

The Electrical Safety Guide

An Educational Training Manual
for Industry Professionals

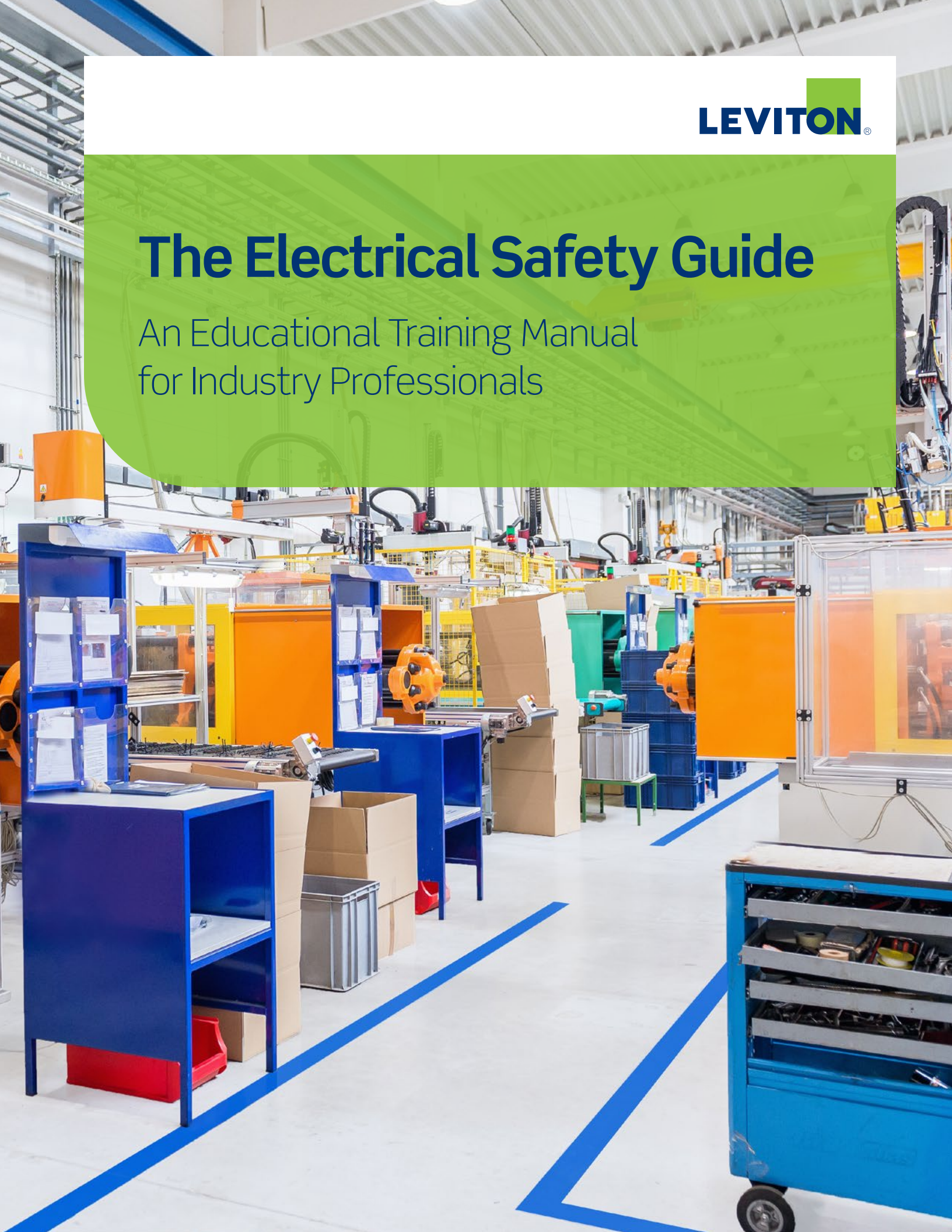
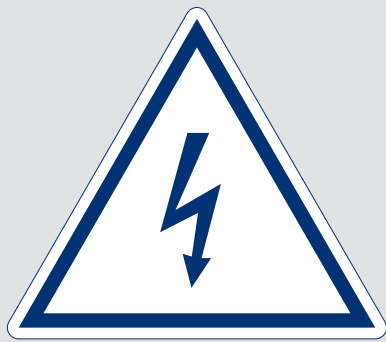






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The Electrical Safety Guide

Traveling through the maze of information on electrical safety can be difficult. Some companies make the mistake of attempting to satisfy Occupational Safety and Health Administration (OSHA) requirements rather than establishing a policy that protects its employees. Simply avoiding the wrath of OSHA does not provide a safe workplace. If a company establishes a comprehensive policy that is supported by upper-level management, then requirements of OSHA can be satisfied easily. Workers will know that their employers have the workers' best interests in mind, and a safe workplace will result, with knowledgeable workers. The policy must be the basis for an Electrical Safety Program that adopts procedures and work practices tailored to the company's needs, a program that trains its workers, and then maintains the safety program. This Electrical Safety Guide can help to guide a company through the ins and outs of regulations and standards and help choose the equipment, procedures, and work practices to implement an Electrical Safety Program.

AN INTRODUCTION TO ELECTRICAL SAFETY

In the period from 2010 to 2017, there have been approximately 1,100 deaths in the US from accidental contact with electricity AND there have been over 14,000 non-fatal electrical injuries resulting in time away from work. That's nearly 3 deaths and 40 non-fatal injuries per week, every week during this period! This is a serious, widespread occupational hazard that affects workers in many industries, across a wide range of job titles and job functions. While these statistics might seem shocking, the fact is that workplace safety regulations have had a significant impact in reducing the number of electrical injuries and fatalities in the workplace.

These statistics alone should encourage companies to ensure that none of their employees will be included in these reports. The best way to begin protecting employees from electrical trauma is to put in place an Electrical Safety Program. A vast array of information is available, and various rules, regulations, and standards can help. Among them are the following:

- NFPA 70E®, Standard for Electrical Safety in the Workplace
- OSHA 29 CFR 1910 (general industry)
- OSHA 29 CFR 1926 (construction)
- IEEE 3000 Standards Collection™ (formerly The Color Books)

The Electrical Safety Program

Deciding to develop an Electrical Safety Program is an important decision for any company. Maintaining an existing program is equally important.

Employees involved with the "hands-on" work should lead the effort, but support by upper-level management is critical to the program's success. OSHA's General Duty Clause requires that employers provide a safe environment, free from recognized hazards, for their employees. Managers are accountable for their employees' personal safety, and they must take that accountability seriously. Supervisors, in turn, assign the implementation for personal safety to each member of the organization.



Management support is not only a legal responsibility but also proves to be a good economical investment. The investment in of an Electrical Safety Program has been shown to reduce costs for companies in the following areas:

- Workers' compensation costs
- Injury costs
- Healthcare costs
- Property losses
- Insurance premiums
- Litigation costs
- Disability costs
- Business interruptions

The Electrical Safety Manager

The first step a company should take in preparing an Electrical Safety Program is to select a qualified electrical safety manager to be in charge of the program. The electrical safety manager should be a person who is not only a leader, but also one who will devise and implement the electrical safety program. The electrical safety manager should have a strong commitment to preventing electrical incidents and have authority to make necessary decisions in regard to electrical safety.

The electrical safety manager should be technically knowledgeable in electrical safety, capable of creating a safety program that will address all safety concerns within the company, and will ensure that the program is implemented and maintained. He or she will define the following:

1. Compiled by Leviton from the U. S. Department of Labor, Bureau of Labor Statistics, Census of Fatal Occupational Injuries All Worker Profile
 2. U. S. Department of Labor, Bureau of Labor Statistics, Fatal occupational injuries by event or exposure



- **Company Safety Culture** —Establish how important electrical safety is to the company and how much value will be placed on personal electrical safety.
- **Scope** —Decide if the program will be corporate-wide or site-specific and identify all electrical equipment and situations to be included in the safety program.
- **Policies and procedures** —Outline the policies and identify necessary procedures.
- **Budget** —Work with upper-level management to provide necessary funds.

The electrical safety manager will set the tone for the program. He or she should question why a workplace practice should be acceptable or not acceptable as part of a job task. Senior management and the electrical safety manager should set the goals for electrical safety: a goal of “zero electrical incidents” is realistic, and many companies embrace this concept.

The Electrical Safety Team

The electrical safety manager should identify key electrical and safety personnel within the company and name them to an electrical safety team. Participation in the electrical safety program should be an integral part of their duties. The team members certainly should be knowledgeable about hazards of working with electricity and should include electrical engineers, safety professionals, electricians, and other personnel.

An Electrical Safety Program must be in writing and available to all employees. The program will be a document of procedures written to address the working tasks for individual sites and equipment. The electrical safety team should identify what work procedures are needed and either write them or engage outside help in producing the procedures. It is critical, however, that the procedures be specific to each work task performed on all equipment installed on the company’s site(s). The program can include only a few or many procedures

since every program is different. Each procedure should include, at a minimum, the purpose of the task, the hazards involved, the safe work practices and precautions and the personnel protection equipment required.

A single person should have the responsibility for drafting a procedure, but the following people should be involved in the process of reviewing and generating a procedure:

- Qualified person involved in the operation and maintenance of the equipment
- First-line supervisor responsible for the equipment
- Manager overseeing the equipment
- Safety professional
- Person knowledgeable of consensus standards and legal requirements⁴

Procedures are available from external sources.

An example of an electrical lockout/tagout procedure can be found in an Annex G in NFPA 70E. The company can be guided by an external procedure, but each company must write its own lockout/tagout procedure.

In addition to the electrical safety team's duties of identifying and writing procedures, team members should participate in site safety audits, be available for explanation and clarification of procedures, and sit on incident review panels. Some companies might use their electrical safety team members to present the Electrical Safety Program to different sites.



APPLICABLE RULES AND REGULATIONS

In the late 1890s and early 1900s, electrical distribution systems were being established in large populated areas of the U.S. The large cities in the northeast were replacing gas and oil street lamps with electrical lights. The “old lamp lighter” was an occupation that was on the way out. Factories were installing electrical motors to provide the power necessary for their machinery.

Use of electrical energy was new, and workers had neither standards nor experience with electrical wires and equipment. Each installation was a learning experience, and many serious accidents occurred. People were exposed to potential electrocution due to faulty installations. Inadequate splices and connections resulted in many fires. The loss of life and property accelerated as the use of electrical energy expanded. Such losses were deemed unnecessary and quite expensive.

The National Electrical Code® (NEC®)

In 1896 members of several organizations met in New York City to determine the best way to avoid the human and economic losses associated with the use of electricity. In June of 1897 several existing codes were compiled into one national code. This code was unanimously approved by The National Board of Fire Underwriters and called “National Electrical Code of 1897”. In 1911 ownership of the NEC was transferred to National Fire Protection Association® (NFPA®). Initially, the NEC contained all electrical installation requirements. It covered residential, commercial, industrial and utility installations. Since utility installations are vastly different from other types, utility requirements were removed from the NEC in 1913 and placed into the National Electrical Safety Code® (NESC®). Since that time, the NEC and the NESC coexist and cover all electrical installations.

The initial purpose of the NEC was to reduce exposure to fire and shock, the only two recognized hazards associated with the use of electrical energy. Since its first publication, the NEC has been written in language that could be directly adopted by governmental bodies. Many different governmental bodies have adopted the NEC as one part of the building code that applies to

4. Mastrullo, Kenneth, Ray A. Jones, and Jane G. Jones. The Electrical Safety Program Book. Quincy, MA: NFPA, 2003.



local installations. The NFPA does not enforce the NEC. However, when a governmental body adopts the NEC, the requirements are enforced by the authority having jurisdiction (AHJ) for that organization. Since the NEC may be adopted through several different processes; the enforced edition of the code may vary from one jurisdiction to another.

Occupational Safety & Health Administration (OSHA)

In the late 1960s, the U.S. Congress was alerted to the substantial burden of 14,000 on-the-job deaths and 2.5 million injuries each year, along with the hindrance to interstate commerce in terms of lost production, lost wages, medical expenses, and disability compensation expenses that resulted from these workplace casualties. When an employee was injured, his or her contribution to company productivity was lost until the employee returned to work. If the incident resulted in a fatality, a new employee had to be hired and trained. Equipment or systems damaged in the event had to be repaired or replaced. All of these factors caused considerable expense to industry.

Employers were also aware of the high costs associated with these events and the resulting injuries. Although an employer might feel some responsibility, competitive pressures kept individual employers from taking corrective actions. Employers believed that spending money on a safety program would increase the cost of doing business. Therefore, individual employers were reluctant to implement a safety program.

Having constitutional power to regulate interstate commerce and provide for general welfare, the U.S. Congress had the authority to take steps and deemed it appropriate to reduce the burden. A bill was introduced in the Senate of the 91st Congress as S. 21935, which was intended to reduce the number of workplace casualties. The bill, known as the Williams-Steiger bill, was adopted and signed by President Nixon on December 29, 1970, becoming Public Law 91-596. Public Law 91-596 is intended to “ensure safe and healthful working conditions for every working man and woman as far as possible and to preserve human resources”⁵. Public Law 91-596 is known as the Occupational Safety and Health Act, or The OSH Act.

The OSH Act indicates that employers and employees have separate but dependant rights and responsibilities. The OSH Act provided the impetus for employers to develop and institute safety and health programs. Section 6(b) of the OSH Act established assigned authority to the Occupational Safety and Health Administration (OSHA) to enforce either adopted consensus standards or standards that are generated internally by a company.

Section 5 of the OSH Act assigns duties to employers. The employer is charged with the duty to “furnish to each of his employees employment and a place of employment which is free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees.” This section of the OSH Act is known as the general duty clause. Essentially, this clause requires an employer to take all necessary steps to comply with generally accepted safety practices.

Section 5 of the OSH Act also assigns duties to employees. Employees are assigned the responsibility to comply with rules, regulations, and orders issued pursuant to the OSH Act that are applicable to his or her own actions and conduct.



State Programs

The OSH Act provides for states to define their own safety standards. Standards developed or implemented by a state must be at least as protective as standards developed by OSHA. In most cases, the state standards mirror the federal standards.

OSHA Standards

The OSH Act authorizes OSHA to establish a system of inspection and fines to require employers to comply with OSHA's safety and health standards. The enforcement systems are complex and will not be discussed here. However, the OSH Act provides authority for OSHA to demand access to any workplace under the legal jurisdiction of the U.S.

After the OSH Act was passed, OSHA accepted many of

the existing consensus standards as the initial definition of their requirement. For instance, OSHA adopted the National Electrical Code® (NEC®) as the electrical standard for general industry. Section 6 of The OSH Act defines the process that provides the opportunity for maximum input from the general public. The revision and review process can exceed three or four years.

OSHA recognized several basic problems associated with selecting the NEC as the electrical standard. OSHA Section 6(b) procedure requires public notice, comments and hearings resulting in possible conflict between OSHA standards, local and national standards.

The NEC is intended for designing, installing and inspecting electrical installations, not workplace safety.

OSHA requirements for electrical safety-related work and maintenance of electrical systems are not within the scope of the NEC.

5. Public Law 91-596 - The OSH Act

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Because OSHA could not solve these problems, the electrical technical office of OSHA approached NFPA and requested that a new technical committee be established to draft a new standard to address personal safety in the workplace. If the NEC contained requirements that impacted personal safety, the new committee was to extract those requirements and insert a similar requirement in the new standard. The new technical committee was to be assigned the responsibility to generate requirements covering workplace practices. The NFPA Standards Council agreed with the request and determined that the new technical committee must report to the association through the Electrical Correlating Committee.

NFPA 70E: STANDARDS FOR ELECTRICAL SAFETY IN THE WORKPLACE®

The new technical committee was called the Committee on Electrical Safety Requirements for Employee Workplaces. As requested by OSHA, the new committee was charged with the task of generating a standard that would address personal safety of employees in the workplace.

If specific requirements of the NEC were applicable to employee safety, the new committee was to extract those requirements from the NEC. The new committee was to report to the NFPA through the Electrical Correlating Committee and the consensus standard it would produce would be the NFPA 70E - Electrical Safety in the Workplace.

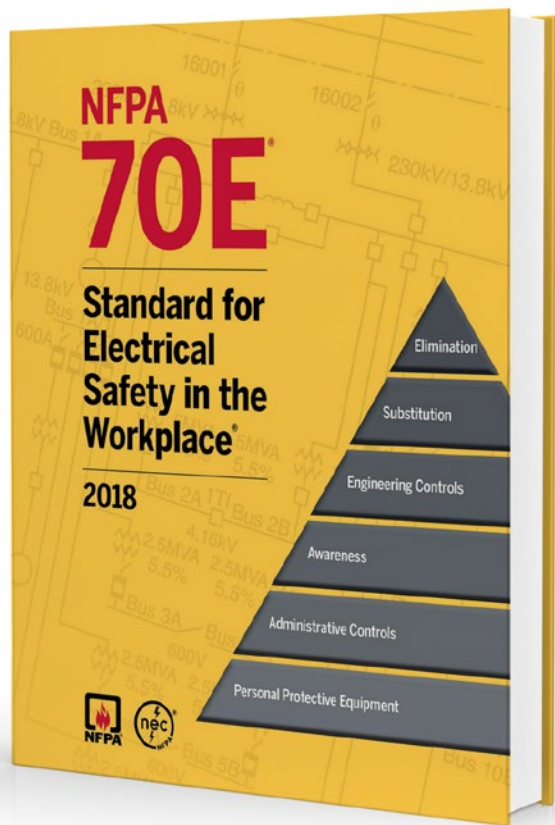
The NFPA 70E Technical Committee began work soon after its charter was generated and in 1979 completed the first edition of the standard. Although the first edition contained only requirements extracted from the NEC, the organization of the standard was set for the future. Requirements would be separated into sections for installation practices, safety-related work practices, safety-related maintenance practices, and safe practices associated with special equipment.

The work of the Technical Committee on Electrical Safety Requirements for Employee Workplaces (NFPA 70E) completed Part II covering work practices in 1987. After NFPA published the standard, OSHA began the process of generating the current content of 29 CFR 1910 Subpart S. NFPA 70E has been revised four times since it served as the basis for the current electrical safety regulation for general industry.

All safety incidents and injuries can be categorized as having one of three basic causes: unsafe equipment, unsafe conditions, or unsafe work practices. If all injuries were categorized accordingly, unsafe conditions and unsafe equipment would account for about one-third of the injuries. The remaining two-thirds of the injuries would be the result of unsafe work practices. Both unsafe conditions and unsafe equipment can be identified through audits.

Unsafe work practices, however, are behavior related and more difficult to identify through audits. Since unsafe work practices account for about two-thirds of all injuries, this behavior-related issue is the most fertile for intervention. Attention and effort aimed at improving work practices are likely to yield the most return on time invested.

Chapter 1 of NFPA 70E– 2018 Safety-Related Work Practices introduces definitions, establishing safe work conditions and work involving electrical hazards. Implementing the requirements of Chapter 1 provides significant benefits for both employers and employees.



Chapter 2 of NFPA 70E– 2018 Safety-Related Maintenance Requirements covers general maintenance requirements, equipment maintenance, hazardous locations, tools, equipment, personal safety and protective equipment. The standard avoids describing how to perform the maintenance but rather uses performance language intended to provide guidance.

Chapter 3 of NFPA 70E– 2018 Safety Requirements for Special Equipment covers electrolytic cells, battery and battery room safety, lasers and power electronic equipment. Processes using electrical energy in unique ways such as electrolytic processes generate electrical energy within electrochemical processes. These processes have unique hazards and must be assessed by unique procedures.

As the applications of electrical energy change, hazards associated with electrical energy also change. Chapter 3 modifies some Chapter 1 requirements to enable the requirements to adapt to changing conditions.

IMPORTANCE OF WORK PRACTICES

An electrical installation that follows all manufacturers' instructions and meets the requirements of the NEC is considered to be safe. When electrical equipment is operating normally workers may interact without concern for an electric incident. However, when equipment within a facility is not operating normally workers may be exposed to an electrical injury. Electrical equipment that has deteriorated from usage, age or lack of maintenance might fail unexpectedly. An electrical failure could initiate an arcing fault causing an intense arc flash and arc blast.

Most arc-faults are the direct result of movement. This movement could be energizing an electrical contactor, switching a disconnect switch, a door opening or closing, or a screwdriver slipping. Electrical shock is also the result of movement; the movement is likely the result of a worker's movement. Maintenance workers troubleshooting or repairing equipment should know that their exposure to electrical hazards is much greater when doors are opened or covers are removed exposing energized electrical components. To avoid injury, the maintenance worker must use safe work practices. Planning, following proper maintenance procedures and the use of personal protective equipment is required.

ELECTRICAL HAZARDS

We all use electricity every day and don't consider the degree to which electricity affects our daily life. Electrical energy is normally safe and reliable. However, when working on or near electrical equipment, workers should be aware that an electrical incident could occur. Electrical hazard awareness should be a top priority. Statistics compiled by the National Institute of Occupational Safety and Health (NIOSH) indicate that someone is electrocuted almost every day in the workplace, and another person is electrocuted at home every day. The major electrical hazards are organized in NFPA 70E Annex K into three categories: electric shock, arc-flash and arc-blast.

Electric Shock

According to the Bureau of Labor Statistics, in private industry in 2016 there were 154 deaths, and 1640 injuries that resulted in time away from work due to exposure to electricity. Electrocution continues to be the seventh leading cause of workplace fatalities.

Approximately 52% of the reported electrical injuries in 2016 came from goods producing industries – construction, manufacturing, and mining – which means that nearly half of these injuries came from service providing industries such as professional and business services, education and health services, and leisure and hospitality. This shows that exposure to electricity is a risk in nearly all workplaces, and must be addressed accordingly.

Electrical equipment, including tools, is used without a second thought that some exposure to an electrical hazard might exist. Maintenance workers routinely perform circuit analysis and repair without adequate protection from electrical exposure.

If a worker touches an electrically energized part and a grounded surface, as in Figure 1 (next page), electrical current flows through the body from one hand to the other hand or body part. This is called “touch potential”, and the severity of the shock depends on the source voltage, the body resistance and how long the worker is in contact with the voltage. If a person is using a hand tool, as in Figure 2 (next page), that is not properly maintained and grounded, current may flow from the tool to a hand and then exit the body at a different point. This is another illustration of “touch potential”.

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Contact also could occur between a person's feet, as illustrated in Figure 3. Current flows from one foot to the other foot. This type of contact is called "step potential."

Step potential is what happens when a person is in the vicinity of a lightning strike or faulty underground wiring. A voltage difference exists between a person's feet, and current flows. If lightning strikes an object, a voltage difference exists between that object and earth. Since earth has electrical resistance, the voltage difference becomes less as the distance from the strike becomes greater.

An electrical shock can cause symptoms ranging from a tingling sensation to immediate cardiac arrest. The severity of a shock depends on the current path through the body, the amount of current passing through the body and the length of time that the current flows through the body. Table 1 illustrates typical body reactions based on current flow.

The human body is protected by the skin which is a poor conductor of electricity when dry. But when the skin is wet or broken, the skin becomes a good conductor of electricity. A man touching 120 volts household voltage with dry skin might get a slight shock. If his skin is wet he might be at the "let-go" threshold and have difficulty breathing. Internally the human body consists of water and salts which are very good conductors. As a result current flow through the body might affect internal organs. The blood vessels and nerve system conduct electricity much like wires. If the path of the electric current is through the chest, the heart could go into cardiac arrest. High current flow through the body could also cause internal burning of blood vessels and nerve system.

Most workers are aware that electrical shock is a hazard associated with electricity. However, most workers are not aware that the difference in the amount of current flow between a small shock and electrocution is very small. Table 1 suggests that if a current on the order of 0.01 amperes flows through a person's body, a painful shock is felt. If the current flow increases to 0.10 amperes, the victim's heart probably goes into fibrillation in about three seconds. If the current flow increases to 0.20 amperes, fibrillation likely occurs in one second or less. After fibrillation begins, only application of a defibrillator can revive the victim. A fatality is likely if the current flow is in this range.

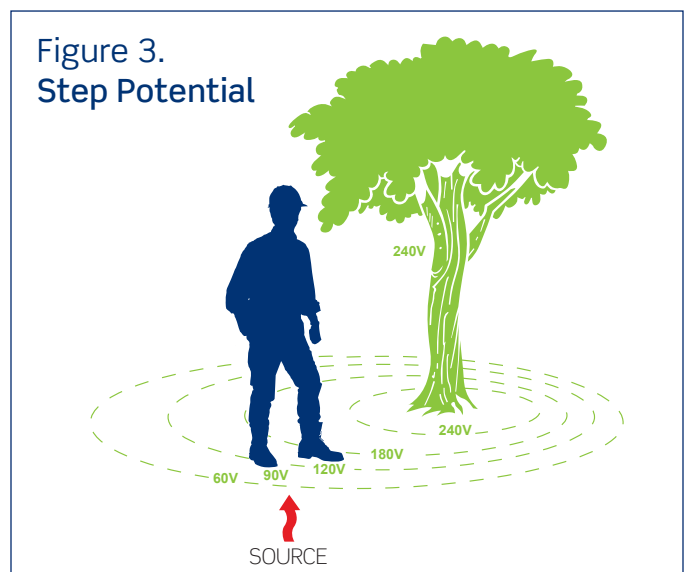
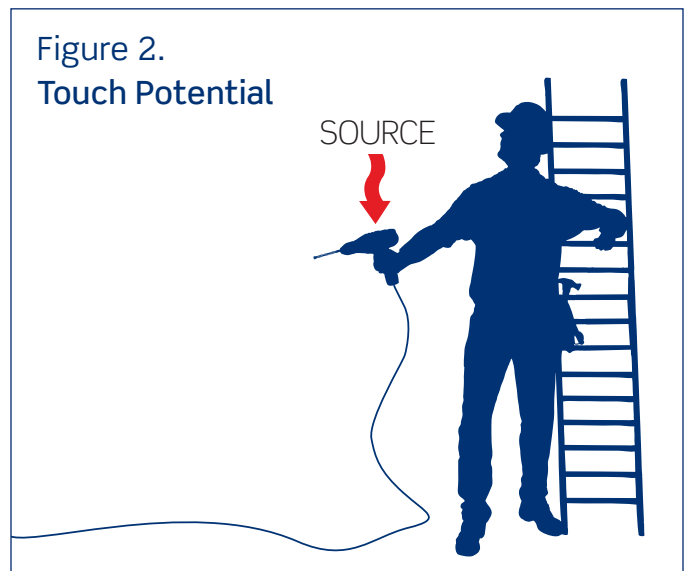
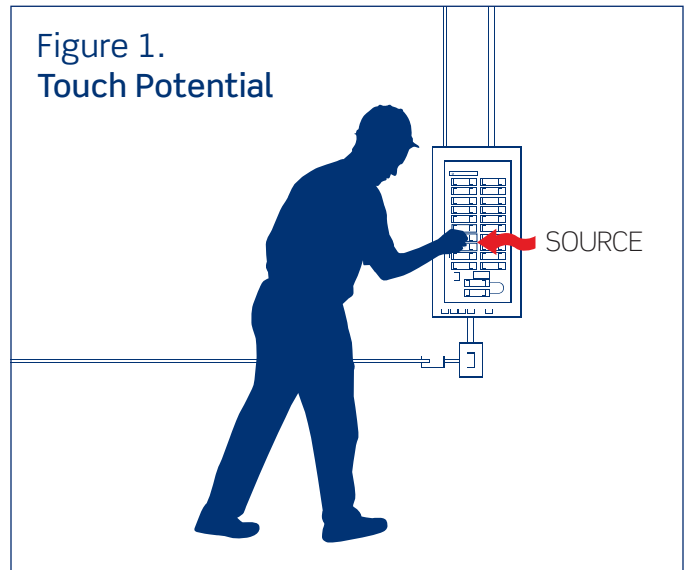


Table 1. How Electrical Current Affects the Human Body.⁶

CURRENT LEVEL (in milliamperes)	PROBABLE EFFECT ON HUMAN BODY
1 mA	<p>Perception level. Slight tingling sensation. Still dangerous under certain conditions. Wet conditions are common during low-voltage electrocutions. Under dry conditions, human skin is very resistant. Wet skin dramatically drops the body's resistance.</p> <ul style="list-style-type: none"> • Dry Conditions: Current = Volts/Ohms = 120/100,000 = 1mA a barely perceptible level of current • Wet Conditions: Current = Volts/Ohms = 120/1,000 = 120mA sufficient current to cause ventricular fibrillation
5 mA	<p>Slight shock felt; not painful but disturbing. Average individual can let go. However, strong involuntary reactions to shocks in this range may lead to injuries. If the extensor muscles are excited by the shock, the person may be thrown away from the circuit. Often, this can result in a fall from elevation that kills a victim even when electrocution does not.</p>
6-30 mA	<p>Painful shock, muscular control is lost. This is called the freezing current or "let-go" range.</p>
50-150 mA	<p>Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go. Death is possible. When muscular contraction caused by stimulation does not allow the victim to free himself from the circuit, even relatively low voltages can be extremely dangerous, because the degree of injury increases with the length of time the body is in the circuit. LOW VOLTAGE DOES NOT IMPLY LOW HAZARD!</p>
1000-4300 mA	<p>Ventricular fibrillation (the rhythmic pumping action of the heart ceases.) Muscular contraction and nerve damage occur. Death is most likely. Note that a difference of less than 100 milliamperes exists between a current that is barely perceptible and one that can kill.</p>
10,000 mA	<p>Cardiac arrest, severe burns and probable death. High voltage electrical energy greatly reduces the body's resistance by quickly breaking down human skin. Once the skin is punctured, the lowered resistance results in massive current flow.</p>

STRATEGIES FOR MITIGATING EXPOSURE OF WORKERS

Several strategies can be used to mitigate the exposure of workers to electrical hazards. Training, documented procedures, planning, and use of proper personal protective equipment (PPE) are all important strategies. However, the best strategy is to take away the source of electrical energy.

Creating an Electrically Safe Work Condition

The most effective way to prevent an electrical incident is to completely remove the source of electrical energy and eliminate the possibility of its reappearance. To do

that, disconnecting means of each source of electrical energy must be located and identified. Workers must review accurate drawings that identify all potential sources of energy.

After all sources of electrical energy have been located and identified the worker must open all of the disconnect switches. Caution should be taken since some disconnect switches are not rated to be operated under load. In other instances, a disconnect switch could fail, and all phases of the circuit might not be disconnected. A worker must ensure that the disconnect switch safely interrupts the circuit and then ensure that all electrical sources are disconnected and de-energized.

6. U.S. Department of Labor, Occupational Safety & Health Administration, OSHA Construction eTool, Electrical Incidents, How Electrical Current Affects the Human Body, 2010



The next step is having the employee install his or her own lock and personal lockout tags on each of the disconnecting means that have been opened. Keys to the locks should be controlled rigidly so that each employee who might be exposed has confidence that the switches cannot be closed without his or her knowledge. Each employee should sign and install individual lockout tags that identify the employee and the date the tag was affixed.

Once locks and tags have been installed, the worker must verify that electrical energy has indeed been removed from the circuit and equipment. It is critical that a functioning and adequately rated voltmeter be used to determine that no voltage is present. The functionality of the voltmeter must be verified both before and after checking for absence of voltage. The voltmeter should be considered safety equipment and have no economic limitations. Employees must ensure that the selected test equipment is rated at least as

great as the expected circuit parameter.

Even after all of this care has been taken to ensure that a voltage is not present, a failure in other electrical equipment could cause the conductor or equipment that has been locked and tagged to become re-energized. Safety grounds must be installed on these circuits if it is determined that the conductors might be energized from another source. The safety grounds must be adequately rated to mitigate any potential safety.

Personnel Training

Another strategy is to provide safety training to all employees. The objective of the training should be to increase awareness of electrical hazards and how employees are, or may be, exposed to those hazards.

The majority of electrical injuries result from unsafe work practices. Personal behavior is affected by many different factors, including knowledge, skill and

Figure 5. Typical Training Record

Training Subject	Name of Person Trained	Date of Training	Name of Person who Provided Training
Lockout/tagout			
Electrical accident response			
Removing/inserting starters			

experience. An employer should provide training that will increase an employee’s knowledge and skill associated with specific work tasks.

Standards and regulations use the term “qualified” and “unqualified” employee or worker. In some instances, the terms are used almost generically, as if an employee is either qualified or unqualified. In reality, however, a person can be qualified for one task and unqualified for another task. For instance, a worker might be qualified in troubleshooting lighting circuits or control circuits and unqualified in troubleshooting a power circuit. Each employee must know the limits of his or her qualification.

Employee training should center on electrical hazards and how each employee is or might be exposed to each hazard. All employees are exposed to electrical hazards and each employee should understand all hazards to which he or she might be exposed. Employees must be capable of recognizing where exposure to an electrical hazard exists and understand which standing guidance (such as a procedure or written practice) applies to the work task.

Employees must be able to determine the nominal voltage of electrical equipment. Employees who are expected to work on or near energized electrical equipment must be capable of determining if a conductor and equipment is energized or de-energized. The employee must be able to implement the requirements of any lockout/tagout procedure that is provided by his or her employer.

Employees who understand both the degree and exposure to electrical hazards are less inclined to take unnecessary risks. These employees are inclined to verify that the circuit is de-energized before the work is started.

Frequently, on-the-job or apprentice training passes on bad work habits from one generation to another. The electrical safety training program should be developed to provide information to “old hands” and “new hands” alike.

Employees should understand that avoiding exposure to electrical hazards will avoid injuries.

Planning

Almost all injuries are the result of inadequate or incomplete planning. In many instances where an injury occurred, no work plan existed. Planning the work process affords workers the opportunity to identify if or how much exposure to an electrical hazard might exist. Both the planning process and the plan are important. Developing a work plan provides the planner with the chance to determine a work method that avoids unnecessary exposure to electrical hazards.

The planning process requires the person developing the plan to think through the physical steps that are necessary to accomplish a job or work task safely.

The plan should be sufficiently detailed to identify all discrete work steps and the person who will perform each step. Developing the plan enables the worker to identify work tasks that could be performed simultaneously. All tools and safety equipment must be identified in the plan.

The plan identifies if, when, and how a worker is or might be exposed to an electrical hazard. The plan indicates what steps the worker must take to minimize or avoid that exposure. The plan will identify the necessary PPE and when it should be used.

Figure 6. Typical Task Plan

Changing on Substation # 2
1. Retrieving filters from plant stores.
2. Unlock door to substation area.
3. Return keys.
4. Check equipment status.
5. (etc.)

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After the plan is completed, the planner must ensure that all workers associated with the job or work task understand who will do what. The plan should be reviewed in detail with all workers associated with the task and modified if a better idea is discussed. It is critical that all workers have the same plan in mind before the work is performed. It is also critical that all work stop should an unexpected condition or unexpected failure be identified. The work should continue only after the plan is revised to consider the new conditions.

CONTROLS AND AUTHORIZATION

If an electrical hazard exists, the worker is exposed to some risk. In some instances, the worker might determine if the risk is acceptable or not acceptable. Many injuries occur when the worker simply makes the wrong choice.

Significant anecdotal information suggests that supervisors and managers are more reluctant to accept an elevated risk of injury. In many instances, a manager or supervisor attempts to find a way to eliminate the risk rather than to reduce it to a lower level. NFPA 70E-2015 has a requirement for working on or near energized electrical equipment to be reviewed by management. Annex J, NFPA 70E-2015 is a sample permit for energized electrical work.

The permit requires the signature of qualified electrical worker(s) that will perform the task, safety manager and the signature of a senior supervisor or manager. The reason for the permit is to ensure that the decision to accept elevated risk of injury from exposure to live parts is made at a high level in the organization. Experience suggests that, in many instances, the electrical circuit is de-energized before the work is performed.

The ability to identify when and where risk of injury exists is dependent upon the accuracy and availability of records and drawings. Workers must be able to identify and locate all energy sources that might be capable of delivering electrical energy to a conductor or equipment in the vicinity of the work location.

Workers must have the tools or knowledge that is necessary to make this determination. It is possible that labels and tags provide enough information, such as lighting circuits or other loads that have no chance of becoming confused or intermingled with other circuit conductors.

STRATEGIES FOR MITIGATING EXPOSURE OF PUBLIC

In the United States, the supply of electricity is reliable. In fact, the source of electricity is so reliable that most people expect that electricity will be available whenever it is needed. People always expect that electrical equipment will be safe and function as intended.

Consensus codes and standards define requirements that serve to mitigate potential exposure to electrical shock. Installations that meet the requirements of generally accepted codes and standards are safe for use by an uninformed public when the equipment is operating normally. Unless the integrity of the manufactured equipment that is installed as required by local codes is breached, the public can safely interact with and use the equipment.

Importance of Installation Safety

Installation standards effectively prevent hazardous exposure to the general public. When a person is injured from exposure to an electrical shock, the exposure generally can be traced to inadequate system maintenance or improper use of an electrical component.

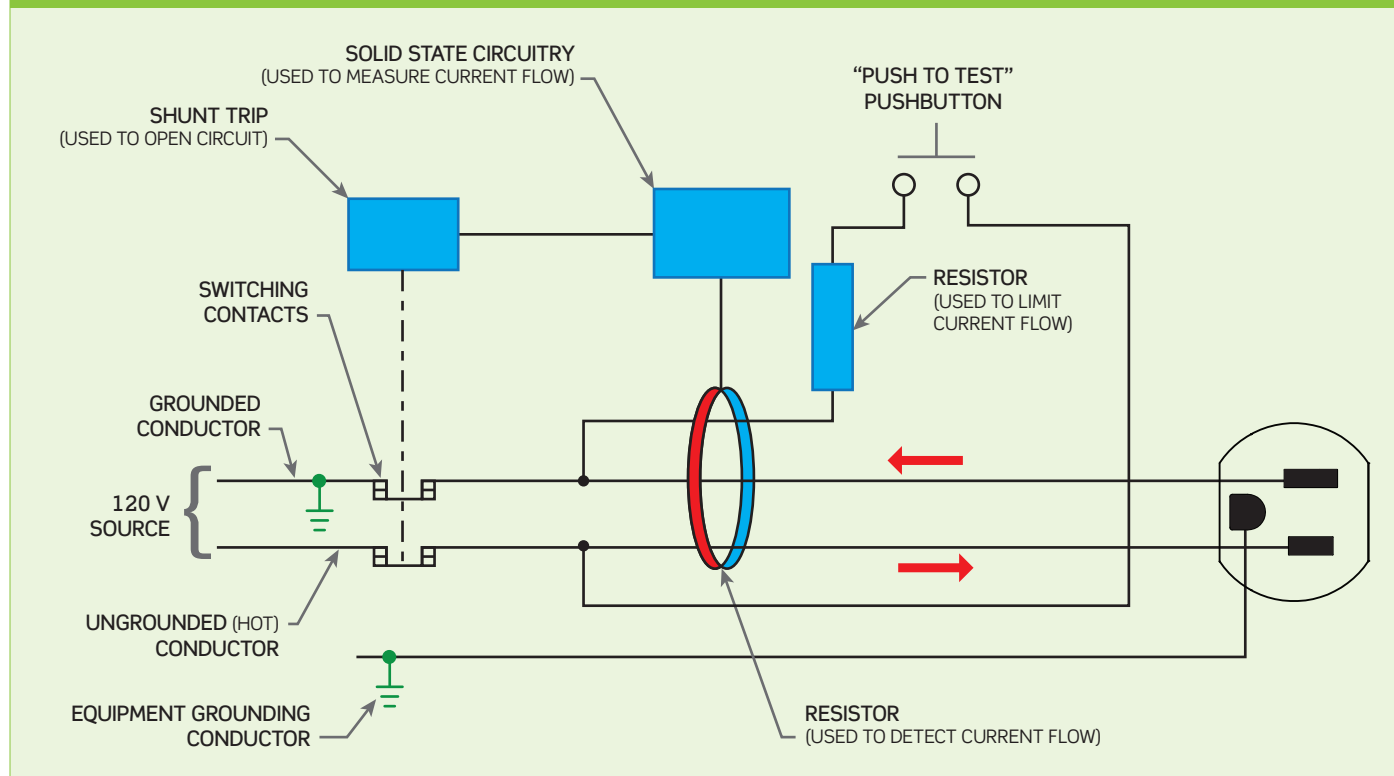
Installation codes and standards rely upon select strategies to limit public exposure to electrical hazards. Eliminating touch potential is one of those strategies. A person cannot receive an electrical shock unless a current flows through the body from “touching” two points that are at different voltages. Since the NEC requires that all conductive parts that are not part of the electrical circuit be electrically connected together by a low-impedance conductor, there should be no voltage difference between these parts. If no voltage difference exists, no current can flow, and no electrical shock can occur.

Another strategy that is applied is providing overcurrent devices that rapidly remove the source of voltage (current) if the circuit is shorted or overloaded. If a current in a circuit exceeds the rating of the overcurrent device, the overcurrent device should open the circuit, removing the voltage. Without this action, the conductor could overheat and potentially result in a fire.

A third strategy is monitoring the amount of leakage current to ground. This strategy is implemented by ground-fault circuit interrupters (GFCIs). In the mid 1970s, the ground-fault circuit interrupter was introduced; if a

Figure 7. GFCI

A GFCI functions by comparing the amount of current in the ungrounded (hot) conductor with the amount of current in the neutral conductor.



leakage current exceeds a selected level, the GFCI would open the circuit, removing the source of energy. (See Figure 7, above).

When the OSHA regulations began to require that GFCIs be used on all construction sites, the number of fatalities from electrocution decreased significantly.

For any electrical safety program to be effective, workers must have confidence that the state of the electrical equipment is adequate to eliminate exposure to electrical hazards. When a facility is first constructed, the installation is inspected, and compliance with recognized installation standards was verified by inspection. As time passes, a maintenance program must ensure that the condition of the electrical equipment does not deteriorate and expose workers to electrical hazards. Only adequate maintenance can assure workers that the electrical equipment is in good condition.

Preventing the public from electrical hazards demands implementation of several different strategic concepts, such as the following:

- Third-party certification of equipment

- Consensus installation requirements
- Isolation of electrical equipment
- Insulation of electrical conductors
- Equipment grounding
- System grounding
- Overcurrent protection

Third-Party Certification

The system of codes and standards in the United States provides the opportunity for manufacturers to participate in the development of standards that define minimum construction and performance requirements for electrical equipment. The National Electrical Manufacturers Association (NEMA) provides the forum for these requirements to be developed. Once a consensus standard defines manufacturing requirements, our system provides for third-party certification by a nationally recognized testing lab (such as UL, CSA, ETL, etc.) that the equipment or device meets these requirements.



Several standards-development organizations publish third-party standards for safety. These safety standards generally are designed to ensure that the equipment does not expose a person to electrical hazards under normal conditions. The consensus standards define test parameters to provide assurance that the equipment is not destroyed under defined conditions. Third-party certification is one mechanism that provides the public with confidence that electrical equipment will not expose the user to electrical hazards.

Isolation of Equipment with Exposed Conductors

For a person to receive an electrical shock or be electrocuted, the person must come in contact with the electrified circuit. However, for an arc-flash injury to occur, the person has only to be nearby when the energy release occurs. If the electrical equipment is installed so that a person cannot be in the immediate vicinity, the chance of being engulfed in an arcing fault is eliminated.

A major strategy implemented by the National Electrical Safety Code (NESC) requirements is isolation. The NESC is concerned with transmission and distribution of electrical energy. Overhead power lines are installed at elevations that are expected to minimize exposure to electrical hazards associated with the conductors. They are isolated by elevation from being touched by anyone in a normal situation. Human contact with the power lines, which are usually uninsulated, is virtually impossible unless the person's reach is extended by some artificial means. Vehicles, trucks, cranes, or any other articulating boom can cause a situation that is not normal, acting as an extension of a person's reach and make touching an overhead power line possible. Should any portion of the vehicle make direct contact with an overhead power line, people in the vicinity of the vehicle are in danger of electrical incident.

Flying a kite or handling a long conductive object can penetrate the safe zone that surrounds overhead power

lines. The isolation strategy is effective as long as the isolation is recognized and respected. If this isolation is breached, the situation becomes abnormal and hazardous.

Equipment Grounding

If no voltage difference exists between conductive enclosures or objects of electrical equipment, then people are not exposed to electrical shock.

The best strategy for avoiding a voltage difference between pieces of electrical equipment is to connect objects together with a grounding conductor. If all conductive exposed objects and enclosures are interconnected, no voltage difference should be present. Electrical conductors can be enclosed in metallic conduit that serves as the grounding conductor, or a grounding conductor might be installed along with the power conductors. If all exposed conductive objects are interconnected by means of a grounding conductor, there is little chance for a person to receive an electrical shock or of being electrocuted. Connections or splices in electrical conductors sometimes fail, resulting in a high-resistance connection and a voltage difference.

The system ground provides a ground fault-current path for an electrical source. Without a system ground, ground fault-current cannot flow, and overcurrent devices cannot operate, possibly exposing people to electrical shock and electrocution.

Overcurrent Protection

Electrical conductors have a defined capacity to carry electrical current. When the current of a conductor exceeds its capacity, excessive heat is developed, resulting in a possible fire. To protect conductors, overcurrent protection is employed.

Fuses and circuit breakers are common types of overcurrent devices. Normally, fuses contain a conductive element that melts at a specified amount of current flow. Melting is not instantaneous. However, if the current greatly exceeds the ability of the fuse to conduct current, melting occurs very rapidly.

A circuit breaker contains a magnetic and/or thermal element that sends a signal to another component that causes the circuit breaker to trip and remove the energy source.

Fuses and circuit breakers are intended to limit the amount of current flow to ensure that the conductor and electrical equipment does not overheat and cause a fire. Fuses and circuit breakers are not designed to prevent electrical shock or electrocution but rather are designed to protect conductors and equipment.

System Grounding

To avoid an electrical voltage between electrical equipment and the ground (earth) caused by lightning, faulty electrical equipment or other electrical sources, the electrical system is connected to earth by a grounding system such as a ground rod or city water pipe. The grounding conductor is then connected to the system ground.

In industrial buildings, resistors sometimes are installed between the system supply voltage and ground. The resistor can be either high resistance or lower resistance. Resistance grounded systems control the amount of fault-current that can flow in an electrical fault. Normally, resistance-grounded systems have devices that monitor the amount of current flowing through the resistor and signal a circuit breaker if a fault occurs.

Warnings

Consensus standards and codes define requirements for signs and labels to warn the public that an electrical hazard exists. Signs that communicate a danger are normally installed at places where they are likely to be visible to the public. Gates, doors, and covers that provide isolation from a shock hazard have been required for many years. In recent years, signs that provide warning from a potential arc-flash hazard also are required.

A strategy of warning signs and labels is effective only if people read the warning and heed the instructions. As the numbers of signs and warning labels increase, the public are inclined to pay less and less attention. Although warning signs and labels are effective for a short period of time, they are less effective than other protective strategies.

SUMMARY

Contact with electricity causes people to die every day, both in the workplace and at home. For this reason alone, electrical safety is an important subject for everyone. Through the Occupational Safety and Health Administration in the United States, steps have been taken to protect workers from the hazards of electricity. The National Electrical Code is a standard that helps to ensure safe electrical equipment installation. The Standard for Electrical Safety in the Workplace helps workers understand and comply with safe work practices. Many organizations write equipment standards that are accepted widely in this country. In a company's electrical safety program, steps are taken to keep workers safe through practices and procedures. Even after all of these important steps have been taken, people are still being shocked, burned, and electrocuted.

Investigation of most of the incidents involving injury by contact with electric current comes down to one conclusion: poor work practices. One person takes a chance he or she should not have taken; the person was not properly trained for the task; the victim was distracted, tired, hungry, angry, uncomfortable, in a hurry, or one of any number of things—in short, a human being. Given all of the information collected about electrical safety, the fact is that each person must be accountable for his or her own safety. People who work around electrical equipment must learn all that they can learn. They must insist on training, they must insist on excellent diagnostic equipment and tools, and they must refuse to do any work that they believe to be unsafe. Workers must believe that their role in electrical safety is the most important role of all.





Leviton Safety Products

As more of the world becomes electrified, safety will remain a priority issue. Leviton sets the standard in electrical safety by developing, designing and manufacturing products that improve electrical safety while ensuring a safe work environment.

The following section summarizes some common electrical safety hazards that can easily be eliminated simply by utilizing the proper equipment.

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- Personnel Protection
 - Portable Personnel Protection
 - Power Pendants
 - Outdoor or Indoor Wet and Damp Locations
 - Receptacles In Wet and Damp Locations
 - Mechanical Interlocks
 - Motor Controls
 - Control of Hazardous Energy (Lockout/Tagout)
 - Surge Protection
 - Wire Management

PERSONNEL PROTECTION

Hazard: Permanently installed non-GFCI receptacles installed in wet or damp indoor locations, on roofs or other outdoor locations.

Summary: The NEC requires GFCI protection for power outlets in all wet or damp locations.

Remedy: Install Leviton's SmartLock Pro GFCI receptacles, with safety features including tamper-resistant shutters, pilot and guide lights, and weather-resistant versions.

Applicable Standards: NEC Article 210.8(B), OSHA 29 CFR PART 1910.304(b)(3), 1926.404(b)(1), NFPA 70E Article 110.6



PORTABLE PERSONNEL PROTECTION

Hazard: Portable power tools being used on circuits without GFCI Protection.

Summary: A portable GFCI must be able to trip if a neutral wire is open.

Remedy: Use Leviton GFCI cordsets, available in both automatic and manual reset, providing open-neutral protection for added safety.

Applicable Standards: NFPA 70 (NEC) Article 590.6(A)(1), OSHA 29 CFR PART 1926.404(B)(1), NFPA 70E Article 110.5(D)



POWER PENDANTS

Hazard: Using standard electrical boxes that are not listed for use as pendants.

Summary: NEC Article 110.12 requires unused openings in boxes be closed off to provide the same level of protection they would get from a wall. Using wall boxes as pendants violates this provision.

Remedy: Use Leviton non-metallic portable outlet boxes that are designed for this purpose. Coverplates with weather-resistant flip lids provide NEMA 3-R protection to receptacles not in use.

Applicable Standards: NEC Article 590.4(I), OSHA 29 CFR PART 1910.303(b)(1), 1926.403(b)(1)



OUTDOOR OR INDOOR WET AND DAMP LOCATIONS

Hazard: Plugs and connectors are failing due to contact from moisture and debris.

Summary: Unless identified for use in the operating environment, electrical conductors must not be used in damp or wet locations where they may be subjected to liquids, vapors, or other deteriorating agents having a deteriorating effect on the conductors.

Remedy: Utilize Leviton Wetguard® watertight plugs and connectors, featuring environmental ratings of NEMA 4, 4X, 6 & 6P and IEC IP66, IP67, and IP69K.

Applicable Standards: NEC Article 110.11, OSHA 29 CFR PART 1910.303(b)(6), 1926.432(a)(1)



RECEPTACLES IN DAMP OR WET LOCATIONS

Hazard: Receptacles mounted outdoors or in wet or damp locations are subject to corrosion and damage from water and UV exposure. They also do not have appropriate covers installed.

Summary: All 15A and 20A, 125V and 250V receptacles installed in damp or wet locations must be listed as weather resistant and be protected by a weatherproof cover when not in use.

Remedy: Use Leviton weather-resistant receptacles paired with Leviton's weatherproof covers.

Applicable Standards: NEC Article 406.9(A) and (B)



MECHANICAL INTERLOCKS

- Hazard:** Plugs and connectors are disconnected under load, potentially damaging or shortening the lifespan of both the connectors and connected equipment.
- Summary:** Not all disconnecting devices are rated for interrupting load currents. Disconnecting “live” circuits can result in arcing that can damage the device and connected equipment, while at the same time creating a safety hazard for the operator. Powerswitch® mechanical interlocks provide the required level of safety by preventing the unplugging of a device under load – the safety disconnect will de-energize the circuit before allowing the plug to be disconnected.
- Remedy:** Install a Leviton LEV Series Mechanical Interlock, which prevent the unplugging of a device under load. The safety disconnect will de-energize the circuit before allowing the plug to be disconnected.

Applicable Standards: NEC 430.102(B), 430.109(F), UL 60947-4-1 (supersedes UL 508), NFPA 70E Article 120



MOTOR CONTROLS

- Hazard:** Motor driven machines have not been placed in an electrically safe work condition for servicing.
- Summary:** NFPA 70E mandates that machines must be completely disconnected from all sources of power, and be prevented from being re-energized until work is complete.
- Remedy:** Install a Leviton Safety Disconnect Switch, which provides means for disconnecting power and provisions for OSHA and NFPA compliance..

Applicable Standards: NEC Article 430.75(A), 430.102, 430.103, OSHA 29 CFR PART 1910.303(f)(1), 1910.305(j)(4), 1910.147, NFPA 70E Article 120



- Hazard:** Equipment power feeds are not placed close enough to controlled equipment to satisfy line-of-sight requirements.
- Summary:** The NEC requires that a disconnecting means for a motor and controller be located within line-of-sight (50 feet) of the controlled equipment.
- Remedy:** Install a Leviton Safety Disconnect switch between the power feed and controlled equipment, providing LO/TO protection.

Applicable Standards: NEC Article 430.102, OSHA 29 CFR PART 1926.417

- Hazard:** The space available around equipment does not allow compliance with the line-of-sight disconnecting means.
- Summary:** The Standards require that you must supply a means for disconnecting the circuit to a controller, as well as provide a means for isolating a motor from other loads on the circuit.
- Remedy:** Install a Leviton Manual Motor Controller that is also rated “Suitable As Motor Disconnect”.

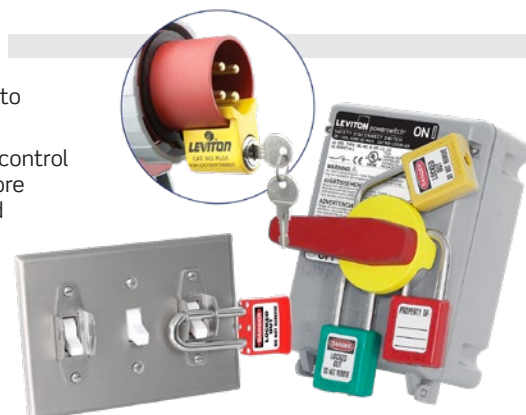
Applicable Standards: NEC Article 430.102, UL 60947-4-1 (supersedes UL 508), OSHA 29 CFR PART 1926.417



CONTROL OF HAZARDOUS ENERGY (LOCKOUT/TAGOUT)

- Hazard:** Workers performing service or maintenance on machinery may be exposed to injuries from the unexpected startup of the machinery.
- Summary:** Employers must establish an energy control program, consisting of energy control procedures, employee training, and periodic inspections to ensure that before service and maintenance is performed, machines and equipment that could unexpectedly startup are isolated from their energy source(s).
- Remedy:** Leviton offers a variety of devices that can be used to prevent accidental reenergization of equipment, providing provisions for LO/TO.

Applicable Standards: NFPA 70E Article 120, OSHA 29 CFR PART 1910.147



SURGE PROTECTION

Hazard: Machine controls, and safety interlocks, emergency system loads, fire pumps, computers and other sensitive electronic equipment damaged by transient voltage spikes and surges.

Summary: Some statistics indicate that as much as 80% of all power source related downtime can be traced to transient activity. It is also estimated that protecting electrical and electronic equipment from voltage spikes and surges (transients) can increase the normal lifespan by a factor of two or three. These surges are not only generated from outside the facility (e.g. lightning or utility switching), but also inside the facility (motor load switching). Therefore, you must install sufficient protection to reduce the effects of both internally and externally generated spikes and surges.

Remedy: Implement an effective surge protective network – including service entrance, branch, and point-of-use protection – that protects the entire facility from the damaging effects of transient spikes and surges.

Note: In the National Electrical Code, there are now requirements to provide surge protection for critical operations, data centers, industrial machinery with safety interlock circuits, and emergency systems' switchboards and panelboards.



Applicable Standards: UL 1449, NEC Article 280, 285, 620.51, 645.18, 670.6, 694.7, 695.15, 700.8, 708.20

WIRE MANAGEMENT

Hazard: Cable connections pull out or become damaged due to excessive motion or vibration. Strain reliefs used on bus drops don't provide sufficient strain relief or cable bend control.

Summary: Flexible cords must be connected in such a way that strain relief is provided which will prevent pull from being directly transmitted to joints or terminal screws. Flexible cords are permitted for use in bus drops for portable or stationary equipment, provided that appropriate strain relief grips are provided at the busway plug-in device and equipment terminations.

Remedy: Utilize Leviton wire mesh cable support grips to reduce strain on cable connections and control bend radius.

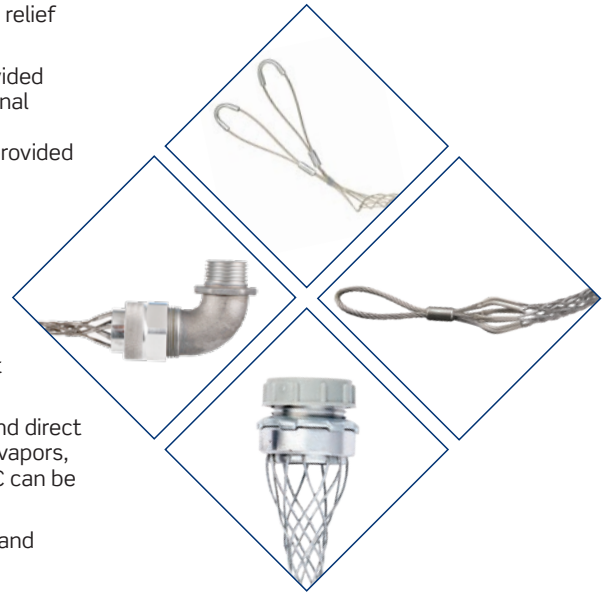
Applicable Standards: NEC Article 400.10, OSHA 29 CFR PART 1910.305(g)(2), 1910.305(g)(2)(iii), 1926.405(g)(2), NFPA 70E Article 205.14(2)

Hazard: Cable entrance to boxes, enclosures, cabinets and pushbuttons are not adequately protected from water ingress or cable strain.

Summary: Liquidtight Flexible Nonmetallic Conduit is frequently used in outdoor and direct burial applications where protection of the contained conductors from vapors, liquids and other debris is required. Only fittings listed for use with LFNC can be used.

Remedy: Utilize Leviton cord sealing grips to reduce strain on cable connections and control bend radius in wet or damp locations.

Applicable Standards: NEC Article 356.42, OSHA 29 CFR PART 1910.305(e)(1), 1910.305(g)(2)(iii), 1926.405(g)(2)(iv)



This compilation of technical materials has been assembled by the developers for the benefit of training others about "Electrical Safety". It is being presented to illustrate the critical nature of electrical safety practices. While not the only method(s) or answer(s), or perhaps not even the best method(s) or answer(s), in the opinion of the developers/presenters the content is an accurate, acceptable, and positive way to present the subject material. By creating awareness of the potential hazards and describing workable solutions by which the hazards can be controlled, minimized or eliminated, it is hoped that injury will be reduced and lives will be saved.

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