of the energy to be controlled, and the method or means to control the energy. It may be helpful to have floor drawings, one line diagrams and the assistance of the facility electrician and employees who work with the equipment.

Step 2 - *Powering Down:* The machine or equipment shall be turned off or shut down in an orderly manner using established procedures.

Step 3 - *Isolating the Power Source:* All energy isolating devices that are needed to control the energy to the machine or equipment shall be physically located and operated in such a manner as to isolate the machine or equipment from the energy source(s). This involves flipping a power switch, breaking a circuit, closing a valve, etc. If the equipment has more than one shutdown point, be sure that all are isolated from power.

Step 4 - ***Applying the Lock and/or Tag:*** Lockout or tagout devices shall be affixed to each energy isolating device by authorized personnel. Lockout devices, where used, shall be affixed in a manner that will hold the energy isolating devices in a "safe" or "off" position. Tagout devices, where used, shall be affixed in such a manner as will clearly indicate that the operation or movement of energy isolating devices from the "safe" or "off" position is prohibited.

Step 5 - ***Releasing Residual Energy:*** Following the application of lockout/tagout devices, all potentially hazardous stored or residual energy shall be relieved, disconnected, restrained, and otherwise rendered safe. If there is a possibility of reaccumulation of stored energy to a hazardous level, verification of isolation shall be continued until the servicing or maintenance is completed, or until the possibility of such accumulation no longer exists.

Step 6 - ***Try to Power Up:*** Prior to starting work on machines or equipment that have been locked out or tagged out, authorized personnel shall verify that isolation and de-energization of the machine or equipment has been accomplished. This requires personnel to turn all controls of the equipment or machinery in the "ON" position to ensure that all energy sources have been isolated and that it will not start up while work is being performed on it. Before trying to power up, be sure that no one is near the equipment or machinery in case the equipment continues to have power. Lastly, the employee should verify that the isolation point cannot be moved to the "ON" position. The employee can then perform his servicing or conducting maintenance work.

Removing the Lock/Tag

Step 1 - ***Machine and/or Equipment Inspection***: Inspect the work area to ensure that all nonessential items (tools, spare parts, debris, etc.) have been removed, and that machine or equipment components are operationally intact.

Step 2 - ***Give Notification to Personnel***: Notify all personnel in the vicinity before removal of the lockout and start up. Be sure that no one is in the way of possible danger upon start up.

Step 3 - ***Remove the Lockout/Tagout Device***: Each lockout/tagout device should be removed by the person who placed it. When more than one person has applied a lock, the last person to remove his lock should remove the hasp or other multiple lock device. When all locks have been removed and the machine/equipment is determined to be operating safely, other personnel may be notified that the equipment is now operational.

G. Stored Energy Systems

Simply because the electrical circuit has been opened may not mean the system is safe to work on.

- Capacitors may store hazardous energy, even after the equipment has been de-energized and may build up a dangerous residual charge without an external source.
- Capacitors may also be used to store large amounts of energy. An internal failure of one capacitor in a bank frequently results in an explosion when all other capacitors in the bank discharge into the fault.
- High-voltage cables should be treated as capacitors because they have capacitance and thus can store energy.

H. IP2X (Finger-Safe) Ratings

The NPFA 70E requires that a guard be used to prevent access to voltages above 50 volts. Guarding and the installation of insulating barriers must be completed if work is to be performed while the equipment is energized.

Note: *The placement of barriers may effectively protect personnel from shock hazards, but may not protect personnel from arc-flash hazards. Therefore, placement of barriers may reduce the chance for electrical shock but does not always eliminate the requirements of flash protection if the task involves work inside the flash hazard boundary.*

Guarding however may also prevent accidental contact by tools and other conductive materials that could cause an arc-flash. A practical approach to providing these guards would be to adopt standards which address this issue. **IEC 60204-1** is a standard written for Electrical Equipment used in Industrial Machines. Section 6 of the standard refers to the requirements for protecting people against electrical shock. In general, electrical equipment must provide protection against people coming into direct or indirect contact with energized electrical parts within an enclosure.

When working in an enclosure with energized components the standard requires the worker to be protected against contact to at least **IP1X** *(The letter 'X' here is used in place of the second number to indicate that tests for ingress of liquid is not required, or applicable)*. Live parts that could easily be touched while resetting, adjusting or replacing nearby components must provide protection against direct contact to at least an **IP2X** rating.

IP2X is often referred to as "Finger-Safe" meaning that a probe, the approximate size of a finger, must not be able to access or make contact with hazardous energized parts. The standard detailing the rating system used is IEC 529. Principally, this standard defines the degree of protection provided by an enclosure (barriers/guards) classified under the International Protection (IP) Code and the testing conditions required to meet these classifications.

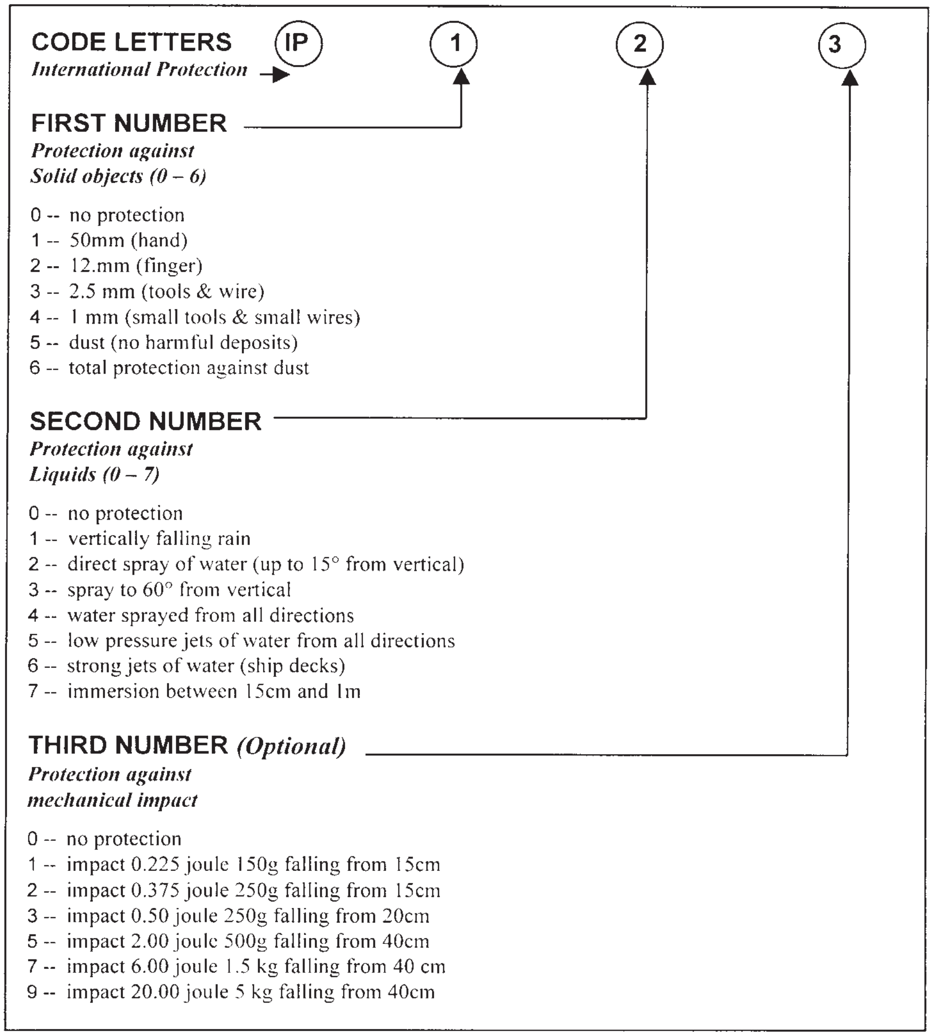


Figure 6. IP Environmental Ratings for Enclosures (IEC 529)

*Note: The terminology used for this program includes the term **"Finger-Safe"** for any product with an IP2X designation. IP20 rated products represent products with no protection against liquids.*

I. Grounding and Ground Fault Circuit Interrupters (GFCI)

A key element of a safe installation is effective grounding. The term "ground" has many different meanings, but all are related to a connection with the earth. Ground is used to refer to a return path used for fault to enable the proper operation of an overcurrent device.

Safety Grounding Equipment

It is important to minimize any voltage difference between adjacent or nearby conductive points. In order to avoid a voltage difference (shock), a low impedance path is required between the two (or more) conductive surfaces. Should a person be in contact with both surfaces when a fault occurs, no significant voltage is impressed across the person's body, eliminating possible current flow.

Protecting Equipment Grounding Conductors (EGC)

The discussion of safety is not complete without an analysis of equipment grounding conductors. Table 250.122 of the 2002 NEC provides minimum sizing for equipment grounding conductors. As noted below the table, equipment grounding conductors may need to be sized larger in order to "be capable of safely carrying the maximum fault likely to be imposed on it". (Section 250.4(A)(5))

In order for the fuse to open or the circuit breaker to operate properly, a low impedance equipment grounding conductor must be available for fault current to return to its source. Otherwise, any equipment experiencing a fault will become energized at the system voltage, presenting a shock hazard for the employee. Providing protection for the equipment grounding conductor therefore is a safety issue. Using a current-limiting, overcurrent device is the best way to reduce the energy that could be seen by the grounding conductor.

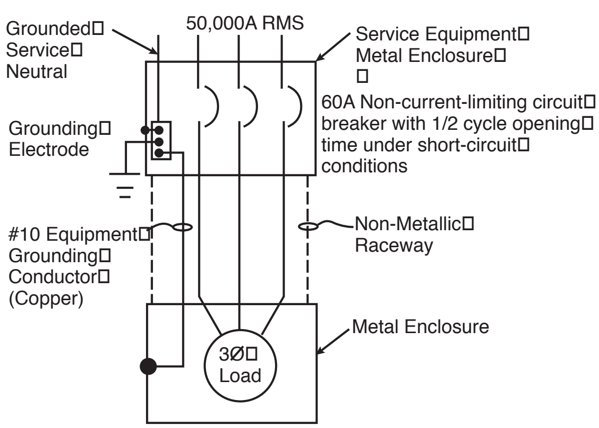


Figure 7: Violates Section 110.10 and 250.4(A)(D)

Would need to increase Equipment Grounding Conductor to a #2 copper to remain tight under the lug after the fault occurs

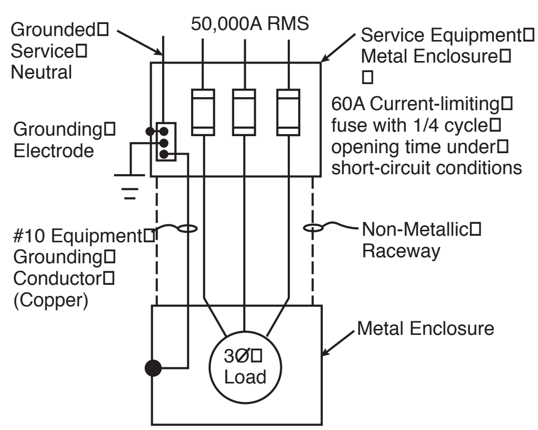


Figure 8: Complies with NEC Section 110.10 and 250.4(A)(5)

The problem of protecting equipment grounding conductors was first recognized more than 30 years ago when Eustace Soares wrote a popular grounding book called, “Grounding Electrical Distribution Systems for Safety”. In his book, he states that the “validity” rating corresponds to the amount of current and time required to cause a copper conductor to become loose under a lug after the conductor has had a chance to cool down after a fault. This validity rating is based upon raising the copper temperature to 250˚C (the annealing point of copper) and then reducing the temperature back to normal running temperatures.

Good engineering practice then requires an investigation of the adequacy of the important ground return path. Let-through currents for overcurrent protective devices must be compared with the short-circuit ratings of the equipment grounding conductors. Wherever let-through values exceed the “minimum” equipment grounding conductor withstand ratings, the equipment grounding conductor size must be increased until the withstand ratings are not exceeded.

Ground Fault Circuit Interrupters (GFCIs)

GFCIs are designed to protect a person from electric shock when he or she simultaneously contacts a “live” (usually 120 V) wire or part and a grounded object. The GFCI works by sensing a difference between the supply and return currents. When the difference exceeds 4 - 6 mA, indicating that current is flowing to ground (through the person), the device is designed to open the circuit.

GFCIs do not protect against a line-to-neutral or a line-to-line shock. Although the GFCI is an effective safety device, it is not a guarantee against shock in every situation. In addition, if GFCI protected equipment contains transformers, a ground fault (shock) on the secondary side of the transformer may not trip the GFCI.

GFCIs are normally installed as either circuit breakers or receptacles. In either case, the GFCI may be wired to protect multiple receptacles. Individual GFCI plug-in adapters are also available.

J. Voltage Testing—1,000 Volts and Below

Three basic safety issues are associated with the task of testing for voltage in instances where the maximum voltage level is 1,000 volts and below. The first issue involves selecting and using the right meter for the job at hand; the second issue is protecting the person from potential exposure to an energized source; and the third issue is the work process of executing the test.

On occasion, voltage-testing devices can be the source of an incident or injury, as in the following instances:

- Leads can fall out of their plugs and initiate a phase-to-phase short circuit.
- Internal components can fail, resulting in a phase-to-phase short circuit.
- Probes can slip while a reading is being observed.
- Leads can be inserted into incorrect plugs, resulting in failure.
- The device indication can be confusing, resulting in incorrect observations.
- Hands can slip off the probe.

The selected voltage-testing device must minimize all of these possibilities.

When a voltage test is performed, the person should perform the work practice as if the energy source is present (source is energized). Even if the disconnecting means has been opened, until the absence of voltage has been satisfactorily verified, a safe work condition does not exist. The person performing the test should be protected from any accidental release of energy until the absence of voltage has been satisfactorily verified.

Selection of a voltage-testing device

Voltage testers should be selected based upon the intended use. Several types of voltage testers are manufactured for specific uses, and each device has limitations. When used to test for the absence or presence of voltage as a part of establishing an electrically safe work condition, voltage testers should have the following characteristics where direct contact can be made:

- Retractable, insulated-tip test probes
- Self-contained fault protection or limitation devices, such as internal current-limiting fuses or probe current-limiting resistors
- Voltage/current path from the probes that is not routed through the mode switch

In addition, voltage testers should conform to national consensus standards, such as UL 1244, MIL-T-28800C.

Along with the above requirements, voltage testers that are used only to test for the absence or presence of voltage should have the following characteristics:

- Single-function, voltage-only test devices or automatic mode devices that check for voltage before switching to other modes (i.e., resistance, continuity)
- Test leads that cannot be improperly connected (i.e., only two jacks are present or leads are permanently connected)

NOTE: High-impedance voltage testers are subject to "phantom" readings from induced voltage. Verification of the absence of voltage may required with a low-impedance voltage tester, such as a solenoid-type voltage tester. Solenoid Testers may have an adverse effect on digital control systems (DCS), programmable logic controllers (PLC), or similar equipment.

NOTE: Solenoid-type voltage testers typically are assigned a "duty cycle" by the manufacturer. In most instances, this duty cycle is 15 seconds. The "duty cycle" rating must not be exceeded.

Personal protective equipment

Prior to opening doors or removing covers for access to electrical conductors, a person should conduct a hazard analysis. The hazard analysis should be as formal and detailed as warranted by the task to be performed. Any personal protective equipment (PPE) necessary to avoid injury should be in place and worn before any existing enclosure is abridged, i.e., removing any cover or opening any door. The hazard analysis must consider both shock and arc flash.

NOTE: Many arc-flash incidents occur at the moment a door is opened or a cover removed. The person performing the test should be aware of this fact and exhibit an appropriate mind set. The mind set should consider that all electrical conductors and contact points within the enclosure are energized.

In determining appropriate PPE, the hazard anaalysis must consider the arc-flash boundary as well as the shock approach boundaries, paying particular attention to the prohibited and restricted. Where the task involves measuring a voltage, the probes, of course, cross the prohibited boundary. Therefore, the person must be protected from unintended contact with conductive parts. Voltage-testing devices that meet the above criteria include a preventive method to minimize the possibility of a person's hand or fingers slipping down the probes. Therefore, electrical insulation is not necessarily required. However, if hands (or other body parts) are inside the enclosure while the person is executing the task, some exposure to shock exists through unintentional contact with energized or potentially energized parts. Voltage-rated gloves should be worn. They do not hinder the task and can avoid unintentional contact with electrical conductors or contacts.

In every instance where an electrical circuit is present, an arc-flash boundary exists. Depending upon the arc-flash boundary, flash-protective equipment should be worn. Any body part that is within the arc-flash boundary must be protected from arc flash. If the arc-flash boundary is 2 inches or less, leather gloves and ordinary safety glasses for the eyes provide sufficient protection. As the arc-flash boundary extends beyond 2 inches, flame-resistant clothing and face protection should be worn. Leather gloves that are one component of voltage-rated gloves provide arc-flash protection for hands. Therefore, appropriate voltage-rated gloves should be worn. *Voltage-rated gloves selected in accordance with ASTM D 120 provide protection from both shock and arc flash, in most instances.*

NOTE: Class 00 gloves have a voltage limit of 500 volts and are adequate in many instances for measuring voltage.

Executing the task

The person testing for voltage should be trained to understand how the meter works and what each possible meter indication means. After the person selects the appropriate volt meter, reacts to the hazard analysis, and understands how to interpret any meter indication, he or she should execute the following sequence of steps:

1. Open the disconnecting means.

2. Open door or remove cover(s)

3. Inspect the compartment interior for missing barriers, signs of arcing or burning, and any extraneous parts or components.

4. Inspect the voltmeter and probes for signs of mistreatment; verify that the probe covers move freely.

5. Insert one probe into the holder on the meter; place the meter in a stable position or ask a second person to hold the meter, if necessary, to see the indication. (Any second person must wear the same PPE as the first person.)

6. Verify that the voltmeter functions satisfactorily on a know energized voltage source.

NOTE: If the meter is auto ranaging, a nearby 110-volt receptacle is satisfactory. If not auto ranging, the known source must be within the same voltage range.

7. Place the probe that is in the meter holder into good physical contact with a grounded point within the compartment.

8. Place the second probe into good physical contact with the opened side of the disconnecting means and before (ahead of) any fuses or any other circuit element.

NOTE: Normally, in the case of a disconnect switch, the movable side of the knife blades is available to contact with the probe. In case of a circuit breaker, the load conductor termination should be contacted.

9. Read and interpret the meter indication.

10. Repeat steps 7 and 8 for phases B and C.

11. Place the probe that is in the meter holder into good physical contact with phase A on the opened side of the disconnecting means and before (ahead of) any fuses or other circuit element.

NOTE: Normally, in the case of a disconnect switch, the movable side of the knife blades is available to contact with the probe. In case of a circuit breaker, the load conductor termination should be contacted.

12. Place the probe in the meter holder into good physical contact with phase B in the same relative physical location.

13. Repeat steps 11 and 12, except contact phases B and C.

14. Repeat steps 11 and 12, except contact phases A and C.

NOTE: Tests for absence of voltage should be conducted at each point within the enclosure. If the compartment contains fuses, a voltage test should be conducted at both the line and load sides of each fuse, both between phases and between each phase conductor and ground. Each test should be taken at the fuse clip instead of at the fuse ferrule (endbell).

15. Measure voltage between each point within the enclosure where contact is expected.

16. Verify that thevolt meter functions satisfactorily on a know energized voltage source.

NOTE: If the meter is auto ranging, a nearby 110-volt receptacle is satisfactory. If the meter is not auto ranging, the know energized source must be within the same voltage range.

Troubleshooting tips
When it is suspected that a fuse has opened, both indicating and nonindicating fuses should be removed from the circuit and checked for continuity. In some knife blade fuse constructions, both the fuse barrel and endcap are insulated. Care must be taken to make certain that any measurements are taken from the uninsulated portion of the device such as the fuse terminal (knifeblade) or at the fuse clip instead of the ferrule.

To minimize exposure to electrical hazards, troubleshooting should be performed on deenergized equipment, where possible. Resistance measurements are as reliable as voltage measurements.

VII. Establishing an Electrical Safety Program

Reducing and even eliminating exposure to electrical hazards requires continuous attention. An overall electrical safety program must be implemented that emphasizes specific areas of concern. The program must be well thought out and based upon solid principles, resulting in a program which includes an action plan and required tasks. People who are well-versed in safety standards and procedures must write the program. Program authors should include safety professionals, technical professionals, and practitioners. And the program must be published and readily available to all employees.

This page does not PRINT!

This page does not PRINT!

There are at least three good reasons for practicing electrical safety:

- Personal reasons, which affect us as caring individuals and employers
- Business reasons, because safety makes good business sense
- Regulatory and legal reasons, because violations can result in fines and / or imprisonment.

An essential element in an effective electrical safety program is training. From both a legal and effective point of view, training records are important. Training should be based on the program and procedures in place within an organization. The training should focus first on building knowledge and understanding of electrical hazards and second on how to avoid exposure to these hazards. As a person completes a specific segment of training, a record should be established and maintained.

There are five objectives of an electrical safety program:

- To make personnel aware that there are rules, responsibilities and procedures for working safely in an electrical environment.
- To demonstrate the employer's intention to fully comply with the federal law.
- To document general requirements and guidelines for providing workplace facilities free from unauthorized exposure to electrical hazards.
- To document general requirements and guidelines to direct the activities of personnel, who could be deliberately, or accidentally, exposed to electrical hazards.
- To encourage, and make it easier for each employee to be responsible for his or her own electrical safety self-discipline.

VIII. Planning Work Procedures

All electrical work should be planned before the work begins. For non-hazardous electrical work, the plan is typically unwritten. Written or not, all plans must consider all hazards and guard against them. Jobs that are done repeatedly should have a written procedure, which is followed each time the work is performed. If at any time the plan is not clear, all work must stop and the plan reviewed.

A. Procedures

Procedures typically come in two varieties: plans written specifically for a particular job, or one that may take the form of a more general procedure which may include a check list or simply a verbal plan.

Written procedures should be prepared by a person who understands the work to be done and the hazards involved (qualified person). He, or she, should also be familiar with the equipment being worked on. Procedures for work performed should be reviewed with the appropriate individuals responsible.

Written procedures must include a step-by-step outline of the work to be performed and a one-line diagram or other appropriate drawings to be used to discuss the job.

B. Documentation

When planning electrically hazardous tasks, the following documentation may be required:

- **Hazard/Risk Analysis**. This will include a review of the available hazards including a flash hazard analysis.
- **Approach Distances to Exposed Energized Electrical Conductors and Circuit Devices**. Use Table VII for these distances. Note: the flash hazard boundary can be calculated using the formulas in section VI, C. of this handbook.
- **Requirements Checklist for Electrical Hazardous Tasks**. This should be a checklist developed by the proper authorities, which outlines the protection requirements, requirements for review and approval, etc. for various work tasks, voltage levels and approach boundaries, etc.

IX. Principles for Safety

Electrical safety starts with training, planning and education. To reduce electrical hazards, we need to address each hazard as the work is being assigned and planned. An excellent overview of electrical safety requirements can be found in 29 CFR Parts 1910.331 - 1910.335, “Safety-Related Work Practices.” These requirements contain information on “qualified” vs. “unqualified” persons, training requirements, work practice selection, use of electrical equipment, and safeguards for personnel protection. If these requirements had been followed completely few, if any, injuries or deaths would occur.

Shock and Burn Recommendations:

- Review programs for the inspection and/or repair of portable electrical equipment for completeness and effectiveness.
- Review policies concerning work permits on “live” circuits with a goal of reducing the frequency of such work.
- Emphasize electrical worker training in certain areas such as the following:
    - Lockout/tagout practices
    - Use of protective equipment
    - Use of insulated tools

- Minimum approach distances
- Meter selection/testing/use
- Electrical rescue/CPR
- Include a pre-task review of the following for supervision of selected electrical work:
    - Goals of the task
    - Task methodology (live vs. lockout/tagout)
    - Qualifications of assigned personnel - proper instrumentation/tools
    - Adequate protective equipment and usage
    - Methods of preventing a fall should a shock occur
    - Perform an inventory of energized electrical circuits with a goal of disconnecting unused circuits from the source and removing the wiring

Employees should be provided training that covers information regarding electrical risks such as inadequate grounding and reverse polarity and likely electric shock producing equipment, including extension cords, plugs, and portable power tools. The dangers of energized and unattended appliances should be stressed in this training as well as the theory behind lockout and tagout procedures. Employees working with electricity must also be informed on how to recognize electric shock victims, safe methods of rescue, and cardiopulmonary resuscitation.

A. TRAINING, PLANNING AND WRITTEN PROCEDURES

Here are some principles which, when implemented, will help ensure proper preparation for working on electrical equipment:

1. **PLAN EVERY JOB**. Most accidents occur when something unexpected happens. Take time to prepare a plan that considers all possible eventualities. Before you start the job, think about each step and try to visualize the potential for a hazard. Conduct a “Flash Protection Boundary” analysis. NFPA 70E Section 2-1.3.3.2 has requirements to define the safe work distance from potential arc hazards.

2. **ANTICIPATE UNEXPECTED RESULTS**. When thinking about a job, break each task into small steps. Understand that plans can change, so be ready to modify the plan if necessary. Make sure that everyone involved in the job is working according to the same plan. Whenever work is required near an electrical hazard, a written plan is needed to outline the scope of the job.

3. **USE PROCEDURES AS TOOLS**. Procedures are the best way to help you prepare, execute, and complete the job. Like any tools, make sure your procedures are maintained.

4. **<u>IDENTIFY THE HAZARD</u>**. After your work plan is complete, review each step. Consider that the equipment might be perfectly safe under normal conditions and very unsafe when systems are not working properly. Also consider potential hazards that may be unrelated to electrical energy.

5. **<u>ASSESS PEOPLE'S ABILITIES</u>**. Any person assigned to tasks associated with electrical energy must be qualified and trained for the job at hand. He or she must be able to identify electrical hazards, avoid exposure to those hazards, and understand the potential results of all action taken. Don't forget to include yourself in this analysis. And don't forget to establish and maintain training records.

B. PROVIDING AN ELECTRICALLY SAFE WORK CONDITION

"Electrically Safe Work Condition" is a concept first introduced in a consensus standard, NFPA 70E. The concept embraces several ideas and suggests that six different steps must be taken before an electrical circuit is safe to touch without personal protective equipment. Electricians and other workers tend to believe that a circuit is safe to touch if it is deenergized. The fact that injuries continue rather frequently, based upon this belief, proves that additional steps are needed.

It seems people believe that if a lock and tag are placed on a labeled disconnecting means, the equipment is safe to work on. However, issues need to be considered. For example, labels can be marked incorrectly, equipment can be supplied from more than one source, or a temporary conductor could have been installed. It's also feasible that an unrelated energized circuit conductor could contact the conductor leading to the work area.

In still different instances, other workers or complicated systems can affect the work area. We sometimes take for granted that if the contact point is tested for absence of voltage, the point is safe for executing the task. But this only proves that there is no voltage present at the time of the voltage test. Voltage can be absent due to a process interlock being open, or a second source of energy could simply be turned off for the moment. Avoiding accidents and injury requires training, planning and preparation.

Section 2-1.1.3 of the NFPA 70E requires a process of six discrete and independent steps be executed prior to declaring the existence of an electrically safe work condition. Only after these six steps have been executed can work begin without possible exposure to an electrical hazard. The six steps are as follows:

- Determine all possible sources of energy. Review all reliable and up-to-date drawings, documentation, and identification tags and labels. Drawings must include ALL energy sources, including temporary and back up power sources.

- After properly interrupting the load, open all disconnecting devices for the circuit. At this point, the equipment or circuit is simply de-energized.
- Where possible, visually verify that all disconnecting devices, including drawout circuit breakers are open. Also check that all disconnecting devices meet proper codes and standards.
- Apply lockout/tagout devices in accordance with documented and established policy. An established policy is an enforced written procedure made available to all employees.
- Use adequately rated voltage testers to verify the absence of voltage on each point where physical contact is expected. Employees are required to use only voltage testing equipment that is rated by a third party.
- Where the possibility of induced voltage or stored energy exists, ground the phase conductors before touching them. Where it is reasonable to expect that the conductors could be re-energized due to accidental contact with another source of energy, install grounding devices rated for the available fault current.

Until these six steps have been adequately executed, there exists some potential of exposure to an electrical hazard

Here are some additional principles which, when implemented, will help to ensure a safe work area:

1. **USE THE RIGHT TOOL FOR THE JOB**. Use the appropriate tools for the job at hand, keeping them accessible and in good working condition. Using a screwdriver for a job that requires a fuse puller is an invitation to an accident.

2. **ISOLATE THE EQUIPMENT**. The best way to avoid an accident is to reduce exposure to hazards. Keep doors closed. Keep barricades in place. Install temporary voltage-rated blankets covering exposed live parts.

3. **PROTECT THE PERSON.** Use the proper personal protective equipment for the job. This may include safety glasses or goggles, head protection, voltage-rated gloves, safety belts and harness, or flame-resistant clothing.

4. **MINIMIZE THE HAZARD**. If it is impossible to establish an electrically safe work environment, be sure to shut down every possible energy source. Understand that sometimes a de-energized circuit can become re-energized and to do something to lessen the risk.

5. **AUDIT THESE PRINCIPLES**. A principle is something you believe in enough to be willing to do. Are you willing to take the steps necessary to avoid injury? Review these principles often. Add to them when necessary.

C. DESIGNING AN ELECTRICAL SYSTEM FOR SAFETY

Here are some principles which, when added to electrical system and equipment specifications, will improve safety for workers.

1. **ISOLATE THE CIRCUIT**. Electrical systems must be designed to support preventative maintenance, with easy access to the equipment. Designers need to make it easy to isolate equipment for repair with a disconnecting means that provides for proper implementation of lockout/tagout procedures.

A sound design provides disconnecting means at all motor loads. This is in addition to the disconnecting means required at the controller that can be locked in the open position. Disconnecting means at the motor provide improved isolation and safety for maintenance and for use in case of an emergency.

- **Isolate the Circuit - Motor Disconnecting Means**
  NEC 430.102 requires a disconnecting means within sight, and on the line side, of every low voltage motor controller. In general, a disconnecting means is also required in sight of every motor. There are exceptions for large industrial facilities with written electrical safety programs where only qualified personal work on equipment and for situations where the disconnect would introduce additional or increased hazards.

  It is good practice to place a disconnect at every motor or machine. This allows for the immediate shut down of a motor or machine if someone gets "caught-up" in the equipment. Can you imagine being hung-up in a machine and having to wait while someone runs some distance to a motor control center, tries to find the right bucket, and finally disconnects the circuit? Finally, some industrial plants do not allow a disconnect on the other side of an isle from the motor/machine, for those times when a lift truck might be blocking the aisle.

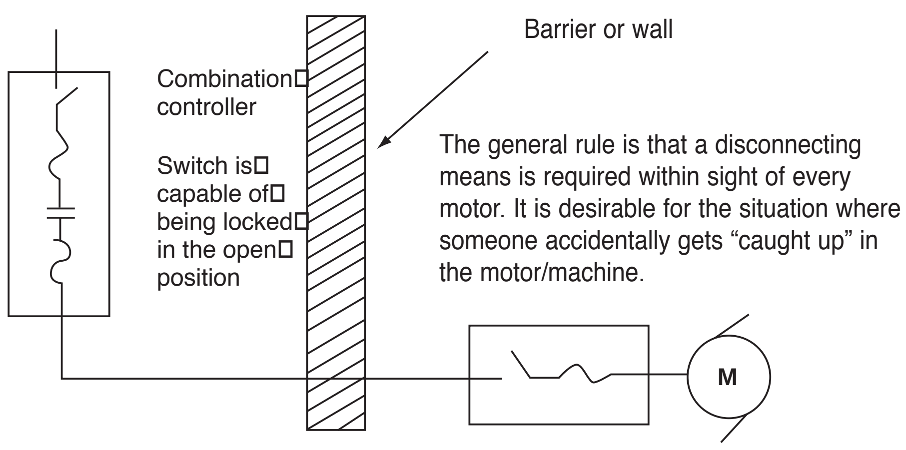


Figure 9: Use of Motor Disconnecting Means

An orderly system shutdown should also be required to minimize the hazards to personnel and equipment, resulting from an electrical event. To address this situation the National Electrical Code provides for a system of coordinated overcurrent protection devices.

- **Isolate the Circuit - Selective Coordination**

  Today, more than ever, one of the most important parts of any installation is the electrical distribution system. Nothing will stop all activity, paralyze production, inconvenience and disconcert people, and possibly cause a panic more effectively than a major power failure.

  Isolation of a faulted circuit from the remainder of the installation is MANDATORY in today's modern electrical systems. Power Blackouts cannot be tolerated.

  Isolating the faulted circuit can also be a serious safety issue. Per NEC 240.12, where an orderly shutdown is required to minimize hazards to personnel and equipment, a system of coordinated short-circuit protection shall be permitted.

  Therefore it is not enough to select protective devices based solely on their ability to carry the system load current and interrupt the maximum fault current at their respective levels. A properly engineered system will allow ONLY the protective device nearest the fault to open, leaving the remainder of the system undisturbed and preserving continuity of service.

  Selective coordination is considered the act of isolating a faulted circuit from the remainder of the electrical system, thereby eliminating unnecessary power outages. The faulted circuit is isolated by the selective operation of only that overcurrent protective device closest to the overcurrent condition.

2. <u>COVER EXPOSED COMPONENTS</u>. Equipment must be "Finger-Safe" (IP2X) where possible to avoid potential contact with energized conductors. It is not always possible to de-energize the equipment before working on it. If energized metal components could be exposed during routine maintenance, covers, shields, and insulating barriers must be used in accordance with safety standards.

   Insolating barriers provide increased protection from an electrical shock hazard. If possible, place the barrier on while the equipment is temporarily shut down. For new equipment, or equipment being modified, provide equipment that meets IP2X requirements.

   Note: The use of IP2X devices or the placement of insulating barriers may effectively protect personnel from shock hazards, but may not protect personnel from flash hazards. Therefore, the use of these devices may change the electrical shock hazard classification but does not always eliminate the requirements of flash protection if the task involves work inside the flash hazard boundary.

3. <u>LIMIT THE ENERGY</u>. Circuits should also be designed to limit the available arc-flash energy. The use of smaller or higher impedance transformers and current-limiting overcurrent devices will help to reduce the flash energy. This will provide improved protection for both equipment and employees.

   - **Limit the Energy - TYPE "2" - "No Damage" Coordinated Motor Starter Protection**

     Today's commercial and industrial facilities cannot afford unscheduled motor circuit downtime <u>caused by damaged equipment. Nor can they accept injury to individuals working on, or near, energized equipment</u>. To minimize unscheduled downtime, the engineer must choose branch circuit overcurrent devices that limit or prevent damage due to faults in motor circuits. Just because a starter is listed to UL 508 does not mean that the starter will be reusable after a fault occurs. In fact, UL 508 allows a significant amount of damage to occur. UL 508 allows contacts to be permanently welded and the overload relays to vaporize in the event of a fault.

     UL 508 testing is conducted within an approved enclosure. Damage to the motor starter is permitted within the following allowable damage criteria provided in the standard (UL 508 Table 53.1). This table includes the following items:

     – The motor control device may be inoperative at the conclusion of the test.
     – The contacts of the motor control device may weld or completely disintegrate.
     – Discharge of parts or any risk of a fire shall not occur.
     – The door or cover shall not be blown open, and it shall be possible to open the door or cover. Deformation of the enclosure is acceptable, but shall not result in the accessibility of live parts as determined by the use of the rods specified in 6.17.1 of the standard.

While this may be acceptable within an enclosure, work in or near these devices may be necessary when the enclosure door is open and the equipment is energized. The engineer must choose the level of protection required (Type “1” or Type “2”).

Today there’s a choice of protection (coordination levels). Both IEC 947-4-1 and UL508E (outline of investigation) differentiate between two types of protection (coordination levels) for motor circuits.

Type “1”

“Requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons (with enclosure door closed) or installation and may not be suitable for further service without repair and replacement of parts.” (Damage is allowed, requiring partial or complete component replacement. Short-circuit protective devices interrupt the fault current, but are not required to provide component protection. The requirements for Type “1” protection are similar to the requirements for listing to UL 508.)

Type “2”

“Requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons (with enclosure door closed) or installation and shall be suitable for further use.” (No damage is allowed to either the contactor or overload relay. Light contact welding is permitted, but contacts must be easily separable. “No damage”
protection for NEMA and IEC motor starters can only be provided by a “current-limiting” device.)

While Type “2” Coordination (“No Damage” Protection) cannot keep a short circuit from occurring, it does assure that all other components in the motor starter are not damaged under short circuit conditions. Simple “listing” to UL 508 does not assure that the starter won’t need to be replaced.

Motor starter manufacturers test combinations of contactors, overload relays and branch circuit protection to verify that they meet Type “2” coordination requirements. Tests are performed on both IEC and NEMA type devices. The tests include a low level and a high level (typically 100,000 amps) short circuit. Overload relays are tested before and after both short circuit tests to assure that they remain calibrated. Dielectric tests are also conducted to prove insulation integrity after both the high and low level short circuit tests.

NEC Section 110.10 states that the SCPD shall protect against *excessive damage* to down stream devices. (In Canada, refer to CEC Part 1 14-012 Appendix B)

- **Limiting the energy - with Current Limitation**
  Today, most electrical distribution systems are capable of delivering very high short-circuit currents, some in excess of 200,000 amperes. If the components are not capable of handling these short-circuit currents, they could easily be damaged or destroyed. The current-limiting ability of some overcurrent devices (primarily modern current limiting fuses) allow components with low short-circuit withstand to be specified in spite of high available fault currents.

  Section 240.2 of the NEC offers the following definition of a current limiting device (In Canada, refer to C22.2 No. 248.1):

  "A current-limiting overcurrent protection device is a device which, when interrupting currents in its current-limiting range, will reduce the current flowing in the faulted circuit to a magnitude substantially less than that obtained in the same circuit if the device were replaced with a solid conductor having comparable impedance."

  The concept of current-limitation is pointed out in the following graph, where the prospective available fault current is shown in conjunction with the limited current resulting when a current-limiting fuse clears. The area under the current curve is indicative of the amount of short-circuit energy being dissipated in the circuit. Since both magnetic forces and thermal energy are directly proportional to the square of the current, it is important to limit the short-circuit current to as small a value as possible. Magnetic forces vary as the square of the peak current and thermal energy varies as the square of the RMS current.

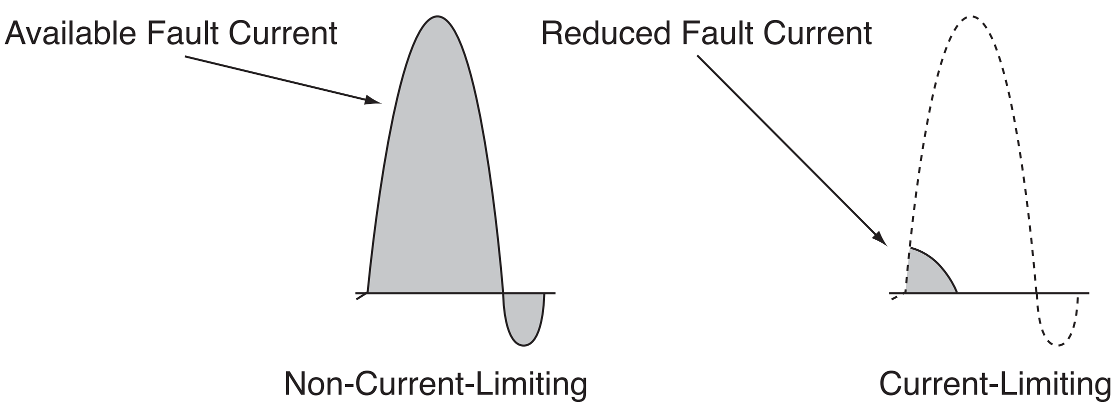


Figure 10: Current Limitation

X. Costs Associated with Safety

What are the costs associated with accidents, incidents, and injuries, and for implementing a good safety program?

In most cases, employer safety efforts are intended for two purposes.

- As an inherent benefit to employees.
- To build a legal defense, just in case an injury occurs.

Gathering and compiling information related to costs of incidents and injuries is very difficult. Employers and owners tend to avoid public access to that type of information. However, the National Safety Council has established some data associated with these costs in an attempt to identify a cost/benefit ratio. Some injury costs are in the public realm.

The most recent figures from the National Safety Council estimate that the total occupational death and injury cost in 1996 was $121 billion. This includes wage and productivity losses of $60.2 billion, medical costs of $19.0 billion, and administrative expenses of $25.6 billion. While this dollar figure is not specific to the electrical industry, it is staggering.

A paper presented at the IEEE Petroleum and Chemical Industry Conference in 1990 entitled "Maintaining Safe Work Practices in a Competitive Environment" contains information on costs. This paper, published in the *IEEE Transactions* in 1991, is available from the IEEE.

When an incident involving injury occurs, associated costs may be viewed as either direct costs or indirect costs. Direct costs include repair or replacement of the failed equipment and production loss due to the failure. Indirect costs include costs which are difficult to calculate.

Direct costs associated with an accident or injury may include:

- Equipment repair or replacement
- Lost production and employee down time

Indirect costs may include:

- Citation costs
- Incident investigation
- Creation and maintenance of documentation for legal purposes
- Insurance

- Ineffective work as employees talk about the incident and poor general morale
- Management reviews and reports
- Identification of procedural shortcomings and enacting “fixes”
- Litigation expenses
- Medical costs

Estimates of the ratio of direct to indirect costs are reported to vary from 1 to 4 on the low end to 1 to 8 on the upper end. Of course, legal expenses may be extreme should litigation result from the injury.

Employers are subject to inspection by field representatives from OSHA. Frequently, OSHA inspectors identify violations and assess fines. Most OSHA citations are small, in the hundreds of dollars. However, some are cited as serious violations. The Act (OSHA) does contain considerable “teeth”. Section 666 provides that an employer can be issued a civil penalty of $7,000 for a serious violation and up to $70,000 for each willful or repeated violation of the Act. In addition, an employer can be liable under the Act for criminal sanctions, including monetary fines and imprisonment.

Lockout/tagout citations have declined in recent years, but every year the standard ranks as one of OSHA’s most-violated rules. Between October 1994 and June 1997, there were 10,272 violations of the standard. The total cost of these penalties - $15 million.

To this point we have discussed only costs. Spending money today to avoid safety incidents and injuries avoids future expenditures. An effective safety program is the best possible legal defense. It is also the best way to document the employer’s efforts should the employer experience an OSHA inspection.

Dollars expended in an effective safety program are reported to be an excellent investment. In fact, money invested in a safety program reportedly results in a 400 percent return on investment (ROI).

In one instance, an electrical contractor was near bankruptcy. After a review of where the money was going, the contractor established an effective safety program. Although criticized for that “soft” expenditure, the result was a significant improvement in profitability. As the contractor’s safety experience improved, the contractor’s business increased dramatically, and overhead costs were significantly lowered. Safety is good business.

XI. Standards Designed for Safety

Understanding safety standards will provide insight into safe work practices. Many consensus standards are designed to provide protection for workers.

For example:

OSHA 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 can be safety energized. The repetitive manual reclosing of circuit breakers or reenergized circuits through replaced fuses is prohibited.

While a machine operator may feel pressure to maintain a machines operation, it is a violation of this OSHA standard to continue to reenergize the device without knowing the cause of the problem. Note that when it can be determined that the device operated because of an overload rather than a fault condition, no examination of the circuit may be needed before the circuit is reenergized.

XII. References / Glossary of Terms

- NFPA 70E-2000 (Available by calling 1-800-344-3555)
- OSHA 1910 Subpart S (www.osha.gov)
- OSHA 1926 Subpart K (www.osha.gov)
- NFPA 70 - NEC®
- Canadian Electrical Code Part 1 C22.1-98
- EC&M June 1997, “Protecting Yourself When Working On High-Power Circuits”
- 1996 PCIC Electrical Safety Workshop, “Flash Hazard Analysis & Methodology of Calculations”, Dan Halliburton, E. I. DuPont
- IEEE Transactions on Industrial Applications, May/June 1982, “The Other Electrical Hazard: Electrical Arc Blast Burns”, by Ralph H. Lee
- Record of Conference Papers IEEE IAS 45th Annual Petroleum and Chemical Industry Conference, September 28-30, 1998, “Predicting Incident Energy to Better Manage The Electrical Arc Hazard on 600 V Power Distribution Systems,” by R.L. Doughty, T.E. Neal, and H.L. Floyd II.

Glossary of Terms

Accessible. Capable of being removed or exposed without damaging the building structure or finish, or not permanently closed in by the structure or finish of the building.

Branch Circuit. The circuit conductor between the final overcurrent protection device protecting the circuit and the outlet(s).

Controller. A device or group of devices that serves to govern, in some predetermined manner, the electric power delivered to the apparatus to which it is connected.

Dead Front. Without live parts exposed to a person on the operating side of the equipment.

Disconnecting Means. A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply.

Enclosure. The case or housing of apparatus, or the fence or walls surrounding an installation to prevent personnel from accidentally contacting energized parts, or to protect the equipment from physical damage.

Equipment Grounding Conductor. The conductor used to connect the non-current-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor and/or the grounding electrode conductor of the circuit at the service equipment or at the source of a separately derived system.

Exposed. (Live Parts) Capable of being inadvertently touched or approached nearer than a safe distance by a person. It is applied to parts that are not suitably guarded, isolated, or insulated.

Feeder. All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device.

Grounded Conductor. A system or circuit conductor that is intentionally grounded. Note that all neutrals are grounded conductors but not all grounded conductors are neutrals.

Grounding Conductor. A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

Guarded. Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger.

Isolated. Not readily accessible to persons unless special means for access are used.

Overcurrent. Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fa

Overload. Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of rated ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload.

Qualified Employee. "An employee who has sufficient training and experience on a particular type of electrical equipment to demonstrate to supervision that he or she is competent to complete the work to be done and is fully aware of the hazards involved."

Readily Accessible. Capable of being reached quickly for operation, renewal, or inspection, without requiring those to whom ready access is required to climb over or remove obstacles or to resort to portable ladders, chairs, etc.

Switches.

- **General-Use Switch.** A switch intended for use in general distribution and branch circuits. It is rated in amperes, and it is capable of interrupting its rated current at its rated voltage.

- **Isolation Switch.** A switch intended for isolating an electric circuit from the source of power. It has no interrupting rating, and it is intended to be operated only after the circuit has been opened by some other means.

- **Motor-Circuit Switch.** A switch, rated in horsepower, capable of interrupting the maximum locked-rotor current of a motor of the same horsepower rating as the switch at the rated voltage.

Switching Device. A device designed to close and / or open one or more electric circuits. Switching devices include:

- **Circuit Breakers.** A switching device capable of making, carrying, and breaking currents under normal circuit conditions, and also making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions, such as those of short circuit.

- **Disconnecting (or Isolating) Switch (Disconnector, Isolator).** A mechanical switching device used for isolating a circuit or equipment from a source of power.

- **Disconnecting Means.** A device, group of devices, or other means whereby the conductors of a circuit can be disconnected from their source of supply.

- **Interrupter Switch.** A switch capable of making, carrying, and interrupting specified currents.

XIII. Appendix

A. Checklist for Victim of Electrical Accident

Name of injured person ______________________________

1. When and where did the accident occur? ______________________________

____

2. What was the victim doing at the time of the accident? ______________________________

____

YES	NO	
❒	❒	3. Did the victim come in direct contact with electricity?
❒	❒	Was an arc the source of electrical current exposure?
		Explain. ______________________________
❒	❒	4. Could the victim have inhaled metal vapors or extremely hot air caused by arc flash?
		5. What was the duration of exposure to electricity? ______________________________
		6. Please identify the following as related to the incident:
		Voltage ______________________________
		Available short circuit current ______________________________
		Source of electrical hazard ______________________________
❒	❒	7. Did the victim fall? If "yes," explain. ______________________________
❒	❒	8. Was the victim wearing protective or insulated clothing, safety boots, or gloves?
		If "yes," what protective equipment? ______________________________
❒	❒	9. Were others involved in the accident?
		If "yes," explain. ______________________________
❒	❒	10. Before the accident, had the hazard been identified?
❒	❒	11. Did the victim seem dazed, confused, or lose consciousness at any point following the accident? If "yes," please elaborate. ______________________________
❒	❒	12. Did the victim require CPR?
❒	❒	13. Was the victim treated as if bones might be broken, especially in the neck?
❒	❒	14. Did the accident involve an explosion?
❒	❒	15. Did the accident occur in a closed space? If "yes," please elaborate. ______________________________
❒	❒	16. Did other hazards exist at the time of the accident, such as combustibles, heavy loads, moving or fixed machines, vehicles and equipment, or extreme ambient temperatures? If "yes," explain. ______________________________
❒	❒	17. Name and telephone number of person who can provide further information about the accident events. ______________________________

Bussmann® Safety BASICs

B. Sources of Information

Where to Obtain Standards Information

Name of SDO	Address	Telephone No.	Internet URL
National Fire Protection Association	1 Batterymarch Park Quincy MA 02269-9101	1-800-344-3555	www.nfpa.org
Institute of Electrical and Electronics Engineers	445 Hoes Lane PO Box 1331 Piscataway, NJ 08855-1331	1-800-678-IEEE	www.ieee.org
Occupational Safety and Health Administration	1	1	www.osha.gov
International Electrotechnical Commission[2]	11 W. 42nd Street New York, NY 10036	1-212-642-4900	www.iec.ch
National Electrical Manufacturers Association	Global 15 Inverness Way East Englewood, CO 80112-5776	1-800-854-7179	www.nema.org
American National Standards Institute	11 W. 42nd Street New York, NY 10036	1-212-642-8908	www.ansi.org
National Standards System Network	3	3	www.nssn.org
Underwriters Laboratory	333 Pfingsten Rd Northbrook, IL 60062	1-847-272-8400	www.ul.com

1 OSHA maintains many offices throughout the United States. OSHA standards are available from many organizations and commercial outlets. All OSHA standards and OSHA-related information are available on the Worldwide Web. The OSHA Web site contains interpretive information in addition to all regulations.

2 IEC standards are available from several outlets in the United States. A visit to the IEC Worldwide Web home page will provide information on all available outlets.

3 The National Standards System Network is a service provided by ANSI that supplies information on all ANSI-related standards developing organizations. All American National Standards are available for purchase through this network.

XIV. Safety BASICs - Safety Awareness Quiz

Date:____________

Name:________________________________ Title:________________________________

Company:____

Q1: The American National Standards Institute writes its own standards.
True or False

Q2: The actions of people account for what percentage of accidents that result in injury?
A. 25% B. 50% C. 75% D. 100%

Q3: The National Electrical Code is:
A. NFPA70 B. NFPA70B C. NFPA70E D. NFPA73

Q4: Compliance with the NEC/CEC is all that is required to assure a safe and dependable system.
True or False

Q5: Lockout/tagout is covered in OSHA -
A. 1910.7 B. 1910.137 C. 1910.147 D. 1926.400-449

Q6: OSHA violations can result in jail time for employers.
True or False

Q7: NFPA70E suggests that:
A. Electrical hazards include shock, arc flash, and blast.
B. The best way to avoid injury or incident is to establish an electrically safe work condition prior to beginning the work.
C. Procedures and training are extremely important if injury is to be avoided.
D. All of the above

Q8: The standard which covers "Electrical Equipment Maintenance" is:
A. NFPA79 B. IEC947-4-1 C. NESC D. Red Book E. NFPA 70B

Q9: The CE mark:
A. Is required by OSHA for work under 29CFR 1910.269
B. Is a NEMA standard for classified environments.
C. Is a mark required within the European union to assure compliance with safety standards.
D. Was developed by the NESC.

Q10: Of those people that were electrocuted on low voltage systems (600 volts and below), approximately what percentage were working on "hot" energized equipment?
A. 25% B. 50% C. 75% D. 100%

Q11: When the skin is broken:
A. The body's resistance goes down, exposing the body to greater current.
B. The body's resistance goes down, exposing the body to less current.
C. The body's resistance goes up, exposing the body to greater current.
D. The body's resistance goes up, exposing the body to less current.

Q12: GFCI's operate in the range of:
A. .001 amps B. .05 amps C. .0005 amps D. .5 amps E. none of the above

Q13: The "let-go" threshold refers to:
A. The amount of current that causes the hand to let-go of an energized part.
B. The amount of voltage that causes the hand to let-go of an energized part
C. The amount of current that causes the hand to be unable to let-go of an energized part.
D. The amount of voltage that causes the hand to be unable to let-go of an energized part.

Q14: Tissue and organs can burn at currents of 1.5 amperes.
True or False

Q15: The temperature at the terminal of an arc can reach:
A. 1/2 the temperature of the surface of the sun.
B. the temperature of the surface of the sun.
C. almost twice the temperature of the surface of the sun.
D. almost four times the temperature of the surface of the sun.
E. almost ten times the temperature of the surface of the sun.

Q16: Skin at 200°F for one second will be unhurt.
True or False

Q17: Copper expands by a factor of:
A. 1,670 times when it vaporizes.
B. 67,000 times when it vaporizes.
C. 167,000 times when it vaporizes.
D. None of the above.

Q18: A 25KA low voltage arc can exert:
A. 160 lbs. of force on the average worker.
B. 320 lbs. of force on the average worker.
C. 480 lbs. of force on the average worker.
D. 480 lbs./sq. ft. of force on the average worker.

Q19: Facilities should know, before an electrical accident ever occurs, which medical facilities specialize in electrical trauma.
True or False

Q20: The first action when coming to the aid of an electrical accident victim is to:
A. Call OSHA
B. Apply first aid.
C. Treat for shock.
D. Elevate burned limbs.
E. Make sure the power is off.

Q21: If the victim's pulse or breathing has stopped, brain damage will begin in:
A. One minute
B. Two to three minutes
C. Four to six minutes
D. Eight to ten minutes

Q22: Who must provide a safe workplace?
A. Employers B. Employees C. Both A & B

Q23: Who is responsible for implementing the safety program and procedures?
A. Employers B. Employees

Q24: Any person within the Prohibited Approach Boundary must be "qualified".
True or False

Q25: What is the flash protection boundary for a 277/480 volt system if no calculation is made?
A. 4 ft. B. 10 ft. C. 3 ft. 6 in. D. 1 ft. E. 1 inch

Q26: The flash-over distance for a 208/120 volt system is:
A. .03 in B. .07 in. C. .19 in. D. 1.5 in.

Q27: The value in Q25 is always adequate.
True or False

Q28: D_c (Flash Protection Boundary) only needs to be calculated at the maximum available fault current.
True or False

Q29: If an arc could be initiated on the line side of a 30 amp switch, with 10 amp fuses, D_c should be based upon the device (and opening time) of the overcurrent device which feeds the disconnect.
True or False

Q30: For the circuit described in the previous question, D_c could be based upon the 10 amp fuse if work were planned for a downstream controller, ten feet away.
True or False

Q31: Any part of a person's body within an arc flash boundary must be protected with appropriate personal protective equipment, such as flame resistant clothing.
True or False

Q32: Tagout must be used unless the employer can demonstrate that the utilization of a lockout system will provide full employee protection.
True or False

Q33: The use of a disconnecting means at every motor, even where not required,
A. is a waste of money.
B. creates confusion during an electrical accident.
C. provides a quick means of de-energizing.
D. B. & C.

Q34: Can a circuit shock you even if all external sources of power have been removed?
Yes or No

Q35: Which rating provides the greater protection against electrical shock?
A. IP1X B. IP2X C. IP0X D. IP3X

Q36: Sizing an equipment grounding conductor per Table 250.122 of the 2002 NEC or Table 16 of the 1998 CEC assures an adequate, safe ground return path.
True or False

Q37: Training records need to be kept for legal reasons.
True or False

Q38: Every employee working with electricity must be able to provide CPR.
True or False

Q39: The concept of an "Electrically Safe Work Condition" was introduced in:
A. NFPA70 B. NFPA70B C. NFPA70E D. NFPA79 E. OSHA

Q40: After determining that the circuit is de-energized, it is never necessary to use grounding straps.
True or False

Q41: Which NEC Section covers requirements for selective coordination?
A. 110.9 B.110.10 C. 240.3 D. 240.12 E. 430.52

Q42: A good way to limit the exposure to flash energy is to:
A. use smaller transformers.
B. use higher impedance transformers.
C. use current-limiting overcurrent protective devices.
D. All of the above.

Q43: Magnetic forces vary with the:
A. square of the RMS current
B. square of the peak current
C. RMS current
D. peak current

Q44: Litigation expenses are:
A. Direct costs or B. Indirect costs

Q45: It is a violation of OSHA 1910-334 (b)(2) for a machine operator to reset a circuit breaker without knowing if it was a short circuit or an overload that caused the breaker to trip.
True or False

Answers for the Safety Awareness Quiz may be obtained from your local Bussmann District Sales Engineer.

This Handbook provided to you by:

Cooper Bussmann, Inc.
P.O. Box 14460 • St. Louis, MO 63178-4460
Phone: 636-394-2877 • Fax: 800-544-2570
http://www.bussmann.com

Reorder No. 3060

10-02-15m