Chapter 3 Safety Requirements for Special Equipment

ARTICLE 300 Introduction

300.1 Scope. Chapter 3 covers special electrical equipment in the workplace and modifies the general requirements of Chapter 1.

300.2 Responsibility. The employer shall provide safety-related work practices and employee training. The employee shall follow those work practices.

300.3 Organization. Chapter 3 of this standard is divided into articles. Article 300 applies generally. Article 310 applies to electrolytic cells. Article 320 applies to batteries and battery rooms. Article 330 applies to lasers. Article 340 applies to power electronic equipment. Article 350 applies to research and development (R&D) laboratories.

ARTICLE 310 Safety-Related Work Practices for Electrolytic Cells

310.1 Scope. The requirements of this article shall apply to the electrical safety-related work practices used in the types of electrolytic cell areas.

Informational Note No. 1: See Informative Annex L for a typical application of safeguards in the cell line working zone.

Informational Note No. 2: For further information about electrolytic cells, see *NFPA 70*, *National Electrical Code*, Article 668.

310.2 Definitions. For the purposes of this article, the definitions that follow shall apply.

Battery Effect. A voltage that exists on the cell line after the power supply is disconnected.

Informational Note: Electrolytic cells can exhibit characteristics similar to an electrical storage battery and a shock hazard could exist after the power supply is disconnected from the cell line.

Safeguarding. Safeguards for personnel include the consistent administrative enforcement of safe work practices. Safeguards include training in safe work practices, cell line design, safety equipment, PPE, operating procedures, and work checklists.

310.3 Safety Training.

(A) General. The training requirements of this chapter shall apply to employees exposed to electrical hazards in the cell line working zone defined in 110.2 and shall supplement or modify the requirements of 120.1, 130.2, 130.3, and 130.8.

(B) Training Requirements. Employees shall be trained to understand the specific electrical hazards associated with electrical energy on the cell line. Employees shall be trained in safety-related work practices and procedural requirements to provide protection from the electrical hazards associated with their respective job or task assignment.

310.4 Employee Training.

(A) Qualified Persons.

(1) Training. Qualified persons shall be trained and knowledgeable in the operation of cell line working zone equipment and specific work methods and shall be trained to avoid the electrical hazards that are present. Such persons shall be familiar with the proper use of precautionary techniques and PPE. Training for a qualified person shall include the following:

(1) Skills and techniques to avoid a shock hazard:

a. Between energized surfaces, which might include temporarily insulating or guarding parts to permit the employee to work on energized parts

b. Between energized surfaces and grounded equipment, other grounded objects, or the earth itself, that might include temporarily insulating or guarding parts to permit the employee to work on energized parts

(2) Method of determining the cell line working zone area boundaries

(2) Qualified Persons. Qualified persons shall be permitted to work within the cell line working zone.

(B) Unqualified Persons.

(1) Training. Unqualified persons shall be trained to identify electrical hazards to which they could be exposed and the proper methods of avoiding the hazards.

(2) In Cell Line Working Zone. When there is a need for an unqualified person to enter the cell line working zone to perform a specific task, that person shall be advised of the electrical hazards by the designated qualified person in charge to ensure that the unqualified person is safeguarded.

310.5 Safeguarding of Employees in the Cell Line Working Zone.

(A) General. Operation and maintenance of electrolytic cell lines might require contact by employees with exposed energized surfaces such as buses, electrolytic cells, and their attachments. The approach distances referred to in Table 130.4(D)(a) and Table 130.4(D)(b) shall not apply to work performed by qualified persons in the cell line working zone. Safeguards such as safety-related work practices and other safeguards shall be used to protect employees from injury while working in the cell line working zone. These safeguards shall be consistent with the nature and extent of the related electrical hazards. Safeguards might be different for energized cell lines and de-energized cell lines. Hazardous battery effect voltages shall be dissipated to consider a cell line de-energized.

Informational Note No. 1: Exposed energized surfaces might not present an electrical hazard. Electrical hazards are related to current flow through the body, causing shock and arc flash burns and arc blasts. Shock is a function of many factors, including resistance through the body and the skin, return paths, paths in parallel with the body, and system voltages. Arc flash burns and arc blasts are a function of the current available at the point involved and the time of arc exposure.

Informational Note No. 2: A cell line or group of cell lines operated as a unit for the production of a particular metal, gas, or chemical compound might differ from other cell lines producing the same product because of variations in the particular raw materials used, output capacity, use of proprietary methods or process practices, or other modifying factors. Detailed standard electrical safety-related work practice requirements could become overly restrictive without accomplishing the stated purpose of Chapter 1.

(B) Signs. Permanent signs shall clearly designate electrolytic cell areas.

(C) Electrical Arc Flash Hazard Analysis. The requirements of 130.5, Arc Flash Risk Assessment, shall not apply to electrolytic cell line work zones.

(1) Arc Flash Risk Assessment. Each task performed in the electrolytic cell line working zone shall be analyzed for the likelihood of arc flash injury. If there is a likelihood of personal injury, appropriate measures shall be taken to protect persons exposed to the arc flash hazards, including one or more of the following:

(1) Providing appropriate PPE *[see 310.5(D)(2)]* to prevent injury from the arc flash hazard
(2) Altering work procedures to reduce the likelihood of occurrence of an arc flash incident
(3) Scheduling the task so that work can be performed when the cell line is de-energized

(2) Routine Tasks. Arc flash risk assessment shall be done for all routine tasks performed in the cell line work zone. The results of the arc flash risk assessment shall be used in training employees in job procedures that minimize the possibility of arc flash hazards. The training shall be included in the requirements of 310.3.

(3) Nonroutine Tasks. Before a nonroutine task is performed in the cell line working zone, an arc flash risk assessment shall be done. If an arc flash hazard is a possibility during nonroutine work, appropriate instructions shall be given to employees involved on how to minimize the risk associated with arc flash.

(4) Arc Flash Hazards. If the likelihood of occurrence of an arc flash hazard exists for either routine or nonroutine tasks, employees shall use appropriate safeguards.

(D) Safeguards. Safeguards shall include one or a combination of the following means.

(1) Insulation. Insulation shall be suitable for the specific conditions, and its components shall be permitted to include glass, porcelain, epoxy coating, rubber, fiberglass, and plastic and, when dry, such materials as concrete, tile, brick, and wood. Insulation shall be permitted to be applied to energized or grounded surfaces.

(2) Personal Protective Equipment (PPE). PPE shall provide protection from electrical hazards. PPE shall include one or more of the following, as determined by authorized management:

(1) Footwear for wet service
(2) Gloves for wet service
(3) Sleeves for wet service
(4) Footwear for dry service
(5) Gloves for dry service
(6) Sleeves for dry service
(7) Electrically insulated head protection
(8) Protective clothing
(9) Eye protection with nonconductive frames
(10) Face shield (polycarbonate or similar nonmelting type)
   a. Standards for PPE. Personal and other protective equipment shall be appropriate for conditions, as determined by authorized management, and shall not be required to meet the equipment standards in 130.7(C)(14) through 130.7(F) and in Table 130.7(C)(14) and Table 130.7(F).
   b. Testing of PPE. PPE shall be verified with regularity and by methods that are consistent with the exposure of employees to electrical hazards.

(3) Barriers. Barriers shall be devices that prevent contact with energized or grounded surfaces that could present an electrical hazard.

(4) Voltage Equalization. Voltage equalization shall be permitted by bonding a conductive surface to an electrically energized surface, either directly or through a resistance, so that there is insufficient voltage to create an electrical hazard.

(5) Isolation. Isolation shall be the placement of equipment or items in locations such that employees are unable to simultaneously contact exposed conductive surfaces that could present an electrical hazard.

(6) Safe Work Practices. Employees shall be trained in safe work practices. The training shall include why the work practices in a cell line working zone are different from similar work situations in other areas of the plant. Employees shall comply with established safe work practices and the safe use of protective equipment.

(a) Attitude Awareness. Safe work practice training shall include attitude awareness instruction. Simultaneous contact with energized parts and ground can cause serious electrical shock. Of special importance is the need to be aware of body position where contact may be made with energized parts of the electrolytic cell line and grounded surfaces.

(b) Bypassing of Safety Equipment. Safe work practice training shall include techniques to prevent bypassing the protection of safety equipment. Clothing may bypass protective equipment if the clothing is wet. Trouser legs should be kept at appropriate length, and shirt sleeves should be a good fit so as not to drape while reaching. Jewelry and other metal accessories that may bypass protective equipment shall not be worn while working in the cell line working zone.

(7) Tools. Tools and other devices used in the energized cell line work zone shall be selected to prevent bridging between surfaces at hazardous potential difference.

Informational Note: Tools and other devices of magnetic material could be difficult to handle in the area of energized cells due to their strong dc magnetic fields.

(8) Portable Cutout-Type Switches. Portable cell cutout switches that are connected shall be considered as energized and as an extension of the cell line working zone. Appropriate procedures shall be used to ensure proper cutout switch connection and operation.

(9) Cranes and Hoists. Cranes and hoists shall meet the requirements of 668.32 of *NFPA 70*, *National Electrical Code*. Insulation required for safeguarding employees, such as insulated crane hooks, shall be periodically tested.

(10) Attachments. Attachments that extend the cell line electrical hazards beyond the cell line working zone shall use one or more of the following:

(1) Temporary or permanent extension of the cell line working zone
(2) Barriers
(3) Insulating breaks
(4) Isolation

(11) Pacemakers and Metallic Implants. Employees with implanted pacemakers, ferromagnetic medical devices, or other electronic devices vital to life shall not be permitted in cell areas unless written permission is obtained from the employee's physician.

Informational Note: The American Conference of Government Industrial Hygienists (ACGIH) recommends that persons with implanted pacemakers should not be exposed to magnetic flux densities above 10 gauss.

(12) Testing. Equipment safeguards for employee protection shall be tested to ensure they are in a safe working condition.

310.6 Portable Tools and Equipment.

Informational Note: The order of preference for the energy source for portable hand-held equipment is considered to be as follows:

(1) Battery power
(2) Pneumatic power
(3) Portable generator
(4) Nongrounded-type receptacle connected to an ungrounded source

(A) Portable Electrical Equipment. The grounding requirements of 110.4(B)(2) shall not be permitted within an energized cell line working zone. Portable electrical equipment shall meet the requirements of 668.20 of *NFPA 70*, *National Electrical Code*. Power supplies for portable electric equipment shall meet the requirements of 668.21 of *NFPA 70*.

(B) Auxiliary Nonelectric Connections. Auxiliary nonelectric connections such as air, water, and gas hoses shall meet the requirements of 668.31 of *NFPA 70*, *National Electrical Code*. Pneumatic-powered tools and equipment shall be supplied with nonconductive air hoses in the cell line working zone.

(C) Welding Machines. Welding machine frames shall be considered at cell potential when within the cell line working zone. Safety-related work practices shall require that the cell line not be grounded through the welding machine or its power supply. Welding machines located outside the cell line working zone shall be barricaded to prevent employees from touching the welding machine and ground simultaneously where the welding cables are in the cell line working zone.

(D) Portable Test Equipment. Test equipment in the cell line working zone shall be suitable for use in areas of large magnetic fields and orientation.

Informational Note: Test equipment that is not suitable for use in such magnetic fields could result in an incorrect response. When such test equipment is removed from the cell line working zone, its performance might return to normal, giving the false impression that the results were correct.

ARTICLE 320
Safety Requirements Related to Batteries and Battery Rooms

320.1 Scope. This article covers electrical safety requirements for the practical safeguarding of employees while working with exposed stationary storage batteries that exceed 50 volts, nominal.

Informational Note: For additional information on best practices for safely working on stationary batteries, see the following documents:

(1) NFPA 1, *Fire Code*, Chapter 52, Stationary Storage Battery Systems, 2015
(2) *NFPA 70*, *National Electrical Code*, Article 480, Storage Batteries, 2014
(3) IEEE 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*, 2010
(4) IEEE 937, *Recommended Practice for Installation and Maintenance of Lead-Acid Batteries for Photovoltaic Systems*, 2007
(5) IEEE 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*, 2005 (R 2011)
(6) IEEE 1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems*, 2006
(7) IEEE 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*, 2005 (R 2010)
(8) IEEE 1657, *Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries,* 2009
(9) OSHA 29 CFR 1910.305(j)(7), "Storage batteries"
(10) OSHA 29 CFR 1926.441, "Batteries and battery charging"
(11) DHHS (NIOSH) Publication No. 94-110, *Applications Manual for the Revised NIOSH Lifting Equation,* 1994

320.2 Definitions. For the purposes of this article definitions that follow shall apply.

Authorized Personnel. The person in charge of the premises, or other persons appointed or selected by the person in charge of the premises who performs certain duties associated with stationary storage batteries.

Battery. A system consisting of two or more electrochemical cells connected in series or parallel and capable of storing electrical energy received and that can give it back by reconversion.

Battery Room. A room specifically intended for the installation of batteries that have no other protective enclosure.

Cell. The basic electrochemical unit, characterized by an anode and a cathode used to receive, store, and deliver electrical energy.

Electrolyte. A solid, liquid, or aqueous immobilized liquid medium that provides the ion transport mechanism between the positive and negative electrodes of a cell.

Nominal Voltage. The value assigned to a cell or battery of a given voltage class for the purpose of convenient designation; the operating voltage of the cell or system may vary above or below this value.

Pilot Cell. One or more cells chosen to represent the operating parameters of the entire battery (sometimes called "temperature reference" cell).

Prospective Short-Circuit Current. The highest level of fault current that could theoretically occur at a point on a circuit. This is the fault current that can flow in the event of a zero impedance short circuit and if no protection devices operate.

Valve-Regulated Lead Acid (VRLA) Cell. A lead-acid cell that is sealed with the exception of a valve that opens to the atmosphere when the internal pressure in the cell exceeds atmospheric pressure by a pre-selected amount, and that provides a means for recombination of internally generated oxygen and the suppression of hydrogen gas evolution to limit water consumption.

Vented Cell. A type of cell in which the products of electrolysis and evaporation are allowed to escape freely into the atmosphere as they are generated. (Also called "flooded cell.")

320.3 Safety Procedures.

(A) General Safety Hazards.

(1) Battery Risk Assessment. Prior to any work on a battery system, a risk assessment shall be performed to identify the chemical, electrical shock, and arc flash hazards and assess the risks associated with the type of tasks to be performed.

(2) Battery Room or Enclosure Requirements.

(a) Personnel Access to Energized Batteries. Each battery room or battery enclosure shall be accessible only to authorized personnel.

(b) Illumination. Employees shall not enter spaces containing batteries unless illumination is provided that enables the employees to perform the work safely.

Informational Note: Battery terminals are normally exposed and pose possible shock hazard. Batteries are also installed in steps or tiers that can cause obstructions.

(3) Apparel. Personnel shall not wear electrically conductive objects such as jewelry while working on a battery system.

(4) Abnormal Battery Conditions. Instrumentation that provides alarms for early warning of abnormal conditions of battery operation, if present, shall be tested annually.

Informational Note: Battery monitoring systems typically include alarms for such conditions as overvoltage, undervoltage, overcurrent, ground fault, and overtemperature. The type of conditions monitored will vary depending upon the battery technology. One source of guidance on monitoring battery systems is IEEE 1491, *Guide for the Selection and Use of Battery Monitoring Equipment in Stationary Applications*.

(5) Warning Signs. The following warning signs or labels shall be posted in appropriate locations:

(1) Electrical hazard warnings indicating the shock hazard due to the battery voltage and the arc flash hazard due to the prospective short-circuit current, and the thermal hazard.

Informational Note No. 1: Because internal resistance, prospective short-circuit current, or both are not always provided on battery container labels or data sheets, and because many variables can be introduced into a battery layout, the battery manufacturer should be consulted for accurate data. Variables can include, but are not limited to, the following:

a. Series connections
b. Parallel connections
c. Charging methodology
d. Temperature
e. Charge status
f. Dc distribution cable size and length

Informational Note No. 2: See 130.5(D) for requirements for equipment labeling.

(2) Chemical hazard warnings, applicable to the worst case when multiple battery types are installed in the same space, indicating the following:

a. Potential presence of explosive gas (when applicable to the battery type)
b. Prohibition of open flame and smoking
c. Danger of chemical burns from the electrolyte (when applicable to the battery type)

(3) Notice for personnel to use and wear protective equipment and apparel appropriate to the hazard for the battery

(4) Notice prohibiting access to unauthorized personnel

(B) Electrolyte Hazards.

(1) Battery Activities That Include Handling of Liquid Electrolyte. The following protective equipment shall be available to employees performing any type of service on a battery with liquid electrolyte:

(1) Goggles and face shield appropriate for the electrical hazard and the chemical hazard
(2) Gloves and aprons appropriate for the chemical hazards
(3) Portable or stationary eye wash facilities within the work area that are capable of drenching or flushing of the eyes and body for the duration necessary to the hazard.

Informational Note: Guidelines for the use and maintenance of eye wash facilities for vented batteries in nontelecom environments can be found in ANSI/ISEA Z358.1, *American National Standard for Emergency Eye Wash and Shower Equipment*.

(2) Activities That Do Not Include Handling of Electrolyte. Employees performing any activity not involving the handling of electrolyte shall wear safety glasses.

• Informational Note: Battery maintenance activities usually do not involve handling electrolyte. Batteries with solid electrolyte (such as most lithium batteries) or immobilized electrolyte (such as valve-regulated lead acid batteries) present little or no electrolyte hazard. Most modern density meters expose a worker to a quantity of electrolyte too minute to be considered hazardous, if at all. Such work would not be considered handling electrolyte. However, if specific gravity readings are taken using a bulb hydrometer, the risk of exposure is higher — this could be considered to be handling electrolyte, and the requirements of 320.3(B)(1) would apply.

(C) Testing, Maintenance, and Operation.

• **(1) Direct-Current Ground-Fault Detection.** Ground-fault detection shall be based on the type of dc grounding systems utilized.

Informational Note: Not all battery systems have dc ground-fault detection systems. For personnel safety reasons, it is important to understand the grounding methodology being used and to determine the appropriate manner of detecting ground faults. If an unintended ground develops within the system (e.g., dirt and acid touching the battery rack), it can create a short circuit that could cause a fire. Commonly used dc grounding systems include, but are not limited to, the following:

(1) Type 1. An ungrounded dc system, in which neither pole of the battery is connected to ground. If an unintentional ground occurs at any place in the battery, an increased potential would exist, allowing fault current to flow between the opposite end of the battery and the ground. An ungrounded dc system is typically equipped with an alarm to indicate the presence of a ground fault.
(2) Type 2. A solidly grounded dc system, in which either the most positive or most negative pole of the battery is connected directly to ground. If an unintentional ground occurs, it introduces a path through which fault current can flow. A ground detection system is not typically used on this type of grounded system.

(3) Type 3. A resistance grounded dc system, which is a variation of a Type 1 system, in which the battery is connected to ground through a resistance. Detection of a change in the resistance typically enables activation of a ground-fault alarm. Introducing an unintentional ground at one point of the battery could be detected and alarmed. A second unintentional ground at a different point in the battery would create a path for short-circuit current to flow.
(4) Type 4. A solidly grounded dc system, either at the center point or at another point to suit the load system. If an unintentional ground occurs on either polarity, it introduces a path through which short circuit current can flow. A ground detection system is not typically used on this type of grounded system.

(2) Tools and Equipment.

(a) Tools and equipment for work on batteries shall be equipped with handles listed as insulated for the maximum working voltage.

(b) Battery terminals and all electrical conductors shall be kept clear of unintended contact with tools, test equipment, liquid containers, and other foreign objects.

(c) Nonsparking tools shall be required when the risk assessment required by 110.1(F) justifies their use.

(D) Cell Flame Arresters and Cell Ventilation. When present, battery cell ventilation openings shall be unobstructed. Cell flame arresters shall be inspected for proper installation and unobstructed ventilation and shall be replaced when necessary in accordance with the manufacturer's instructions.

ARTICLE 330
Safety-Related Work Practices for Use of Lasers

330.1 Scope. The requirements of this article shall apply to the use of lasers in the laboratory and the workshop.

330.2 Definitions. For the purposes of this article, the definitions that follow shall apply.

Fail Safe. The design consideration in which failure of a component does not create additional hazards or increased risk. In the failure mode, the system is rendered inoperative or nonhazardous.

Fail-Safe Safety Interlock. An interlock that in the failure mode does not defeat the purpose of the interlock; for example, an interlock that is positively driven into the off position as soon as a hinged cover begins to open, or before a detachable cover is removed, and that is positively held in the off position until the hinged cover is closed or the detachable cover is locked in the closed position.

Laser. Any device that can be made to produce or amplify electromagnetic radiation in the wavelength range from 100 nm to 1 mm primarily by the process of controlled stimulated emission.

Laser Energy Source. Any device intended for use in conjunction with a laser to supply energy for the excitation of electrons, ions, or molecules. General energy sources, such as electrical supply services or batteries, shall not be considered to constitute laser energy sources.

Laser Product. Any product or assembly of components that constitutes, incorporates, or is intended to incorporate a laser or laser system.

Laser Radiation. All electromagnetic radiation emitted by a laser product between 100 nm and 1 mm that is produced as a result of a controlled stimulated emission.

Laser System. A laser in combination with an appropriate laser energy source with or without additional incorporated components.

330.3 Safety Training.

(A) Personnel to Be Trained. Employers shall provide training for all operator and maintenance personnel.

(B) Scope of Training. The training shall include, but is not limited to, the following:

(1) Familiarization with laser principles of operation, laser types, and laser emissions
(2) Laser safety, including the following:
   a. System operating procedures
   b. Risk assessment and risk control procedures
   c. Need for personnel protection
   d. Accident reporting procedures
   e. Biological effects of the laser upon the eye and the skin
   f. Electrical and other hazards associated with the laser equipment, including the following:
      i. High voltages (>1 kV) and stored energy in the capacitor banks
      ii. Circuit components, such as electron tubes, with anode voltages greater than 5 kV emitting X-rays
      iii. Capacitor bank explosions
      iv. Production of ionizing radiation
      v. Poisoning from the solvent or dye switching liquids or laser media
      vi. High sound intensity levels from pulsed lasers

(C) Proof of Qualification. Proof of qualification of the laser equipment operator shall be readily available.

330.4 Safeguarding of Employees in the Laser Operating Area.

(A) Eye Protection. Employees shall be provided with eye protection as required by federal regulation.

(B) Warning Signs. Warning signs shall be posted at the entrances to areas or protective enclosures containing laser products.

(C) Master Control. High-power laser equipment shall include a key-operated master control.

(D) High-Power Radiation Emission Warning. High-power laser equipment shall include a fail-safe laser radiation emission audible and visible warning when it is switched on or if the capacitor banks are charged.

(E) Beam Shutters or Caps. Beam shutters or caps shall be used, or the laser switched off, when laser transmission is not required. The laser shall be switched off when unattended for 30 minutes or more.

(F) Aiming. Laser beams shall not be aimed at employees.

(G) Label. Laser equipment shall bear a label indicating its maximum output.

(H) Personal Protective Equipment (PPE). PPE shall be provided for users and operators of high-power laser equipment.

330.5 Employee Responsibility. Employees shall be responsible for the following:

(1) Obtaining authorization for laser use
(2) Obtaining authorization for being in a laser operating area
(3) Observing safety rules
(4) Reporting laser equipment failures and accidents to the employer

ARTICLE 340
Safety-Related Work Practices: Power Electronic Equipment

340.1 Scope. This article shall apply to safety-related work practices around power electronic equipment, including the following:

(1) Electric arc welding equipment
(2) High-power radio, radar, and television transmitting towers and antennas
(3) Industrial dielectric and radio frequency (RF) induction heaters
(4) Shortwave or RF diathermy devices
(5) Process equipment that includes rectifiers and inverters such as the following:
   a. Motor drives
   b. Uninterruptible power supply systems
   c. Lighting controllers

340.2 Definition. For the purposes of this article, the definition that follows shall apply.

Radiation Worker. A person who is required to work in electromagnetic fields, the radiation levels of which exceed those specified for nonoccupational exposure.

340.3 Application. The purpose of this article is to provide guidance for safety personnel in preparing specific safety-related work practices within their industry.

340.4 Reference Standards. The following are reference standards for use in the preparation of specific guidance to employees as follows:

(1) International Electrotechnical Commission IEC 60479, *Effects of Current Passing Through the Body*:
   a. 60479-1 Part 1: General aspects
   b. 60479-1-1 Chapter 1: Electrical impedance of the human body
   c. 60479-1-2 Chapter 2: Effects of ac in the range of 15 Hz to 100 Hz
   d. 60479-2 Part 2: Special aspects
   e. 60479-2-4 Chapter 4: Effects of ac with frequencies above 100 Hz
   f. 60479-2-5 Chapter 5: Effects of special waveforms of current
   g. 60479-2-6 Chapter 6: Effects of unidirectional single impulse currents of short duration
(2) International Commission on Radiological Protection (ICRP) Publication 33, *Protection Against Ionizing Radiation from External Sources Used in Medicine*

340.5 Effects of Electricity on the Human Body. The employer and employees shall be aware of the following hazards associated with power electronic equipment.

(1) Effects of Power Frequency Current:
   a. At 0.5 mA, shock is perceptible.
   b. At 10 mA, a person may not be able to voluntarily let go of an energized electrical conductor or circuit part.
   c. At about 40 mA, the shock, if lasting for 1 second or longer, can be fatal due to ventricular fibrillation.
   d. Further increasing current leads to burns and cardiac arrest.

(2) Effects of Direct Current:
   a. A dc current of 2 mA is perceptible.
   b. A dc current of 40 mA is considered the threshold of the let-go current.

(3) Effects of Voltage. A voltage of 30 V rms, or 60 V dc, is considered safe, except when the skin is broken. The internal body resistance can be as low as 500 ohms, so fatalities can occur.

(4) Effects of Short Contact:
   a. For contact less than 0.1 second and with currents just greater than 0.5 mA, ventricular fibrillation can occur only if the shock is during a vulnerable part of the cardiac cycle.
   b. For contact of less than 0.1 second and with currents of several amperes, ventricular fibrillation can occur if the shock is during a vulnerable part of the cardiac cycle.
   c. For contact of greater than 0.8 second and with currents just greater than 0.5 A, cardiac arrest (reversible) can occur.
   d. For contact greater than 0.8 second and with currents of several amperes, burns and death are probable.

(5) Effects of Alternating Current at Frequencies Above 100 Hz. When the threshold of perception increases from 10 kHz to 100 kHz, the threshold of let-go current increases from 10 mA to 100 mA.

(6) Effects of Waveshape. Contact with voltages from phase controls usually causes effects between those of ac and dc sources.

(7) Effects of Capacitive Discharge:
   a. A circuit of capacitance of 1 μF having a 10 kV capacitor charge can cause ventricular fibrillation.
   b. A circuit of capacitance of 20 μF having a 10 kV capacitor charge can be dangerous and probably will cause ventricular fibrillation.

340.6 Hazards Associated with Power Electronic Equipment. The employer and employees shall be aware of the hazards associated with the following:

(1) High voltages within the power supplies

(2) Radio frequency energy–induced high voltages

(3) Effects of RF fields in the vicinity of antennas and antenna transmission lines, which can introduce electrical shock and burns

(4) Ionizing (X-radiation) hazards from magnetrons, klystrons, thyratrons, cathode-ray tubes, and similar devices

(5) Nonionizing RF radiation hazards from the following:
   a. Radar equipment
   b. Radio communication equipment, including broadcast transmitters
   c. Satellite–earth-transmitters
   d. Industrial scientific and medical equipment
   e. RF induction heaters and dielectric heaters
   f. Industrial microwave heaters and diathermy radiators

340.7 Specific Measures for Personnel Safety.

(A) Employer Responsibility. The employer shall be responsible for the following:

(1) Proper training and supervision by properly qualified personnel, including the following:
   a. Identification of associated hazards
   b. Strategies to reduce the risk associated with the hazards
   c. Methods of avoiding or protecting against the hazard
   d. Necessity of reporting any incident that resulted in, or could have resulted in, injury or damage to health

(2) Properly installed equipment

(3) Proper access to the equipment

(4) Availability of the correct tools for operation and maintenance

(5) Proper identification and guarding of dangerous equipment

(6) Provision of complete and accurate circuit diagrams and other published information to the employee prior to the employee starting work (The circuit diagrams should be marked to indicate the components that present an electrical hazard.)

(7) Maintenance of clear and clean work areas around the equipment to be worked on

(8) Provision of adequate and proper illumination of the work area

(B) Employee Responsibility. The employee shall be responsible for the following:

(1) Understanding the hazards associated with the work

(2) Being continuously alert and aware of the possible hazards

(3) Using the proper tools and procedures for the work

(4) Informing the employer of malfunctioning protective measures, such as faulty or inoperable enclosures and locking schemes

(5) Examining all documents provided by the employer relevant to the work, especially those documents indicating the location of components that present an electrical hazard

(6) Maintaining good housekeeping around the equipment and work space

(7) Reporting any incident that resulted in, or could have resulted in, injury or damage to health

(8) Using and appropriately maintaining the PPE and tools required to perform the work safely

ARTICLE 350
Safety-Related Work Requirements: Research and Development Laboratories

350.1 Scope. The requirements of this article shall apply to the electrical installations in those areas, with custom or special electrical equipment, designated by the facility management for research and development (R&D) or as laboratories.

350.2 Definitions. For the purposes of this article, the definitions that follow shall apply.

Competent Person. A person who meets all the requirements of *qualified person*, as defined in Article 100 in Chapter 1 of this standard and who, in addition, is responsible for all work activities or safety procedures related to custom or special equipment and has detailed knowledge regarding the exposure to electrical hazards, the appropriate control methods to reduce the risk associated with those hazards, and the implementation of those methods.

Field Evaluated. A thorough evaluation of nonlisted or modified equipment in the field that is performed by persons or parties acceptable to the authority having jurisdiction. The evaluation approval ensures that the equipment meets appropriate codes and standards, or is similarly found suitable for a specified purpose.

Laboratory. A building, space, room, or group of rooms intended to serve activities involving procedures for investigation, diagnostics, product testing, or use of custom or special electrical components, systems, or equipment.

Research and Development (R&D). An activity in an installation specifically designated for research or development conducted with custom or special electrical equipment.

350.3 Applications of Other Articles. The electrical system for R&D and laboratory applications shall meet the requirements of the remainder of this document, except as amended by Article 350.

Informational Note: Examples of these applications include low-voltage–high-current power systems; high-voltage–low-current power systems; dc power supplies; capacitors; cable trays for signal cables and other systems, such as steam, water, air, gas, or drainage; and custom-made electronic equipment.

350.4 Specific Measures and Controls for Personnel Safety. Each laboratory or R&D system application shall be assigned a competent person as defined in this article to ensure the use of appropriate electrical safety-related work practices and controls.

350.5 Listing Requirements. The equipment or systems used in the R&D area or in the laboratory shall be listed or field evaluated prior to use.

Informational Note: Laboratory and R&D equipment or systems can pose unique electrical hazards that might require mitigation. Such hazards include ac and dc, low voltage and high amperage, high voltage and low current, large electromagnetic fields, induced voltages, pulsed power, multiple frequencies, and similar exposures.