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.

With 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 idea will be discussed further in the section on IP finger-safe ratings.

III. 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. 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. The following are 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 increasing 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.

An electrical safety program should accomplish the following objectives:

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

IV. Electrical Safety Program

An electrical safety program is vital in establishing an electrically safe work place and is required:

> *NFPA 70E 110.7 Electrical Safety Program.*
>
> *(A) General. The employer shall implement an overall electrical safety program that directs activity appropriate for the voltage, energy level, and circuit conditions.*
>
> *FPN: Safety-related work practices are just one component of an overall electrical safety program.*

To reduce electrical hazards, each hazard must be addressed, as the work is being assigned and planned. An overview of electrical safety requirements can be found in OSHA 29 CFR 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. In addition, *NFPA 70E* addresses all the key aspects of electrical safety and electrical safe work practices. If these requirements are followed completely, injuries and deaths can be prevented.

A. Electrical safety program principles

The following principles, when implemented, can help ensure safer work places:

1. **Identify and minimize the hazards in electrical systems.** For new systems, designers should address minimizing hazards in the electrical system design stage. For existing systems, implement upgrades or retrofits that reduce the hazards.
2. **Plan every job.** Most incidents 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. If needed, conduct a flash hazard and shock hazard analysis; *NFPA 70E* 110.8(B)(1)(a) & (b) have requirements for these analyses.

3. **If possible, put circuit or equipment in an electrically safe work condition.** An *electrically safe work condition* is an important principle. If the industry only worked on equipment or circuits that are in an electrically safe work condition, there would be far fewer injuries and deaths of an electrical origin. For more on electrically safe work condition, refer to Electrical Incident and Hazard Prevention Section.
4. **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.
5. **Identify and minimize the hazards for each job.** 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 might be unrelated to electrical energy. If it is impossible to establish an electrically safe work condition, be sure to shut down every possible energy source. Understand that sometimes a de-energized circuit can become re-energized, and do something to lessen the risk.
6. **Assess a worker's abilities.** Make sure that any person assigned to tasks associated with electrical energy is 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.
7. **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 incident. Unless the component is listed for the purpose, fuses must never be installed or removed when the circuit is energized.
8. **Isolate the equipment.** The best way to avoid an incident is to reduce exposure to hazards. Keep doors closed. Keep barricades in place. Install temporary voltage-rated blankets covering exposed live parts.
9. **Protect the person.** Use appropriate PPE for the job. This equipment might include safety glasses or face shield, head protection, voltage-rated gloves, safety belts and harness, or flame-resistant clothing.
10. **Inspect/evaluate the electrical equipment.** Be sure the equipment is suitable for its use, where it is applied, and in good working condition.
11. **Maintain the electrical equipment's insulation and enclosure integrity.** As an example, if repairs or changes must be made, use components meeting the original specifications.
12. **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.

B. Electrical safety program controls

Controls can ensure the electrical safety program is implemented properly. Some controls include the following:

1. Implement an ***Energized Work Permit*** procedure and culture.
2. **All conductors or equipment are considered energized** until verified otherwise.
3. **No "bare-hand" work** on exposed conductors or circuits above 50V to ground that have not been placed in an electrically safe work condition, unless the "bare-hand" method is necessary and properly used.
4. **The tasks while de-energizing and putting a conductor or circuit in an *electrically safe work condition* are in themselves hazardous.** Take proper precautions and wear the appropriate PPE while putting circuits in an electrically safe work condition.
5. **Responsibilities:** employers develop programs and training, and the employees apply them.
6. **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.
7. **Train employees to qualify them** for working in an environment influenced by the presence of electrical energy.
8. **Hazard determination:** use a logical approach to determine the potential hazards associated with doing tasks.
9. **Precautions:** identify and use precautions appropriate to the working environment.

C. Electrical safety program procedures

All electrical work should be planned before the work begins, and the work should be done to approved procedures that comply with safe work practices. For non-hazardous electrical work, the plan is typically unwritten. Jobs that are done repeatedly should have a written procedure, which is followed each time the work is performed. Written or not, all plans must consider all hazards and guard against them. A qualified person who understands the work to be done and hazards involved as well as is familiar with the equipment being worked on, should prepare written procedures. Written procedures must include a step-by-step outline of the work to be performed and a single-line diagram or other appropriate drawings that can be used to discuss the job. Procedures for work performed should be reviewed with the appropriate individuals responsible.

Procedures typically come in two varieties: those written specifically to plan a particular job or more general procedures that include a checklist or a simple verbal plan. Procedures can include:

- Purpose of task
- Number of workers and their qualifications
- Hazardous nature and extent of task
- Shock approach boundaries and flash protection boundaries
- Safe work practices to be utilized
- Personal protective equipment required
- Insulating materials and tools required
- Special precautionary techniques
- Electrical diagrams and one-line diagrams
- Equipment details
- Sketches of unique features
- Reference data

D. Hazard risk evaluation

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, special precautions, energy source controls, and PPE requirements. If the work tasks include working on or near exposed electrical parts that have not been put in an electrically safe work condition, then 70E-110.8(B)(1) requires an electrical hazard analysis. This includes a shock hazard analysis and flash hazard analysis. If necessary, these analyses will determine the appropriate shock approach boundaries, flash protection boundaries, personal protective equipment, and tools required for specific tasks. The analyses should be documented and retained.

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 is defined in terms of the amount of voltage and energy available in the system while the work is executed.

Note: *The preferred work practice is to establish an electrically safe work condition prior to executing the task. PPE is necessary until the electrically safe work condition is established.*

NFPA 70E has a sample risk/hazard analysis flow diagram in Annex G.

E. Job briefing

NFPA 70E 110.7(G) requires that prior to the start of a job the involved workers shall be briefed on such topics as hazards associated with the job, work procedures, special precautions, energy source controls, and PPE required. If the day's work is repetitive or similar, a job briefing shall be conducted prior to the first job of the day. Contractors typically do a tailgate briefing at the beginning of the day. During the course of the day's work, if there are significant changes, additional briefing(s) shall be conducted. If the work is routine, then the briefing can be short. A more in-depth briefing is required if the work is complicated, hazardous, or the workers cannot be expected to recognize the hazards involved. See *NFPA 70E* Annex I, Job Briefing and Planning Checklist.

F. Incident and injury prevention

The following actions should be undertaken in every electrical safety program:

- Review programs for the inspection and/or repair of portable electrical equipment for completeness and effectiveness.
- Review policies concerning work permits on energized circuits with a goal of reducing the frequency of such work.
- Emphasize electrical worker training in the following areas:
  - 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 (energized 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 must be provided training that includes information about electrical risks, such as inadequate grounding, reverse polarity, and probable 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.

G. Designing an electrical system for safety

It is advisable that the electrical safety program includes a process to consider improvements to existing electrical systems and better designs for worker safety for new systems. There are numerous electrical system and equipment design considerations that can improve safety for workers. Some ideas for system design and system upgrades are presented in Suggestions for Limiting the Arc-flash and Shock Hazards, Section X.

V. Electrical Hazards

Electricity has become such an integral part of our society that it often is taken for granted. Yet, electricity remains a very dangerous hazard for people working on or near it. 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 might also result in bruises, bone fractures, and even death from collisions or falls.

The following are recognized as common electrical hazards that can cause injury, and even death, while a person works on or near electrical equipment and systems:

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

In the next several sections, electrical shock, arc-flash, and arc-blast will be discussed in more depth. In addition, a section on the term "electrically safe work condition" explains the steps necessary to achieve this condition. *NFPA 70E* 110.8(B)(1) requires an electrical hazard analysis if workers will be exposed to electrical parts that have not been placed in an electrically safe work condition. This shall include a Shock Hazard Analysis and Flash Hazard Analysis, which will also be covered in other sections.

> *OSHA 1910 Subpart S - 1910.333(a)*
>
> *Safety-related work practices shall be employed to prevent electric shock or other injuries resulting from either direct or indirect electrical contacts, when work is performed near or on equipment or circuits which are or may be energized. The specific safety-related work practices shall be consistent with the nature and extent of the associated electrical hazards...*

A. Electrical shock

More than 30,000 non-fatal electrical shock incidents are estimated to occur each year. The National Safety Council estimates that from 600 to 1,000 people die every year from electrocution. Of those killed with voltages less than 600V, nearly half were working on exposed energized circuits 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 incidents).

Most personnel are aware of the danger of electrical shock, even electrocution. It is the one electrical hazard around which most electrical safety standards have been built. However, few really understand just how little current is required to cause injury, even death. Actually, the current drawn by a 7½W, 120V lamp, passing across the chest, from hand-to-hand or hand-to-foot, is enough to cause fatal electrocution.

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

- Circuit characteristics (current, resistance, frequency, and voltage)
- Contact resistance and internal resistance of the body
- The current's pathway through the body, determined by contact location and internal body chemistry
- Duration of the contact
- Environmental conditions that affect the body's contact resistance