



## Goddard Procedural Requirements (GPR)

**DIRECTIVE NO.** GPR 1700.7B  
**EFFECTIVE DATE:** February 6, 2017  
**EXPIRATION DATE:** February 6, 2022

**APPROVED BY Signature:** Original Signed By  
**NAME:** Richard D. Barney  
**TITLE:** Director, Safety and Mission Assurance

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### COMPLIANCE IS MANDATORY

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**Responsible Office:** 360/Safety Division

**Title:** Electrical Safety

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## PREFACE

### P.1 PURPOSE

This directive sets forth the minimum electrical safety requirements within the framework of Goddard Space Flight Center's (GSFC) safety policies and constraints. It is primarily for use by qualified persons who routinely engage in facility-related electrical work; however, it also applies to electrical equipment in office and laboratory environments. It is not an instruction manual for untrained personnel, nor is it a substitute for detailed procedures judged necessary for the safe conduct of a specific electrical task by individuals and their supervisors.

### P.2 APPLICABILITY

- a. This directive applies to all GSFC civil servants, contractors, tenants, and other persons involved in the design, construction, operation, maintenance, research and development of nonspacecraft electrical/electronic systems on GSFC property, including all permanent and temporary sites. This includes non-facility related electrical operations, such as extension cords and temporary wiring setups. Electrical/electronic systems and hardware that are 50 volts AC (rms)/DC or less are exempt from the requirements of this GPR. The term "Safety Office" applies equally to the safety offices at both Greenbelt (Code 360) and Wallops Flight Facility (Code 803).
- b. In this directive, all document citations are assumed to be the latest version unless otherwise noted.
- c. In this directive, all mandatory actions (i.e., requirements) are denoted by statements containing the term "shall." The terms "may" or "can" denote discretionary privilege or permission; "should" denotes a good practice and is recommended but not required; "will" denotes expected outcome; and "are/is" denotes descriptive material.

### P.3 AUTHORITIES

- a. Occupational Safety and Health Administration (OSHA) 1910, General Industry Standards
- b. OSHA 1926, Construction Industry Regulations
- c. National Fire Protection Association (NFPA) 70E, Standard for Electrical Safety in the Workplace
- d. National Electrical Safety Code (NESC)

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#### **P.4 APPLICABLE DOCUMENTS AND FORMS**

- a. NFPA 70, National Electrical Code
- b. NFPA 70B, Recommended Practice for Electrical Equipment Maintenance
- c. NPR 8715.3, NASA General Safety Program Requirements
- d. GPR 1700.1, Occupational Safety Program at Goddard Space Flight Center
- e. GPR 1700.5, Control of Hazardous Energy (Lockout/Tagout)
- f. GPR 1700.6, Confined Space Program Requirements
- g. GPR 8719.1, Lifting Devices and Equipment (LDE) Certifications and Operations
- h. GPR 8621.4, GSFC Mishap Preparedness and Contingency Plan
- i. GSFC Form 23-83, Energized Electrical Work Permit.
- j. GSFC Form 8-6, On-the-Job Training (OJT)
- k. IEEE 1584, Guide for Performing Arc Flash Hazard Calculations

#### **P.5 CANCELLATION**

GPR 1700.7A, Electrical Safety

#### **P.6 SAFETY**

As described throughout this directive.

#### **P.7 TRAINING**

Civil Servant and Contractor Supervisors will ensure that all personnel under their authority are qualified for the type of activity/operation required to perform their electrical work safely and effectively.

1. The qualified person(s) (see Section 2.1) will be trained in and knowledgeable of the installation, construction and/or operation and maintenance of electrical equipment and be able to recognize and avoid the electrical hazards that are present with respect to equipment or work procedures.
2. Training will meet, at minimum, requirements set forth in NASA, NFPA, OSHA, and national consensus electrical standards.
3. Civil service and contractor supervisors will maintain copies of current training records, and identify training requirements for each of their employees tasked to perform electrical activities.

See Section 3 for specific Electrical Safety Training Requirements.

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**P.8 RECORDS**

<b>Record Title</b>	<b>Record Custodian</b>	<b>Retention</b>
Records of Electrical Safety Training	Office of Human Capital Management	<u>NASA Records Retention Schedule (NRRS) 3/33C*</u> – Destroy 5 years after employee discontinues or completes training.
Physician Report That Evaluates the Employee’s Ability to Conduct High Voltage Work.	Health Unit	<u>NRRS 1/127A*</u> – Retain until employee is transferred or separated. Upon transfer, ship medical record to medical office of new assignment. Within 30 days after separation, transfer to National Personnel Records Center.
Energized Electrical Work Permit Form 23-83	Organizations Conducting Electrical Operations and Safety Office	<u>NRRS 1/123*</u> – Destroy after organization determines analysis is no longer relevant.
Waiver/Deviation of Standards Documentation	Safety Office	<u>NRRS 1/120E*</u> - Retire to Federal Records Center (FRC) when the risk/safety assessment/analysis is complete/inactive. Destroy when 15 years old.
Inspection Records	Organizations Conducting Electrical Operations	<u>29 CFR 1960.73</u> - Records and reports shall be retained for 3 years following the end of the fiscal year to which they relate.
Building Drawings	FMD	<u>NRRS 8/48B2*</u> - *Permanent* May retire to FRC 2 Years after disposal of installation. Transfer to National Archive and Records Administration (NARA) 25 years after disposal of installation.

\*NRRS – NASA Records Retention Schedules ([NRRS 1441.1](#))

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## **P.9 MEASUREMENT/VERIFICATION**

The Safety Office will gather metrics from the following activities and analyze them for trends and lessons learned:

- a. Periodic Audits/inspections of electrical safety operations to ensure organizational program compliance; and
- b. Review close calls, lost-time incidents, and property damage due to electrical mishaps in order to prevent future occurrences.

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## PROCEDURES

### 1. RESPONSIBILITIES

#### 1.1 Director of Safety and Mission Assurance or designee shall:

- a. Appoint the chair of the Electrical Safety Committee (ESC) in writing.

#### 1.2 Directors Of shall:

- a. Directors Of whose workers engage in electrical work shall appoint in writing Electrical Safety Officer(s) (ESO) to serve as their Directorate's representative to the Electrical Safety Committee (ESC) and ensure that appropriate time is allotted and resources are provided for ESOs to perform their assigned duties; and
- b. Be final approver for Energized Electrical Work Permits (EEWPs) or designate an authorized representative as such.

#### 1.3 Division Chiefs

Division Chiefs whose employees engage in electrical work shall be responsible for ensuring that safe electrical work is accomplished within their area of responsibility, and:

- a. Ensure full implementation of electrical safety requirements throughout their organizations;
- b. Ensure full implementation of the applicable requirements of this GPR; and
- c. Address and resolve deficiencies noted during electrical inspections.

#### 1.4 Supervisors

Supervisors are responsible for ensuring that the requirements herein are adhered to in the design, construction, modification, operation, and maintenance of electrical systems. Supervisors who authorize electrical work (e.g., area work supervisors, team leaders, foremen, facility managers, project leaders, etc.) shall:

- a. Ensure that safe work is accomplished within their area(s) of responsibility;
- b. Ensure that written Hazard Analysis and Operational Procedures involving the use, exposure to, generation of, or control of electrical safety hazards are reviewed annually and updated as needed;
- c. Ensure that personnel are notified of any changes or modifications to policies or systems used to control electrical safety hazards;
- d. Review and approve Task Safety Analysis and hazardous operating procedures for working with energized equipment;

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- e. Ensure that subordinate workers are qualified and have received training as required by this GPR to identify electrical hazards and the protective measures required to safely work and that this training is documented and current;
- f. Ensure prime and subcontractors are provided with descriptions of site-specific hazards for proposed work;
- g. Ensure that workers have the required tools, Personal Protective Equipment (PPE), and other resources to perform their work safely;
- h. Authorize the performance of energized electrical work using approved Energized Electrical Work Permits (EEWPs) as applicable (see Section 4.2); and
- i. Report all mishaps or close calls as described in GPR 8621.4.

### 1.5 All Implementing Organizations

Organizations that engage in electrical work at a GSFC-managed site, or site controlled by the GSFC including contractors, inclusive of lower tier subcontractors, and consultants, will implement the requirements contained in this GPR. This is primarily done by defining, establishing, and understanding individual accountabilities, authorities, interfaces, and responsibilities as defined in this document. Furthermore, each organization shall:

- a. Incorporate and implement the requirements of this GPR into the organization's Safety and Health Plan as required by Agency Contract Clause (for contractors);
- b. Implement Quality Control/Quality Assurance functions to monitor and ensure that electrical work performed by the organization is performed in accordance with OSHA, NFPA, and GSFC standards. Quality Control/Quality Assurance functions shall include:
  - 1) Inspection of electrical installations as covered by the National Electrical Code (NEC);
  - 2) Maintenance of records of all electrical inspections, including the date of such inspections, a summary of any violations found to exist, and a record of the final disposition of all violations;
  - 3) Verification that safe electrical work practices are followed; and
  - 4) Verification that electrical systems are de-energized and placed in an electrically safe work condition as required in GPR 1700.5.
- c. Respond to ESC-initiated assessments and action items;
- d. Submit to the Facilities Management Division (FMD) updates to Facility-related electrical systems drawings and specifications for approval, prior to performing any work;
- e. At the Wallops Flight Facility, all electrical utility / power distribution electrical changes will be performed by the Wallops Integrated Institutional Contract (WICC) or by a Facilities Management Branch (FMB) approved contract.
- f. Develop Pre-Emergency Outage Plans (as appropriate) to address realistic scenarios in order to prevent the need for exposing workers to energized circuits during emergency situations.
- g. Submit to the Facilities Management Division (FMD) drawings and specifications for any facility related electrical work for approval, in advance of performing any work.

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## 1.6 Safety Office

The Safety Office shall:

- a. Provide assistance to organizations for assessing GSFC compliance to the requirements of this GPR and electrical codes;
- b. In conjunction with the Office of Human Capital Management, identify adequate electrical safety training resources;
- c. Review contractor health and safety plans to ensure that the applicable provisions of this GPR are properly incorporated;
- d. Ensure contractor health and safety plans meet the requirements of NPR 8715.3 and recommend approval to the Contracting Officer;
- e. Conduct annual organizational electrical safety program reviews to ensure operating activities are complying with requirements; and
- f. Conduct periodic inspections of job sites to ensure work activities comply with the requirements of this GPR.

## 1.7 Organizations Procuring Electrical Work

Organizations procuring electrical work shall:

- a. Include the requirements of this GPR in all contracts for the design, construction, operation and maintenance of facilities, and electrical systems operating under the auspices of GSFC, or on GSFC property;
- b. Ensure contractor solicitations meet the requirements of NPR 8715.3; and
- c. Take necessary remedial action when the contractor is in violation of the requirements of this GPR or a deficiency in performance of work impacting a contractual provision is identified.

## 1.8 Facilities Management Division (FMD)

The Facilities Management Division shall:

- a. Meet the requirements set forth in Section 1.5 of this GPR;
- b. Manage the Outage Approval Process;
- c. Develop and maintain electrical systems drawings for the Center in accordance with Section 5.2;
- d. Authorize connection of premises, buildings, or additions to the source of electrical supply, and authorize connection of equipment to the source of electrical supply; and
- e. Develop and implement design, construction standards, and specifications for facilities electrical work and facility electrical systems under the auspices of GSFC, or on GSFC property, including all permanent and temporary sites.

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## 1.9 Electrical Safety Committee (ESC)

The ESC will be composed of a representative from each Directorate performing work governed by this GPR. The committee shall:

- a. Develop a Committee Charter that describes the purpose, chairmanship, membership, goals/objectives, responsibilities, etc.;
- b. Assist in the implementation of the GSFC Electrical Safety Program, and in the maintenance of this GPR and its companion documents;
- c. Evaluate and recommend the adoption of new or revised standards, codes, and requirements for electrical work;
- d. Provide a forum for electrical workers to address and resolve workplace electrical safety issues;
- e. Evaluate the impact of electrical safety requirements or interpretations;
- f. Review mishaps and close calls that involve electrical issues and participate in the root-cause analyses

## 1.10 Electrical Safety Officer (ESO)

Collateral-duty ESO(s) will be appointed by each Directorate engaged in electrical work covered by this GPR. Each ESO shall:

- a. Assist in the development of and provide concurrence with EEWPs initiated by their organization;
- b. Facilitate corrective actions regarding work performed under the direction of their organization, including stopping work or activities that do not meet GSFC electrical safety requirements;
- c. Provide clarification of codes, standards, and regulations within their organization(s), and request formal interpretations through the ESC as necessary.

## 1.11 Electrical Quality Assurance (QA) Representative

Electrical QA Representatives (for organizations that utilize them) shall:

- a. Inspect electrical installations as covered by the NEC;
- b. Whenever any installation subject to inspection is covered or concealed, be authorized to require that such work be exposed for inspection;
- c. Keep records of all electrical inspections, including dates of such inspections, findings, and a summary of violations, and a record of final disposition of violations. Annually turn over all such records to FMD;
- d. Verify that electrical systems are either disconnected or placed in an electrically safe work condition as required by GPR 1700.5; and
- e. Require that safe work practices be followed at all times.

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**1.12 Qualified Persons** (as defined by NFPA 70E) shall be responsible for performing electrical work safely by assessing and controlling hazards and by adhering to safety-related work practices in accordance with NFPA 70E. Responsibilities include:

- a. Maintaining qualification by participating in electrical safety and Arc Flash training as described in this document;
- b. Reviewing the scope of work, developing the hazard analysis, and determining hazard mitigation techniques for each assigned work task;
- c. Develop EEWPs if their equipment must remain energized;
- d. Using required PPE appropriately;
- e. Stopping work immediately or excusing themselves from a job when an operation is perceived to be imminently hazardous or if they do not believe they possess the competency to perform the work safely;
- f. Informing an immediate supervisor of any electrical task or deficiency that exceeds the worker's resources, competency, or level of authority;
- g. Maintaining an approved copy of the EEWP at the work site when energized work is being performed; and
- h. Immediately report all close calls and mishaps to their supervisor.

## 2 QUALIFICATIONS

### 2.1 Qualified Persons

- a. Installation, maintenance and repair qualified persons - qualifications shall meet those specified in OSHA 29 CFR 1910.332, NFPA 70E and Section 3 of this document.
- b. Laboratory qualified persons – qualifications shall meet those specified in Section 3 of this document.

### 2.2 Electrical Safety Officer

An ESO shall be a person designated by their organization to oversee the electrical safety program within their work area. This person should have knowledge of the applicable electrical/electronic safety requirements, or have access to subject matter experts who possess that knowledge.

### 2.3 Electrical Quality Assurance Representative

An Electrical QA Representative shall be a Qualified Person knowledgeable of applicable electrical safety requirements, as well as experience with the NEC and local specifications.

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### 3. TRAINING REQUIREMENTS

Qualified Persons shall be trained and experienced in the work methods required by their electrical work assignments and have safety training, including Arc Flash training if applicable, on the operation of the equipment and the use of safe work practices per OSHA 29 CFR 1910.332.

**3.1** Technical training commensurate with the assignments of the Qualified Person shall be documented and the requirements of their job description. Refresher technical training is taken as required by the qualified person's job assignments and certification requirements.

**3.2** An individual who is undergoing on-the-job technical training shall be under the direct supervision of a Qualified Person. This individual is required to complete safety training on the hazards involved prior to performing the work.

**3.3** The degree of training necessary is determined by their supervisor based on the work to be performed and the risk to the employee. Training for Qualified Persons shall include, but not be limited to, the following:

- a. The safety-related electrical work practices pertinent to the equipment or job at hand;
- b. The required procedures on how to perform jobs safely and properly;
- c. The use, care, and limitations of the PPE necessary to perform jobs safely and properly;
- d. The skills and techniques necessary to distinguish exposed energized parts from other parts of electrical equipment;
- e. The skills and techniques necessary to determine the nominal voltages, currents, power levels, and energy levels of exposed energized parts; and
- f. The minimum approach distances, flash protection boundaries, and the corresponding voltages to which the qualified person could be exposed when working on energized electrical systems.

	Required Training	Type and Frequency	
		Initial	*Every 3 Years
<b>Installation, Maintenance and Repair Qualified Persons</b>	<ul style="list-style-type: none"> <li>• NFPA 70E</li> <li>• Arc Flash Awareness</li> <li>• Low Voltage Safety (working with voltages from 50 to 599)</li> <li>• High Voltage Safety (working with voltages 600+)</li> <li>• Lockout/Tagout</li> <li>• Confined Space Entry (if applicable)</li> <li>• Job Specific Tasks*</li> </ul>	Comprehensive	Refresher
<b>Laboratory/ Research Qualified Persons</b>	<ul style="list-style-type: none"> <li>• High voltage safety (working with voltages 600+)</li> <li>• Low voltage safety (working with voltages from 50 to 599)</li> <li>• Job Specific Tasks</li> <li>• Lockout/Tagout (if involved in maintenance and repair of laboratory equipment)</li> <li>• Arc Flash Awareness (if work presents arc flash capability)</li> </ul>	Comprehensive	Refresher

*\* Task specific refreshers shall also be conducted if there is change to a process, system or equipment.*

**Table 1 – Training Requirements**

### 3.4 On-the-Job Training

**3.4.1** Training shall include site-specific and equipment-specific information, including safety plans, standing procedures, and acceptable work practices and requirements.

**3.4.2** Prior to performing work on electrical equipment, qualified persons will be trained in and familiar with the safety-related work practices and procedures (including applicable emergency

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procedures, lockout/tag out, etc.), and other safety requirements that pertain to their job assignments. This training shall cover:

- a. Features of the equipment, including any specialized configuration
- b. Location of all energy sources to, and within, the equipment
- c. Location of all energy-isolating devices
- d. Techniques, tools, and PPE including arc-flash PPE used for the specific equipment
- e. Relevant documents such as wiring diagrams, schematics, service manuals, and operating, testing, and calibration procedures
- f. The system's energy control procedures, including energy-isolating devices, grounding and shorting procedures, and other energy-control procedures
- g. Specific operations in which energized work is anticipated (if any), and the process to obtain a valid Energized Electrical Work Permit (EEWP) (if required), at the appropriate level.

**3.4.3** This training may be accomplished through group safety meetings, job safety meetings, written local policies, standing procedures and other methods.

**3.4.4** On-the-job training for specified equipment or classes of equipment shall be documented to ensure that training is adequate and consistent for all employees with similar tasks. This documentation must be reviewed and approved by a person who is knowledgeable in safe electrical work practices, and is familiar with the hazards involved in the apparatus. Utilize GSFC Form 8-6 or equivalent to document on-the-job training.

## **4. SAFE ELECTRICAL SYSTEM REQUIREMENTS**

### **4.1 Mitigating Electrical Hazards**

Employees performing electrical work where any person might be exposed to live parts shall put these parts in an electrically safe work condition as determined by the appropriate ESO before beginning work unless it can be demonstrated that de-energizing the systems introduces additional or increased hazards.

Where equipment or systems cannot be placed into an electrically safe condition and the work must be done with a circuit energized, an EEWP shall be submitted and approved prior to the start of the work. See Section 4.3.

**Exemption:** EEWPs are not normally required for routine tasks performed on or near live parts such as testing, troubleshooting, and voltage measuring of electrical systems to include flight hardware and associated flight ground support equipment. If there is a question as to whether the scope of work is “routine” the organization will contact the Safety Office for guidance. These activities are exempt

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from an EEWP provided that such work is performed by a Qualified Person and that the appropriate safe work practices and PPE are utilized in accordance with NFPA 70E.

Where equipment or systems are placed into an electrically safe condition, the lockout/tagout requirements of GPR 1700.5 shall be met.

An electrically safe workplace shall be ensured by:

- a. Implementing electrical safety requirements during construction, modification, maintenance, and utilization, including research and development (R&D) activities, of GSFC facilities and equipment;
- b. Establishing training programs for electrical workers to meet the qualification requirements and to implement safety-related work practices;
- c. Promoting electrical safety awareness at the workplace;
- d. Complying with the most recent OSHA and other applicable electrical regulations and standards;
- e. Continuously reducing the quantity and severity of electrical safety incidents, injuries and close calls; and
- f. Meeting the requirements of NFPA 70E for an Electrical Safety Program.

## 4.2 Hazard Control Hierarchy

The following hazard control hierarchy shall be used to mitigate electrical hazards:

- a. Hazard Elimination, such as de-energize and lockout/tagout.
- b. Engineering controls, such as panels, shields, and barriers, to isolate employees from the energized components.
- c. Administrative controls, such as the EEWP, use of a two person rule, and electrically qualified worker training.
- d. PPE to isolate workers from exposed hazardous electrical conductors.
- e. Safe work practices to support the development of safe working habits.

### 4.2.1 Engineering Controls

**4.2.1.1** Engineering controls shall be used when feasible, after attempts have been made to eliminate hazards, to reduce the potential for direct contact with exposed and energized electrical components. Engineering controls may include non-conductive panels used as barriers to isolate persons from energized components and/or conductive ground paths.

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**4.2.1.2** Opaque or transparent non-conductive panels used as barriers to isolate persons from energized components may have small openings for tool access to allow troubleshooting, measurement, and/or calibration of equipment with access panels open.

**4.2.1.3** The use of barriers that allow the safety interlocks to be defeated for diagnostics and testing shall only be used when specifically authorized. This process must be approved, documented, and the time period must be specified.

**4.2.1.4** Ground Fault Circuit Interrupters (GFCIs) shall be used to supply temporary power during construction, remodeling, maintenance, repair, or demolition of buildings, structures, equipment or similar activities. As required by the NEC, GFCIs will be used for all portable power tools, outdoor work, work on or near conductive surfaces, for resistive heating elements such as heater tapes, wet locations, rooftops, within 6 feet of any wet sink, bathrooms, kitchens and other areas that could present an electrical shock hazard should the worker come in contact with the energized conductor of a tool or instrument.

**4.2.1.5** Sufficient access and working space shall be provided and maintained about all electric equipment with all covers and guides in place to permit ready and safe operation and maintenance at GSFC. Distance will be measured from the live parts, if such are exposed, or from the enclosure front or opening if such are enclosed.

#### **4.2.2 Administrative Controls**

Administrative controls shall be used to control hazards that cannot be entirely eliminated by engineering controls. Administrative controls may include (but are not limited to) the following:

- a. Signage of all kinds (e.g., Danger High Voltage) and administrative tagging of isolated equipment
- b. Lockout/Tag out of hazardous energy prior to maintenance,
- c. EEWP
- d. Use of a two person rule

#### **4.2.3 Personal Protective Equipment (PPE)**

**4.2.3.1** Qualified workers who are potentially exposed to electrical hazards that cannot be eliminated or controlled through some engineering means shall be provided with and use personal protective equipment that:

- a. Is appropriate for the specific work to be performed;
- b. Is appropriate for the associated hazard level;
- c. Complies with OSHA standard 1910.269;

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- d. Complies with NFPA 70E PPE requirements; and
- e. Is selected based on a written workplace hazard assessment.

**4.2.3.2** PPE shall be used to mitigate the hazards of electrical shock and electrical burns from arc-flash when work is to be performed on energized equipment and personnel are within the approach boundaries for shock protection as defined in NFPA 70E.

**4.2.3.3** PPE shall be selected based on the requirements of NFPA 70E, Art 130, Table 130.7(C)(15)(a) defining hazard/risk category for electrical tasks and Table 130.7(c)(16) defining required PPE based on hazard/risk categories.

**4.2.3.4** All insulated safety devices shall be rated as PPE and tested, used, and stored as such.

**4.2.3.5** Sufficient protection in the form of rated, insulated tools and insulated protective equipment, such as gloves, blankets, sleeves, shoes, mats, etc., shall be used while working on energized circuits.

**4.2.3.6** Protective equipment shall be maintained in a safe, reliable condition.

**4.2.3.7** Workers shall be trained on proper selection, use, maintenance and storage of the PPE they may use before using it.

**4.2.3.8** Protective equipment shall be visually inspected before each use.

#### **4.2.4 Testing and Inspecting of Protective Devices**

Each organization is responsible for the use and maintenance of protective devices and shall define and follow a process to ensure that the equipment meets the following requirements:

- a. Electrical protective equipment shall be tested periodically as specified in NFPA 70E.
- b. Hot sticks shall be tested every 24 months.
- c. Insulating gloves and sleeves shall be tested every 6 months by a certified testing firm or replaced with new ones. ANSI/ASTM D120-02 outlines electrical testing procedures for rubber gloves. Sleeve testing procedures are outlined in ANSI/ASTM D1051-02.
- d. Insulating blankets or mats are required to be tested every 12 months by a certified testing firm or replaced with new ones.
- e. Insulating gloves, sleeves, blankets, mats and hot sticks shall be inspected before use.
- f. Rubber insulating gloves shall be used with leather protectors.

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### 4.3 Energized Electrical Work Permit (EEWP)

Per NFPA 70E, Section 130.1, EEWPs (GSFC Form 23-83) is required for work on or near exposed energized electrical equipment and systems that do not fit the profile of tasks described in the exemption in Section 4.1. If there is no reasonable method of obtaining an outage, or de-energizing the equipment, then the following requirements shall apply:

- a. The EEWP shall be initiated by the organization that requires the electrical work be performed while energized.
- b. The EEWP shall include an electrical hazard assessment, by a Qualified Person who would perform the work, of the specific electrical hazards associated with each task or activity. The electrical hazard assessment will include all the elements listed in NFPA 70E, Section 130.1 (A)(2).
- c. The EEWP shall be approved by the qualified person, their supervisor, and the appropriate ESO, with final approval resting with the Codes' Director Of (or a designee).
- d. Unexpected (non-routine) and off-hour and emergency energized electrical work may be approved by the on-site cognizant supervisor in order to facilitate abating the immediate hazard. After the work has been a performed, an EEWP shall be completed at the earliest opportunity to justify the decisions made for working energized.
- e. Completed EEWPs shall be maintained by the ESO and a copy provided to the Safety Office for retention.
- f. Two Person Rule for all energized work that requires an EEWP shall be enforced.

### 4.4 Electrical Two Person Rule

Certain work may require two qualified persons. This occurs when work is considered electrically hazardous, per OSHA 1910.269(I)(1)(i) and (ii) or the work supervisor.

When the "Two Person Rule" is required, both workers must be present at the work site, and each worker must be aware of the other worker's tasks and must:

- a. Be a qualified or task trained person.
- b. Be able to de-energize equipment.
- c. Know the location of nearest telephones, and how to alert emergency rescue personnel.
- d. Remain in visual and audible contact with the workers performing the work.
- e. Follow any additional guidelines per NFPA 70E.

Note: Both workers may perform separate work tasks so long as safety is not compromised.

Under limited conditions, the Electrical Two Person Rule may allow for a second person that is not a qualified person. During the briefing process the qualified person will assess the qualifications of the second person to determine that the work may proceed safely. The second person may not enter the limited approach boundary or the flash protection boundary. Additionally, the second person must be

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briefed in emergency procedures and the electrical work being performed and must follow any additional guidelines per NFPA 70 E. The second person shall be trained per NFPA 70E-110.2.

#### 4.5 Temporary Wiring

- a. All temporary electrical wiring are required to comply with Article 590 of the NEC.
- b. Temporary electrical wiring shall be permitted during emergencies, tests, experiments, developmental work, maintenance and repair not to exceed 90 days without Safety Office approval.
- c. Temporary electrical wiring shall not be run directly on ungrounded conductive surfaces but will be supported by suitable wood or other insulating materials.
- d. Temporary electrical wiring and portable electrical cords shall be kept out of water at all times unless the cable is approved by the NEC for that purpose.
- e. Temporary electrical wiring shall be removed immediately upon completion of construction, or the purpose for which the wiring was installed.

#### 4.6 Extension Cords

NEC Article 400.8. "Flexible Cords and Cables," and Article 590, "Temporary Installations" do not permit flexible cords and cables to be used as a substitute for permanent building wiring. Use of extension cords and relocatable multiple outlet power strips are to be used in a manner compatible with a Nationally Recognized Testing Laboratory (NRTL), for example, Underwriters Laboratory and Factory Mutual rating and listing. They shall not be used in a manner that substitutes for the installation of permanent building branch circuits.

- a. Extension cords usage shall abide by the restrictions for temporary wiring as delineated in Section 4.5. Note: A surge protector power strip is a special type of extension cord intended to protect computers and related office equipment from damaging power fluctuations. They may be used indefinitely;
- b. Where extension cords are utilized, they shall not be:
  - (1) Used as a substitute for the fixed wiring of a structure;
  - (2) Routed through holes in walls, doorways, under rugs/carpet, windows, ceilings, floors, or attached to building surfaces;
- c. High-current equipment (5 amps or greater), e.g., microwave ovens, some refrigerators, space heaters, coffee pots, etc., shall not be plugged directly into a power strip/surge protector;
- d. Extension cords used in outdoor or wet locations shall utilize integral or separate Ground Fault Circuit Interrupters (GFCIs) for shock protection.

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#### 4.7 Shock and Flash Hazards

Hazards associated with shock and flash shall be mitigated in compliance with NFPA 70E Sections 130.2 (shock) and 130.3 (flash). Results of any shock or flash analysis are required to be included as part of the EEWP.

#### 4.8 Labeling of Electrical Equipment

Labeling of electrical equipment shall be in accordance with NFPA70E.

### 5. ELECTRICAL SAFETY PROGRAM DOCUMENTATION

**5.1 Documented Procedures.** External organizations and contractors performing electrical work at GSFC shall have, and work in accordance with, a written Electrical Safety Program that utilizes the guidance in Appendix E of NFPA 70E and establishes policies, processes, and procedures applicable to their particular activities, projects or contracts. The document will be controlled such that it is kept up to date. The following lists of topics are general and are not all inclusive. They should be addressed as appropriate depending on the types and categories of electrical work performed.

- 1) Electrical Safety and Approval Process
- 2) Electrical Hazards (medium-high)
- 3) Controls for Electrical Work and Electrical Equipment
- 4) Work on Electrical Components and Systems
- 5) Work Clearances and Illumination
- 6) Temporary Wiring
- 7) Extension Cords
- 8) Ground Fault Circuit Interrupters
- 9) Portable Electric Tools Equipment and Instruments
- 10) Equipment Grounding
- 11) Unknown Electrical Hazards (e.g., penetrations)
- 12) De-Energized Electrical Work
- 13) Personal Protective Equipment
- 14) Welding, Cutting, or Burning
- 15) Lockout/Tagout Procedure
- 16) Confined Space Entry
- 17) Work > 600 Volts and Protective Grounding
- 18) Underground Utilities and Operations
- 19) Energized Cables in Manholes
- 20) Cutting and Splicing Power Cables
- 21) Racking Medium and HV Circuit Breakers
- 22) HV Switching

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- 23) Working Space Around Equipment
- 24) Cranes, Lifting Equipment, and Ladders (fixed/portable) Adjacent to Exposed Energized Parts
- 25) Initial Energization of Electrical Systems Above 600 Volts
- 26) Infrared (IR) Thermography
- 27) Work in Energized Substations

## 5.2 Facility Electrical System Drawings

**5.2.1 Drawing Control.** Facility Drawings shall be controlled and updated by FMD in accordance with the following requirements. Note this does not apply to flight project related equipment or sub-systems.

- a. It shall be the responsibility of the organizations engaging in electrical work at a GSFC managed site, or site controlled by GSFC to prepare facility associated design drawings detailing the proposed electrical work, including interconnections to the facility electrical systems, and to submit the drawings to FMD for approval prior to the start of work. Upon completion of the electrical work, the organization must update drawings to reflect the as-built condition and initiate action to document changes to the facilities drawings maintained by FMD. In the event that changes are made to the systems and drawings are not produced prior to the changes, the organization performing the work are responsible for preparing drawings of such detail that the information can be entered onto the record drawings. Such updates shall be provided to FMD for incorporation into the building drawings.
- b. It is the intent that all building drawings and diagrams be updated to the “as-built” configuration. As projects and system modifications occur, drawings shall be updated to reflect the “as-built” configuration. Information should be field verified for accuracy prior to implementing any design changes.
- c. No changes shall be made to drawings without the approval of FMD.

## 5.2.2 Types of Drawings

The following types of drawings shall be maintained by FMD:

- a. Low voltage and high voltage single line diagrams for each building and substation;
- b. Protective relaying diagrams for GSFC substations;
- c. Underground utility drawings, including the locations of underground electrical utilities; and
- d. Record Drawings for GSFC facilities including floor plans, equipment location plans, system schematics, and/or elementary wiring diagrams. Note: Does not include special purpose/test facilities except where they connect to the facility electrical system.

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### 5.3 Drawing Accessibility

Hardcopies of the Electrical Systems Drawings are available from FMD and are provided to organizations performing work on electrical systems at GSFC on an as-needed basis.

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## Appendix A – Definitions

Following are some key definitions related to electrical safety. Many additional related definitions are contained within referenced documents such as the NFPA 70, National Electrical Code (NEC), NFPA 70E, Standard for Electrical Safety in the Workplace, and the National Electrical Safety Code (NESC).

Unless expressly stated elsewhere herein, the following terms shall have the meanings indicated below:

- A.1 Barrier** – A physical obstruction that is intended to prevent contact with exposed energized electrical conductors or circuit parts. Barriers can be temporary or permanent.
- A.2 De-energized** – Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth.
- A.3 Electrical Hazard** – A dangerous condition such that inadvertent or unintentional contact or equipment failure can result in shock, arc flash-burn, thermal burn, or blast.
- A.4 Electrical Quality Assurance Representative** – An individual who is authorized by line management to perform electrical inspections for code compliance and quality.
- A.5 Electrical Safety Officer** – A collateral-duty position that refers to an identified person who by ensures the organization complies with electrical safety standards.
- A.6 Electrically Safe Work Condition** – A state in which the conductor or circuit part to be worked on or near has been disconnected from energized parts, locked and tagged in accordance with GPR 1700.5.
- A.7 Electrical Work** – (1) Working on or near energized electrical parts over 50 volts; (2) Assembly or fabrication of potentially energized electrical equipment over 50 volts, (3) Installation, maintenance, and repair of electrical conductors, equipment, and systems over 50 volts.
- A.8 Energized** – Electrically connected to or having a voltage source. NOTE: “De-energized” parts that have not been placed into an electrically safe work condition are considered energized.
- A.9 Energized Electrical Work Permit (EWP)** – A Director Of approved written permit (GSFC Form 23-83) required by the National Fire Protection Association (NFPA) 70E for non-routine work on energized equipment 50v and above that cannot be placed in an electrically safe work condition.
- A.10 Exposed** (as applied to energized parts) – Capable of being inadvertently touched or approached nearer than a safe distance by a person, especially parts that are not suitably guarded, isolated, or insulated.
- A.11 Facility** – Relating to Center infrastructure and/or utilities. The term facility does not include specific test equipment such as thermal/vac chambers or test cells.
- A.12 Field Verified** – (as applied to electrical configuration controlled drawings): Verification that the drawing accurately depicts the configuration of installed systems or equipment by

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visual comparison and by point-to-point wire checks prior to placing the system into service. Point-to-point wire checks require ringing out or talking down the wiring between points of termination and are usually done during installation.

- A.13 Flash Hazard** – A dangerous condition associated with the release of energy caused by an electric arc.
- A.14 Functionally Verified** (as applied to electrical configuration controlled drawings) – Verification that the drawing accurately depicts the configuration of a functional system or equipment by visual comparison.
- A.15 Grounded** – Connected to earth or to some conducting body that serves in place of the Earth.
- A.16 Guarded** – Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger.
- A.17 Hazard Analysis** – The identification and evaluation of existing and potential electrical hazards and the recommend mitigation for the hazard sources found
- A.18 Live Part** – An energized conductive component.
- A.19 Lockout/Tagout (LOTO)** – The full procedure of determining what is required to make a system safe; the action of making the system safe; and the placing of locks, locking devices, and “Do Not Operate” tags to preclude changing from the safe condition. See GPR 1700.5 for LOTO requirements.
- A.20 Qualified Person** – One who has been trained in and demonstrates adequate knowledge of the installation, construction, and/or operation and maintenance of electrical equipment and has received safety training on the hazards involved.
- A.21 Service Point** – The point of connection between the facilities of the serving utility and the premises wiring. Service points for buildings at GSFC are defined as the line side of the first service disconnecting means for the facility.
- A.22 Shock Hazard** – A dangerous condition associated with the possible release of energy caused by contact or approach to live parts.
- A.23 Two Person Rule** – The practice of employing a second electrically qualified person to directly observe the electrical work of a Qualified Person working on, or near (unguarded) energized electrical equipment.
- A.24 Unqualified Person** – Individuals, who do not meet the requirements of Section 2.1, but work with or use electrical equipment. They are protected from risk of exposure to electrical hazards by the presence of protective barriers. Unqualified persons shall be trained in, and familiar with, any electrical safety-related practices necessary for their safety.
- A.25 Voltage (of a circuit)** – The greatest root-mean-square (rms) (effective) difference of electrical potential between any two conductors of the circuit concerned.
- A.26 Voltage, High** – Electric power system and equipment operating at greater than 600 volts Nominal and above.
- A.27 Voltage, Low** – Electric power system and equipment operating at less than or equal to 600 volts Nominal

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**A.28 Working on (live parts)** – Coming in contact with exposed energized electrical conductors or circuit parts with the hands, feet, or other body parts, with tools, probes, or with test equipment, regardless of the personal protective equipment a person is wearing.

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## Appendix B – Acronyms

<b>AC</b>	Alternating Current
<b>CPR</b>	Cardio Pulmonary Resuscitation
<b>DC</b>	Direct Current
<b>EEWP</b>	Energized Electrical Work Permit
<b>ESC</b>	Electrical Safety Committee
<b>ESO</b>	Electrical Safety Officer
<b>FMB</b>	Facilities Management Branch
<b>FMD</b>	Facilities Management Division
<b>FRC</b>	Federal Records Center
<b>GFCI</b>	Ground Fault Circuit Interrupter
<b>GPR</b>	Goddard Procedural Requirements
<b>LOTO</b>	Lockout/Tagout
<b>NARA</b>	National Archive and Records Administration
<b>NEC</b>	National Electric Code (NFPA 70E)
<b>NFPA</b>	National Fire Protection Association
<b>NRRS</b>	NASA Records Retention Schedules
<b>NRTL</b>	Nationally Recognized Testing Laboratory
<b>OJT</b>	On-the-Job Training
<b>OSHA</b>	Occupational Health and Safety Administration
<b>PPE</b>	Personal Protective Equipment
<b>QA</b>	Quality Assurance
<b>R&amp;D</b>	Research and Development
<b>RF</b>	Radio Frequency
<b>UPS</b>	Uninterruptable Power Supply
<b>WICC</b>	Wallops Integrated Institutional Contract
<b>WFF</b>	Wallops Flight Facility

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## **Appendix C - Hazard Analysis Tool**

### **1.0 MODES OF WORK ON ELECTRICAL EQUIPMENT**

Under normal operation of listed or approved electrical equipment the user/operator is protected by engineering controls, including insulation, enclosures, barriers, grounds and other methods to prevent injury. When engineering controls are not yet in place, not approved, or removed for diagnostics, maintenance, or repair, the activity will fall into one of the following categories

- Mode 0 – Electrically Safe Work Condition
- Mode 1 – Establishing an Electrically Safe Work Condition
- Mode 2 – Energized Diagnostics and Testing
- Mode 3 – Energized Work

#### **1.1 Mode 0 – Electrically Safe Work Condition**

An Electrically Safe Work Condition is a state in which the conductor (s) or circuit part (s) to be worked on or near have been (1) disconnected and isolated from a hazardous energized source or parts; (2) locked/tagged out (or equivalent) in accordance with established standards; (3) tested to ensure the absence of voltage; and (4) grounded if determined necessary. All work on hazardous electrical systems shall be done in an electrically safe work condition unless there is a compelling reason as defined in this chapter.

#### **1.2 Mode 1 – Establishing an Electrically Safe Work Condition**

To achieve Mode 0, an electrically safe work condition, a worker conducts Mode 1 work. If the Mode 1 process exposes the worker to any hazard, the activity must be covered by work control procedures, and a hazard analysis must be performed. The work is energized electrical work, as covered by Mode 1, until an electrically safe work condition is achieved (Mode 0). This Mode does NOT require an Energized Electrical Work Permit (EEWP). To establish an electrically safe work condition, a qualified person uses the following procedure:

1. Determine all sources of electrical supply to the specific equipment.
2. Check applicable drawings, diagrams, and identification tags, including equipment specific LOTO procedures.
3. Turn off equipment.
4. Don correct PPE and establish barricades as necessary for access control.
5. Open the disconnecting means (e.g., plug, breaker, or disconnect device).
6. If it is possible, visually verify that the plug is fully removed, all blades of the disconnecting devices are fully open, or that draw-out type circuit breakers are withdrawn to the fully disconnected position.
7. If applicable, test the controls and attempt to restart the equipment.

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8. Apply lockout/tagout devices, assure that the plug is in total control of the worker, or use other engineering controls that are approved by the Authority Having Jurisdiction (such as capture key control systems that have been approved).
9. If grounds have not been applied, use a correctly rated voltmeter to test each normally energized conductor or circuit part to verify they are de-energized, Note: for high voltage or large capacitive systems using a correctly rated voltmeter may not be a safe procedure, skip this step for such systems and go to step 11.
10. If the possibility of induced voltages exists, apply grounds to the normally energized conductors or circuit parts before touching them.
11. If stored electrical energy exists (e.g., capacitors), discharge or remove the stored energy and apply grounds to the normally energized conductors.

### **1.3 Mode 2 – Energized Diagnostics and Testing**

In Mode 2 measurements, diagnostics, testing, and observation of equipment functions are conducted with the equipment energized and with some or all of the normal protective barriers removed and interlocks bypassed. Verification of a safe condition with a voltage rated instrument is covered by the Mode 1 process and is not considered Mode 2.

Work is considered Mode 2 if proper voltage rated instruments are used to contact the energized conductors. If any portion of the worker's body passes the Restricted Approach Boundary then appropriate shock PPE must be worn. If any portion of the worker's body passes the Prohibited Approach Boundary then this is considered Mode 3, Energized Work, and the appropriate controls must be in place. If any portion of the worker's body passes the Arc Flash Boundary then the appropriate arc flash PPE must be worn.

The use of appropriate Personal Protective Equipment (PPE) may be required. Some examples of Mode 2 operations are:

1. making voltage measurements with a multimeter on energized components
2. performing tests while working in close proximity to exposed energized components
3. following manufacturer's instructions for diagnostics and troubleshooting of energized circuits
4. working on experimental facilities that operate in this mode. Performing Mode 2 work does not require an EEWP.

### **1.4 Mode 3 – Energized Work**

Mode 3 operations involve physically moving energized conductors and parts, or moving parts that are near energized conductors (within the Prohibited Boundary), and are conducted with the equipment fully energized and with some or all of the normal protective barriers removed.

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Mode 3 work in Hazard Classification categories above X.0 and X.1 shall be treated as an electrical hazard that is permitted only when justified by a compelling reason. Tasks performed in this mode will be conducted under close supervision and control. Work control with an approved EEWP is required, with exceptions as indicated in the hazard classification tables.

Energized Work is permitted only if:

1. Additional or increased hazards would exist due to establishing an electrically safe work condition;
2. Equipment design or operational limitations make it infeasible to perform the work in a de-energized state; or
3. If all exposed energized conductors and parts operate at 50 V or less with respect to ground.

An Energized Electrical Work Permit shall include, but not be limited to:

1. A description of the circuit and equipment to be worked on and their location;
2. Justification for why the work must be performed in an energized condition;
3. A description of the safe work practices to be employed;
4. Results of the shock hazard analysis;
5. Determination of shock protection boundaries;
6. Results of the arc hazard analysis;
7. The arc flash protection boundary;
8. The necessary Personnel Protective Equipment to safely perform the assigned task;
9. Means employed to restrict the access of unqualified persons from the work area;
10. Evidence of completion of a job briefing, including a discussion of any job-specific hazards; and
11. Energized work approval (authorizing or responsible management, safety officer, owner, etc.

## **2.0 ADMINISTRATIVE CONTROLS FOR ELECTRICAL WORK**

Administrative controls to mitigate electrical hazards can be divided into four basic categories:

1. worker rules:
  - a) working alone rule
  - b) two person rule
  - c) safety watch rule
2. qualification and training
3. work control (including EEWP)
4. personal protective equipment (PPE)

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## 2.1 Working Alone, Two Person, and Safety Watch Practices

Many sites use two person and safety watch rules to provide a second person in case of emergency, or to provide a “second set of eyes”.

Each electrical safety task should be analyzed to determine if risk of injury to a worker, while working alone, warrants a second person to be present. If the risk of injury from accidental contact with an electrical conductor is minimal, then a person may work alone.

If contact with an electrical conductor could result in ventricular fibrillation, serious burn, a no-let-go response, or other injury, the two person practice should be followed. The second person should be a worker qualified to work on energized circuits, and should understand the work activities and the hazards present. The second person should know what to do in case of an electrical accident involving the other worker.

A safety watch is a more stringent hazard control measure than the two person practice and should be implemented when there are grave consequences from a failure to follow safe work procedures. The safety watch should be a worker qualified to work on energized circuits who accepts responsibility for monitoring qualified worker(s) performing high-hazard electrical work.

Recommended working alone, two person, and safety watch practices are provided for each of the four Modes of Work on electrical equipment for each of the 54 Electrical Hazard Classes.

## 2.2 Qualification and Training

Electrical safety training can be divided into three primary categories: (a) general classroom training, (b) specific classroom training, and (c) On-the-Job training (OJT).

General electrical safety classroom training can be broken into three basic types: (1) general awareness training, (2) non-Energized electrical worker, and (3) Energized electrical worker. Recommended general training requirements are given for each of the three Modes of Work on energized electrical equipment (Mode 1, 2, and 3) for each of the 54 Electrical Hazard Classes.

On-the-Job Training (OJT) may be important for certain classes of electrical hazards, or more specifically, for certain tasks with electrical hazards. Examples of relevant OJT include: how to use a personal safety ground (ground hook) to discharge a capacitor, how to use certain PPE, how to use a multimeter to diagnose a circuit while energized, etc.

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### 2.2.1 Work Control

All hazardous electrical work shall follow documented work control procedures. The Electrical Hazard Classification control tables specify when an Energized Electrical Work Permit (EEWP) is required.

### 2.2.2 Personal Protective Equipment

Shock protection PPE is required whenever any portion of the worker's body passes the Restricted Approach Boundary. Arc flash PPE is required whenever any portion of the worker's body passes the Arc Flash Boundary. Recommended use of shock and arc flash PPE are given for each of the four Modes of Work on electrical equipment for each of the Electrical Hazard Classes. In many cases the shock and arc flash boundaries must be determined or obtained by the worker. In a few special cases additional PPE may be required, e.g., for capacitor discharging, or for working on lead acid batteries.

## 3.0 HAZARD ASSESSMENT TABLES AND RECOMMENDED CONTROLS

The hazard classification charts cover five broad areas, ranging from R&D, to capacitors, to batteries. These charts represent most of the electrical hazards found in electrical equipment. All charts and classes should be considered when identifying the hazards associated with any given piece of electrical equipment. A single piece of equipment may have multiple electrical hazard classifications, and the combination of hazards must be addressed by appropriate safety-related work practices. In order to aid hazard identification, each table has cross-reference notes in the upper right hand corner. For example, the R&D table has cross-reference notes to capacitance, battery, and facility hazard tables. Workers should have a thorough understanding of the equipment they are analyzing for hazards. Consulting manuals and schematics and speaking with factory service representatives and Electrical Safety Subject Matter Experts are ways to ensure that all of the hazards are fully understood and that all the pertinent charts and classes are taken into account. Some guidelines on use of the hazard classification charts are given. They are general, and there may be exceptions to each one:

- If you do not understand these guidelines and your equipment, consult an electrical SME.
- All equipment gets its power from the facility (Classes 1.x) or batteries (Classes 4.x). Thus, equipment starts with one of those classes.
- Most small appliances, hand tools, and portable laboratory equipment plugs into Class 1.2. In general, if you can carry it, most likely it uses 120 to 240 V.
- Larger facility and laboratory equipment may use up to 600 V (Class 1.3).

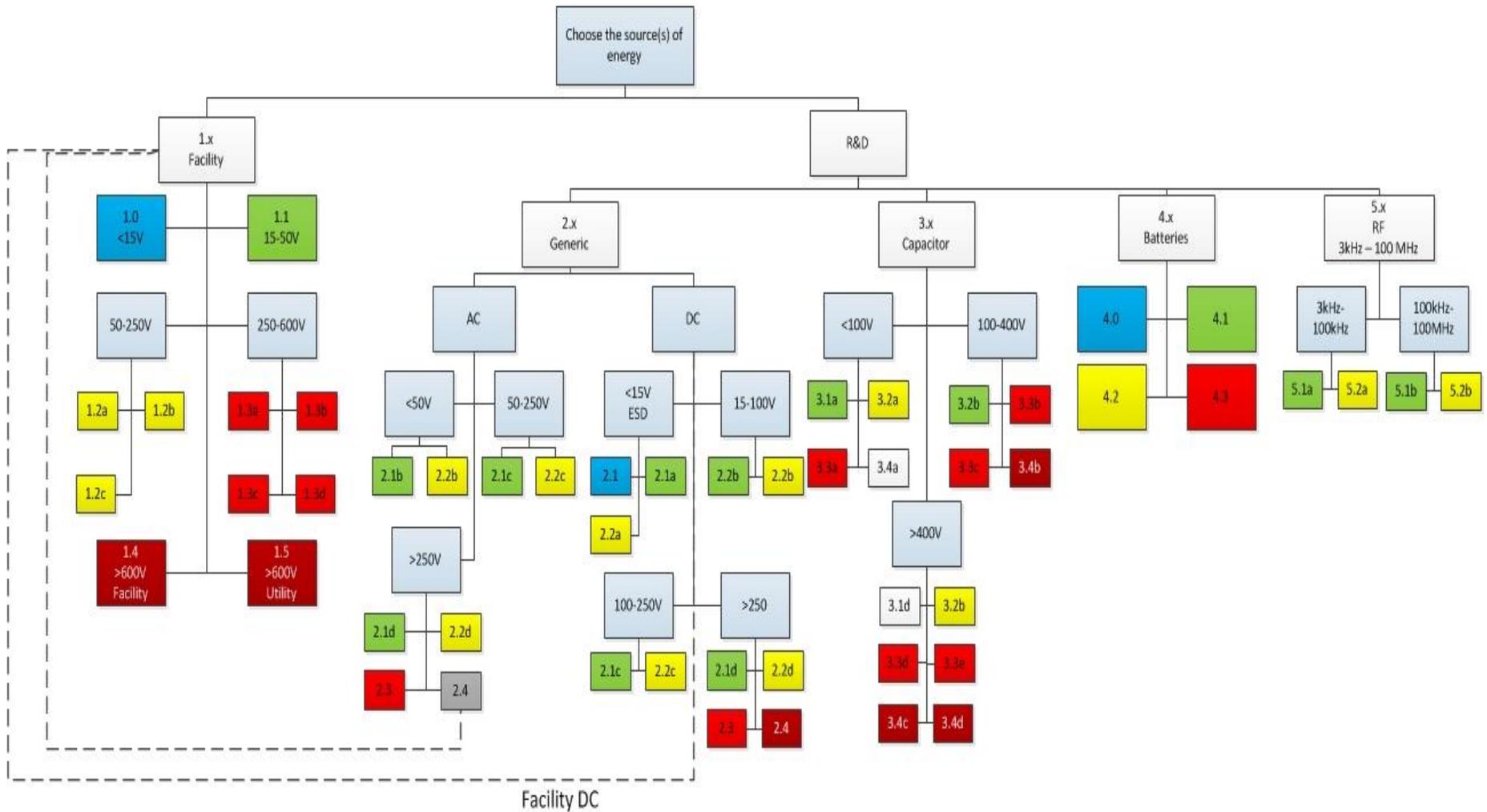
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- All electronic equipment and much other R&D equipment converts facility power into DC. All DC power supplies have some capacitance. Thus, DC power supplies have hazards in Classes 2.x and 3.x. Both must be evaluated.
- All UPSs have hazards in Classes 4.x as well as 1.x, since they usually are tied into facility power (input), and produce facility type power (output).

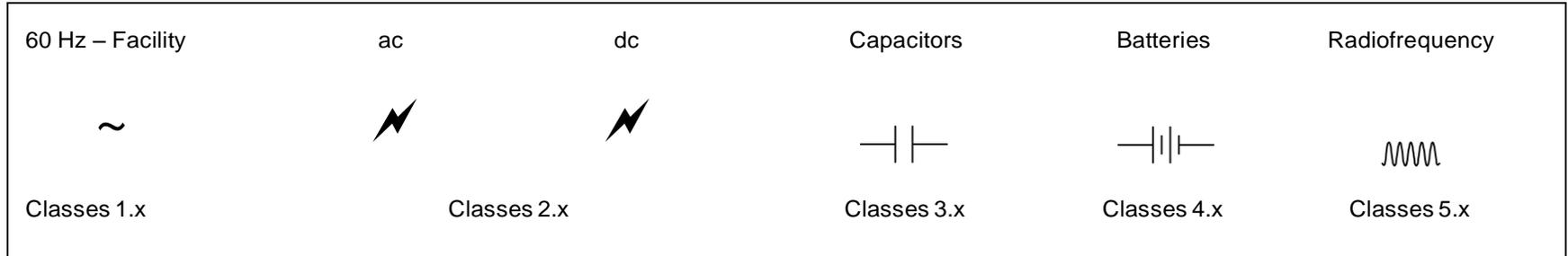
The colors used in each hazard Class box are organized in increasing hazard: blue, green, yellow, red, and maroon. Some general statements can be made about each color. There may be exceptions. Renumber

- 
  - A blue Class (X.0) indicates no hazard, no engineering or administrative controls are needed.
- 
  - A green Class (X.1) indicates little to no hazards, few or no engineering or administrative controls are needed.
- 
  - A yellow Class (X.2) indicates injury or death could occur by close proximity or contact; often the hazard is shock or contact burn; engineering controls are necessary for operation (e.g., listing or equipment approval), and administrative controls are necessary for electrical work in this Class.
- 
  - A red Class (X.3) indicates injury or death could occur by proximity or contact; often the hazard is shock, contact burn, or arc-flash burn; engineering controls are necessary for operation (e.g., listing or equipment approval), and administrative controls are necessary for electrical work in this Class.
- 
  - A maroon Class (X.4 and X.5) is the highest level of risk; significant engineering and administrative controls are necessary to manage the hazard in these Classes.



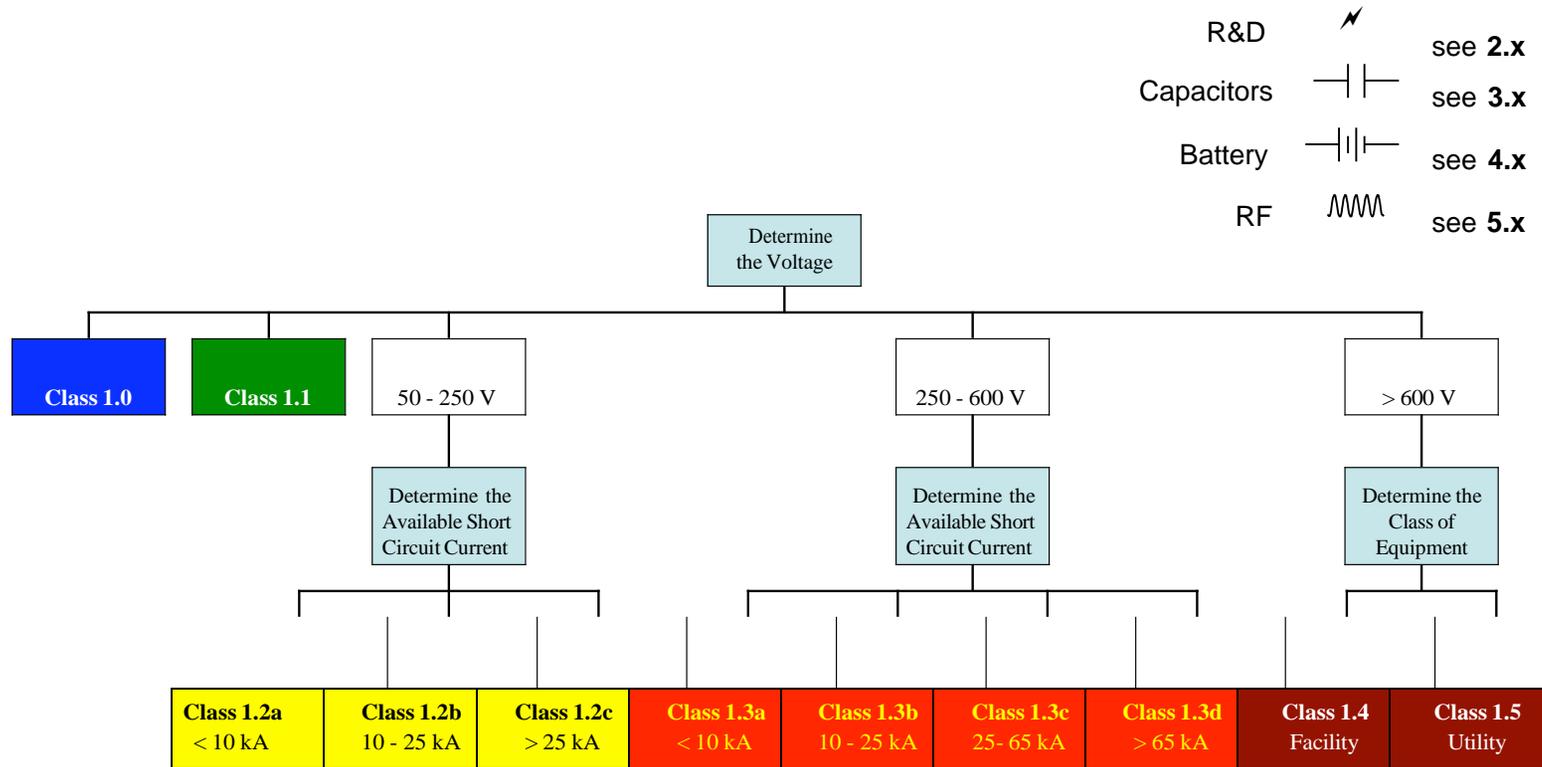
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**Fig. 3-1. Complete electrical hazard classification system showing 5 major groups and 54 classes.**

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Note: for DC facility power refer to Classes 2.x: R&D DC

**Fig. 3-2. Class 1.x: Hazard classes 1.x, for 60 Hz power.**

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**Table 3-1. Controls for work in hazard Classes 1.x.**

Class	Mode	Qualified Worker(s)	Training	Work Control	PPE
1.0	ALL	Alone	None	None	None
1.1	ALL	Alone	Non-Energized	None	None
1.2a	0-	Alone	Non-Energized and LOTO	None	None
	1	Alone	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	2	Alone	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	3 <sup>2</sup>	Two person	Energized	YES, EEWP	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
1.2b	0	Alone	Non-Energized and LOTO	None	None
	1	Alone	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	2	Alone	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	3 <sup>2</sup>	Two person	Energized	YES, EEWP	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
1.2c	0	Alone	Non-Energized and LOTO	None	None
	1	Alone	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	2	Alone	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	3 <sup>2</sup>	Two person	Energized	YES, EEWP	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
1.3a	0	Alone	Non-Energized and LOTO	None	None
	1	Two person	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	2	Two person	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	3 <sup>2</sup>	Two person	Energized	YES, EEWP	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
1.3b	0	Alone	Non-Energized and LOTO	None	None
	1	2 <sup>nd</sup>	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	2	2 <sup>nd</sup>	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>

Class	Mode	Qualified Worker(s)	Training	Work Control	PPE
1.3c	0	Alone	Non-Energized and LOTO	None	None
	1	2 <sup>nd</sup>	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	2	Safety Watch	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
1.3d	0	Alone	Non-Energized and LOTO	None	None
	1	Safety Watch	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	2	Safety Watch	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
1.4	0	Alone	Non-Energized and LOTO	None	None
	1	Safety Watch	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	2	Safety Watch	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP	Shock Hazard Analysis and Flash Hazard Analysis <sup>1</sup>
1.5	0	Alone	Non-Energized	YES	Refer to 29CFR1910.269
	1	Safety Watch	Lineman	YES	Refer to 29CFR1910.269
	2	Safety Watch	Lineman	YES	Refer to 29CFR1910.269
	3 <sup>2</sup>	Safety Watch	Lineman	YES	Refer to 29CFR1910.269

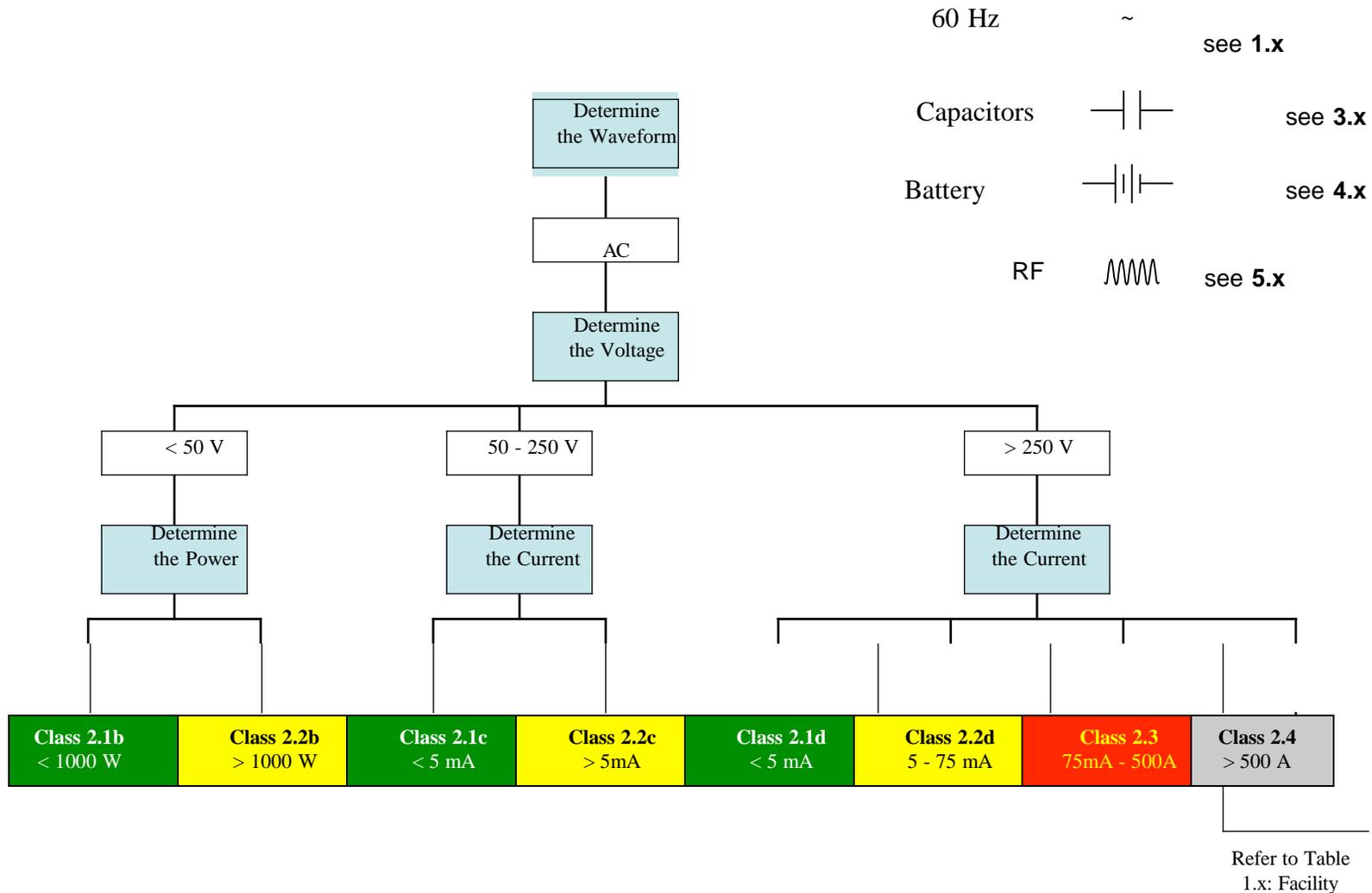
<sup>1</sup> Perform a shock and arc flash analysis or see NFPA 70E tables

<sup>2</sup> This mode of work should be avoided.

Notes on use of hazard Classes and control Table 1.x:

- (a) The voltage is the root mean square (rms) voltage for 60 Hz power.
- (b) The current is the available fault current.
- (c) The primary difference between subclasses a, b, c, and d in Classes 1.2 and 1.3 is the arc-flash hazard, since the arc fault current increases to the right.
- (d) Class 1.4 is work on facility circuits above 600 V.
- (e) Class 1.5 is work on utility circuits above 600 V.
- (f) For R&D (AC or DC, not 60 Hz), use hazard Classes 2.x.
- (g) For capacitors, use hazard Classes 3.x.
- (h) For batteries, use hazard Classes 4.x.
- (i) For ac frequencies above 3 kHz (rf) use hazard Classes 5.x.

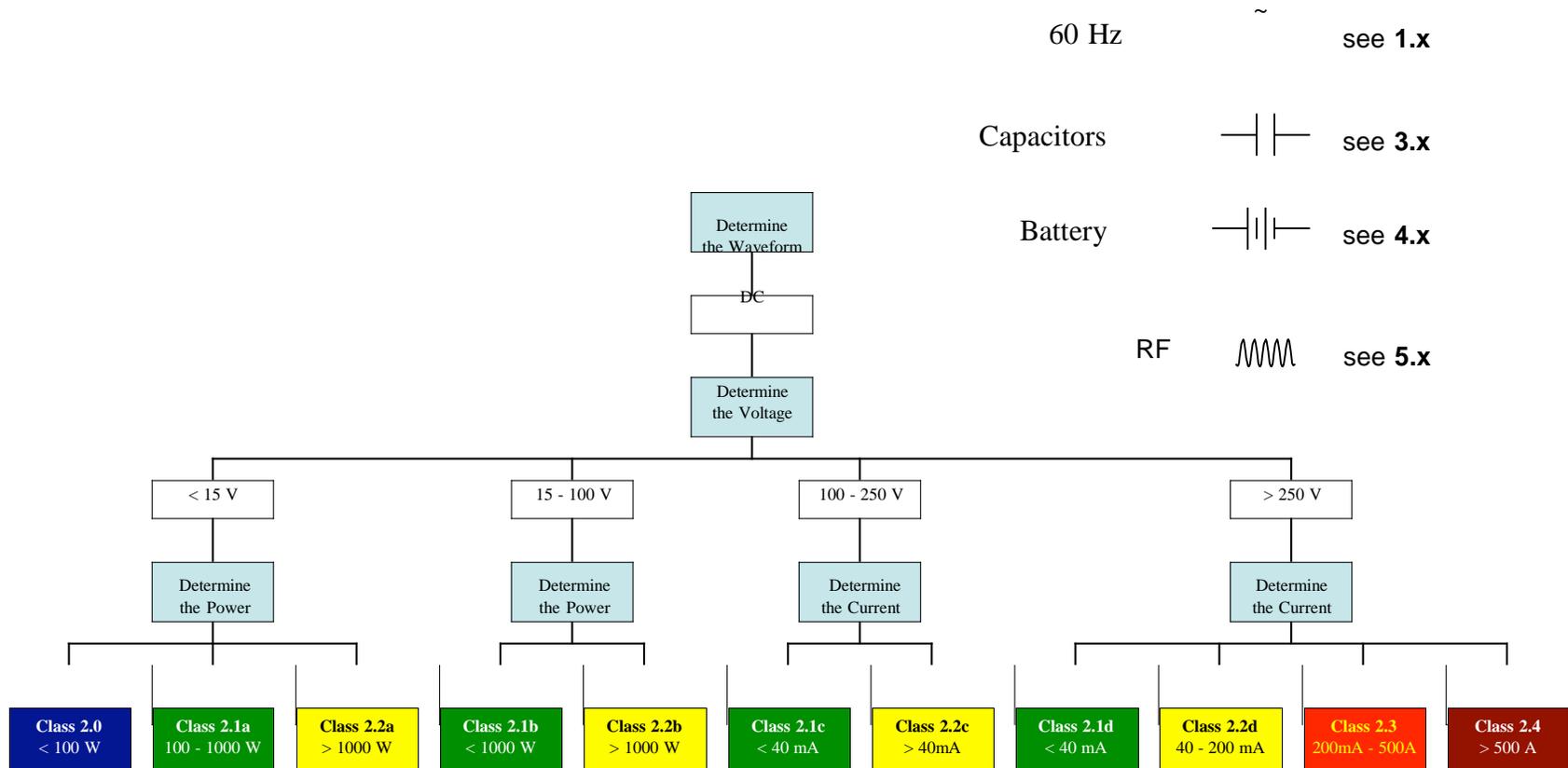
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**Fig. 3-3. Hazard Classes 2.x, AC R&D and electronics**

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**Fig. 3-4. Hazard Classes 2.x, DC R&D and electronics**

**Table 3-2. Control Table for work in hazard Classes 2.x.**

Class	Mode	Qualified Worker(s)	Training	Work Control	PPE
2.0	ALL	Alone	None	None	None
2.1 ALL	ALL	Alone	Non-Energized	None	None
2.2a	0	Alone	Non-Energized and LOTO	None	None
	1	Alone	Energized	YES	Shock Hazard Analysis
	2	Two person	Energized	YES	Shock Hazard Analysis
2.2b	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP	Shock Hazard Analysis
	0	Alone	Non-Energized and LOTO	None	None
	1	Alone	Energized	YES	Shock Hazard Analysis
2.2c	2	Two person	Energized	YES	Shock Hazard Analysis
	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP	Shock Hazard Analysis
	0	Alone	Non-Energized and LOTO	None	None
2.2d	1	Alone	Energized	YES	Shock Hazard Analysis
	2	Two person	Energized	YES	Shock Hazard Analysis
	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP	Shock Hazard Analysis
2.3	0	Alone	Non-Energized and LOTO	None	None
	1	Two person	Energized	YES	Shock Hazard Analysis
	3 <sup>3</sup>	Safety Watch	Energized	YES	Shock Hazard Analysis
2.4 <sup>1</sup>	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP	Shock Hazard Analysis
	0	Alone	Non-Energized and LOTO	None	None
	1	Safety Watch	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis
	2 <sup>2</sup>	Safety Watch	Energized	YES	Shock Hazard Analysis and Flash Hazard Analysis
	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP	Shock Hazard Analysis and Flash Hazard Analysis

<sup>1</sup> For AC, refer to Table 1.x: Facility.

<sup>2</sup> This mode of work should be avoided.

<sup>3</sup> DO NOT move probes while energized.

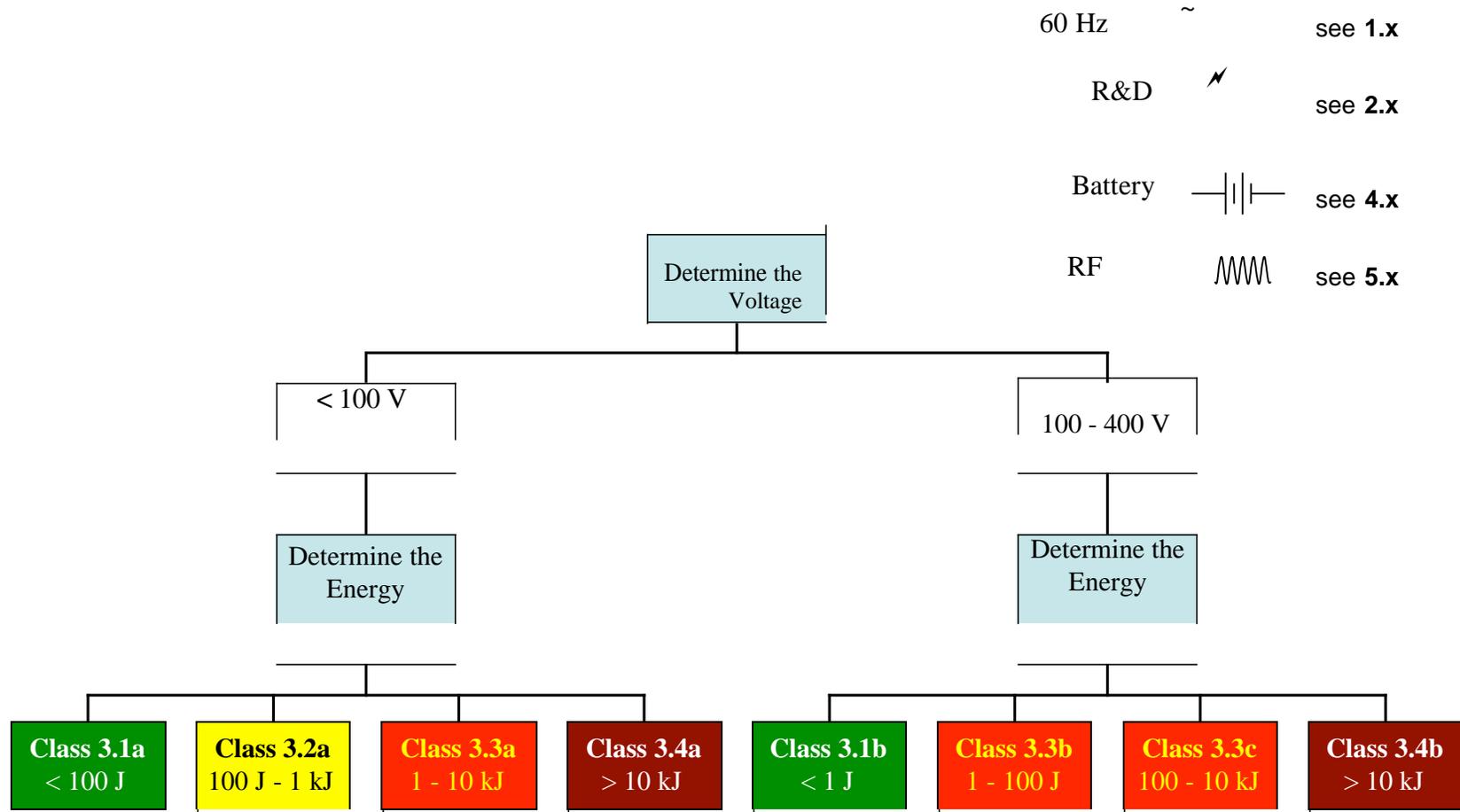
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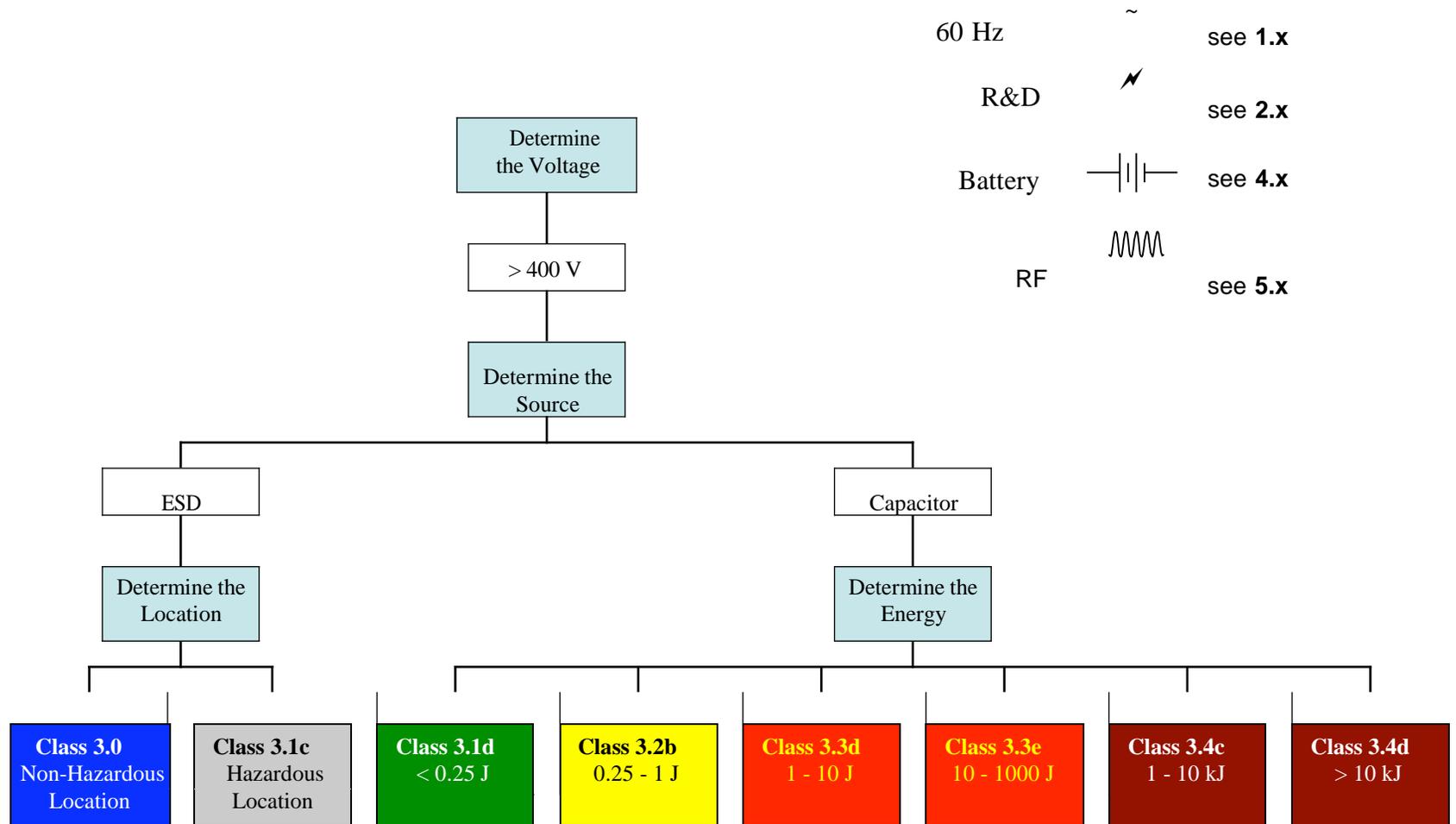
Notes on use of hazard Classes and control Table 2.x:

This control Table is NOT to be used for 60 Hz power.

- (a) The primary difference between Class 1.x and 2.x is the lack of available fault current in Class 2.x to create an arc-flash hazard. If significant fault current exists, Class 2.4, the worker must perform an arc-flash analysis, for ac or dc.
- (b) AC R&D includes ac frequencies from 1 Hz to 3 kHz (sub RF AC), that is not 60 Hz power.
- (c) Voltage is rms for AC, or DC voltage.
- (d) Power is available short-circuit power.
- (e) Current is available short-circuit current.
- (f) For 60 Hz facility power use hazard Classes 1.x.
- (g) For capacitors use hazard Classes 3.x.
- (h) For batteries use hazard Classes 4.x.
- (i) For AC frequencies above 3 kHz (RF) use hazard Classes 5.x.



**Fig. 3-5. Hazard Classes 3.x, capacitors, < 400 V**



**Fig. 3-6. Hazard Classes 3.x, capacitors, > 400 V.**

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**Table 3-3. Control Table for work in hazard Classes 3.x.**

Class	Mode	Qualified Worker(s)	Training	Work Control	PPE
3.0	ALL	Alone	None	None	None
3.1a,b,d	ALL	Alone	Non-Energized	None	None
3.1c <sup>3</sup>	ALL				
3.2a	0	Alone	Non-Energized	None	None
	1	Alone	Energized	YES	Eye, No Jewelry
	2	Two person	Energized	YES	Eye, No Jewelry
	3	Two person	Energized	YES	Eye, No Jewelry
3.2b	0	Alone	Non-Energized	None	None
	1	Alone	Energized	YES	<sup>1</sup>
	2	Two person	Energized	YES	<sup>1</sup>
	3	Two person	Energized	YES, EEWP	<sup>1</sup>
3.3a	0	Alone	Non-Energized	None	None
	1	Two person	Energized	YES	Eye, No Jewelry
	2	Two person	Energized	YES	Eye, No Jewelry
	3	Safety Watch	Energized	YES, EEWP	Eye, No Jewelry
3.3b	0	Alone	Non-Energized	None	None
	1	Two person	Energized	YES	Eye, <sup>1</sup>
	2	Two person	Energized	YES	Eye, <sup>1</sup>
	3 <sup>4</sup>	Safety Watch	Energized	YES, EEWP	Eye, <sup>1</sup>
3.3c	0	Alone	Non-Energized	None	None
	1	Safety Watch	Energized	YES	Eye, Ear, <sup>1,2</sup>
	2 <sup>5</sup>	Safety Watch	Energized	YES	Eye, Ear, <sup>1,2</sup>
	3 <sup>4</sup>	Safety Watch	Energized	YES, EEWP	Eye, Ear, <sup>1,2</sup>
3.3d	0	Alone	Non-Energized	None	None
	1	Two person	Energized	YES	Eye, <sup>1</sup>
	2	Two person	Energized	YES	Eye, <sup>1</sup>
	3 <sup>4</sup>	Two person	Energized	YES, EEWP	Eye, <sup>1</sup>
3.3e	0	Alone	Non-Energized	None	None
	1	Safety Watch	Energized	YES	Eye, Ear, <sup>1</sup>
	2 <sup>5</sup>	Safety Watch	Energized	YES	Eye, Ear, <sup>1</sup>
	3 <sup>7</sup>				

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Class	Mode	Qualified Worker(s)	Training	Work Control	PPE
<b>3.4a</b>	0	Alone	Non-Energized	None	None
	1	Safety Watch	Energized	YES	Eye, No Jewelry
	2 <sup>5</sup>	Safety Watch	Energized	YES	Eye, No Jewelry
	3 <sup>4</sup>	Safety Watch	Energized	YES, EEWP	Eye, No Jewelry
<b>3.4b</b>	0	Alone	Non-Energized	None	None
	1	Safety Watch	Energized	YES	Eye, Ear, <sup>1,2</sup>
	2 <sup>5</sup>	Safety Watch	Energized	YES	Eye, Ear, <sup>1,2</sup>
	3 <sup>4</sup>	Safety Watch	Energized	YES, EEWP	Eye, Ear, <sup>1,2</sup>
<b>3.4c</b>	0	Alone	Non-Energized	None	None
	1	Safety Watch	Energized	YES	Eye, Ear, <sup>1,2</sup>
	2 <sup>6</sup>	Safety Watch	Energized	YES	Eye, Ear, <sup>1,2</sup>
	3 <sup>7</sup>				
<b>3.4d</b>	0	Alone	Non-Energized	None	None
	1	Safety Watch	Energized	YES	Eye, Ear, <sup>1,2</sup>
	2 <sup>6</sup>	Safety Watch	Energized	YES	Eye, Ear, <sup>1,2</sup>
	3 <sup>7</sup>				

<sup>1</sup> Determine by a shock hazard analysis.

<sup>2</sup> Determine by a flash hazard analysis.

<sup>3</sup> For Class 3.1c refer to explosive safety.

<sup>4</sup> This mode of work should be avoided.

<sup>5</sup> This mode of work should be avoided or done remotely.

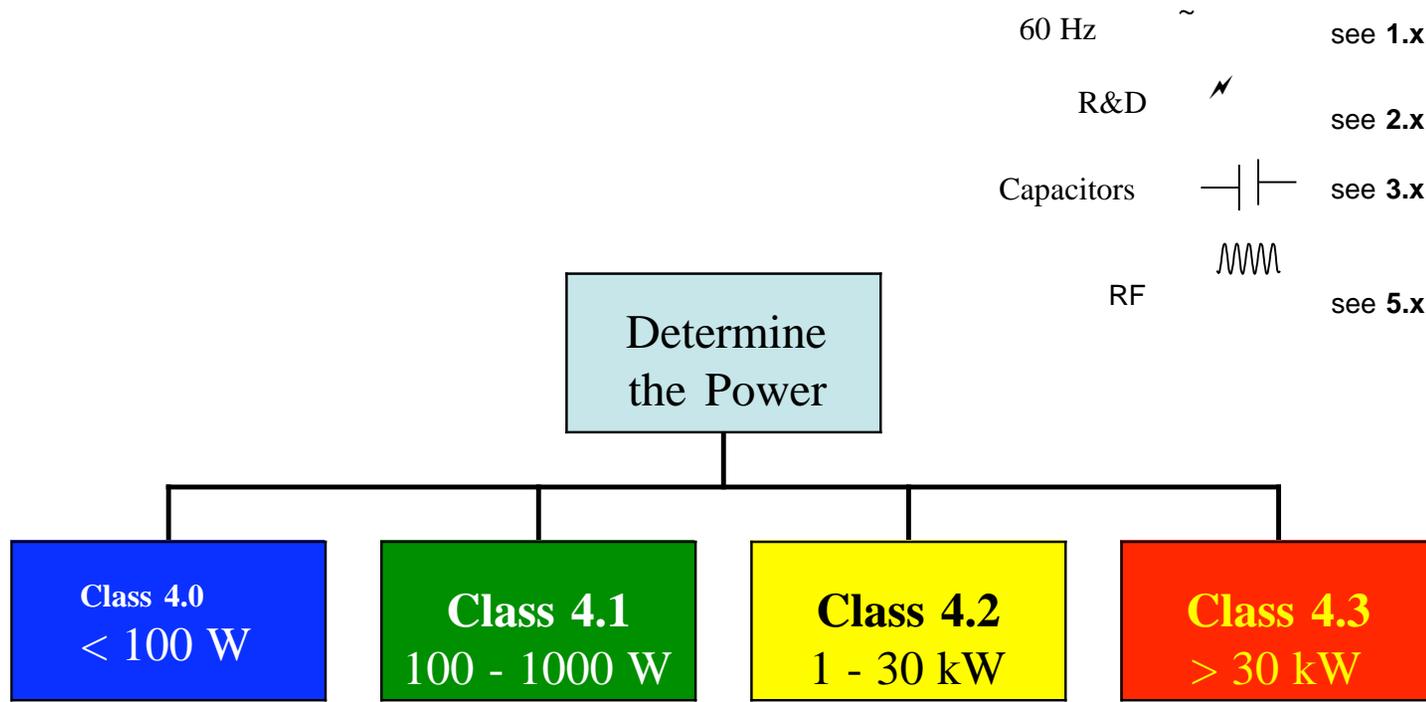
<sup>6</sup> Do this mode of work remotely.

<sup>7</sup> DO NOT do this mode of work.

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Notes on use of hazard Classes and control Table 3.x:

- (a) Voltage is AC rms or DC maximum charge voltage on the capacitor.
- (b) Energy is maximum energy stored in the capacitor as determined by  $\frac{1}{2}CV^2$ .
- (c) PPE – eye is proper eye protection, either goggles or a face shield, for higher energies.
- (d) PPE – no jewelry for low-voltage capacitors, means no jewelry on the hands (e.g., rings, watches) and no dangling jewelry or other objects (e.g., badge).
- (e) Column ‘Energy Removal’ is the method used to discharge lower-energy capacitors, or  
apply a safety ground on higher-energy capacitors. See definitions in Chapter 13 for definitions of hard and soft ground hooks.
- (f) Performing ‘Energy Removal’ remotely means using engineering methods to discharge and verify the capacitors without worker presence (e.g., a capacitor “dump” system).
- (g) Performing Mode 2 remotely means using sensors and instruments that are placed during a Mode 0 condition, then observed from a safe location during Mode 2 work.
- (h) The hazards for less than 100 V, Classes 3.2a, 3.3a, and 3.4a, are high current through a short circuit, such as tools and jewelry.
- (i) The hazards for 100 – 400 V, Classes 3.3b, 3.3c, and 3.4b, are high current through a short circuit, and a shock hazard.
- (j) The hazards for greater than 400 V, Classes 3.2b, 3.3d, 3.3e, 3.4c, and 3.4d, are high current through a short circuit, and a shock hazard with a strong reflex action for Class 3.2d, and serious tissue injury and/or death for 3.3d and above.
- (k) Classes 3.4b, 3.4c, and 3.4d have the added hazards of mechanical damage due to high currents and strong pulse magnetic forces during a short circuit.
- (l) For 60 Hz facility power, use hazard Classes 1.x.
- (m) For R&D (not 60 Hz), use hazard Classes 2.x.
- (n) For Batteries use, hazard Classes 4.x.
- (o) For AC frequencies above 3 kHz (RF), use hazard Classes 5.x.



Note: > 100 V also refer to Table 2.x: R&D DC to classify the shock hazard.

**Fig. 3-7. Hazard Classes 4.x, batteries and battery banks.**

**Table 3-4. Control Table for work in hazard Classes 4.x.**

Class	Mode	Qualified Worker(s)	Training	Work Control	PPE
4.0	ALL	Alone	None	None	None
4.1 <sup>1</sup>	ALL	Alone	Non-Energized	None	No Jewelry
4.2	2	Two person	Non-Energized	YES	Eye, No Jewelry
	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP <sup>3</sup>	Eye, No Jewelry
4.3	2	Safety Watch	Energized	YES	Eye, No Jewelry
	3 <sup>2</sup>	Safety Watch	Energized	YES, EEWP <sup>3</sup>	Eye, No Jewelry, Special Battery Tools

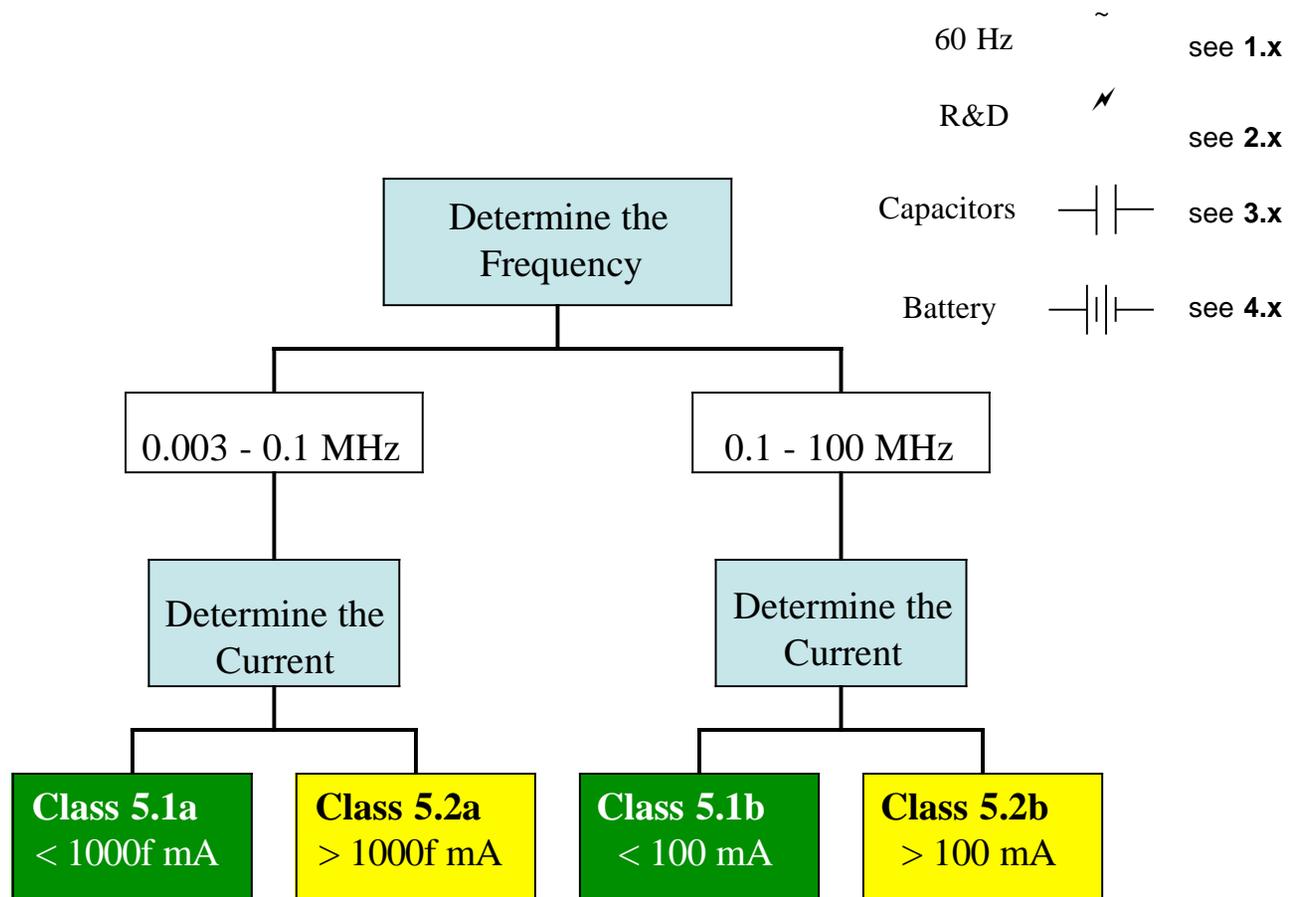
<sup>1</sup> Terminal voltage is less than 100 V.

<sup>2</sup> Break up bank for work.

<sup>3</sup> An EEWP is required if the terminals are exposed, or if the terminal voltage exceeds 100 V.

Notes on use of hazard Classes and control Table 4.x:

- (a) Power is the short circuit available power from the battery. This can be obtained by multiplying the short circuit available current by the battery terminal voltage. The short circuit available current can be obtained from the manufacturer's specifications.
- (b) There can be no Mode 0 or 1 for batteries, as they are always energized.
- (c) Additional PPE is necessary for vented lead-acid batteries, depending on the work activity (e.g., chemical PPE).
- (d) Although all work on Class 4.2 (e.g., automotive batteries) is Energized Work, some of this work (e.g., jump starting cars) is commonly done by the public. Caution should be used, however, and appropriate training and controls in place.
- (e) Class 4.1 batteries (e.g., desktop UPS batteries) may have adequate engineering controls, such as recessed terminals, to reduce the need for controls.
- (f) 'Energized Worker' training requires LOTO and CPR. Neither is necessary for low voltage battery work, unless the facility power source for a large UPS must be locked out and verified.
- (g) For 60 Hz facility power, use hazard Classes 1.x.
- (h) For R&D (not 60 Hz), use hazard Classes 2.x.
- (i) For capacitors, use hazard Classes 3x.
- (j) For ac frequencies above 3 kHz (RF), use hazard Classes 5.x.



**Fig. 3-8. Hazard Classes 5.x, RF circuits 3 kHz to 100 MHz (f is in MHz).**

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**Table 3-5. Control Table for work in Classes 5.x.**

Class	Mode	Qualified Worker(s)	Training	Work Control	PPE
5.1a,b	ALL	Alone	Non-Energized & RFMW	None	None
5.2a	0	Alone	Non-Energized & RFMW	None	None
	1 <sup>4</sup>	Alone	Energized & RFMW	YES	<sup>2</sup>
	2 <sup>3</sup>	Alone	Energized & RFMW	YES	<sup>2</sup>
	3 <sup>1</sup>				
5.2b	0	Alone	Non-Energized & RFMW	None	None
	1 <sup>4</sup>	Alone	Energized & RFMW	YES	<sup>2</sup>
	2 <sup>3</sup>	Alone	Energized & RFMW	YES	<sup>2</sup>
	3 <sup>1</sup>				

<sup>1</sup> DO NOT do this mode of work.

<sup>2</sup> No PPE is available for high current shock. Must avoid proximity.

<sup>3</sup> DO NOT move probes while energized.

<sup>4</sup> Must verify zero energy remotely.

Notes on use of Control Table 4.x:

- (a) f in the Chart is frequency in MHz.
- (b) Classes 5.x and control Table ONLY addresses the RF shock hazard. It does NOT address the exposure to electromagnetic fields.
- (c) The allowable shock currents are much higher than 60 Hz (e.g., 100 mA is allowed for 100 kHz).
- (d) There is no shock PPE for RF, thus Modes 1, 2, and 3 must NOT expose the worker to a shock hazard in Class 5.2..
- (a) For 60 Hz facility power use hazard Classes 1.x.
- (b) For R&D (not 60 Hz) use hazard Classes 2.x.
- (c) For capacitors use hazard Classes 3x.
- (d) For batteries use hazard Classes 4.x.

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**CHANGE HISTORY LOG**

<b>Revision</b>	<b>Effective Date</b>	<b>Description of Changes</b>
Baseline	01/12/2009	Initial Release
A	11/10/2010	Administratively Revised to update the Responsible Office Code, Organization Title and Organization Name within the document.
B	02/06/2017	Updated to clarify the required electrical safety program components listed in NFPA 70E, also Appendix C has been added to provide a hazard analysis tool not only for facility work but also to include research and development work involving electricity.