NFPA®

70B

Standard for Electrical Equipment Maintenance

2023

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Standard for Electrical Equipment Maintenance

2023 Edition

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NFPA® 70B

Standard for

Electrical Equipment Maintenance

2023 Edition

This edition of NFPA 70B, *Standard for Electrical Equipment Maintenance*, was prepared by the Technical Committee on Electrical Equipment Maintenance and released by the Correlating Committee on National Electrical Code®. It was issued by the Standards Council on December 27, 2022, with an effective date of January 16, 2023, and supersedes all previous editions.

This edition of NFPA 70B was approved as an American National Standard on January 16, 2023.

Origin and Development of NFPA 70B

The National Electrical Code Committee had received several requests to include maintenance recommendations in the *National Electrical Code® (NEC®)*. The National Electrical Code Correlating Committee determined that the *NEC* was not the proper document in which to cover the maintenance of electrical equipment. However, the committee recognized that "lack of maintenance" frequently resulted in serious injuries and fatalities as well as high monetary damage. An ad hoc committee on electrical equipment maintenance was authorized by NFPA in 1967 to determine the need for the development of a document on the subject.

Equipment manufacturers typically provide maintenance needs for specific types of equipment, and general maintenance guidance was available from several sources. Therefore, it was determined that compiling that information into a single document under the NFPA process in the form of general guidelines was advantageous.

On June 27, 1968, NFPA authorized the establishment of the Committee on Electrical Equipment Maintenance with the following scope: "To develop suitable texts relating to preventive maintenance of electrical systems and equipment used in industrial-type applications with the view of reducing loss of life and property. The purpose is to correlate generally applicable procedures for preventive maintenance that have broad application to the more common classes of industrial electrical systems and equipment without duplicating or superseding instructions that manufacturers normally provide. Reports to the Association through the Correlating Committee of the National Electrical Code Committee."

In 1973, NFPA 70B-T, *Tentative Recommended Practice for Electrical Equipment Maintenance*, covered "Why an Electrical Preventive Maintenance (EPM) Program Pays Dividends," "What Is an Effective Electrical Preventive Maintenance Program?," and "Planning and Developing an Electrical Preventive Maintenance Program." The document was revised in 1974 to include a chapter on the fundamentals of electrical equipment maintenance, general maintenance requirements for various types of equipment, and a new appendix, "How to Instruct." The tentative recommended practice was adopted as NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance*, in 1975.

For the 1977 edition, added chapters included Electronic Equipment, Ground-Fault Protection, Wiring Devices, and Maintenance of Electrical Equipment Subject to Long Intervals Between Shutdowns. New appendices addressed NEMA plug and receptacle configurations and guidelines for long-term maintenance.

In the 1983 edition, chapters on cable tray systems and on deenergizing and grounding of equipment to provide protection for maintenance personnel were added. An appendix covering equipment storage and maintenance during construction was also added.

The 1987 edition included distribution transformers as well as power transformers.

A chapter on uninterruptible power supply systems was added in the 1990 edition.

Three new chapters were added to the 1994 edition to cover power system studies, power quality, and vibration analysis pertaining to rotating machinery. Other revisions were made to comply with the NFPA *Manual of Style*.

For the 1998 edition, the chapter on power quality was rewritten and expanded. Maintenance techniques for stationary batteries and infrared inspections were updated and revised. Special handling and disposal considerations were introduced, and employee training was focused to emphasize workplace safety.

The 2002 edition was restructured to comply with the *Manual of Style for NFPA Technical Committee Documents*. The scope was revised to include preventive maintenance for electronic and communications equipment. A chapter was added for grounding maintenance issues. A new section for gas insulated substations addressed the maintenance issues resulting from regulatory changes in the electrical utility industry.

The chapter on power quality was enhanced with information on the latest technology on voltage fluctuation. A new annex suggested maintenance intervals for electrical equipment.

The 2006 edition included a new chapter on safety placed up front to provide more complete and updated coverage, as well as to emphasize the importance of safety. An important part of maintenance is having a properly installed system with baseline performance data, and so a chapter on commissioning the electrical system at a new facility was added. With the industry trend shifted from routine maintenance to reliability-centered maintenance (RCM), a chapter on how to apply RCM and an extensive annex with detailed reliability data on many types of electrical equipment also was added.

The 2010 edition was reorganized to group like topics and equipment into a more logical arrangement. The chapter on testing and test methods centralized test procedures formerly located in the individual equipment chapters.

A section on emergency preparedness and electrical system and equipment restoration was added to Chapter 6 to respond to the concerns of electrical equipment owners and maintainers. Chapter 6 included new material covering outsourcing of electrical equipment maintenance. The requirements on personnel safety were revised to correlate with and directly reference *NFPA 70E*.

Significant material supporting reliability centered maintenance was added to Annex N.

Four new chapters were added to the 2013 edition: Chapter 32, Electrical Disaster Recovery; Chapter 33, Photovoltaic Systems; Chapter 34, Electrical Vehicle Charging Systems; and Chapter 35, Wind Power Electrical Systems and Associated Equipment.

For the 2016 edition, torque recommendations were added to assist in minimizing electrical issues associated with poor connections. Battery testing and maintenance recommendations were enhanced to provide greater detail regarding proper battery testing and safety considerations for persons performing battery maintenance.

The 2019 edition incorporated several editorial and stylistic updates to improve the consistency of the document.

The recommended practice has been converted to the *Standard for Electrical Equipment Maintenance* standard for the 2023 edition.

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Committee Scope: This Committee shall have primary responsibility for documents on minimizing the risk of electricity as a source of electric shock and as a potential ignition source of fires and explosions. It shall also be responsible for text to minimize the propagation of fire and explosions due to electrical installations.

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have the primary responsibility for documents relating to preventive maintenance of electrical, electronic, and communications systems and equipment used in industrial and commercial type applications with the view of: (1) reducing loss of life and property, and (2) improving reliability, performance, and efficiency in a cost-effective manner. The purpose is to provide generally applicable procedures for preventive maintenance that have broad application to the more common classes of industrial and commercial systems and equipment without duplicating or superseding instructions that manufacturers normally provide. This Committee shall report to Correlating Committee of the National Electrical Code.

Contents

NFPA 70B

Standard for

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2023 Edition

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Information on referenced publications can be found in Chapter 2 and Annex R.

Chapter 1 Administration

1.1 Scope. This standard covers the preventive maintenance of electrical, electronic, and communications systems and equipment.

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1.2 Purpose. The purpose of this standard is to provide for the practical safeguarding of persons, property, and processes from the risks associated with failure, breakdown, or malfunction and a means to establish a condition of maintenance of electrical equipment and systems for safety and reliability.

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N 1.3 Application.

N 1.3.1 This standard applies to maintenance for electrical, electronic, and communications systems and equipment and is not intended to duplicate or supersede instructions provided by manufacturers. Systems and equipment covered are typical of those installed for industrial plants, institutional and commercial buildings, and large multifamily residential complexes.

N 1.3.2 Consumer appliances and equipment intended primarily for use in the home are not covered.

N 1.4 Equivalency. Nothing in this standard is intended to prevent the use of systems, methods, or devices of equivalent or superior quality, effectiveness, and safety over those prescribed by this standard.

N 1.5 Units of Measurement.

N 1.5.1 Primary Units. Primary units of measurement are in accordance with the modernized metric system known as the International System of Units (SI), except where specific units are customary for industry practice.

N 1.5.2 Secondary Units and Conversions.

N 1.5.2.1 Secondary units of measurement, where provided, are in accordance with US customary units (inch-pound units), except where specific units are customary for industry practice.

N 1.5.2.2 Where secondary units are not provided, converted values and converted trade sizes can be used.

N 1.5.2.3 Where extracted text contains values expressed in only one system of units, the values in the extracted text have been retained without conversion to preserve the values established by the responsible technical committee in the source document.

N 1.5.3 Unit Application and Enforcement.

N 1.5.3.1 The values presented in this standard are expressed with a degree of precision that is appropriate for practical application and enforcement.

N 1.5.3.2* Either the primary units or secondary units are acceptable for satisfying the requirements in this standard.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

Δ 2.2 NFPA Publications. (Reserved)

2.3 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

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2.4 References for Extracts in Mandatory Sections.

NFPA 70®, National Electrical Code®, 2023 edition.

NFPA *70E®, Standard for Electrical Safety in the Workplace®,* 2021 edition.

Chapter 3 Definitions

Δ 3.1 General.

N 3.1.1 The definitions contained in this chapter shall apply to the terms used in this standard.

N 3.1.2 Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used.

N 3.1.3 *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

N **3.2.3 Labeled.** Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

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N **3.2.5 Shall.** Indicates a mandatory requirement.

N **3.2.6 Standard.** An NFPA standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA manuals of style. When used in a generic sense, such as in the phrases "standards development process" or "standards development activities," the term "standards" includes all NFPA standards, including codes, standards, recommended practices, and guides.

3.3 General Definitions.

N **3.3.1* Adjustable Speed Drive.** Power conversion equipment that provides a means of adjusting the speed of an electric motor. [**70,** 2023]

N **3.3.2 Appliance.** Utilization equipment, generally other than industrial, that is fastened in place, stationary, or portable; is normally built in a standardized size or type; and is installed or connected as a unit to perform one or more functions such as clothes washing, air-conditioning, food mixing, deep frying, and so forth. [**70,** 2023]

3.3.3 Arc Flash Hazard. A source of possible injury or damage to health associated with the release of energy caused by an electric arc. [***70E,*** 2021]

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N **3.3.4 Bonded (Bonding).** Connected to establish electrical continuity and conductivity. [**70,** 2023]

N **3.3.5 Bonding Conductor (Bonding Jumper).** A conductor that ensures the required electrical conductivity between metal parts that are required to be electrically connected. [**70,** 2023]

N **3.3.6 Bonding Jumper, Equipment.** The connection between two or more portions of the equipment grounding conductor. [**70,** 2023]

N **3.3.7 Busway.** A raceway consisting of a metal enclosure containing factory-mounted, bare or insulated conductors, which are usually copper or aluminum bars, rods, or tubes. [**70,** 2023]

N **3.3.8 Cable Tray System.** A unit or assembly of units or sections and associated fittings forming a structural system used to securely fasten or support cables and raceways. [**70,** 2023]

N **3.3.9* Circuit Breaker.** A device designed to open and close a circuit by nonautomatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating. [**70,** 2023]

3.3.10 Commissioning. The process, procedures, and testing used to set up and verify the initial performance, operational controls, safety systems, and sequence of operation of electrical devices and equipment, prior to it being placed into active service. [**70,** 2023]

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N **3.3.11 Condition of Maintenance.** The state of the electrical equipment considering the manufacturers' instructions, manufacturers' recommendations, and applicable industry codes, standards, and recommended practices. [***70E,*** 2021]

N **3.3.12 Continuous Monitoring.** An uninterrupted method of data collection that utilizes permanently mounted counters, sensors, or controllers to measure a condition or state.

3.3.13 Coordination Study. A system planning process used to assist in selecting and setting protective devices to improve power system reliability.

3.3.14* Corona. An electrical discharge phenomenon occurring in gaseous substances, such as air.

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N **3.3.15 Disconnecting Means.** A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply. [**70,** 2023]

N **3.3.16* Electrical Maintenance Program (EMP).** A managed program of inspecting, testing, monitoring, analyzing, and servicing electrical systems and equipment with the purpose of maintaining safe operations and production by reducing or eliminating system interruptions and equipment failures.

N **3.3.17 Electrically Safe Work Condition.** A state in which an electrical conductor or circuit part has been disconnected from energized parts, locked/tagged in accordance with established standards, tested to verify the absence of voltage, and, if necessary, temporarily grounded for personnel protection. [***70E,*** 2021]

N **3.3.18 EMP Coordinator.** The individual responsible for coordinating the implementation and operation of the EMP.

N **3.3.19* Energy Storage System (ESS).** One or more devices installed as a system capable of storing energy and providing electrical energy into the premises wiring system or an electric power production and distribution network. [**70,** 2023]

N **3.3.20 Equipment, Mobile (Mobile Equipment).** Equipment with electrical components that is suitable to be moved only with mechanical aids or is provided with wheels for movement by a person(s) or powered devices. [**70,** 2023]

N **3.3.21* Fault Current, Available (Available Fault Current).** The largest amount of current capable of being delivered at a point on the system during a short-circuit condition. [**70,** 2023]

3.3.22 Ground. The earth. [**70,** 2023]

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3.3.23 Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection. [**70,** 2023]

3.3.24 Grounded Conductor. A system or circuit conductor that is intentionally grounded. [**70,** 2023]

3.3.25 Ground Fault. An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non–current-carrying conductors, metal enclosures, metal raceways, metal equipment, or earth. [**70,** 2023]

3.3.26* Ground-Fault Circuit Interrupter (GFCI). A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a ground-fault current exceeds the values established for a Class A device. [**70,** 2023]

Δ **3.3.27* Ground-Fault Protection of Equipment.** A system intended to provide protection of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device. [**70,** 2023]

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N **3.3.28 Grounding Conductor, Equipment (EGC).** A conductive path(s) that is part of an effective ground-fault current path and connects normally non–current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both. [**70,** 2023]

3.3.29 Grounding Electrode. A conducting object through which a direct connection to earth is established. [**70,** 2023]

3.3.30 Grounding Electrode Conductor. A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system. [**70,** 2023]

3.3.31 Grounding Electrode System. The interconnection of grounding electrodes.

3.3.32 Grounding Terminal. A terminal, lug, or other provision provided on some equipment cases (enclosures) to connect the conductive portion of the enclosure to the equipment-grounding conductor.

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Δ **3.3.33* Ground Loop.** Multiple intentional or unintentional connections from a conductive path to ground or the conductive body that serves in place of earth.

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3.3.34 Harmonics. Voltages or currents whose frequencies are integer multiples of the fundamental system frequency.

3.3.35* Interharmonics. Voltages or currents whose frequencies are not integer multiples of the fundamental system frequency.

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3.3.36* Long-Duration Undervoltage. A decrease of the supply voltage to less than 90 percent of the nominal voltage for a time duration greater than 1 minute.

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N **3.3.37 Maintenance Interval.** The frequency of inspecting, testing, monitoring, analyzing, and servicing electrical equipment that is determined by the type, criticality, and condition of the equipment.

N **3.3.38 Motor Control Center.** An assembly of one or more enclosed sections having a common power bus and principally containing motor control units. [**70,** 2023]

3.3.39 Noise. Undesirable electrical signals in an electrical or electronic circuit.

Δ **3.3.39.1** ***Noise, Common Mode.*** Undesirable electrical signals that exist between a circuit conductor and the grounding conductor.

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N **3.3.40 Overcurrent.** Any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault. [**70,** 2023]

N **3.3.41 Overcurrent Protective Device, Branch-Circuit (Branch-Circuit Overcurrent Protective Device).** A device capable of providing protection for service, feeder, and branch circuits and equipment over the full range of overcurrents between its rated current and its interrupting rating. [**70,** 2023]

N **3.3.42 Overload.** Operation of equipment in excess of normal, full-load rating, or of a conductor in excess of its ampacity that, when it persists for a sufficient length of time, would cause damage or dangerous overheating. A fault, such as a short circuit or ground fault, is not an overload. [**70,** 2023]

N **3.3.43 Panelboard.** A single panel or group of panel units designed for assembly in the form of a single panel, including buses and automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet, enclosure, or cutout box placed in or against a wall, partition, or other support; and accessible only from the front. [**70,** 2023]

N **3.3.44 Portable Equipment.** Equipment with electrical components suitable to be moved by a single person without mechanical aids. [**70,** 2023]

N **3.3.45 Power Quality.** Electrical phenomena that can be used to quantify the quality of the electrical supply, including, but not limited to, voltage transients, voltage sags, voltage swells, voltage interruptions, voltage and current harmonics, voltage fluctuations resulting in light flicker, voltage and current unbalance, power frequency deviations, voltage and current interharmonics, and electrical noise (conducted or radiated).

N **3.3.46 Predictive Techniques.** Analytics, algorithms, or software that interpret and analyze data from input sources and provide recommendations to address identified problems.

Δ **3.3.47 Qualified Person.** One who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify the hazards and reduce the associated risk. [***70E,*** 2021]

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N **3.3.48* Reconditioned.** Electromechanical systems, equipment, apparatus, or components that are restored to operating conditions. This process differs from normal servicing of equipment that remains within a facility, or replacement of listed equipment on a one-to-one basis. [**70,** 2023]

3.3.49 Risk Assessment. An overall process that identifies hazards, estimates the likelihood of occurrence of injury or

damage to health, estimates the potential severity of injury or damage to health, and determines if protective measures are required. [*70E,* 2021]

Δ **3.3.50* Sag.** A decrease to between 10 percent and 90 percent of the normal voltage at the power frequency for durations of 0.5 cycle to 1 minute.

N **3.3.51* Service Point.** The point of connection between the facilities of the serving utility and the premises wiring. [**70,** 2023]

N **3.3.52* Servicing.** The process of following a manufacturer's set of instructions or applicable industry standards to analyze, adjust, or perform prescribed actions upon equipment with the intention to preserve or restore the operational performance of the equipment. [**70,** 2023]

N **3.3.53 Single-Line Diagram.** A diagram that shows, by means of single lines and graphic symbols, the course of an electric circuit or system of circuits and the component devices or parts used in the circuit or system. [*70E,* 2021]

N **3.3.54* Ground-Fault Circuit Interrupter, Special Purpose (SPGFCI). (Special-Purpose Ground-Fault Circuit Interrupter)** A device intended for the detection of ground-fault currents, used in circuits with voltage to ground greater than 150 volts, that functions to de-energize a circuit or portion of a circuit within an established period of time when a ground-fault current exceeds the values established for Class C, D, or E devices. [**70,** 2023]

N **3.3.55* Stationary Standby Battery.** A battery that spends the majority of the time on continuous float charge or in a high state of charge, in readiness for a discharge event.

3.3.56* Survey. The collection of accurate data on the electrical system and the evaluation of this data to obtain the necessary information for developing the EMP.

3.3.57 Sustained Voltage Interruption. The loss of the supply voltage to less than 10 percent on one or more phases for a period greater than 1 minute.

Δ **3.3.58 Swell.** An increase to between 110 percent and 180 percent of the normal voltage at the power frequency for durations from 0.5 cycle to 1 minute.

N **3.3.59* Switchboard.** A large single panel, frame, or assembly of panels on which are mounted on the face, back, or both, switches, overcurrent and other protective devices, buses, and usually instruments. [**70,** 2023]

N **3.3.60* Switchgear.** An assembly completely enclosed on all sides and top with sheet metal (except for ventilating openings and inspection windows) and containing primary power circuit switching, interrupting devices, or both, with buses and connections. The assembly may include control and auxiliary devices. Access to the interior of the enclosure is provided by doors, removable covers, or both. [**70,** 2023]

N **3.3.61 Tests.**

N **3.3.61.1* *Acceptance Tests.*** Tests that are performed on new equipment prior to energization to determine whether the equipment complies with the purchase and design specifications.

N **3.3.61.2 *As-Found Tests.*** Tests performed on equipment before maintenance work is performed.

N **3.3.61.3 *As-Left Tests.*** Tests performed on equipment after maintenance work is performed.

N **3.3.61.4* *Enhanced Tests.*** Tests performed on equipment that is thought or known to be defective or equipment that has been subjected to conditions that could adversely affect its condition or operating characteristics.

N **3.3.61.5 *Standard Tests.*** Tests that are performed at regular intervals over the service life of equipment, typically in conjunction with maintenance on the equipment.

3.3.62 Transformer. Equipment, either single-phase or polyphase, that uses electromagnetic induction to convert current and voltage in a primary circuit into current and voltage in a secondary circuit. [**70,** 2023]

N **3.3.62.1 *Transformer, Power.*** A transformer rated greater than 500 kVA.

Δ **3.3.63* Transients.** Very short duration, high amplitude excursions outside of the limits of the normal voltage and current waveform.

3.3.64 Unbalanced Voltages. Unequal voltage values on 3-phase circuits that can exist anywhere on the power distribution system.

N **3.3.65 Utilization Equipment.** Equipment that utilizes electric energy for electronic, electromechanical, chemical, heating, lighting, or similar purposes. [**70,** 2023]

N Chapter 4 General

N **4.1 General Requirements.**

N **4.1.1** Electrical equipment shall be maintained in accordance with the manufacturer's instructions and applicable codes and standards.

N **4.1.2** This standard is not intended to duplicate or supersede manufacturer's instructions.

N **4.1.3** In the absence of manufacturer's instructions, equipment shall be maintained in accordance with industry consensus standards.

N **4.2 Electrical Maintenance Program (EMP).**

N **4.2.1 General.** The equipment owner shall implement and document an overall EMP that directs activity appropriate to the safety and operational risks.

N **4.2.2 Inspection.**

N **4.2.2.1** The EMP shall include elements to verify that electrical equipment or systems have been inspected to comply with applicable installation codes and standards.

N **4.2.2.2** Equipment-specific maintenance tasks shall be developed utilizing the information gathered during the inspection.

N **4.2.3 Condition of Maintenance.** The EMP shall include elements that consider current condition of maintenance of electrical equipment and systems as well as the potential safety and operational risks to maintenance and operational personnel.

N **4.2.4 EMP Principles.** The EMP shall identify the principles upon which it is based and the goals to be achieved.

N **4.2.4.1** The EMP shall be designed to function in conjunction with the applicable electrical safety program.

N **4.2.4.2*** The EMP shall include the following elements:

(1) An electrical safety program that addresses the condition of maintenance
(2) Identification of personnel responsible for implementing each element of the program
(3) Survey and analysis of electrical equipment and systems to determine maintenance requirements and priorities
(4) Developed and documented maintenance procedures for equipment
(5) A plan of inspections, servicing, and suitable tests
(6) A maintenance, equipment, and personnel documentation and records-retention policy
(7) A process to prescribe, implement, and document corrective measures based on collected data
(8) A process for incorporating design for maintainability in electrical installations
(9) A program review and revision process that considers failures and findings for continuous improvement

N **4.2.5 EMP Controls.** The EMP shall identify the controls by which it is measured and monitored.

N **4.2.6 Incident Investigations.** The EMP shall include a method to utilize all associated reports for feedback and EMP refinement, including the following:

(1) Electrical safety incidents
(2) Equipment malfunctions
(3) Unintended operations or alarms
(4) Operation of protective devices

N **4.2.7 EMP Audit.** The EMP shall be audited at intervals not to exceed 5 years to verify that the principles and procedures of the EMP comply with this standard.

N **4.3 Personnel.**

N **4.3.1 EMP Coordinator.** The EMP shall identify an EMP coordinator.

N **4.3.2 Maintenance Personnel.** Personnel assigned to EMP duties shall be qualified for the assigned tasks.

N **4.3.3 Electrical Maintenance Training.** A qualified person responsible for conducting electrical maintenance shall be trained in the specific maintenance tasks, test methods, test equipment, PPE usage (as applicable), and hazards associated with the electrical equipment or system being serviced.

N **4.3.3.1** A person who is undergoing on-the-job training for the purpose of obtaining the skills and knowledge necessary to be considered a qualified person, and who in the course of such training demonstrates an ability to perform specific duties safely at his or her level of training, and who is under the direct supervision of a qualified person shall be considered to be a qualified person for the performance of those specific duties.

N **4.3.3.2** The employer shall determine through regular supervision or through inspections conducted on at least an annual basis that each employee is complying with the electrical maintenance procedures and testing required by this standard.

N **4.3.3.3** A person responsible for conducting electrical maintenance shall be provided additional training (or retraining) if any of the following conditions exists:

(1) The supervision or annual inspections indicate the person is not complying with the maintenance procedures and testing requirements.
(2) New technology, new types of equipment, or changes in procedures necessitate the use of maintenance procedures and testing requirements different from those that the person would normally use.
(3) The person needs to review tasks that are performed less often than once per year.
(4) The person needs to review maintenance procedures and testing requirements that they do not normally use during regular job duties.
(5) The person's job duties change.
(6) A new edition of this standard is adopted that includes changes applicable to the person's job duties.

N **4.3.3.4** Training shall be documented in accordance with the following:

(1) Documentation shall be issued when the person demonstrates proficiency in the electrical maintenance procedures and testing requirements.
(2) Documentation shall be retained for the duration of the person's employment.
(3) Documentation shall specify the content of the training, the person's name, and the dates of training.

N **4.4 Survey and Analysis.**

N **4.4.1** The EMP coordinator shall determine the scope of the work to be performed and develop a prioritized plan for the electrical maintenance of the electrical equipment or system.

N **4.4.2** Electrical equipment and systems shall be evaluated to determine the appropriate scope and frequency of maintenance.

N **4.4.3** Environmental, physical, or operating conditions of a specific installation shall be considered in determining the frequency of electrical maintenance.

N **4.5 Planned Inspections.** The following considerations shall be reviewed during development of planned inspections:

(1) Potential of equipment failure to endanger or threaten personnel safety
(2) Manufacturer's recommended service and maintenance practices and procedures
(3) Operating environment
(4) Operating load conditions and equipment rating
(5) Failure and repair of equipment causing extensive downtime and lost production dollars
(6) Equipment condition
(7) Production and operating schedules
(8) Failure history
(9) Inspection history

N **4.6 Acceptance Test Report.** A copy of the acceptance test reports, if available, shall be included with the maintenance records.

N **4.7 Impact of Additions/Rework to Retrofitting Equipment.**

N **4.7.1*** Safety certifications shall be maintained for repaired or rebuilt equipment.

N **4.7.2*** When repairing, rebuilding, or remanufacturing equipment, the work shall be conducted by a qualified person or organization to assure that no changes are made to the equip-

ment that might prevent the equipment from meeting the applicable performance and safety requirements.

N **4.7.3** Refurbished or remanufactured equipment shall be marked to identify it as such.

N **4.8* Equipment Cleaning.** Electrical equipment cleaning shall be a part of the EMP.

N **4.8.1 Cleaning Personnel.**

N **4.8.1.1** Electrical equipment cleaning shall be performed by personnel who are familiar with the cleaning materials required and methodologies necessary for effective removal of contaminants, debris, and other foreign materials that compromise electrical equipment performance.

N **4.8.1.2** The persons assigned to the task of electrical equipment cleaning shall be trained in the following:

(1) Potential damage to the equipment from cleaning procedures
(2) Potential personal injury
(3) Specific cleaning procedures
(4) Equipment not to be cleaned

N Chapter 5 Personnel Safety

N **5.1 Introduction.**

N **5.1.1** Electrical maintenance shall be performed only by qualified persons.

N **5.1.2*** Electrical safety-related work practices shall be instituted and followed, in accordance with applicable state, federal, or local codes and standards, to identify the hazards and reduce the associated risks.

N Chapter 6 Single-Line Diagrams and System Studies

N **6.1 Introduction.**

N **6.1.1*** System studies shall be completed in accordance with this chapter.

N **6.1.2** Single-line diagrams shall be maintained in accordance with this chapter.

N **6.2 Single-Line Diagrams.** Up-to-date single-line diagrams shall be the primary reference for system studies.

N **6.2.1** Single-line diagrams shall be maintained in a legible condition.

N **6.2.2** Single-line diagrams shall be kept accurate.

N **6.2.3** Single-line diagram shall indicate the date of the last revision.

N **6.2.4** When single-line diagrams are not available, the facility or equipment owner shall be responsible for providing an equally effective means of obtaining the necessary information.

N **6.3* Short-Circuit Studies.**

N **6.3.1** Where a short-circuit study does not exist, one shall be created, as necessary to support the arc-flash risk assessment and equipment evaluations.

N **6.3.2** The short-circuit study shall be updated when changes occur in the electrical distribution system that could affect the results of the study.

N **6.3.3** The short-circuit study shall be reviewed for accuracy at intervals not to exceed 5 years.

N **6.3.4** The most recent study shall be made available to the EMP coordinator.

N **6.3.5** When the short-circuit study is updated, an electrical equipment rating evaluation shall be completed for the equipment within the scope of the study.

N **6.4* Coordination Studies.**

N **6.4.1** A coordination study shall be created as necessary to support risk assessments and the intended system design goals.

N **6.4.2** The coordination study shall be updated when changes occur in the electrical distribution system that could affect the results of the study.

N **6.4.3** The coordination study shall be reviewed for accuracy at intervals not to exceed 5 years.

N **6.4.4** The most recent study shall be made available to the EMP coordinator.

N **6.4.5** When the coordination study is updated, the electrical equipment overcurrent protective devices and equipment ratings shall be reviewed and verified for the equipment within the scope of the study.

N **6.5* Load-Flow Studies.**

N **6.5.1** If a load-flow study is needed to allow maintenance to be performed, the load-flow study shall be updated when changes occur that could affect the results of the study.

N **6.5.2** The load-flow study shall be reviewed for accuracy at intervals not to exceed 5 years.

N **6.5.3** The most recent study shall be made available to the EMP coordinator.

N **6.6* Reliability Studies.**

N **6.6.1** A reliability study shall be conducted as necessary on critical or important facility electrical systems to identify equipment and circuit configurations that can lead to unplanned outages.

N **6.6.2** Spare parts shall be monitored and inspected periodically to ensure that they will be available when needed.

N **6.6.3** The reliability study shall be reviewed for accuracy at intervals not to exceed 5 years.

N **6.6.4** The study shall be kept current and revised whenever a significant change to the electrical system has been made.

N **6.7* Incident Energy Analysis (Arc-Flash Study).**

N **6.7.1** The incident energy analysis shall be updated when changes occur in the electrical distribution system that could affect the results of the analysis.

N **6.7.2** The analysis shall be reviewed for accuracy at intervals not to exceed 5 years.

N **6.7.3** The most recent study shall be made available to the EMP coordinator.

N 6.8* Electrical Maintenance-Related Design. Where a recognized hazard presents an increased risk during maintenance, a study shall be conducted to develop design options that could be implemented to reduce risk.

N Chapter 7 Fundamental Tests

N 7.1 Fundamental Tests. The fundamental test procedures described in this chapter shall be used where required elsewhere in this standard.

N 7.2 Bolted Bus Connections, Conductor Terminations, and Conductor Connectors.

N 7.2.1 The quality of undisturbed bolted electrical bus connections, conductor terminations, and conductor connectors shall be verified using one or more of the methods described in 7.2.1.1 through 7.2.1.4.

N 7.2.1.1 Infrared Thermographic Inspection of Electrical Connections. Infrared thermographic inspection of electrical connections and terminations shall be performed in accordance with Section 7.4.

N 7.2.1.2 Thermal Sensors. Permanently mounted thermal sensors shall be permitted to monitor the temperature of electrical connections and terminations.

N 7.2.1.3 Contact Resistance Test.

N 7.2.1.3.1 A calibrated tester shall be used to obtain contact resistance test values.

N 7.2.1.3.2 Where contact resistance tests are used, the resistance values shall not exceed the maximum values published by the manufacturer.

N 7.2.1.3.3 If contact resistance values exceed the maximum values published by the manufacturer, the cause for the excess values shall be investigated.

N 7.2.1.4 Torque Verification.

N 7.2.1.4.1 When using a calibrated torque wrench to confirm the torque of previously installed threaded hardware, the retightening value shall not exceed 90 percent of the manufacturer's specified initial torque value.

N 7.2.1.4.2 Where initial threaded hardware torque value data is not available, torque values shall be in accordance with Table 7.2.1.4.2(a), Table 7.2.1.4.2(b), or Table 7.2.1.4.2(c).

N 7.2.2 Newly Installed Threaded Hardware Torque Values.

N 7.2.2.1 Newly installed threaded hardware connections shall be torqued to the manufacturer's published data.

N 7.2.2.2 Where the manufacturer's data is not available, torque values shall be in accordance with Table 7.2.1.4.2(a), Table 7.2.1.4.2(b), or Table 7.2.1.4.2(c) based on the hardware used.

N 7.3 Insulation Resistance Quality.

N 7.3.1 For equipment rated up to 1000 volts, the quality of electrical insulation (insulation resistance) shall be verified using a dc insulation resistance test set.

N 7.3.1.1 Insulation Resistance Testing. The applied test voltage shall not exceed the value specified by the manufacturer.

N Table 7.2.1.4.2(a) Bolt-Torque Values for Electrical Connections, US Standard Fasteners — Cadmium or Zinc Plated

Bolt Diameter (in.)	Torque (Pound-Feet)
1/4	6
5/16	11
3/8	20
7/16	32
1/2	48
9/16	70
5/8	96
3/4	160
7/8	240
1.0	370

Notes:
(1) Consult the manufacturer for equipment supplied with metric fasteners.
(2) The table is based on national coarse thread pitch.
(3) The grade is SAE 5.
(4) The minimum tensile (strength) is 105,000 lbf/in.^{2}.

N Table 7.2.1.4.2(b) Bolt-Torque Values for Electrical Connections, US Standard Fasteners — Silicon Bronze

	Torque (Pound-Feet)	
Bolt Diameter (in.)	Nonlubricated	Lubricated
5/16	15	10
3/8	20	15
1/2	40	25
5/8	55	40
3/4	70	60

Notes:
(1) Consult the manufacturer for equipment supplied with metric fasteners.
(2) This table is based on national coarse thread pitch.
(3) This table is based on bronze alloy bolts having a minimum 70,000 lb/in.^{2} tensile strength.

N Table 7.2.1.4.2(c) Bolt-Torque Values for Electrical Connections, US Standard Fasteners — Aluminum

Bolt Diameter (in.)	Torque (Pound-Feet), Lubricated
5/16	10
3/8	14
1/2	25
5/8	40
3/4	60

Notes:
(1) Consult the manufacturer for equipment supplied with metric fasteners.
(2) This table is based on national coarse thread pitch.
(3) This table is based on aluminum alloy bolts having a minimum 55,000 lb/in.^{2} tensile strength.

N 7.3.1.1.1 Where manufacturer's value is not available, test voltage shall be in accordance with appropriate industry standard.

N 7.3.1.1.2 The test instrument used to perform an insulation-resistance test shall be calibrated.

N 7.3.2 For equipment rated in excess of 1000 volts, the electrical insulation quality test method shall be determined by the EMP.

N 7.3.2.1 The test method shall be one or more of the following:

(1) dc insulation resistance
(2) ac or dc dielectric withstand testing
(3) dc overpotential (hipot) testing
(4) ac insulation power factor/dissipation factor testing
(5) Very low frequency (VLF) testing
(6) Damped alternating current (DAC) voltage test
(7) Acoustical ultrasonic testing
(8) Partial discharge (PD) testing

N 7.4 Infrared Thermography.

N 7.4.1 Infrared thermography shall be used when required to verify temperature differences (ΔT) of the following:

(1) Similar electrical components under similar loading
(2) Comparison between electrical components and ambient air temperatures

N 7.4.2 All accessible and necessary covers shall be removed prior to infrared thermography inspection to provide a clear line of sight to the equipment being scanned.

N 7.4.3 Temperature differences between the area of concern and the reference area shall be documented.

N 7.4.4 Infrared thermography inspections shall be performed at normal circuit loading.

N 7.4.5 Where normal circuit loading is not feasible, circuit loading of not less than 40 percent of nominal circuit loading shall be permitted.

N 7.4.6 Circuit loading characteristics shall be documented and retained for future reference.

N Chapter 8 Field Testing and Test Methods

N 8.1 Introduction. Field testing and test methods shall be conducted in accordance with this chapter to assess the overall condition of electrical equipment and systems and to accomplish the following objectives:

(1) Ascertain the ability of the device under test to continue to perform its function as designed
(2) Determine whether any corrective maintenance or replacement is necessary
(3) Document the condition of the equipment over its service life
(4) Provide results to ascertain the overall condition of maintenance of the device under test

N 8.2 Risk Assessment Special Considerations. Where the following special considerations are present, a risk assessment shall be performed to identify hazards and determine if additional protective measures are required prior to beginning work:

(1) Electrical, as follows:
    (a) X-ray
    (b) Overpotential
(2) Mechanical, as follows:
    (a) Stored energy
    (b) Mass energy
(3) Chemical, as follows:
    (a) SF_6gas fault by-products
    (b) Electrolytes
(4) Environmental, as follows:
    (a) Asbestos
    (b) SF_6 gas
    (c) Insulating fluids, as follows:
        (i) PCBs
        (ii) Tetrachloroethylene

N 8.3* Testing Category Types. Electrical maintenance testing tasks shall be identified as one of the following category types:

(1) Category 1 — Online standard test
(2) Category 1A — Online enhanced test
(3) Category 2 — Offline standard test
(4) Category 2A — Offline enhanced test

WARNING: Testing of electrical equipment while it is connected to the source of supply introduces additional hazards to the worker. Workers should understand the hazards and risks of the test being performed.

N 8.3.1 Category 1 — Online Standard Test. Online standard tests shall include testing procedures performed while the electrical equipment or device is connected to the source of supply.

N 8.3.2 Category 1A — Online Enhanced Test. Online enhanced tests shall include certain testing procedures performed while the electrical equipment or device is connected to the source of supply and that are not typically performed in normal electrical maintenance activities and that provide additional diagnostic information. *(See A.8.3.)*

N 8.3.3 Category 2 — Offline Standard Test. Offline standard tests shall include testing procedures performed while the electrical equipment or device is disconnected from the source of supply or is connected to an external test voltage source of supply.

N 8.3.4 Category 2A — Offline Enhanced Test. Offline enhanced tests shall include certain testing procedures performed while the electrical equipment or device is disconnected from the source of supply or is connected to an external test voltage source of supply and that are not typically performed in normal electrical maintenance activities and that provide additional diagnostic information. *(See A.8.3.)*

N 8.4 Qualifications of Testing Personnel.

N 8.4.1 Testing personnel shall be qualified to operate the test equipment used in the type of test to be performed.

N 8.4.2 Testing personnel shall be qualified to perform the test procedure on the specific equipment to be tested.

N 8.5 Test Equipment and Tools.

N 8.5.1 The test equipment shall be maintained in satisfactory mechanical and electrical condition.

N 8.5.2 The test equipment shall be applied in accordance with the manufacturer's specifications.

N **8.5.3*** Test equipment that provides measurements shall be calibrated.

N **8.5.4** Calibration information shall be readily available for all test equipment.

N **8.5.5** Test equipment calibration intervals shall be appropriate to ensure the accuracy of the test instrument with consideration for the conditions of use.

N **8.5.6** Proper tools, instruments, and other test equipment shall be used when performing maintenance activities.

N **8.6 Test Record.**

N **8.6.1** A test record shall be created for all field tests of electrical equipment.

N **8.6.2** Test records shall contain the following minimum information:

(1) Identification of the testing person and organization
(2) Identification of the equipment under test
(3) Nameplate or label data from the equipment under test
(4) Environmental conditions, such as humidity and temperature, that could affect the results of the tests or calibrations
(5) Date of the test
(6) Indication of test performed
(7) Indication of pass/fail criteria, where applicable
(8) Indication of as-found and as-left test results, where applicable
(9) Test operator's comments or recommendations, where applicable

N **8.7* Condition of Maintenance Indication.** Information shall be made readily available to communicate the condition of maintenance.

N **8.7.1 Conditions of Maintenance.**

N **8.7.1.1 Serviceable.** Equipment that passes all tests and is electrically and mechanically sound shall be designated as serviceable.

N **8.7.1.2* Limited Service.** Equipment that has problems that are not detrimental to the protective operation or design characteristics of the equipment shall be designated as limited service.

N **8.7.1.3* Nonserviceable.** Equipment that has a problem that is detrimental to the proper electrical or mechanical operation of the equipment shall be designated as nonserviceable.

N Chapter 9 Maintenance Intervals

N **9.1 Scope.** This chapter identifies the required frequency of maintenance for electrical equipment.

N **9.1.1* Continuous Monitoring and Predictive Techniques.**

N **9.1.1.1*** Continuous monitoring or predictive techniques shall be permitted to be used as a consideration when determining maintenance intervals.

N **9.1.1.2*** Continuous monitoring or predictive techniques shall be based on manufacturer's recommendations or accepted industry practices.

N **9.1.2 Maintenance Frequency Modifications.**

N **9.1.2.1** Once the initial frequency for inspection and tests has been established based on the intervals listed in Table 9.2.2 and the equipment condition assessment, this frequency shall be adhered to for at least two maintenance cycles unless unexpected failures occur.

N **9.1.2.1.1** For equipment that has unexpected failures, the cause of the failure shall be used to determine if the maintenance interval for the equipment needs to be reduced.

N **9.1.2.1.2*** If more than two inspections are completed without requiring additional service, the equipment owner shall be permitted to resume the original inspection period.

N **9.1.2.2** If more than two inspections are completed without detecting equipment problems, the maintenance cycle shall be permitted to be extended to longer intervals than listed in Table 9.2.2.

N **9.2 Frequency of Maintenance.**

N **9.2.1*** The manufacturer's recommendations shall be followed for each of the maintenance scopes specified in this standard for the required intervals.

N **9.2.2*** Where the manufacturer's recommendations are not provided or available and failure, breakdown, or malfunction of the equipment will present an unacceptable risk for personnel or the environment, equipment maintenance shall be performed at not greater than the intervals specified in Table 9.2.2, in accordance with the equipment condition assessment in Section 9.2, and as modified by the other parts of this chapter.

N **9.2.2.1** The intervals in Table 9.2.2 shall only be required if referenced by a specific section in another chapter.

N **9.2.2.2** The maintenance interval for electrical equipment shall be permitted to be altered based on the potential risk to personnel or facility operations due to a failure of the equipment to operate as expected.

N **9.2.2.3** Any deviations from the maintenance intervals described in Table 9.2.2 to extend the maintenance interval and the justification for the deviation shall be documented in the EMP.

N **9.3 Equipment Condition Assessment.** The equipment condition shall be the highest condition category in accordance with 9.3.1, 9.3.2, and 9.3.3 as determined by the owner or their designee.

N **9.3.1 Physical Condition of Electrical Equipment.** Equipment that is included in the electrical EMP shall be assessed for current equipment condition in accordance with 9.3.1.1 through 9.3.1.3.

N **9.3.1.1** Equipment Physical Condition 1 shall be assigned where all the following criteria apply:

(1) The equipment appears in like new condition.
(2) The enclosure is clean, free from moisture intrusion, and tight.
(3) No unaddressed notification from the continuous monitoring system has occurred.
(4) There are no active recommendations from predictive techniques.
(5) Previous maintenance has been performed in accordance with the EMP.

N **Table 9.2.2 Maintenance Intervals**

Product	Scope of Work	Equipment Condition Assessment		
		Condition 1	Condition 2	Condition 3
All equipment	Infrared thermography	12 months	12 months	6 months
Battery ESSs	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication		Reserved	
	Mechanical servicing		Reserved	
	Electrical testing	60 months	36 months	12 months
Busways	Visual inspection	60 months	60 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
	Special	60 months	36 months	12 months
Cable trays	Visual inspection	12 months	12 months	6 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Electric vehicle power transfer systems	Visual inspection	60 months	36 months	12 months
	Mechanical inspection	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Electronic equipment			Reserved	
Fuses	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
GFCIs	Visual inspection	12 months	12 months	6 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing		Reserved	
Grounding and bonding	Visual inspection	12 months	12 months	6 months
	Cleaning		Reserved	
	Lubrication		Reserved	
	Mechanical servicing		Reserved	
	Electrical testing	60 months	36 months	36 months
High-voltage substation insulators	Visual inspection	12 months	12 months	6 months
	Corona detection	12 months	6 months	4 months
	Maintenance and testing	60 months	36 months	12 months
Lighting	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Servicing	60 months	36 months	12 months

(continues)

N **Table 9.2.2** *Continued*

Product	Scope of Work	Equipment Condition Assessment		
		Condition 1	Condition 2	Condition 3
Lighting control systems			Reserved	
Low-voltage ground-fault protection systems	Visual inspection	12 months	12 months	6 months
	Cleaning	60 months	36 months	12 months
	Lubrication		Reserved	
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Medium-voltage ground-fault protection systems	Visual inspection	12 months	12 months	6 months
	Cleaning	60 months	36 months	12 months
	Lubrication		Reserved	
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Medium-voltage power circuit breakers	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Molded-case/insulated-case/low-voltage power circuit breakers	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Motor control equipment	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Panelboards and switchboards	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical inspections	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Photovoltaic systems	Visual inspection	60 months	36 months	12 months
	Cleaning		Reserved	
	Lubrication		Reserved	
	Mechanical servicing		Reserved	
	Electrical testing	60 months	36 months	12 months
Portable electrical tools and equipment	Visual inspection	Before each use	Before each use	Before each use
	Cleaning	Before each use	Before each use	Before each use
	Lubrication	In accordance with the manufacturer's instructions	In accordance with the manufacturer's instructions	In accordance with the manufacturer's instructions
	Mechanical servicing	In accordance with the manufacturer's instructions	In accordance with the manufacturer's instructions	In accordance with the manufacturer's instructions

(continues)

N **Table 9.2.2** *Continued*

Product	Scope of Work	Equipment Condition Assessment		
		Condition 1	Condition 2	Condition 3
	Electrical testing	3 months	3 months	3 months
Power and distribution transformers	Visual inspection	12 months	12 months	6 months
	Cleaning	60 months	36 months	12 months
	Lubrication		Reserved	
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Power cables	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Mechanical servicing	Reserved	Reserved	
	Electrical testing	60 months	36 months	12 months
Power-factor correction capacitors	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication		Reserved	
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
	Special		Reserved	
Protective relays, electromechanical	Visual inspection	36 months	24 months	12 months
	Cleaning	36 months	24 months	12 months
	Lubrication		Reserved	
	Mechanical servicing	36 months	24 months	12 months
	Electrical testing	36 months	24 months	12 months
Protective relays, solid state and microprocessor	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication		Reserved	
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Public pools, fountains, and similar installations			Reserved	
Rotating equipment	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Stationary standby batteries	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Mechanical servicing		Reserved	
	Electrical testing	60 months	36 months	12 months
Substations	Visual inspection	12 months	12 months	6 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
	Special	60 months	36 months	12 months
	Mechanical checks	60 months	36 months	12 months

(continues)

N Table 9.2.2 *Continued*

Product	Scope of Work	Equipment Condition Assessment		
		Condition 1	Condition 2	Condition 3
Switches	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Switchgear	Visual inspection	12 months	12 months	6 months
	Cleaning	60 months	36 months	12 months
	Lubrication	60 months	36 months	12 months
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
	Special	60 months	36 months	12 months
Uninterruptible power supplies	Visual inspection	6 months	3 months	1 month
	Cleaning	12 months	6 months	3 months
	Lubrication		Reserved	
	Mechanical servicing	12 months	6 months	3 months
	Electrical testing	12 months	6 months	3 months
	Special procedures	24 months	24 months	24 months
Wind power electric systems	Visual inspection	60 months	36 months	12 months
	Cleaning	60 months	36 months	12 months
	Lubrication		Reserved	
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months
Wiring devices	Visual inspection	12 months	3 months	1 month
	Cleaning	60 months	36 months	12 months
	Lubrication		Reserved	
	Mechanical servicing	60 months	36 months	12 months
	Electrical testing	60 months	36 months	12 months

N 9.3.1.2 Equipment Physical Condition 2 shall be assigned where all of 9.3.1.1 apply, and where any of the following criteria apply:

(1) Maintenance results deviate from past results or have indicated more frequent maintenance in accordance with manufacturer's published data.
(2) The previous maintenance cycle has revealed issues requiring the repair or replacement of major equipment components.
(3) There have been notifications from the continuous monitoring system since the prior assessment.
(4) There are active recommendations from predictive techniques.

N 9.3.1.3 Equipment Physical Condition 3 shall be assigned where changes in operation are noted or where any of the following criteria applies:

(1) The equipment has missed the last two successive maintenance cycles in accordance with the EMP.
(2) The previous two maintenance cycles have revealed issues requiring the repair or replacement of major equipment components.
(3) There is an active or unaddressed notification from the continuous monitoring system.
(4) There are urgent actions identified from predictive techniques.

N 9.3.1.4 Nonserviceable Equipment.

N 9.3.1.4.1 Equipment that poses an imminent risk of injury or negative health effects to personnel shall be designated as nonserviceable in accordance with 8.7.1.3.

N 9.3.1.4.2 Access to nonserviceable equipment by unqualified persons shall be restricted.

N 9.3.1.5 Nonconforming Equipment. Equipment exhibiting characteristics that do not conform to any of the above conditions shall be identified as requiring corrective measures before returning it to a normal operating condition.

N 9.3.2* Criticality Condition of Equipment.

N 9.3.2.1* Criticality Condition 1 or Criticality Condition 2 shall be permitted to be assigned where the failure of the equipment or system will not endanger personnel.

N 9.3.2.2 Criticality Condition 3 shall be assigned where the failure of the equipment or system will endanger personnel.

N 9.3.3 Operating Environment Condition of Equipment.

N 9.3.3.1 Operating Environment Condition 1 or Operating Environment Condition 2 shall be permitted to be assigned where the equipment is used in an operating environment for which it is rated.

N 9.3.3.2 Operating Environment Condition 3 shall be assigned where the equipment is used in an environment with harsh chemicals, contaminants, or extreme operating conditions for which it is not specifically rated or evaluated.

N Chapter 10 Hazardous (Classified) Location Electrical Equipment

N 10.1* General. Electrical equipment designed for use in hazardous (classified) locations shall be maintained through regular inspections, testing, and servicing, as recommended by the manufacturer.

N 10.1.1 Documentation shall be readily available to identify the classification, group, temperature code specification, and extent of the classified area.

N 10.1.2* Repairs and maintenance, including access to and removal of components, shall not be performed inside the hazardous (classified) area unless a documented risk assessment to determine the risk of igniting an explosive atmosphere is conducted by a qualified person.

N 10.1.3 Electrical maintenance documentation shall identify where the maintenance is to be performed and what precautions are necessary.

N 10.1.4 A thorough inspection shall be performed after any maintenance work to ensure the equipment is restored to a safe operational condition.

N 10.2 Maintenance Personnel for Hazardous (Classified) Locations.

N 10.2.1 Maintenance shall be performed only by qualified persons who are trained in safe maintenance practices and the special considerations necessary to maintain electrical equipment for use in the specific class of hazardous (classified) locations.

N 10.2.2* Qualified persons shall be trained to evaluate and eliminate ignition sources and to identify the need for special tools, procedures, equipment, tests, and protective clothing.

N 10.3 Elimination of Hazardous Atmospheres. For maintenance involving permanent electrical installations, the following procedures shall be followed:

(1) Hazardous vapors, dust, or fibers/flyings shall be removed from the area.
(2) Enclosed or trapped hazardous vapors shall be cleared.
(3) Atmosphere shall be tested to confirm it is within safe limits for the required maintenance.

N 10.4 Elimination of Ignition Sources.

N 10.4.1* An electrically safe work condition shall be established, and all other ignition sources abated before maintenance is performed.

N 10.4.2 Before opening any enclosure, time shall be allowed for parts to cool and electrical charges to dissipate, as identified in the risk assessment or manufacturer's instructions.

N 10.4.3 Bonding jumpers shall be applied as required to dissipate and prevent static electrical charges.

N 10.5 Equipment Reassembly.

N 10.5.1 Electrical equipment designed for use in hazardous (classified) locations shall be fully reassembled with original components or approved replacement components before the hazardous atmosphere is reintroduced.

N 10.5.2 Covers shall not be interchanged unless identified for the purpose.

N 10.5.2.1* Prior to reinstalling covers, they shall be checked for proper closure of mating joints and seals.

N 10.5.2.2 Mating joints or seals that do not make a proper closure shall be repaired or replaced in accordance with the manufacturer's instructions.

N 10.6 Conduit and Equipment Seals.

N 10.6.1 An approved system of conduit and equipment seals shall be maintained.

N 10.6.2* Corrective action shall be taken on any seal that is found to be damaged or missing.

N 10.7 Bolts and Screws. Where bolts or screws used to secure an electrical equipment cover require torqueing to meet installation specifications, the bolts or screws shall be maintained with the torque specified by the manufacturer.

N 10.7.1 All bolts and screws shall be replaced with original components or as specified by the manufacturer.

N 10.8* Handling of Equipment, Components, and Tools. Electrical equipment used in hazardous (classified) locations shall not be subjected to damage from tools that pry, impact, or abrade components.

N 10.8.1 Where grease, paint, or dirt must be cleaned from machined joints, a nonmetallic bristle brush, an acceptable noncorrosive solvent, or other methods recommended by the manufacturer shall be used.

N 10.8.2 Prior to replacing a cover on an enclosure designed to prevent flame propagation upon an explosion, mating surfaces shall be cleaned and lubricated in accordance with the manufacturer's instructions.

N 10.9* Field Modifications. Field modifications of equipment and parts shall be limited to those changes acceptable to the manufacturer and, where required, approved by the AHJ.

N Chapter 11 Power and Distribution Transformers

N 11.1 Scope.

N 11.1.1 This chapter identifies electrical maintenance requirements for power and distribution transformers.

N **11.1.2** This chapter does not apply to control power and instrument transformers.

N **11.2 Frequency of Maintenance.** The periodic maintenance procedures specified in Section 11.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in Table 11.2.

N **11.3 Periodic Maintenance Procedures.**

N **11.3.1 Visual Inspections.** Transformers shall be visually inspected in accordance with Table 11.3.1.

N **11.3.2 Cleaning.**

N **11.3.2.1** Transformers shall be cleaned to remove buildup of accumulated dirt and debris.

N **11.3.2.2** Transformer bushings and any accessible insulators and conductors shall be wiped clean to remove surface buildup of contaminants.

N **11.3.3 Lubrication. (Reserved)**

N **11.3.4 Mechanical Servicing.** Transformers shall be mechanically serviced in accordance with Table 11.3.4.

N **11.3.5* Electrical Testing.** Transformers shall be electrically tested in accordance with Table 11.3.5.

N **11.3.6 Special. (Reserved)**

N **Table 11.2 Frequency of Maintenance**

	Equipment Condition Assessment			
Scope of Work	**Condition 1**	**Condition 2**	**Condition 3**	**Notes**
Sample insulating fluid and tests	12 months	12 months	6 months	See 11.3.5.

N **Table 11.3.1 Transformer Visual Inspections**

No.	Task	Dry Type, Air-Cooled: Small, Windings, ≤600 Volts, ≤167 kVA 1-ph, ≤500 kVA 3-ph Test Type*	Dry Type, Air-Cooled: Large, Windings, >600 Volts, >167 kVA 1-ph, >500 kVA 3-ph Test Type*	Liquid-Filled Test Type*	Notes
1	Bolted connections	2	2	2	
2	Cooling devices	2	2	2	
3	Liquid level gauge(s) and alarm(s)	NA	NA	2	
4	Neutral grounding impedance devices	2	2	2	
5	Nitrogen bottle pressure system	NA	NA	2	
6	Pressure relief device(s)	NA	NA	2	
7	Sudden pressure relay(s)	NA	NA	2	
8	Tank over/under pressure gauge and alarms	NA	NA	2	
9	Transformer enclosure	1 or 2	1 or 2	1 or 2	Ensure ventilation and equipment enclosure integrity has not been compromised.

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test;Type 1A = online enhanced test;Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 11.3.4 Transformer Mechanical Servicing**

No.	Task	Test Type*			Notes
		Dry Type, Air-Cooled			
		Small, Windings ≤600 V ≤167 kVA 1-ph, ≤500 kVA 3-ph	Large, Windings >600 V >167 kVA 1-ph, >500 kVA 3-ph	Liquid-Filled	
1	Bolted connection	2	2	2	
1A	Verify tightness of accessible bolted electrical connections	2	2	2	
1B	Verify as-left tap connections are as specified	2	2	2	
2	Inspect anchorage, alignment, and grounding	2	2	2	
3	Cooling devices	2	2	2	
4	Transformer enclosures, ventilation filters, and screens inspected and replaced or cleaned, as needed	2	2	NA	
5	Control cabinets connections and cleaning	2	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 11.3.5 Transformer Electrical Tests**

No.	Task	Dry Type, Air-Cooled: Small, Windings, ≤600 Volts, ≤167 kVA 1-ph, ≤500 kVA 3-ph Test Type*	Dry Type, Air-Cooled: Large, Windings, >600 Volts, >167 kVA 1-ph, >500 kVA 3-ph Test Type*	Liquid-Filled Test Type*	Notes
1	Core insulation resistance	NA	2A	2A	
2	Excitation current on each phase	NA	2	2	
3	Insulation power factor	NA	2	2	
4	Insulation power factor tip-up	NA	2A	NA	
5	Main insulation resistance	2	2	2	
6	Neutral grounding impedance devices	NA	2	2	
7	Online partial discharge on MV/HV windings	NA	1A	1A	
8	Insulation power factor on each bushing	NA	NA	2†	
9	Sweep frequency response analysis	NA	NA	2A	
10	Turns ratio on all load tap changer (LTC) taps	NA	NA	2A	
11	Turns ratio on all no-load tap changer (NLTC) taps	2A	2A	2A	
12	Turns ratio on designated tap	2	2	2	
13	Winding resistance at designated tap	2A	2A	2	
14	Bolted connection resistance	2	2	2	
15	Applied voltage test	NA	2A	NA	
16	Sample insulating fluid and test for:				
	Dielectric breakdown	NA	NA	1 or 2	
	Acid neutralization number	NA	NA	1 or 2	
	Specific gravity	NA	NA	1 or 2	
	Interfacial tension	NA	NA	1 or 2	
	Color	NA	NA	1 or 2	
	Visual condition	NA	NA	1 or 2	
	Water content	NA	NA	1 or 2	
	Power factor	NA	NA	1 or 2	
	Dissolved gas analysis	NA	NA	1, 1A or 2, 2A	
	Furan analysis	NA	NA	1, 1A or 2, 2A	
17	Sweep frequency response analysis	NA	NA	2A	
18	Percent oxygen in insulating blanket	NA	NA	2A	
19	Testing of transformer alarms, including temperature, liquid level, nitrogen bottle pressure, tank over/under pressure, sudden pressure	NA	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.
†Transformers applied at voltages greater than 1000 volts.

N Chapter 12 Substations and Switchgear

N 12.1 Scope.

N **12.1.1** This chapter identifies electrical maintenance requirements for substations, switchgear, and surrounding areas, whether fenced or in rooms.

N **12.1.2*** This chapter does not address requirements of individual components of substations and switchgear that are addressed in the chapters for those components.

N **12.2 Frequency of Maintenance.** The periodic maintenance procedures specified in Section 12.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in this chapter.

N 12.3 Periodic Maintenance Procedures.

N **12.3.1* Visual Inspection.** Substations and switchgear shall be visually inspected in accordance with Table 12.3.1.

N **12.3.2 Cleaning.** Electrical equipment surfaces, enclosures, insulating materials, and surrounding areas shall be kept clean to prevent a buildup of contaminants that negatively affect performance, reduce life expectancy, or create a safety hazard.

N **12.3.3 Lubrication.** Terminating devices, mechanical parts, or operating parts that open, close, insert, and trip a circuit breaker, switch, or protective device shall be lubricated as required per the manufacturer's instruction manual.

N **12.3.4* Mechanical Servicing.** Substation and switchgear shall be mechanically serviced in accordance with Table 12.3.4.

N **12.3.5* Electrical Testing.** Substations and switchgear shall be electrically tested in accordance with Table 12.3.5.

N **12.3.6 Special.**

N **12.3.6.1 Miscellaneous Equipment.**

N **12.3.6.1.1*** The availability and condition of required dedicated maintenance or operational tools and other test equipment shall be inspected.

N **12.3.6.1.2** If found to be defective, the dedicated maintenance or operational tools or other test equipment shall be taken out of service, replaced, or repaired, according to the manufacturer's specifications.

N **12.3.6.2 Auxiliary Apparatus.** Area lighting, exit and emergency lighting, room HVAC or ventilation systems, and other auxiliary apparatus shall be checked for proper operation.

N **Table 12.3.1 Substation and Switchgear Visual Inspections**

No.	Task	1000 Volts or Below Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Inspect external physical condition	1	1	This includes condition and integrity of applied labels.
2	Inspect anchorage and grounding	1	1	Document if anchorage is not appropriate in accordance with current seismic requirements so improvements can be considered.
3	Ensure maintenance devices and tools are available for equipment servicing	1	1	
4	Verify circuit breakers, fuses, protective relays, and other type of overload elements are the right sizes and types and correspond to the drawings and the power system studies	1 or 2	1 or 2	Verify against plans, drawings, and pertinent records, as well as against evidence of current load levels. Some devices might be able to be checked while panel doors are closed.
5	For connected communicating addressable devices, verify the device addresses are set in accordance with documentation	1 or 2	1 or 2	Confirm addressing or correct device association where protective devices or the human-machine interface (HMI) are connected to multiple devices via a communication network.
6	Verify instrument transformer ratios are correct as installed	2A	2A	
7	Inspect insulators for damage or contaminated surfaces	2	2	
8	Verify air filters or screens are clean and in place	1 or 2	1 or 2	
9	Check all ventilation openings for obstructions and correct operation of any flap or automatic cover intended to assist in arc resistant ratings	2	2	
10	Inspect arc resistant equipment to ensure all doors are secured and in place	1 or 2	1 or 2	
11	Verify switch phase barriers are in place and in good condition	2	2	
12	For individual components, refer to the appropriate chapter(s) of this standard	NA	NA	
13	Visually inspect environmental controls, where provided	1 or 2	1 or 2	Includes, but is not limited to, fans, heaters, thermostats and humidity control equipment and settings.

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 12.3.4 Substation and Switchgear Mechanical Servicing**

No.	Task	1000 Volts or Below Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Check circuit breakers and switches — mechanical operation	2	2	See manufacturer's instructions, Chapter 15, and Chapter 17.
2	Check bolted connection resistance	2	2	See Chapter 7.
3	Verify lubrication on moving current-carrying parts and sliding surfaces	2	2	See manufacturer's instructions.
4	Verify mechanical interlock systems for correct sequencing	2	2	
5	Verify mechanical systems for correct sequencing, including shutters, racking mechanisms, and similar	2	2	
6	Verify mechanical indicating devices are functional	2	2	
7	Verify filters or screens are clean and in place	1 or 2	1 or 2	Include filters and screens in the room related to the substation or switchgear.
8	Verify fuse holders provide mechanical support and contact integrity	2	2	
9	For individual components, refer to the appropriate chapter(s) of this standard	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 12.3.5 Substation and Switchgear Electrical Tests**

No.	Task	1000 Volts or Below Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Inspect electrical connections for high resistance	2	2	See Section 7.2.
2	Perform ground resistance test	2	2	See 20.3.5. Perform point-to-point test to determine the resistance between the main grounding system and substation/switchgear frames, system neutral, or derived neutral points. Perform fall-of-potential or alternative test on the grounding electrode system.
3	Measure insulation resistance	2	2	
4	Measure insulation resistance of control wiring	2A	2A	
5	Test protective devices and systems	2	2	For surge protective devices, surge arresters, and arc-energy reduction systems, see the manufacturer's instructions.
6	Perform system operational tests	2	2	Include emergency or standby sources of power systems to ensure they are available when needed, automatic throw-overs, paralleling controls, interlock systems, or any other operational or maintenance-related control that might be installed.
7	Perform dielectric withstand test	NA	2A	
8	Perform online partial discharge (PD) survey	NA	1A	
9	Where environmental controls are provided, check for correct operating condition	1 or 2	1 or 2	Includes, but is not limited to, fans, heaters, thermostats and humidity control equipment and settings.
10	Test control power transformers, instrument transformers, and metering to ensure correct operation	1 or 2	1 or 2	
11	Verify operation of communications systems	1 or 2	1 or 2	
12	For individual components, refer to the appropriate chapter(s) of this standard	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 13 Panelboards and Switchboards

N 13.1 Scope.

N 13.1.1* This chapter identifies electrical maintenance requirements for panelboards and switchboards rated 1000 V or below.

N 13.1.2* This chapter does not address requirements of individual components of panelboards and switchboards that are addressed in the chapters for those components.

N 13.2 Frequency of Maintenance. The periodic maintenance procedures specified in Section 13.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in this chapter.

N 13.3 Periodic Maintenance Procedures.

N 13.3.1 Visual Inspection. Panelboards and switchboards shall be visually inspected in accordance with Table 13.3.1.

N 13.3.2 Cleaning. Bus insulation, cable insulation, terminals or terminations, electrical equipment surfaces, enclosures, and insulating materials shall be kept in a clean and contaminant-free state.

N 13.3.3 Lubrication. Terminating devices, mechanical parts, and operating parts that exist to open, close, insert, and trip a circuit breaker, switch, or protective device shall be lubricated as required in accordance with the manufacturer's instructions.

N 13.3.4 Mechanical Servicing. Panelboards and switchboards shall be mechanically serviced in accordance with Table 13.3.4.

N 13.3.5 Electrical Testing. Panelboards and switchboards shall be electrically tested in accordance with Table 13.3.5.

N 13.3.6 Special. (Reserved)

N Table 13.3.1 Panelboard and Switchboard Visual Inspections

No.	Task	Test Type*	Notes
1	Inspect external physical condition	1	This includes condition and integrity of applied labels.
2	Inspect anchorage and grounding	1	
3	Verify circuit breakers, fuses, and overload elements are the right sizes and types and correspond to the drawings and power system studies	2	
4	For connected communicating addressable devices, verify the device addresses are set in accordance with documentation	2	Confirm addressing or correct device association where protective devices or the human machine interface (HMI) are connected to multiple devices via a communication network.
5	Verify instrument transformer ratios are correct	2	
6	Inspect insulators for damage or contaminated surfaces	2	
7	Verify filters are clean and in place	2	
8	Ensure maintenance devices and tools are available for equipment servicing	1	
9	Verify phase barriers are in place	2	
10	Visually inspect environmental controls, where provided	1 or 2	Includes, but is not limited to, fans, heaters, thermostats and humidity control equipment and settings.
11	For individual components, refer to the appropriate chapter(s) of this standard	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 13.3.4 Panelboard and Switchboard Mechanical Servicing**

No.	Task	Test Type*	Notes
1	Inspect mechanical condition	2	
2	Ensure maintenance devices and tools are available for equipment servicing	1 or 2	
3	Inspect anchorage and grounding	2	
4	Mechanically operate circuit breakers and switches	2	
5	Inspect bolted connection integrity	2	See Chapter 7.
6	Verify lubrication on moving current-carrying parts and sliding surfaces	2	See the manufacturer's instructions.
7	Verify mechanical interlock systems for correct sequencing	2	
8	Verify mechanical indicating devices are functional	2	
9	Verify filters are clean and in place	2	
10	Verify fuse holders provide mechanical support and contact integrity	2	
11	For individual components, refer to the appropriate chapter(s) of this standard	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 13.3.5 Panelboard and Switchboard Electrical Testing

No.	Task	Test Type*	Notes
1	Check electrical hardware connections	NA	See Chapter 7.
2	Measure insulation resistance of the main bus	2	
3	Measure insulation resistance of control wiring	2A	
4	Test protective devices and systems	2	For surge protective devices, surge arresters, and arc-fault energy reduction systems, see the manufacturer's instructions.
5	Perform system operational tests	1 or 2	Includes emergency or standby power systems.
6	Test control power transformers, instrument transformers, and metering to ensure correct operation	2	
7	For individual components, refer to the appropriate chapter(s) of this standard	NA	
8	Where environmental controls are provided, check for correct operating condition	1 or 2	Includes, but is not limited to, fans, heaters, thermostats, and humidity control equipment and settings.

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 14 Busways

N 14.1* Scope. This chapter identifies electrical maintenance requirements for busways and associated fittings.

N 14.2 Frequency of Maintenance. The periodic maintenance procedures in Section 14.3 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 14.3 Periodic Maintenance Procedures.

N 14.3.1* Visual Inspection. Busways shall be visually inspected in accordance with Table 14.3.1.

N 14.3.2* Cleaning.

N 14.3.2.1* Accumulations of dust, dirt, and debris shall be removed from busways using a brush, vacuum cleaner, or clean, lint-free rags.

N 14.3.2.2 Compressed air shall not be used to remove dust, dirt, or debris from busways or associated fittings.

N 14.3.3* Lubrication.

N 14.3.3.1 Operating mechanisms and interlocks on plug-in units shall be lubricated in accordance with the manufacturer's instructions.

N 14.3.3.2 Where no manufacturer's instructions are available, non-current-carrying mechanisms and interlocks shall be lubricated with a clean, light grease.

N 14.3.3.3 Excess lubrication shall be wiped off to avoid accumulation of foreign material.

N 14.3.3.4 Where plug-in units are relocated, electrical plug-in connections on plug-in units shall be lubricated in accordance with the manufacturer's instructions with a conductive lubricant labeled for use on electrical power connections.

N 14.3.4 Mechanical Servicing. Busways shall be mechanically serviced in accordance with Table 14.3.4.

N 14.3.5* Electrical Testing. Busways shall be electrically tested in accordance with Table 14.3.5.

N 14.3.6 Special. (Reserved)

N **Table 14.3.1 Busway Visual Inspections**

No.	Task	Busways Rated 600 Volts or Less Test Type*	Busways Rated Over 600 Volts Test Type*	Notes
1	Visually inspect the physical condition of the busway and associated fittings	1	1	Look for evidence of moisture contamination, corrosion, and excessive buildup of dust, dirt, or debris.
2	Visually inspect anchorage, hangers, and alignment of busway system	1	1	Look for loose connections and twisting or bending of lifted supports.
3	Visually inspect all areas near electrical joints, terminations, and connections	2	2	Visually check connections to be certain that they are clean and secure and show no signs of overheating or discoloration.
4	Examine outdoor busway to ensure that weepholes are not obstructed and that the joint shield is installed correctly	1	1	
5	Inspect ventilation openings on busway and associated fittings	1	1	
6	Look for signs of deterioration of visible seals and gaskets	1	1	Outdoor and drip-resistant busways can contain seals and gaskets.
7	For individual components, refer to the appropriate chapter(s) of this standard	NA	NA	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 14.3.4 Busway Mechanical Servicing

No.	Task	Busways Rated 600 Volts or Less Test Type*	Busways Rated Over 600 Volts Test Type*	Notes
1	Adjust or repair anchorage or hangers to ensure support of the busway	2	2	
2	Exercise plug-in unit operating mechanisms and external operators to confirm they operate to their full ON and OFF positions	2	NA	
3	Confirm operation of mechanical interlocks and locking means of plug-in units	2	NA	
4	Clean ventilation openings and weep holes	2	2	
5	Inspect forced-air cooling system	NA	2	Verify operation of forced-air cooling that could be included in metal enclosed bus systems.
6	Inspect for loose, open, or missing covers or doors on busways and associated fittings	2	2	Inspect all plug-in openings, plug-in units, and joints between busway sections. Some covers are not designed to be removed for inspection.
7	For individual components, refer to the appropriate chapter(s) of this standard	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 14.3.5 Busway Electrical Tests

No.	Task	Busways Rated 600 Volts or Less Test Type*	Busways Rated Over 600 Volts Test Type*	Notes
1	Perform bus resistance tests	1 or 2	1 or 2	See Chapter 7.
2	Perform insulation resistance tests	2	2	See A.14.3.5 for additional information.
3	Perform a dielectric withstand voltage test	NA	2	See A.14.3.5 for additional information.
4	Where environmental controls are provided, check for correct operating condition	1 or 2	1 or 2	Includes, but is not limited to, fans, heaters, thermostats, and humidity control equipment and settings.
5	Perform insulation power-factor or dissipation-factor tests	NA	2A	
6	Perform online partial-discharge survey	NA	1A	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 15 Circuit Breakers, Low- and Medium-Voltage

N 15.1 Scope.

N 15.1.1 This chapter identifies electrical maintenance requirements for the following circuit breakers and their enclosures:

(1) Molded-case circuit breakers (MCCBs) rated less than or equal to 1000 V ac
(2) Insulated-case circuit breakers (ICCBs) rated less than or equal to 1000 V ac
(3) Low-voltage power circuit breakers (LVPCBs) rated less than or equal to 1000 V ac
(4) Medium-voltage power circuit breakers (MVPCBs) rated greater than 1000 V ac to less than or equal to 69 kV ac

N 15.2 Frequency of Maintenance. The periodic maintenance procedures in Section 15.3 and Section 15.4 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 15.3 Periodic Maintenance Procedures for Low-Voltage Power Circuit (LVPCB), Molded Case Circuit Breaker (MCCB), and Insulated Case Circuit Breakers (ICCB).

N 15.3.1 Visual Inspections. A visual inspection shall be conducted in accordance with Table 15.3.1.

N 15.3.2 Cleaning.

N 15.3.2.1 Electrical equipment surfaces, enclosures, and insulating materials shall be kept in a clean and contaminant-free state.

N Table 15.3.1 MCCB, ICCB, and LVPCB Visual Inspections

No.	Task	MCCB Test Type*	ICCB Test Type*	LVPCB Test Type*	Notes
1	Verify ratings for proper system application.	1 or 2	1 or 2	1 or 2	
2	Inspect insulating materials and frame for evidence of physical damage, cracks from stresses of operation, or contamination.	2	2	2	
3	Inspect wiring, bus, cables, and connections for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition, including corrosion.	2	2	2	
4	Inspect visible current-carrying parts and control devices if applicable for signs of overheating or deterioration.	2	2	2	
5	Inspect arc chutes for cracks or excessive erosion if applicable.	NA	2	2	
6	Check for cracks or lack of visual indication for all associated indicating status devices.	1 or 2	1 or 2	1 or 2	
7	Check all markings on the circuit breaker are legible.	1 or 2	1 or 2	1 or 2	
8	Inspect operating mechanism.	NA	2	2	
9	Check main contact over travel and arcing contact engagement.	NA	2	2	
10	Check condition of main and arcing contacts.	NA	2	2	
11	Check insulating links/push rods and interphase barriers for cracks and defects.	NA	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: 1 = online standard test, 1A = online enhanced test, 2 = offline standard test, 2A = offline enhanced test.

N 15.3.2.2 If contamination such as dust, dirt, soot, grease, or moisture is found, cleaning shall be performed in accordance with Table 15.3.2.2.

N 15.3.3 Lubrication. Moving and sliding surfaces shall be lubricated in accordance with Table 15.3.3.

N 15.3.4 Mechanical Servicing. Circuit breakers shall be mechanically serviced in accordance with Table 15.3.4.

N 15.3.5* Electrical Testing. Circuit breakers shall be electrically tested in accordance with Table 15.3.5.

N 15.3.6 Special. (Reserved)

N 15.4 Periodic Maintenance Procedures for Medium-Voltage Power Circuit Breakers. Medium-voltage power circuit breakers shall be maintained in accordance with this section.

N 15.4.1 Circuit breakers shall be visually inspected in accordance with Table 15.4.1.

N 15.4.2 Cleaning. Electrical equipment surfaces, enclosures, and insulating materials shall be kept in a clean and contaminant-free state in accordance with Table 15.4.2.

N 15.4.3 Lubrication. Moving and sliding surfaces shall be lubricated in accordance with Table 15.4.3.

N 15.4.4 Mechanical Servicing. Circuit breakers shall be mechanically serviced in accordance with Table 15.4.4.

N 15.4.5 Electrical Testing. Circuit breakers shall be electrically tested in accordance with Table 15.4.5.

N 15.4.6 Special. (Reserved)

N Table 15.3.2.2 MCCB, ICCB, and LVPCB Cleaning

No.	Task	MCCB Test Type*	ICCB Test Type*	LVPCB Test Type*	Notes
1	Clean insulating surfaces of the circuit breaker using a lint-free dry cloth, brush, or vacuum cleaner (avoid blowing material into the circuit breaker or into surrounding equipment)	2	2	2	
2	Clean contact surfaces in accordance with the manufacturer's instructions	NA	2	2	
3	Clean circuit breaker interior frame	NA	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 15.3.3 MCCB, ICCB, and LVPCB Lubrication

No.	Task	MCCB Test Type*	ICCB Test Type*	LVPCB Test Type*	Notes
1	Apply a thin coating of conductive lubricant to exposed contacts as specified by the manufacturer	NA	2	2	
2	Apply nonconductive lubricant as needed to mechanism parts as specified by the manufacturer	NA	2	2	
3	Apply conductive lubricant to pivot points, as well as moving and sliding surfaces as specified by the manufacturer	NA	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 15.3.4 MCCB, ICCB, and LVPCB Mechanical Servicing**

No.	Task	MCCB Test Type*	ICCB Test Type*	LVPCB Test Type*	Notes
1	Check all accessible electrical hardware connections for correct torque	2	2	2	See Chapter 7.
2	Operate the circuit breaker three times	2	2	2	
3	Verify operation and alignment of mechanical safety interlocks, where applicable	2	2	2	
4	Verify correct operation of shutter assemblies on draw-out circuit breakers	2	2	2	
5	Measure and record trip bar force	NA	2A	2A	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 15.3.5 MCCB, ICCB, and LVPCB Electrical Tests

No.	Task	MCCB† 250 Amperes and Less Frame Test Type*	MCCB† Over 250 Amperes Frame Test Type*	ICCB Test Type*	LVPCB Test Type*	Notes
1	Perform infrared thermography	1	1	1	1	
2	Measure contact resistance of each switching pole	2A	2	2	2	
3	Perform insulation-resistance tests, phase-to-phase and phase-to-ground with circuit breaker closed and across each open pole	2A	2	2	2	
4	Operate circuit breaker auxiliary and control devices such as local and remote-control switches, shunt trips coils, close coils, motors, auxiliary switches, and under-voltage coils	2	2	2	2	
5	Verify the calibration of all functions of the trip unit by means of the manufacturer's specified test set for circuit breakers equipped with electronic trip units	2A	2	2	2	
6	Perform inverse time trip test at 300% of rated continuous current of thermal magnetic circuit breakers	2A	2	NA	NA	
7	Perform inverse time trip test at 300% of rated continuous current of electronic trip circuit breakers	2A	2A	2A	2A	
8	Perform the instantaneous overcurrent trip test for thermal-magnetic circuit breakers by "run-up" or "pulse" method	2A	2	NA	2	
9	Perform the instantaneous overcurrent trip test for electronic trip breakers by "run-up" or "pulse" method	2A	2A	2A	2A	
10	Perform rated hold-in test	2A	2A	2A	2A	
11	Test current-limiter resistance	2	2	2	2	
12	Check status of rating plug battery	2	2	2	2	
13	Perform millivolt drop test	2A	2A	2A	2A	
14	Test arc reduction technology in accordance with the manufacturer's instructions	2	2	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.
†The rating of adjustable-trip circuit breakers shall be the maximum setting possible.

N **Table 15.4.1 Medium-Voltage Power Circuit Breakers Visual Inspections**

No.	Task	Air Magnetic Circuit Breakers Test Type*	Vacuum Circuit Breakers Test Type*	Gas Insulated Circuit Breakers Test Type*	Oil Circuit Breakers Test Type*	Notes
1	Verify ratings for proper system application	1 or 2	1 or 2	1 or 2	1 or 2	
2	Inspect insulating materials and frame for evidence of physical damage, cracks from stresses of operation, or contamination	2	2	2	2	
3	Inspect wiring, bus, cables, and connections for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition including corrosion	2	2	2	2	
4	Inspect visible current-carrying parts and control devices, if applicable, for signs of overheating or deterioration	2	2	2	2	
5	Inspect each arc chute for cracks or excessive erosion	2	NA	NA	NA	
6	Inspect ground contact, secondary disconnect, close and trip interlocks, levering latch, mechanism-operated contact (MOC), and truck-operated contact (TOC) switches, and all other interlocks	2	2	2	2	
7	Check all markings on the circuit breaker are legible	1 or 2	1 or 2	1 or 2	1 or 2	
8	Inspect contact erosion indicator mark on vacuum interrupter moving stem	NA	2	NA	NA	Some manufacturers have visual inspections to determine contact erosion.
9	Inspect contact	NA	2	NA	NA	Some manufacturers have visual inspections to determine contact wipe.
10	Verify correct oil level	NA	NA	NA	2	
11	Check for oil leaks	NA	NA	NA	2	
12	Visually inspect bushings for cracks, chips, loss of porcelain, evidence of corona damage, or other physical damage	2	2	2	2	
13	Check for low gas pressure	NA	NA	2A	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 15.4.2 Medium-Voltage Power Circuit Breakers Cleaning

No.	Task	Air Magnetic Circuit Breakers Test Type*	Vacuum Circuit Breakers Test Type*	Gas Insulated Circuit Breakers Test Type*	Oil Circuit Breakers Test Type*	Notes
1	Clean insulating surfaces of the circuit breaker using a lint-free dry cloth, brush, or vacuum cleaner (avoid blowing material into the circuit breaker or into surrounding equipment)	2	2	NA	NA	For vacuum circuit breakers, follow the manufacturer's instructions to avoid shock due to inherent capacitance from the technology used in the circuit breaker.
2	Clean contact surfaces	2	NA	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 15.4.3 Medium-Voltage Power Circuit Breakers Lubrication

No.	Task	Air Magnetic Circuit Breakers Test Type*	Vacuum Circuit Breakers Test Type*	Gas Insulated Circuit Breakers Test Type*	Oil Circuit Breakers Test Type*	Notes
1	Apply a thin coating of conductive lubricant to exposed contacts as specified by the manufacturer	2	2	2	2	
2	Apply nonconductive lubricant as needed to mechanism parts as specified by the manufacturer	2	2	2	2	
3	Apply conductive lubricant to pivot points, as well as moving and sliding surfaces, as specified by the manufacturer	2	2	2	2	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 15.4.4 Medium-Voltage Power Circuit Breakers Mechanical Servicing**

No.	Task	Air Magnetic Circuit Breakers Test Type*	Vacuum Circuit Breakers Test Type*	Gas Insulted Circuit Breakers Test Type*	Oil Circuit Breakers Test Type*	Notes
1	Check all accessible electrical hardware connections for proper torque	2	2	2	2	See Chapter 7.
2	Replace any barriers and parts that have been removed for maintenance	2	2	2	2	
3	Close and open the circuit breaker	2	2	2	2	
4	Verify operation and alignment of mechanical safety interlocks, where applicable	2	2	2	2	
5	Verify the proper operation of all circuit breaker/cell accessories, shutters, auxiliary switches, cell MOC and TOC switches, and key interlocks	2	2	2	2	
6	Verify proper operation of all cell status indicators	2	2	2	2	
7	Charge closing spring and close manually	2	2	2	2	
8	Measure and record trip bar force	2A	2A	2A	2A	
9	Perform gas leakage detection	NA	NA	2	NA	
10	Inspect pneumatic and hydraulic fittings and connections for leaks	2	2	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 15.4.5 Medium-Voltage Power Circuit Breakers Electrical Tests

No.	Task	Air Magnetic Circuit Breaker Test Type*	Vacuum Circuit Breaker Test Type*	Gas Insulated Circuit Breaker Test Type*	Oil Insulated Circuit Breaker Test Type*	Notes
1	Inspect electrical connections for high resistance	1 or 2	1 or 2	1 or 2	1 or 2	See Section 7.2.
2	Measure contact resistance of each switching pole	2	2	2	2	
3	Perform insulation-resistance tests, phase-to-phase and phase-to-ground with circuit breaker closed and across each open pole	2	2	2	2	
4	Verify control power for close and trip functions	2	2	2	2	
5	Perform trip and close tests with control switch	2	2	2	2	
6	Verify operating mechanism charge, anti-pump, and trip-free functions	2	2	2	2	
7	Perform vacuum integrity test by ac overpotential across each vacuum bottle	NA	2	NA	NA	
8	Verify proper operation of space heaters, if equipped	2	2	2	2	
9	Perform an ac overpotential test one pole at a time with the other poles and structure grounded	2A	2A	2A	2A	
10	Perform an ac overpotential test on control wiring	2A	2A	2A	2A	**WARNING:** Do not perform this test on wiring connected to solid-state components.
11	Verify blow-out coil continuity	2	NA	NA	NA	
12	Perform circuit breaker motion analysis	2A	2A	2	2	
13	Perform circuit breaker contact timing test	2	2	2	2	
14	Perform trip/close coil current signature analysis	2A	2A	2A	2A	
15	Perform pickup test on trip and/or close coil	2A	2A	2A	2A	
16	Measure power/dissipation factor	2A	NA	2A	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 16 Fuses

N 16.1 Scope. This chapter identifies electrical maintenance requirements for fuses to protect branch, feeder and service conductors.

N 16.2 Frequency of Maintenance. The periodic maintenance procedures specified in Section 16.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in this chapter.

N 16.3 Periodic Maintenance Procedures.

N 16.3.1* Visual Inspections. Fuses shall be visually inspected in accordance with Table 16.3.1.

N 16.3.2 Cleaning. If contamination is present, fuses shall be cleaned in accordance with Table 16.3.2.

N 16.3.3 Lubrication. (Reserved)

N 16.3.4 Mechanical Servicing. Fuses shall be mechanically serviced in accordance with Table 16.3.4.

N 16.3.5* Electrical Testing. Fuses shall be electrically tested in accordance with Table 16.3.5.

N 16.3.6 Special. (Reserved)

N Table 16.3.1 Fuse Visual Inspections

No.	Task	1000 Volts or Less Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Check for discoloration of fuse terminals and clips caused by heat	1 or 2	1 or 2	
2	Check fuse indicating device status, if applicable	1 or 2	1 or 2	
3	Confirm that fuses, in any one circuit, have the same catalog number to ensure that they have the same current rating, voltage rating, interrupting rating, time delay, and type (e.g., UL class)	1 or 2	1 or 2	
4	Confirm that all fuses match the most recent short-circuit, coordination, and arc flash studies	1 or 2	1 or 2	
5	Where current-limiting fuses are required, confirm that correct rejection-type mountings are used so that the current-limiting fuses cannot be replaced by non-current-limiting fuses	2	2	
6	Verify ratings for correct system application	1 or 2	1 or 2	
7	Inspect insulators for breaks, cracks, tracking, corona, burns, or overheating	NA	2	
8	Inspect contact surfaces for pitting or burning, alignment, and contact pressure	NA	2A	
9	Examine the fuse unit, fuse tube, and renewable element, if used, for evidence of corrosion and wear	NA	2	
10	Inspect bolts, nuts, washers, pins, and terminal connectors to ensure they are in place, in good condition, and properly installed	NA	2	
11	Inspect seals of vented expulsion type fuses	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 16.3.2 Fuse Cleaning

No.	Task	1000 Volts or Less Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Clean fuse terminals and clips that have become corroded or oxidized	2	2	
2	Clean insulators of accumulated dust and foreign matter	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 16.3.4 Fuse Mechanical Servicing

No.	Task	1000 Volts or Less Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Check fuse holder terminations for tightness	2	2	See Chapter 7.
2	Verify that each fuseholder has adequate mechanical support	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 16.3.5 Fuse Electrical Tests

No.	Task	1000 Volts or Less Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Perform infrared thermography	1	1	When equipment has infrared viewing port or is accessible while in operation.
2	Measure fuse connection resistance	2A	2	
3	Measure fuse resistance	2A	2	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 17 Switches

N 17.1 Scope.

N 17.1.1 This chapter identifies electrical maintenance requirements for the following:

(1) Enclosed and dead-front (safety) switches, bolted-pressure switches (BPS), high-pressure contact switches (HPC), automatic transfer switches, bypass-isolation switches, and other transfer switch equipment rated 1000 volts or less
(2) Switches used in metal-enclosed load interrupter switchgear and automatic transfer switches, bypass-isolation switches, and other transfer switch equipment rated over 1000 volts

N 17.2 Frequency of Maintenance. The periodic maintenance procedures specified in Section 17.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in this chapter.

N 17.3* Periodic Maintenance Procedures.

N 17.3.1 Visual Inspection. Switches shall be visually inspected in accordance with Table 17.3.1.

N 17.3.2 Cleaning. If contamination is present, switches shall be cleaned in accordance with Table 17.3.2.

N 17.3.3* Lubrication. Switches shall be lubricated in accordance with Table 17.3.3 and the manufacturer's published instructions.

N 17.3.4 Mechanical Servicing. Switches shall be mechanically serviced in accordance with Table 17.3.4.

N 17.3.5* Electrical Testing. Switches shall be electrically tested in accordance with Table 17.3.5.

N 17.3.6 Special. (Reserved)

N **Table 17.3.1 Switch Visual Inspections**

No.	Task	1000 Volts or Less Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Inspect doors and latches for fit, dents, corrosion, and missing hardware	1 or 2	1 or 2	
2	Inspect insulating materials and switch base for evidence of physical damage, cracks from stresses of operation, or contamination	2	2	
3	Inspect wiring, bus, cables, and connections for damaged insulation, broken leads, tightness of connections, crimping, and overall general condition, including corrosion	2	2	
4	Check that exposed switch contacts, both moving and stationary, are free from environmental contamination	2	NA	
5	Inspect visible current-carrying parts and control devices, if applicable, for signs of overheating or deterioration	2	2	
6	Check that fuses are secured	2	2	
7	Examine switches with exposed contacts for evidence of high short-circuit closing operation	2	NA	
8	Check the main body of the switch blades and the arcing contacts for arc erosion	2	2	Mild pitting and burning is permitted.
9	Inspect each arc chute for cracks or excessive erosion	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 17.3.2 Switch Cleaning**

No.	Task	1000 Volts or Less Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Clean the switch and barriers	2	2	
2	Clean exposed switch contacts with a multi-purpose precision lubricant before lubricating	2	NA	
3	Wipe contact surfaces with a lint-free cleaning cloth	2	NA	
4	Wipe contact surfaces with a noncorrosive cleaning agent	NA	2	
5	Clean insulators	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 17.3.3 Switch Lubrication**

No.	Task	1000 Volts or Less Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Apply a thin coating of conductive lubricant to exposed switch contacts.	2	NA	Enclosed and dead-front (safety) switches do not require lubrication.
2	Apply nonconductive lubricant as needed to mechanism parts as specified by the manufacturer.	2	NA	
3	Apply conductive lubricant to pivot points, as well as moving and sliding surfaces.	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: 1 = online standard test, 1A = online enhanced test, 2 = offline standard test, 2A = offline enhanced test.

N **Table 17.3.4 Switch Mechanical Servicing**

No.	Task	1000 Volts or Less Test Type*	Greater than 1000 Volts Test Type*	Notes
1	If accessible, verify main blade alignment, penetration, travel stops, and mechanical operation	2	2	
2	Check all accessible electrical hardware connections	2	2	See Chapter 7.
3	Operate the switch three times to work the lubricant between the contacts	2	NA	
4	Verify operation and alignment of mechanical interlocks	2	2	
5	Verify the contact pressure is within specification using a force gauge or other device that measures forces	NA	2	
6	With the door closed and latched, close and open the switch three times to confirm the switch and operator lever is operating; view switch position through the window after each operation, where available; when open, verify that switch blades have cleared the arc chutes; when closed, verify that the switch blades are inside the arc chutes and vertical; if they are not, perform alignment adjustments per the manufacturer's instructions	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 17.3.5 Switch Electrical Tests**

No.	Task	1000 Volts or Less Test Type*	Greater than 1000 Volts Test Type*	Notes
1	Perform infrared thermography	1A	1	
2	Measure contact resistance of each switching pole	2A	2	
3	Perform insulation-resistance tests, phase-to-phase and phase-to-ground with switch closed and across each open pole	2A	2	
4	Functional tests only for switches with motor operators: Verify control power for close and trip functions Verify the electrical operation of switch Perform trip and close tests Verify operation of the switch from local switches or terminal blocks	2	2	
5	Functional tests only for switches with shunt trip capabilities	2	2	
6	Measure the resistance between the line and load terminal pads on each phase	NA	2	
7	Verify operation of space heaters, if equipped	NA	2	
8	Perform overpotential test one pole at a time with the other poles and structure grounded	NA	2A	
9	Perform overpotential test on control wiring	NA	2A	**WARNING:** Do not perform this test on wiring connected to solid-state components.
10	Test arc reduction technology in accordance with the manufacturer's instructions	2	2	
11	Perform functional tests for automatic transfer switches, bypass switches, and other transfer switch equipment	1A or 2A	1A or 2A	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 18 Power Cables and Conductors

N 18.1* Chapter Scope.

N 18.1.1 This chapter identifies electrical maintenance requirements for power cables and conductors operating at 1000 volts or less and those that are purpose-built, multilayered, and operating at over 1000 volts.

N 18.1.1.1 This chapter applies to circuit cables and conductors between the service point or other power supply source and the final branch-circuit overcurrent device.

N 18.1.1.2 This chapter does not apply to the cables and conductors between the final overcurrent device protecting the circuit and the outlet(s).

N 18.2 Frequency of Maintenance. The periodic maintenance procedures in Section 18.3 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 18.3 Periodic Maintenance Procedures.

N 18.3.1* Visual Inspections. Readily accessible and visible portions of power cables and conductors shall be visually inspected in accordance with Table 18.3.1.

N 18.3.2 Cleaning. Cable and conductor insulation, jackets, sheaths, terminals or terminations, enclosures, and insulating materials shall be kept clean to prevent a buildup of contaminants that can negatively affect performance, reduce life expectancy, or create a safety hazard.

N 18.3.3 Lubrication. Terminating devices, elbows, or T-bodies shall be lubricated in accordance with the manufacturer's instructions.

N 18.3.4 Mechanical Servicing. (Reserved)

N 18.3.5* Electrical Testing. Power cables and conductors shall be electrically tested in accordance with Table 18.3.5.

N 18.3.6 Special. (Reserved)

N Table 18.3.1 Power Cable and Conductor Visual Inspections

No.	Task	Test Type*	Notes
1	Physical condition, including operating environment	1 or 2	Damage or deterioration, supports or restraints, bending radius, excessive tension, signs of overheating, corrosion, swelling or soft spots
2	Correct labeling or identification	1 or 2	Phasing, cable ID, multiple sources, hazard, other warning labels
3	Grounding/bonding	1 or 2	Damage, missing or loose terminations, clearance from energized parts, protection from physical damage
4	Vaults containing cables	1 or 2	Damage, concrete deterioration, drainage
5	Cable and conductor terminations	1 or 2	Oil or compound leaks, cracks or damaged bodies, cleanliness, terminations
6	Aerial installations	1 or 2	Damage, deteriorating supports, suspension systems, pinched or damaged insulation at dead ends, animal or bird infestation
7	Raceway	1 or 2	Damage or deterioration, abrasion or wear, continuity, tight joints, missing or loose bonding jumpers, corrosion
8	Barriers, guards, and assemblies	1 or 2	Damage or signs of deterioration, arcing, tracking, supports and mounting hardware

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 18.3.5 Power Cable and Conductor Electrical Tests

No.	Task	1000 Volts or Less Test Type*	Over 1000 Volts Test Type*	Notes
1	Airborne ultrasonic acoustic emissions	NA	1A	
2	Insulation resistance	2A	NA	For cables and conductors 1000 volts or less.
3	Insulation resistance:			For cables and conductors over 1000 volts.
	Very low frequency (VLF <1 Hz)	NA	2	
	Overpotential test (hi-pot)	NA	2	
	Dissipation factor/tan delta	NA	2	
	Partial discharge	NA	1 or 2	
	Power frequency	NA	2	
	Oscillating wave	NA	2	
4	Connection quality	1 or 2	1 or 2	Millivolt drop, digital low-resistance ohmmeter, infrared thermography. Circuits tested are based on criticality of the circuit.

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 19 Cable Tray

N 19.1 Scope. This chapter identifies electrical maintenance requirements for cable tray systems, including ladder, ventilated trough, ventilated channel, solid bottom, and other similar structures.

N 19.2 Frequency of Maintenance. The periodic maintenance procedures in Section 19.3 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 19.3 Periodic Maintenance Procedures.

N 19.3.1 Visual Inspections. Cable tray shall be visually inspected in accordance with Table 19.3.1.

N 19.3.2 Cleaning. Cable trays and the cables within shall be kept clean to prevent a buildup of contaminants that can negatively affect performance, reduce life expectancy, or create a safety hazard.

N 19.3.3 Lubrication. (Reserved)

N 19.3.4 Mechanical Servicing. (Reserved)

N 19.3.5 Electrical Testing. Metal cable trays shall be electrically tested in accordance with Table 19.3.5.

N 19.3.6 Special. (Reserved)

N Table 19.3.1 Cable Tray Visual Inspections

No.	Task	Test Type*	Notes
1	Verify equipment grounding and bonding for the following:		
	Cable tray	1 or 2	
	Transition raceways	1 or 2	
2	Check for overfilling	1 or 2	
3	Inspect for the following:		
	Incorrect cables (small, not TC listed)	1A or 2A	
	Cable damage	1A or 2A	
	Cables support damage	1 or 2	
	Intrusive items (e.g., pipes, hangers)	1 or 2	
4	Inspect for the following:		
	Spacing of cables, for cables that have minimum spacing requirements	1 or 2	
	Cable tie-downs	1 or 2	
	Supports of cable trays	1 or 2	
	Damaged tray or supports	1 or 2	
	Expansion joints in sufficient distances	1 or 2	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 19.3.5 Metal Cable Tray Electrical Tests

No.	Task	Test Type*	Notes
1	Perform infrared thermography	1A	Check for inductive heating of the cable tray.
2	Test cable tray effective ground fault current path for continuity	1A	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 20 Grounding and Bonding

N 20.1 Scope. This chapter identifies electrical maintenance requirements for grounding and bonding of electrical systems.

N 20.2 Frequency of Maintenance. The periodic maintenance procedures specified in Section 20.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in this chapter.

N 20.3 Periodic Maintenance Procedures.

N 20.3.1* Visual Inspections. Grounding and bonding shall be visually inspected in accordance with Table 20.3.1.

N 20.3.2 Cleaning. (Reserved)

N 20.3.3 Lubrication. (Reserved)

N 20.3.4 Mechanical Servicing. (Reserved)

N 20.3.5* Electrical Testing. Grounding and bonding shall be electrically tested in accordance with Table 20.3.5.

N 20.3.6 Special. (Reserved)

N Table 20.3.1 Grounding and Bonding Visual Inspections

No.	Task	Test Type*	Notes
1	Inspect physical and mechanical condition of accessible and visible components and connections	2	
2	Inspect anchorage	2	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 20.3.5 Grounding and Bonding Electrical Testing

No.	Task	Test Type*	Notes
1	Measure bolted or mechanical connection resistance	2A	
2	For ground rod electrode systems, perform fall-of-potential test to measure grounding rod to earth resistance	2A	
3	Perform point-to-point test to verify equipment is bonded together	2A	
4	Perform substation grounding electrode system and substation grid integrity test by injecting current in accordance with industry practices	2A	
5	Measure voltage between the equipment grounding conductor and the grounded conductor	1A	
6	Measure current magnitude on the equipment grounding conductor	1A	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 21 Ground-Fault Circuit Interrupters and Ground-Fault Protection of Equipment Systems

N 21.1* Scope. This chapter identifies electrical maintenance requirements for ground-fault circuit interrupter (GFCI) protection for personnel, special-purpose GFCI (SPGFCI), and ground-fault protection of equipment for solidly grounded systems.

N 21.2 Frequency of Maintenance. The periodic maintenance procedures specified in Section 21.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in this chapter.

N 21.3 Periodic Maintenance Procedures.

N 21.3.1* Ground-Fault Circuit Interrupters (GFCIs) and Special-Purpose GFCIs (SPGFCIs).

N 21.3.1.1 Visual Inspections. (Reserved)

N 21.3.1.2 Cleaning. (Reserved)

N 21.3.1.3 Lubrication. (Reserved)

N 21.3.1.4 Mechanical Servicing. (Reserved)

N 21.3.1.5 Electrical Testing. GFCIs shall be electrically tested in accordance with the manufacturer's instructions using either the integral push-to-test button or an external test set.

N 21.3.1.6 Special. (Reserved)

N 21.3.2* Low-Voltage Ground-Fault Protection Systems.

N 21.3.2.1 Visual Inspections. Low-voltage ground-fault protection systems shall be visually inspected in accordance with Table 21.3.2.1.

N 21.3.2.2 Cleaning. If contamination is found, low-voltage ground-fault protection systems shall be cleaned in accordance with Table 21.3.2.2.

N 21.3.2.3 Lubrication. (Reserved)

N 21.3.2.4 Mechanical Servicing. Low-voltage ground-fault protection systems shall be mechanically serviced in accordance with Table 21.3.2.4.

N 21.3.2.5 Electrical Testing. Low-voltage ground-fault protection systems shall be electrically tested in accordance with Table 21.3.2.5.

N 21.3.2.6 Special. (Reserved)

N 21.3.3 Medium-Voltage Ground-Fault Protection Systems.

N 21.3.3.1 Visual Inspections. Medium-voltage ground-fault protection systems shall be visually inspected in accordance with Table 21.3.3.1.

N 21.3.3.2 Cleaning. If contamination is present, medium-voltage ground-fault protection systems shall be cleaned in accordance with Table 21.3.3.2.

N 21.3.3.3 Lubrication. (Reserved)

N 21.3.3.4 Mechanical Servicing. Medium-voltage ground-fault protection systems shall be mechanically serviced in accordance with Table 21.3.3.4.

N 21.3.3.5 Electrical Testing. Medium-voltage ground-fault protection systems shall be electrically tested in accordance with Chapter 35.

N 21.3.3.6 Special. (Reserved)

N **Table 21.3.2.1 Low-Voltage Ground-Fault Protection Systems Visual Inspections**

No.	Task	Circuit Breaker Trip Units or Switches with Integral Ground-Fault Protection Test Type*	Circuit Breakers or Switches with External Ground-Fault Protection Test Type*	Notes
1	Verify ground connection is made on the source side of the neutral disconnect link and any ground fault sensors	2	2	
2	For zero-sequence systems, verify all phase and neutral conductors pass through the sensor in the same direction, and that grounding conductors do not pass through the sensor	NA	2	
3	Verify sensor, wiring, and ground-fault components are not damaged	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 21.3.2.2 Low-Voltage Ground-Fault Protection System Cleaning**

No.	Task	Circuit Breaker Trip Units or Switches with Integral Ground-Fault Protection Test Type*	Circuit-Breakers or Switches with External Ground-Fault Protection Test Type*	Notes
1	Clean the relay case and cover	NA	2	
2	Clean sensors and associated ground faults protection system components	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 21.3.2.4 Low-Voltage Ground-Fault Protection System Mechanical Servicing**

No.	Task	Circuit Breaker Trip Units or Switches with Integral Ground-Fault Protection Test Type*	Circuit Breakers or Switches with External Ground-Fault Protection Test Type*	Notes
1	Inspect bolted electrical connections	NA	2	
2	Verify correct operation of the self-test panel/trip unit functions	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 21.3.2.5 Low-Voltage Ground-Fault Protection System Electrical Testing**

No.	Task	Circuit Breaker Trip Units or Switches with Integral Ground-Fault Protection Test Type*	Circuit Breakers or Switches with External Ground-Fault Protection Test Type*	Notes
1	Measure system neutral-to-ground resistance with the neutral disconnect link removed, and verify no downstream grounds exist on the neutral	2	2	
2	Verify reduced control voltage tripping ability at 55% for ac systems and 80% for dc systems	NA	2A	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 21.3.3.1 Medium-Voltage Ground-Fault Protection Systems Visual Inspections**

No.	Task	Circuit Breaker Trip Units or Switches with Integral Ground-Fault Protection Test Type*	Circuit Breakers or Switches with External Ground-Fault Protection Test Type*	Notes
1	Verify ground connection is made on the source side of the neutral disconnect link and any ground fault sensors	2	2	
2	For zero-sequence systems, verify all phase and neutral conductors pass through the sensor in the same direction, and that grounding conductors either do not pass through the sensor or pass back through the sensor	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 21.3.3.2 Medium-Voltage Ground-Fault Protection System Cleaning**

No.	Task	Circuit Breaker Trip Units or Switches with Integral Ground-Fault Protection Test Type*	Circuit-Breakers or Switches with External Ground-Fault Protection Test Type*	Notes
1	Clean sensors and associated ground-fault protection system components	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 21.3.3.4 Medium-Voltage Ground-Fault Protection System Mechanical Servicing

No.	Task	Circuit Breaker Trip Units or Switches with Integral Ground-Fault Protection Test Type*	Circuit Breakers or Switches with External Ground-Fault Protection Test Type*	Notes
1	Inspect bolted electrical connections	NA	2	
2	Verify correct operation of the self-test panel/trip unit functions	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 22 Lighting

N 22.1 Scope. This chapter identifies electrical maintenance requirements for luminaires and lighting systems.

N 22.2 Frequency of Maintenance. The periodic maintenance procedures in Section 22.3 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 22.3 Periodic Maintenance Procedures.

N 22.3.1 Visual Inspections. An inspection of the readily visible portion of the luminaire shall be conducted to check the physical condition.

N 22.3.2 Cleaning. Luminaires shall be kept clean to prevent a buildup of contaminants that negatively affect performance, reduce life expectancy, or create a safety hazard.

N 22.3.3* Maintenance Program. A maintenance program for any lighting system shall include the following elements:

(1) Periodic inspections
(2) Criteria for determining group or spot replacement options to maintain the required illuminance levels
(3) Repair and replacement strategy
(4) Assessment of illuminance levels

N 22.3.4 Servicing. Servicing shall include inspections of the luminaire system for the following conditions, where applicable:

(1) Aiming or orientation
(2) Pole and pole base condition
(3) Safety chains and/or supports
(4) Socket condition and luminaire mounting hardware when replacing lamps
(5) Compatibility of replacement lamps with existing luminaire

N Chapter 23 Lighting Control Systems (Reserved)

N Chapter 24 Wiring Devices

N 24.1* Scope. This chapter identifies electrical maintenance requirements for receptacles and attachment plugs, pin-and-sleeve devices, heavy-duty industrial-type plugs, cord connectors, and receptacles rated not more than 600 volts.

N 24.2 Frequency of Maintenance. The periodic maintenance procedures specified in Section 24.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in this chapter.

N 24.3 Periodic Maintenance Procedures.

N 24.3.1 Visual Inspections. Wiring devices shall be visually inspected in accordance with Table 24.3.1.

N 24.3.2 Cleaning. Wiring devices shall be cleaned in accordance with Table 24.3.2.

N 24.3.3 Lubrication. (Reserved)

N 24.3.4 Mechanical Servicing. Wiring devices shall be mechanically serviced in accordance with Table 24.3.4.

N 24.3.4.1 Cracked, bent, or broken spring doors or covers are to be replaced.

N 24.3.5 Electrical Testing. Wiring devices shall be electrically tested in accordance with Table 24.3.5.

N Table 24.3.1 Wiring Device Visual Inspections

No.	Task	Test Type*	Notes
1	Check for worn, cracked, or distorted housing	2A	Repair or replace as needed.
2	Pins or contacts are burned, bent, pitted, missing, or discolored	2A	Repair or replace as needed.
3	Securement method for flexible wiring is intact	2A	Repair or replace as needed.
4	Check for corrosion of housing, contacts, and pins	2A	Repair or replace as needed.
5	Confirm gaskets are intact	2A	Replace as needed.

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 24.3.2 Wiring Device Cleaning

No.	Task	Plug Test Type*	Receptacle Test Type*	Notes
1	Clean current-carrying parts and housing faces of foreign material or corrosion	2A	2A	
2	Clean exterior surfaces to maintain visibility of nameplate ratings	2A	2A	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 24.3.4 Wiring Device Cleaning

No.	Task	Test Type*	Notes
1	Confirm secure mating of plug and receptacle components.	2	Replace components with loose contact mating.
2	Confirm cable gland nut is secure and retains cable.	2	Tighten as needed, assuring no damage to the flexible cord jacket.
3	Confirm tightness of all wiring terminals.	2	Wiring terminal discoloration is indication of possible inadequate wire securement.

*Types specified in accordance with Section 8.3, as follows: 1 = online standard test, 1A = online enhanced test, 2 = offline standard test, 2A = offline enhanced test.

N Table 24.3.5 Wiring Device Electrical Servicing

No.	Task	Test Type*	Notes
1	Confirm grounding and bonding for correct installation and secure connection	2A	
2	Confirm proper polarity of contacts	1A or 2A	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 25 Uninterruptible Power Supplies (UPS)

N 25.1 Scope.

N 25.1.1* This chapter identifies electrical maintenance requirements for uninterruptible power supplies (UPS) rated 600 volts or less ac or dc.

N 25.1.2 This chapter does not apply to a UPS that contains no serviceable components.

N 25.2 Frequency of Maintenance.

N 25.2.1 The periodic maintenance procedures specified in Section 25.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in this chapter.

N 25.2.2 The special procedures specified in Section 25.4 shall be performed in accordance with the frequencies specified in Section 25.4 and the EMP.

N 25.3 Periodic Maintenance Procedures.

N 25.3.1 Visual Inspections. UPS shall be visually inspected in accordance with Table 25.3.1.

N 25.3.2 Cleaning. If contamination is present, UPS shall be cleaned in accordance with Table 25.3.2.

N 25.3.3 Lubrication. Rotary-type UPS shall be lubricated in accordance with Table 25.3.3.

N 25.3.4 Mechanical Servicing. UPS shall be mechanically serviced in accordance with Table 25.3.4.

N 25.3.5 Electrical Testing. UPS shall be electrically tested in accordance with Table 25.3.5.

N 25.4 Special Procedures.

N 25.4.1 Equipment Software Upgrades and Revisions. Equipment software upgrades and revisions shall be performed as needed.

N 25.4.2 Load Transfer and Load Testing. System tests shall be performed in accordance with the following:

(1) When warranted by special circumstances, such as repeated failure of a system to pass routine maintenance checks
(2) Periodically, where the desired degree of reliability justifies the procedure

N Table 25.3.1 UPS Visual Inspections

No.	Task	Static Test Type*	Rotary Test Type*	Notes
1	Inspect doors and latches for fit, dents, corrosion, and missing hardware	1	1	
2	Check fans for operation	1	1	
3	Inspect wiring, bus, cables, and connections for damaged insulation, broken leads, tightness of connections, crimping, and overall general condition including corrosion	2	2	
4	Inspect capacitors for swelling and discoloration	2	NA	
5	Check visible current-carrying parts and control devices, if applicable, for signs of overheating or deterioration	2	2	
6	Inspect rectifier and inverter assembly	2	NA	Inspect for signs of overheating or deterioration.
7	Inspect static switch module	2	NA	Inspect for signs of overheating or deterioration.
8	Inspect interface, control, I/O boards, and dc capacitor boards	2	2	Inspect for signs of overheating or deterioration.
9	For individual components, refer to the appropriate chapter(s) of this standard	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 25.3.2 UPS Cleaning

No.	Task	Static Test Type*	Rotary Test Type*	Notes
1	Replace the air filters and verify the vents are clear	2	2	
2	Vacuum enclosure	2	2	
3	Clean exposed switch contacts with a multipurpose precision lubricant before lubricating	2	2	
4	Wipe contact surfaces with a lint-free cleaning cloth	2	2	
5	Wipe contact surfaces with a noncorrosive cleaning agent	2	2	
6	Clean insulators	2	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 25.3.3 UPS Lubrication

No.	Task	Static Test Type*	Rotary Test Type*	Notes
1	Lubricate rotating equipment	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 25.3.4 UPS Mechanical Servicing

No.	Task	Static Test Type*	Rotary Test Type*	Notes
1	Verify operation and alignment of mechanical safety interlocks	2	2	
2	Check electrical hardware connections	2	2	
3	Perform mechanical servicing for system circuit breakers	2	2	
4	Transfer systems	2	2	
5	For individual components, refer to the appropriate chapter(s) of this standard	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 25.3.5 UPS Electrical Tests

No.	Task	Static Test Type*	Rotary Test Type*	Notes
1	Perform infrared thermography of lug terminals	1	1	Conduct on annual basis.
2	Measure the neutral output current during peak loads	1A	1A	Conduct every 3 months or when new equipment is added to the system
3	Record all operating parameters, such as frequency, voltage, and current, at the bypass switch, input, output, batteries, and modules, where applicable	1	1	
4	Test static transfer from normal to bypass and back to normal	1	1	
5	Electrical interlock systems, alarms, and indicator circuits	2	2	
6	Perform operational test on all alarms and emergency shutdowns, where applicable	2	2	
7	For individual components, refer to the appropriate chapter(s) of this standard	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N 25.4.2.1 System Test Conditions.

N 25.4.2.1.1 The UPS shall be placed under load using a load bank during the tests described in 25.4.2.

N 25.4.2.1.2 If the UPS has batteries, the batteries shall be fully charged prior to the tests described in 25.4.2.

N 25.4.2.1.3 While the tests described in 25.4.2 are conducted, critical loads shall be placed on isolation bypass, if available, or connected to another source.

N 25.4.2.1.4 Manual and automatic load transfers from UPS to bypass shall be tested.

N 25.4.2.1.5 Each module shall be individually load-tested to verify that it is functioning prior to parallel load testing.

N 25.4.2.1.6 Simultaneous input and output readings of voltage, current, and frequency shall be recorded.

N 25.4.2.1.7 The external power source shall be removed and reapplied to verify output stability.

N 25.4.2.1.8 Voltage and frequency measurements of UPS operation during load testing shall be performed.

N 25.4.2.1.9 The results of the tests described in 25.4.2 shall be recorded.

N 25.4.2.2 Output Stability.

N 25.4.2.2.1* The load shall be adjusted in steps to determine the performance of the UPS when significant load changes occur.

N 25.4.2.2.2 The voltage regulation and frequency stability shall be within the manufacturer's specifications.

N 25.4.2.2.3 Low Battery Voltage Shutdown.

N 25.4.2.2.3.1 Where applicable, UPS ac input power shall be removed while the system is supplying 100 percent power to a load bank.

N 25.4.2.2.3.2 The elapsed time until low battery voltage shutdown occurs shall be recorded and compared with specifications.

N 25.4.2.2.3.3 Voltage, current, and frequency shall be recorded during tests.

N 25.4.2.2.3.4 Upon restoration of UPS input power, the battery shall be verified as recharging properly.

N Chapter 26 Electronic Equipment (Reserved)

N Chapter 27 Rotating Equipment

N 27.1* Scope. This chapter identifies electrical maintenance requirements for rotating equipment (machines) and their ancillary devices.

N 27.2 Frequency of Maintenance. The periodic maintenance procedures in Section 27.3 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 27.3 Periodic Maintenance Procedures.

N 27.3.1* Visual Inspections. Rotating equipment shall be visually inspected in accordance with Table 27.3.1.

N 27.3.2* Cleaning.

N 27.3.2.1 Electrical equipment surfaces, enclosures, and insulating materials shall be kept clean to prevent a buildup of contaminants that negatively affect performance, reduce life expectancy, or create a safety hazard.

N 27.3.2.2* After cleaning, apparatus shall be dried before being placed in operation if tests indicate that the insulation resistance is below the recommended level.

N 27.3.3* Lubrication.

N 27.3.3.1 Bearings, couplings, and auxiliary devices shall be lubricated as needed.

N 27.3.3.2 Where equipped, lubrication systems shall be maintained in accordance with the manufacturer's instructions.

N 27.3.4* Mechanical Servicing. Rotating equipment shall be mechanically serviced in accordance with Table 27.3.4.

N 27.3.5* Electrical Testing. Rotating equipment shall be electrically tested in accordance with Table 27.3.5.

N 27.3.6* Special. (Reserved)

N Table 27.3.1 Rotating Equipment Visual Inspections

		Test Type*					
		Low-Voltage Machines			Medium-Voltage Machines		
No.	Task	≤200 hp	>200 hp	dc Machines	Induction	Synchronous	Notes
1	Application	1 or 2	1 or 2	1 or 2	1 or 2	1 or 2	Ensure the machinery is installed in accordance with the manufacturer's listing and labeling and applicable codes/standards.
2	Physical condition	1 or 2	1 or 2	1 or 2	1 or 2	1 or 2	
3	Indicating device status	1 or 2	1 or 2	1 or 2	1 or 2	1 or 2	
4	Labeling	1 or 2	1 or 2	1 or 2	1 or 2	1 or 2	
5	Grounding/bonding	1 or 2	1 or 2	1 or 2	1 or 2	1 or 2	
6	Machinery alignment	1 or 2	1 or 2	1 or 2	1 or 2	1 or 2	Intended where signs of misalignment exist.

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 27.3.4 Mechanical Servicing

		Test Type*					
		Low-Voltage Machines			Medium-Voltage Machines		
No.	Task	<=200 hp	>200 hp	dc Machines	Induction	Synchronous	Notes
1	Integrity of accessible bolted connections	2	2	2	2	2	
2	Cooling system operation, as applicable	2	2	2	2	2	
3	Mechanical operation	2	2	2	2	2	
4	Machine guards and assemblies	2	2	2	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 27.3.5 Rotating Equipment Electrical Tests**

No.	Task	Low-Voltage Machines			Medium-Voltage Machines		Notes
		≤200 hp Test Type*	>200 hp Test Type*	dc Machines Test Type*	Induction Test Type*	Synchronous Test Type*	
1	Bolted connection resistance	2A	2A	2A	2	2	
2	Stator/armature winding DAR	2A	2A	2A	2	2	ac stator or dc armature
3	Wound rotor/field winding DAR	2A	2A	2A	2	2	ac wound rotor, synchronous dc rotor, dc fields
4	Stator/armature winding polarization index (PI)	2A	2A	2A	2	2	
5	Wound rotor/field winding PI	2A	2A	2A	2A	NA	
6	Stator winding dc dielectric withstand (overpotential)	2A	2A	2A	2A	2A	
7	Wound rotor/field winding dc dielectric withstand (overpotential)	2A	2A	2A	2A	2A	
8	Stator/armature winding resistance	2A	2A	2A	2	2	
9	Wound rotor/field winding resistance	2A	2A	2A	2	2	
10	Stator winding insulation power factor	NA	NA	NA	2A	2A	Insulation power factor/dissipation factor
11	Stator winding insulation power factor tip-up	NA	NA	NA	2A	2A	Insulation power factor/dissipation factor
12	Stator winding surge comparison	2A	2A	2A	2A	2A	
13	Insulated bearing insulation resistance	2A	2A	2A	2	2	
14	Temperature detection device	2A	2A	2A	2	2	
15	Machine space heater	2	2	2	2	2	
16	Vibration analysis	1A	1A	1A	1A	1A	
17	Current signature analysis	1A	1A	1A	1A	1A	
18	Partial discharge	NA	NA	NA	1A	1A	
19	Surge protection device	2A	2A	NA	2	2	
20	Motor starter	2	2	2	2	2	
21	Current transformers	2A	2A	NA	2	2	
22	Potential transformers	2A	2A	NA	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 28 Motor Control Equipment

N 28.1 Scope.

N 28.1.1 This chapter identifies electrical maintenance requirements for low-voltage single- and three-phase ac and dc motor control equipment and medium-voltage single- and three-phase motor control equipment.

N 28.2 Frequency of Maintenance. The periodic maintenance procedures in Section 28.3 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 28.3 Periodic Maintenance Procedures.

N 28.3.1 Visual Inspections. Motor control equipment shall be visually inspected in accordance with Table 28.3.1.

N 28.3.2 Cleaning. Bus, cables, terminals or terminations, electrical equipment surfaces, enclosures, and insulating materials shall be cleaned to prevent a buildup of contaminants that negatively affect performance, reduce life expectancy, or create a hazard.

N 28.3.3 Lubrication. Moving and sliding surfaces shall be lubricated in accordance with Table 28.3.3.

N 28.3.4 Mechanical Servicing. Motor control equipment shall be mechanically serviced in accordance with Table 28.3.4.

N 28.3.5 Electrical Testing. Motor control equipment shall be electrically tested in accordance with Table 28.3.5.

N 28.3.6 Special. (Reserved)

N Table 28.3.1 Motor Control Equipment Visual Inspections

No.	Task	Low-Voltage Test Type*	Medium-Voltage Test Type*	Notes
1	Inspect physical and mechanical condition	1 or 2	1 or 2	
2	Inspect anchorage and grounding	1 or 2	1 or 2	
3	Physical integrity of contactors	1	1	
4	Verify circuit breakers, fuses, and overload elements are the correct sizes and types and correspond to the drawings	2	2	EMP determines when these inspections can be done energized.
5	Verify instrument transformer ratios are correct	2	2	
6	Inspect insulators for damage, tracking, or contaminated surfaces	2	2	
7	Verify filters are clean and in place	2	2	
8	Ensure maintenance devices are available for servicing	NA	1	
9	Verify switch phase barriers are in place	2	2	
10	Verify fuse expulsion-limiting devices are in place	NA	2	
11	For individual components and exposed conductors, refer to the appropriate chapter(s) of this standard	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 28.3.3 Moving and Sliding Surfaces Lubrication

No.	Task	Test Type*		Notes
		1000 Volts or Less	Greater than 1000 Volts	
1	Apply a thin coating of conductive lubricant to exposed contacts as specified by the manufacturer	2	2	
2	Apply nonconductive lubricant as needed to mechanism parts as specified by the manufacturer	2	2	
3	Apply conductive lubricant to pivot points, as well as moving and sliding surfaces, as specified by the manufacturer	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 28.3.4 Motor Control Equipment Mechanical Servicing

No.	Task	Test Type*					Notes
		Low-Voltage Machines			Medium-Voltage Machines		
		≤200 hp	>200 hp	dc Machines	Induction	Synchronous	
1	Integrity of accessible bolted connections	2	2	2	2	2	
2	Cooling system operation, as applicable	2	2	2	2	2	
3	Mechanical operation	2	2	2	2	2	
4	Machine guards and assemblies	2	2	2	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 28.3.5 Motor Control Equipment Electrical Tests

No.	Task	Low-Voltage Test Type*	Medium-Voltage Test Type*	Notes
1	Inspect electrical connections for high resistance	1 or 2	1 or 2	See Section 7.2.
2	Measure insulation resistance of electrical power circuits	2	2	
3	Measure insulation resistance across each open starter pole	2	2	
4	Measure insulation resistance of control wiring with respect to ground	2A	2A	
5	Test motor protection devices	2	2	
6	Perform control system operational tests	1A	1A	Include automatic throw-overs, paralleling controls, interlock and safety systems, or any other operational or maintenance-related control.
7	Perform vacuum bottle integrity test or a magnetron atmospheric condition (MAC) test on vacuum bottles	NA	2	
8	Perform dielectric withstand test	2A	2A	
9	Measure contact resistance	2	2	
10	For individual components, refer to the appropriate chapter(s) of this standard	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 29 Portable Electrical Tools and Equipment

N 29.1 Scope.

N 29.1.1* This chapter identifies electrical maintenance requirements for portable electrical tools and equipment, both cord and plug connected and temporarily hard-wired.

N 29.1.2 This chapter does not apply to mobile equipment.

N 29.2 Frequency of Maintenance. The periodic maintenance procedures in Section 29.3 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 29.3 Periodic Maintenance Procedures.

N 29.3.1 Visual Inspection.

N 29.3.1.1* Portable electrical tools and equipment shall be visually inspected before each use for the following conditions:

(1) Pinched, crushed, nicked, or frayed cord jacket
(2) Damaged plug or missing pins
(3) Damage to grounding means, such as terminals, straps, or pins
(4) Signs of loosening, fraying, or overheating of the plug, cord, or tool
(5) External casing defects, such as cracks, damaged or loose components, or missing screws
(6) Damaged or missing guards
(7) Damaged wheels or blades
(8) Signs of leaking fluids
(9) Missing cover plates
(10) Loose or frayed conductors at termination points
(11) Damaged strain relief cord connectors

N 29.3.1.2 Portable equipment and flexible cord sets (extension cords) that remain connected once they are put in place and are not exposed to damage shall not be required to be visually inspected until they are relocated.

N 29.3.2 Cleaning. Portable electrical tools and equipment shall be kept free of debris or other substances that could damage components or prevent heat dissipation.

N 29.3.3 Lubrication.

N 29.3.3.1 Manufacturer's instructions shall be followed when lubricating components of portable electrical tools and equipment, except as permitted in 29.3.3.2.

N 29.3.3.2 If manufacturer's instructions are not available, lubrication of portable electrical equipment shall be conducted in accordance with one of the following:

(1) A procedure specified by the EMP
(2) Applicable industry standards

N 29.3.4 Mechanical Servicing. Mechanical servicing of portable electrical tools and equipment shall be carried out according to the manufacturer's instructions.

N **29.3.5* Electrical Testing.** When a GFCI or an assured equipment grounding conductor program is not implemented, electrical testing of portable electrical tools and equipment shall be conducted to verify the following, at a minimum:

(1) Equipment grounding from the tool or equipment to the plug ground pin
(2) Insulation resistance
(3) Correct polarity

N **29.3.6 Special. (Reserved)**

N Chapter 30 Photovoltaic Systems

N **30.1* Scope.** This chapter identifies electrical maintenance requirements for solar photovoltaic (PV) systems and its associated equipment.

N **30.2 Frequency of Maintenance.**

N **30.2.1*** The periodic maintenance procedures in Section 30.4 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N **30.2.2*** The EMP shall identify events that trigger more frequent inspections or maintenance activities.

N **30.3 Documentation and Labeling.**

N **30.3.1*** The equipment owner shall ensure that supporting documentation, including the following, is available:

(1) System designer/installer, with installation and commissioning dates
(2) Emergency contacts for system owner
(3) Specifications
(4) Electrical schematics and as-built drawings
(5) Signage, markings, and labels
(6) Mechanical drawings
(7) Commissioning manual, test plan, and appropriate test results
(8) Operations and maintenance manuals
(9) Materials list of expendable maintenance items, such as filters and fuses

N **30.3.2*** A label that identifies the highest internal dc voltage shall be affixed to combiners, disconnects, and other enclosures with dc voltage.

N **30.4 Periodic Maintenance Procedures.**

N **30.4.1* Visual Inspections.** PV systems and their associated equipment shall be visually inspected in accordance with Table 30.4.1.

N **30.4.2* Cleaning.** The EMP shall determine when and if the installed system requires cleaning.

N **30.4.3 Lubrication. (Reserved)**

N **30.4.4 Mechanical Servicing.** PV systems and their associated equipment shall be mechanically serviced in accordance with Table 30.4.4.

N **30.4.5* Electrical Testing.** PV systems and their associated equipment shall be electrically tested in accordance with Table 30.4.5.

N **30.4.6 Special. (Reserved)**

N **Table 30.4.1 PV System Visual Inspections**

No.	Task	Test Type*	Notes
1	Front of PV modules	1 or 2	Damage, debris, soiling, discoloration, cracks, and broken glass.
2	Backs of PV modules	1 or 2	Damage, debris, discoloration, cracks, and tears.
3	No unintentional shading of the array	1 or 2	Foliage, weeds, trees, or structures.
4	Conductors, connectors, and wiring harnesses are secured	1 or 2	Damaged insulation, melted plastic, broken or missing wiring and raceway supports.
5	Signage, markings, and labels	1 or 2	Arc flash, shock, mechanical hazards, means of isolation location.
6	String fuses are sized in accordance with system design	1A or 2A	Array fires can be caused by improperly sized string fuses. Replacement fuses should be matched to the design criteria.
7	Ensure all electrical equipment enclosures, raceways, structures, and mechanical apparatus are secured	1 or 2	Loose connections or connectors, broken raceways, and supports, missing hardware.
8	Electrical terminations, module interconnections	1	Damage, corrosion, discoloration.
9	Tracking and mechanical systems (e.g., gearbox, drivetrain)	1 or 2	Leaking fluids, bent, broken or damaged drivetrains, array alignment.
10	Grounding and bonding	1 or 2	Secure attachment, missing, damaged or broken connections, protection from physical damage.
11	Battery cells and jumpers	1 or 2	Leaking, bulging, corrosion, fluid levels, damage, melted plastic, discoloration.
12	Roof or wall penetrations	1 or 2	Moisture, dust, and dirt ingress.
13	Site	1 or 2	Storm water runoff channels clear of debris, erosion around piers and pads, vegetation management, animal infestation/nesting/burrowing.

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 30.4.4 PV System Mechanical Servicing**

No.	Task	Test Type*	Notes
1	Tracking and mechanical systems (e.g., gearbox, drivetrain)	1 or 2	Torque of bolted mechanical systems, mechanical alignment.

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 30.4.5 PV System Electrical Tests

No.	Task	Test Type*	Notes
1	Electrical terminations	1 or 2	Any or all the following could be utilized: infrared thermography, contact resistance, millivolt drop, calibrated torque device.
2	Grounding and bonding	1 or 2	Any or all the following could be utilized: infrared thermography, contact resistance, fall of potential, point to point, current reading, calibrated torque device.
3	PV strings and modules	1 or 2	IV curve trace, insulation resistance, operating voltage, and current readings, electroluminescence imaging, infrared thermography.
4	Module interconnections	1	Infrared thermography.

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 31 Wind Power Electric Systems and Associated Equipment

N 31.1 Scope. This chapter identifies electrical maintenance requirements for wind power electric systems and associated equipment.

N 31.2 Frequency of Maintenance. The periodic maintenance procedures in Section 31.3 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 31.3 Periodic Maintenance Procedures.

N 31.3.1* Visual Inspection and Mechanical Testing. Wind power electric systems and associated equipment shall be visually inspected and mechanically tested in accordance with Table 31.3.1.

N 31.3.2 Cleaning. (Reserved)

N 31.3.3 Lubrication. (Reserved)

N 31.3.4 Mechanical Servicing. (Reserved)

N 31.3.5 Electrical Testing. Wind power electric systems and associated equipment shall be electrically tested in accordance with Table 31.3.5.

N 31.3.6 Special. (Reserved)

N Table 31.3.1 Wind Power Electric Systems and Associated Equipment Visual Inspections and Mechanical Tests

No.	Task	Test Type*	Notes
1	Check towers and foundations for:		
	Grounding and bonding	1 or 2	
	Functional navigational warning lights	1 or 2	
	Weather measurement devices	1 or 2	
	Lightning protection	1 or 2	
2	Check yaw systems for damage, wear, and signs of overheating	1 or 2	
3	Check pitch systems for damage, wear, and signs of overheating	1 or 2	
4	Check cables, terminations, and cable support systems for:		
	Structural integrity	1 or 2	
	Signs of vibration damage or abrasion	1 or 2	
	Overheating	1 or 2	
5	In-tower emergency lighting is functioning	1	
6	For other individual components, refer to the appropriate chapter(s) of this standard or manufacturer's instructions	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 31.3.5 Wind Power Electric Systems and Associated Equipment Electrical Tests

No.	Task	Test Type*	Notes
1	Check grounding electrode system resistance	1 or 2	
2	Check emergency stops, safety shutdowns, controls, and warning indicators are functional	1 or 2	
3	Verify supervisory control and data acquisition (SCADA) systems are functional	1 or 2	
4	Check functionality of blade heat trace systems, if installed	1 or 2	
5	For other individual components, refer to the appropriate chapter(s) of this standard or manufacturer's instructions	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 32 Battery Energy Storage Systems

N 32.1 Scope.

N 32.1.1 This chapter identifies electrical maintenance requirements and applies to all battery energy storage systems (ESS) having a capacity greater than 3.6 MJ (1 kWh) that could be stand-alone or interactive with other electric power production sources. These systems are primarily intended to store and provide energy during normal operating conditions.

N 32.1.2* This chapter does not apply to the following:

(1) Stationary standby batteries that meet the requirements of Chapter 36 and are comprised of lead-acid or nickel-cadmium (NiCd) cells
(2) Uninterruptible power supplies (UPS)
(3) Standby battery systems for substation or switchgear control power
(4) Batteries for telecommunications backup power

N 32.2 Frequency of Maintenance. The periodic maintenance procedures in Section 32.4 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in Table 32.2.

N 32.3 Documentation. An installed ESS shall include supporting documentation to include the following:

(1) System designer and installer with installation and commissioning dates
(2) Emergency contacts for system owner
(3) Specifications
(4) Electrical schematics and as-built drawings
(5) Signage, markings, and labels
(6) Mechanical drawings
(7) Commissioning manual, test plan, and appropriate test results
(8) Operations and maintenance manuals
(9) Materials list of expendable maintenance items, such as filters and fuses

N 32.4 Periodic Maintenance Procedures.

N 32.4.1 Visual Inspections. ESS shall be visually inspected in accordance with Table 32.4.1.

N 32.4.2 Cleaning. Electrical equipment surfaces, enclosures, insulating materials, terminals, or terminations shall be kept in a clean and contaminant-free state.

N 32.4.3 Lubrication. (Reserved)

N 32.4.4 Mechanical Servicing. The ventilation system shall be serviced to ensure that airflow is maintained in accordance with the design requirements.

N 32.4.5 Electrical Testing. Energy storage systems shall be electrically tested in accordance with Table 32.4.5.

N 32.4.6 Special. (Reserved)

N Table 32.2 Maintenance Intervals

Test to be Performed	Equipment Condition Assessment			Notes
	Condition 1	Condition 2	Condition 3	
Visual	12 months	12 months	1 month	When batteries are accessible, see Section 36.2 for specific battery technology and maintenance test intervals.
Connection resistances	12 months	12 months	1 month	
Battery management system data and associated alarms	12 months	12 months	1 month	
Battery performance testing	36 months	36 months	12 months	

N **Table 32.4.1 Battery ESS Visual Inspections**

No.	Task	Test Type*	Notes
1	Physical condition, including operating environment	1 or 2	Damage or deterioration, supports or restraints, bending radius, excessive tension, signs of overheating.
2	Correct labeling or identification	1 or 2	Phasing, cable ID, multiple sources, hazard, or other warning labels.
3	Grounding/bonding	1 or 2	Damage, missing or loose terminations, clearance from energized parts, protection from physical damage.
4	Batteries	1 or 2	Damage, leaking, swelling, discolored or melted plastic, terminal corrosion, electrolyte level, restraint systems. See Chapter 36 for stationary standby batteries.
5	Cables	1 or 2	Damage, deterioration, supports, bending radius, excessive tension, discoloration, or evidence of overheating.
6	Fire alarm notification, detection, and suppression systems	1 or 2	Damaged heads, physical obstruction to spray, leaking, corrosion, suppression agent is charged.
7	Raceway/cable tray	1 or 2	Damage or deterioration, cable jacket abrasion or wear when exposed, continuity, tight joints, missing or loose bonding jumpers, corrosion.
8	Barriers, guards, and assemblies	1 or 2	Damage or signs of deterioration, arcing, tracking, supports, and mounting hardware.

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 32.4.5 Battery ESS Electrical Tests**

No.	Task	Test Type*	Notes
1	Infrared thermography or equivalent thermal inspection	1 or 2	Overall battery case(s) and terminations; should be performed under load.
2	Airborne ultrasonic acoustic emissions	1A	
3	Insulation resistance	2	Cables/conductors.
4	Bolted connection resistance	1 or 2	Includes intercell resistance, when accessible.
5	Battery performance test	2	
6	Review of battery management system data and associated alarms	1 or 2	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 33 Electric Vehicle Power Transfer Systems and Associated Equipment

N 33.1 Scope. This chapter identifies electrical maintenance requirements for electric vehicle power transfer systems and associated equipment.

N 33.2 Frequency of Maintenance. The periodic maintenance procedures in Section 33.4 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 33.3 Documentation.

N 33.3.1 The following electric vehicle transfer power system markings shall be maintained:

(1) Emergency contacts for system owner
(2) Signage, markings, and labels
(3) Rating or adjusted rating
(4) Identification that load management is used, if applicable

N 33.3.2 The following supporting documentation shall be available for maintenance:

(1) Mechanical drawings (mounting and structural)
(2) Operations and maintenance manuals
(3) Electrical schematics and drawings

N 33.4 Periodic Maintenance Procedures.

N 33.4.1 Visual Inspection.

N 33.4.1.1 Electric vehicle power transfer system equipment shall be visually inspected in accordance with Table 33.4.1.1.

N 33.4.1.2 The following inspections shall be performed annually:

(1) The cord and cord connector shall be inspected to verify that the strain relief is intact, stress is not placed on the cord terminations, and the pins are not damaged.
(2) The equipment mounting shall be inspected to ensure the integrity of the mounting means.
(3) The physical protection for the equipment shall be inspected to ensure its integrity.

N 33.4.2 Cleaning. (Reserved)

N 33.4.3 Mechanical Servicing. (Reserved)

N 33.4.4 Electrical Testing. (Reserved)

N Table 33.4.1.1 Electric Vehicle Power Transfer System Equipment Visual Inspections

No.	Task	Test Type*	Notes
1	Inspect doors and latches for fit, dents, corrosion, and missing hardware	1 or 2	Damage or deterioration, supports or restraints.
2	Inspect wiring, bus, and connections for damaged insulation, broken leads, tightness of connections, crimping, and overall general condition including corrosion	1 or 2	Excessive tension, signs of overheating, multiple sources, hazard, or other warning labels.
3	Inspect grounding/bonding	1 or 2	Damage, missing or loose terminations, clearance from energized parts, protection from physical damage.
4	Inspect cables	1 or 2	Damage, deterioration, supports, bending radius, excessive tension, cable ID, discoloration, cable jacket abrasion or wear when exposed, or evidence of overheating.
5	Inspect raceway/cable tray	1 or 2	Damage or deterioration, cable jacket abrasion or wear when exposed, continuity, tight joints, missing or loose bonding jumpers, corrosion.
6	Inspect barriers, guards, and assemblies	1 or 2	Damage or signs of deterioration, arcing, tracking, supports and mounting hardware.

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 34 Public Pools, Fountains, and Similar Installations

N 34.1 Scope.

N 34.1.1 This chapter identifies electrical maintenance requirements for the electrical maintenance and inspection of permanently installed public pools, fountains, and similar installations.

N 34.1.2 This chapter does not apply to pools, fountains, and similar installations located at one- and two-family dwellings, storable pools, storable spas, storable hot tubs, pools and tubs for therapeutic use, and hydromassage bathtubs.

N 34.2 Frequency of Maintenance. The periodic maintenance procedures in Section 34.3 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in this chapter.

N 34.3 Periodic Maintenance Procedures.

N 34.3.1* Visual Inspections. Public pools, fountains, and similar installations shall be visually inspected in accordance with Table 34.3.1.

N 34.3.2 Mechanical Inspections. Public pools, fountains, and similar installations shall be mechanically inspected in accordance with Table 34.3.2.

N 34.3.2.1 Luminaires with a discolored lens or evidencing water intrusion shall be replaced.

N 34.3.2.2* Luminaires with cords exhibiting physical damage, repair, or splices or that are an inconsistent type for the luminaire shall be replaced.

N 34.3.2.3* Luminaires or niches with incorrect, missing, or damaged attachment screws or sockets shall be repaired or replaced.

N 34.3.2.4 Insulating (nonconducting) wedges or similar appliances shall be replaced with conducting wedges or similar appliances.

N 34.3.3 Electrical Testing. Public pools, fountains, and similar installations shall be electrically tested in accordance with Table 34.3.3.

N Table 34.3.1 Public Pools, Fountains, and Similar Installation Visual Inspections

No.	Task	Test Type*	Notes
1	Correct labeling or identification	1 or 2	Controls, emergency controls, shutoff indications, schematics, or other information that requires public or operating personnel access.
2	Physical condition of equipment, including corrosion and deterioration	1 or 2	Metal enclosures and other metal parts, including panel connections and busbars.
3	Physical condition of connections	1 or 2	Readily accessible bonding and grounding connections, for corrosion, electrical equipment associated with the pool.
4	Corrosive environment inspection	1 or 2	Investigate areas that exhibit excessive corrosion for corrosive gas, liquid leaks, and ventilation.
5	Electric motor labeling	1 or 2	
6	Overhead conductor clearance	2	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 34.3.2 Public Pools, Fountains, and Similar Installation Mechanical Inspections

No.	Task	Test Type*	Notes
1	Verify operation	1 or 2	Verify accessible means for shutting off the suction and discharge piping for electrically operated pumps.
2	Wet niche pool luminaires	2	Inspect for water intrusion, damaged attachment screws or sockets, insulating wedges or similar appliances, and visible cord damage and/or modification.
3	Operating pressures	1	Verify operating pressures after operating for minimum of 15 minutes.

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 34.3.3 Public Pools, Fountains, and Similar Installation Electrical Tests

No.	Task	GFCI Components Test Type*	Electric Motors and Valves Test Type*	System Grounding and Bonding Test Type*	Notes
1	Test electrically operated valves	NA	1	NA	Test for correct operation.
2	For individual components, refer to the appropriate chapter(s) of this standard.	NA	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 35 Protective Relays

N 35.1 Scope. This chapter identifies electrical maintenance requirements for electromechanical, solid-state, and microprocessor-based relays used to protect and control power system apparatus.

N 35.2 Frequency of Maintenance. The periodic maintenance procedures specified in Section 35.3 shall be performed in accordance with the frequencies specified in Chapter 9, unless otherwise specified in this chapter.

N 35.3 Periodic Maintenance Procedures.

N 35.3.1 Visual Inspections. Protective relays shall be visually inspected in accordance with Table 35.3.1.

N 35.3.2 Cleaning. If contamination is present, protective relays shall be cleaned in accordance with Table 35.3.2.

N 35.3.3 Lubrication. (Reserved)

N 35.3.4 Mechanical Servicing. Protective relays shall be mechanically serviced in accordance with Table 35.3.4.

N 35.3.5 Electrical Testing. Protective relays shall be electrically tested in accordance with Table 35.3.5.

N 35.3.6 Special. (Reserved)

N Table 35.3.1 Protective Relay Visual Inspections

No.	Task	Electromechanical Test Type*	Solid-State Test Type*	Microprocessor Test Type*	Notes
1	Inspect case and windows for cracks and proper seal	2	2	2	
2	Inspect current transformer shorting blocks and voltage disconnects	2	2	2	
3	Check for proper operation of LEDs, targets, and visual displays	2	2	2	
4	Inspect wiring and connections for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition including corrosion	2	2	2	
5	Inspect clearances, mechanical freedom, and condition of contacts and control springs	2	NA	NA	
6	Inspect contact bearing clearances and freedom of movement	2	NA	NA	
7	Check that settings are in accordance with coordination study	2	2	2	
8	Download or document events, oscillographs, and maintenance and statistical data	NA	NA	2A	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 35.3.2 Protective Relay Cleaning**

No.	Task	Electromechanical Test Type*	Solid-State Test Type*	Microprocessor Test Type*	Notes
1	Clean the relay case and cover	2	2	2	
2	Clean relay contacts, disks, and magnets	2	NA	NA	
3	Burnish burned or pitted contacts	2	NA	NA	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N **Table 35.3.4 Protective Relay Mechanical Servicing**

No.	Task	Electromechanical Test Type*	Solid-State Test Type*	Microprocessor Test Type*	Notes
1	Check relay disks for friction, freedom of movement, correct travel, and clearance.	2	NA	NA	
2	Operate targets and reset mechanisms.	2	2	NA	
3	Update to most current firmware.	NA	NA	2A	
4	Check trip and close coil monitoring functions.	NA	NA	2	
5	Check circuit breaker monitoring.	NA	NA	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: 1 = online standard test, 1A = online enhanced test, 2 = offline standard test, 2A = offline enhanced test.

N **Table 35.3.5 Protective Relay Electrical Tests**

No.	Task	Test Type*			Notes
		Electromechanical	Solid-State	Microprocessor	
1	Perform an insulation resistance test on each branch circuit to frame	2	NA	NA	
2	Perform a pickup test to determine the minimum or maximum current, voltage, power, or frequency that causes closure of relay contacts for all active functions	2	2	2A	
3	Perform a timing at three points on the time dial curve to verify the timing characteristics of the relay	2	2	2A	
4	Perform tests as required to check operation of restraint, directional, and other protective elements	2	2	2A	
5	Perform a zero check test to determine proper time dial position when the relay is fixed and moving contacts are closed by the manual rotation of the time dial towards zero	2	NA	NA	
6	Perform relay checks to verify relay status, meter readings (if applicable), and contact inputs/outputs	NA	NA	2	
7	Test arc energy reduction technology in accordance with the manufacturer's instructions	NA	NA	2	
8	Verify each input and output performs the intended function in accordance with control drawings	2A	2A	2A	
9	After testing is complete, clear trip counters, targets, events, and oscillographs from testing	2	2	2A	
10	Review maintenance and statistical data	NA	2	2	
11	Download or document settings, logic, and other parameters when changes are made	NA	2	2	

NA: Not applicable.
*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 36 Stationary Standby Batteries

N 36.1* Scope. This chapter identifies electrical maintenance requirements for all stationary installations of storage stationary standby batteries comprised of lead-acid or nickel-cadmium (NiCd) cells.

N 36.2 Frequency of Maintenance. The periodic maintenance procedures in Section 36.4 shall be performed in accordance with the frequencies in Chapter 9, unless otherwise specified in Table 36.2.

N 36.3 Documentation.

N 36.3.1* Measurements shall be recorded for future reference along with log notations of the visual inspection and corrective action.

N 36.3.2 A stationary standby battery installation shall include supporting documentation to include the following:

(1) Electrical schematics and as-built drawings
(2) Signage, markings, and labels
(3) Commissioning manual, test plan, and test results
(4) Operations and maintenance manuals
(5) Materials list of expendable maintenance items, such as filters and fuses

N 36.4* Periodic Maintenance Procedures.

N 36.4.1* Visual Inspections. Stationary standby batteries and their associated equipment shall be visually inspected in accordance with Table 36.4.1.

N 36.4.2* Cleaning. Terminal connectors, battery posts, and cable ends shall be checked and be cleaned to remove all corrosion and dirt.

N 36.4.3 Lubrication. (Reserved)

N 36.4.4 Mechanical Servicing. (Reserved)

N 36.4.5* Electrical Testing. Stationary standby batteries and their associated equipment shall be electrically tested in accordance with Table 36.4.5.

N 36.5 Special. (Reserved)

N Table 36.2 Maintenance Intervals

Battery Technology	Test to be Performed	Equipment Condition Assessment			Notes
		Condition 1	Condition 2	Condition 3	
Vented lead-acid	Overall float voltage	3 months	3 months	1 month	
	Visual inspections	12 months	12 months	1 month	
	Electrolyte levels	3 months	3 months	1 month	
	Ambient temperature	3 months	3 months	1 month	
	Float current	3 months	3 months	1 month	
	Individual cell/unit float voltages	12 months	12 months	1 month	
	Representative cell temperatures	3 months	3 months	1 month	
	Inspect electrical connection for high resistance	12 months	12 months	1 month	
	Performance testing	60 months	60 months	12 months	
Valve-regulated lead-acid	Overall float voltage	1 month	1 month	1 month	
	Visual inspections	12 months	12 months	1 month	
	Ambient temperature	3 months	3 months	1 month	
	Float current	1 month	1 month	1 month	
	Ohmic testing	3 months	3 months	1 month	
	Individual cell/unit float voltages	3 months	3 months	1 month	
	Representative cell temperatures	3 months	3 months	1 month	
	Inspect electrical connection for high resistance	12 months	12 months	1 month	
	Performance testing	24 months	24 months	12 months	
Ni-Cad	Overall float voltage	3 months	3 months	1 month	
	Visual inspections	12 months	12 months	1 month	
	Electrolyte levels	3 months	3 months	1 month	
	Ambient temperature	3 months	3 months	1 month	
	Float current	3 months	3 months	1 month	
	Individual cell/unit float voltages	12 months	12 months	1 month	
	Representative cell temperatures	3 months	3 months	1 month	
	Inspect electrical connection for high resistance	12 months	12 months	1 month	
	Performance testing	60 months	60 months	12 months	

N **Table 36.4.1 Stationary Standby Batteries Visual Inspections**

No.	Task	Test Type*	Notes
1	Inspect containers, covers, and vent caps for cracks and structural damage	1	
2	Inspect plates and internal parts when visible	1	Document excessive positive plate growth, sulfate crystal formation, buckling, warping, scaling, swelling, cracking, hydration rings, excessive sedimentation, mossing, copper contamination, internal post seal cracks, and changes in color.
3	Inspect interconnection cables, cell connectors, and other conductors for wear, contamination, corrosion, and discoloration	1	
4	Inspect battery racks for corrosion, cleanliness, proper grounding, and structural integrity, seismic protection	1	
5	Inspect electrolyte for containment, leaking, spills, and levels	1	
6	Inspect ventilation equipment operation, dampers, filters, alarms, and other items that might restrict air movement	1	
7	Inspect heating and air conditioning equipment including filters that control ambient room temperature for restricted air movement	1	
8	Verify the functionality of lights, strobes, horns, and related alarm notifications	1	

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Table 36.4.5 Stationary Standby Battery Electrical Tests

No.	Task	Test Type*	Notes
1	Overall float voltage	1	Measured at the battery and verified annually to be in accordance with the battery manufacturer's instructions.
2	Measure cell temperature	1	
3	Specific gravity	1A	No less than 10% of the units in the string(s).
4	Ohmic testing	1A	Resistance, impedance, or conductance.
5	Inspect electrical connection for high resistance	1 or 1A	See Section 7.2.
6	Performance testing	1	
7	Thermal imaging	1	Under full load of performance testing.
8	Float current	1	
9	Individual cell/unit float voltage	1	Record voltage measurements on individual cells or units to two decimal places.

*Types specified in accordance with Section 8.3, as follows: Type 1 = online standard test; Type 1A = online enhanced test; Type 2 = offline standard test; Type 2A = offline enhanced test.

N Chapter 37 Instrument Transformers (Reserved)

N Chapter 38 Control Power Transformers (Reserved)

Annex A Explanatory Material

Annex A is not a part of the requirements of this NFPA document but is included for informational purposes only. This annex contains explanatory material, numbered to correspond with the applicable text paragraphs.

N A.1.5.3.2 Users of this standard should apply one system of units consistently and not alternate between units.

Δ A.3.2.1 Approved. The National Fire Protection Association does not approve, inspect, or certify any installations, procedures, equipment, or materials nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment, or materials, the "authority having jurisdiction" may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure, or use. The "authority having jurisdiction" may also refer to the listings or labeling practices of an organization that is concerned with product evaluations and is thus in a position to determine compliance with appropriate standards for the current production of listed items.

A.3.2.2 Authority Having Jurisdiction (AHJ). The phrase "authority having jurisdiction," or its acronym AHJ, is used in NFPA standards in a broad manner because jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A.3.2.4 Listed. The means for identifying listed equipment may vary for each organization concerned with product evaluation; some organizations do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

N A.3.3.1 Adjustable Speed Drive. A variable frequency drive is one type of electronic adjustable speed drive that controls the rotational speed of an ac electric motor by controlling the frequency and voltage of the electrical power supplied to the motor. [**70,** 2023]

N A.3.3.9 Circuit Breaker. One example of a listing standard for circuit breakers is UL 489, *Molded-Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures.*

*Molded-Case Circuit Breaker (MCCB).*MCCBs are most often available in one-, two-, three-, or four-pole versions and are available in 120 V to 1000 V ratings. All MCCBs, including ICCBs, will include some sort of instantaneous protection, which might be adjustable but cannot be completely disabled.

Insulated-Case Circuit Breaker (ICCB). There is no specific definition or mention of ICCB within the MCCB standard.

However, their stated ratings will be those of MCCBs but they can operate like LVPCBs. ICCBs can either include a two-step stored energy operating mechanism that will require manual charging of closing and opening springs when the circuit breaker is manually operated or include internal charging motors for closing and opening springs. ICCBs are normally housed in a case of dielectric materials providing a layer of insulation between its exterior and internal mechanisms. The characteristics of ICCBs vary widely between models and manufacturers.

Low-Voltage Power Circuit Breaker (LVPCB). LVPCBs are mechanical switching devices consisting of a frame that contains some number of field replaceable component parts or subassemblies capable of making, carrying, interrupting, and breaking currents. Modern LVPCBs are rated 1000 V ac or less, or 1500 V dc or less, and do not include MCCBs. They are typically larger circuit breakers with frames rated at 600 A or more that have a significant degree of maintainability, such as the ability to replace contact structures, arc chutes, and other parts subject to wear. Modern versions are listed to UL 1066, *Low-Voltage AC and DC Power Circuit Breakers Used in Enclosures*, and are commonly installed in switchgear as draw-out devices. More rarely, they might be installed as fixed mounted devices in older equipment. LVPCBs manufactured prior to 2000 generally had metal frames; those manufactured after 2000 tend to use frames made from nonconductive materials. LVPCBs are sometimes also referred to as metal frame or air frame breakers.

A.3.3.14 Corona. High electrical gradients exceeding the breakdown level of air lead to corona discharges. Mild corona has a low sizzling sound and might not be audible above ambient noise in the substation. As the corona increases in activity, the sizzling sound becomes louder and is accompanied by popping, spitting, or crackling as flashover level nears. Corona ionizes the air, converting the oxygen to ozone, which has a distinctive, penetrating odor.

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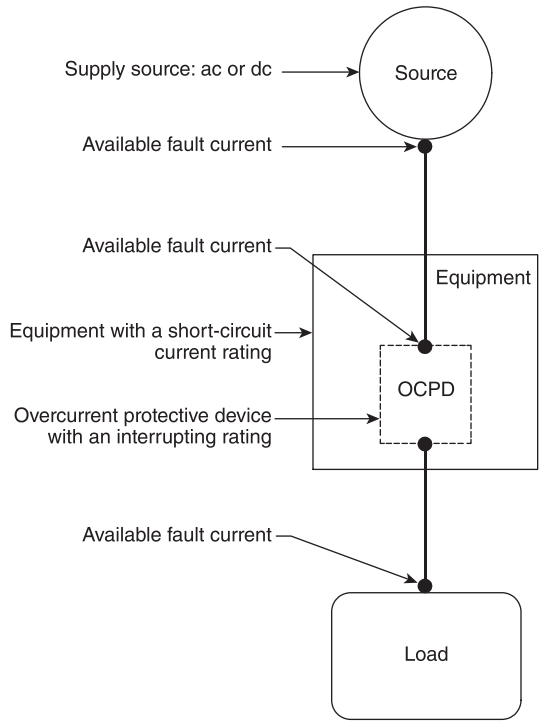
N **A.3.3.16 Electrical Maintenance Program (EMP).** Electrical maintenance relies on knowing the electrical systems and equipment being maintained and on knowing the operating experience, loss exposures, potential for injury, and maintenance resources.

N **A.3.3.19 Energy Storage System (ESS).** An ESS(s) can include but is not limited to batteries, capacitors, and kinetic energy devices (e.g., flywheels and compressed air). An ESS(s) can include inverters or converters to change voltage levels or to make a change between an ac or a dc system. [**70,** 2023]

These systems differ from a stationary standby battery installation where a battery spends the majority of the time on continuous float charge or in a high state of charge, in readiness for a discharge event. [**70,** 2023]

N **A.3.3.21 Fault Current, Available (Available Fault Current).** A short-circuit can occur during abnormal conditions such as a fault between circuit conductors or a ground fault. Available fault current can be different values at different points in the same circuit. See Figure A.3.3.21.

Δ **A.3.3.26 Ground-Fault Circuit Interrupter (GFCI).** See UL 943, *Standard for Ground-Fault Circuit Interrupters*, for further information. Class A ground-fault circuit interrupters trip when the ground-fault current is 6 mA or higher and do not trip when the ground-fault current is less than 4 mA. [**70,** 2023]



N **FIGURE A.3.3.21 Available Fault Current. [70:Informational Note Figure 100.1]**

A GFCI does not eliminate the electric shock sensation since normal perception level is approximately 0.5 mA; nor does it protect from electric shock hazard from line-to-line contact.

Δ **A.3.3.27 Ground-Fault Protection of Equipment.** There are two applications where ground-fault protection of equipment is intended to be used: where there could be excessive ground-fault leakage current from equipment and where equipment and conductors are to be protected from damage in the event of a higher-level ground fault (either solid or arcing). These types of protective equipment are for use only on ac, grounded circuits; they cause the circuit to be disconnected when a current equal to or higher than its pickup setting or rating flows to ground. They are not designed to protect personnel from electrocution. Equipment ground-fault protective devices are intended to operate on a condition of excessive ground-fault leakage current from equipment. The ground current pickup level of these devices is from above 6 mA to 50 mA. Circuit breakers with equipment ground-fault protection are combination circuit breaker and equipment ground-fault protective devices designed to serve the dual function of providing overcurrent protection and ground-fault protection for equipment. The ground current pickup level of these breakers is typically 30 mA. They are intended to be used in accordance with *NFPA 70*, Articles 426 and 427. Ground-fault sensing and relaying equipment is intended to provide ground-fault protection of equipment at services and feeders. They are rated for ground current pickup levels from 4 amperes to 1200 amperes.

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N **A.3.3.33 Ground Loop.** Current will flow in the ground loop if there is voltage difference between the connection nodes. Regrounding of the grounded circuit conductor (neutral)

beyond the service point will result in ground loops. This might or might not be harmful depending on the application.

N **A.3.3.35 Interharmonics.** Not all frequencies that occur on an electrical power system are integer multiples of the fundamental frequency (usually 60 Hz), as are harmonics. Some loads draw currents that result in voltages that are between harmonic frequencies or less than the fundamental frequency. These frequencies are referred to as interharmonics and can be made of discrete frequencies or as a wide-band spectrum. A special category of these interharmonics is called subharmonics, in which the frequencies involved are less than the fundamental power line frequency.

N **A.3.3.36 Long-Duration Undervoltage.** See IEEE 1159, *Recommended Practice for Monitoring Electric Power Quality,* Table 4-2.

N **A.3.3.48 Reconditioned.** The term *reconditioned* is frequently referred to as *rebuilt*, *refurbished*, or *remanufactured*. [**70,** 2023]

N **A.3.3.50 Sag.** If the voltage drops below 10 percent of the normal voltage, then this is classified as an interruption.

N **A.3.3.51 Service Point.** The service point can be described as the point of demarcation between where the serving utility ends and the premises wiring begins. The serving utility generally specifies the location of the service point based on the conditions of service.

N **A.3.3.52 Servicing.** Servicing often encompasses maintenance and repair activities. [**70,** 2023]

N **A.3.3.54 Ground-Fault Circuit Interrupter, Special Purpose (SPGFCI). (Special-Purpose Ground-Fault Circuit Interrupter)** See UL 943C, *Outline of Investigation for Special Purpose Ground-Fault Circuit Interrupters,* for information on Classes C, D, or E special purpose ground-fault circuit interrupters. [**70,** 2023]

N **A.3.3.55 Stationary Standby Battery.** Uninterruptible power supply (UPS) batteries fall under this definition.

N **A.3.3.56 Survey.** The systems and equipment covered in specific parts of the survey should be based on logical divisions of the electrical system.

N **A.3.3.59 Switchboard.** These assemblies can be accessible from the rear or side as well as from the front and are not intended to be installed in cabinets. [**70,** 2023]

N **A.3.3.60 Switchgear.** All switchgear subject to *NEC* requirements is metal enclosed. Switchgear rated below 1000 V or less may be identified as "low-voltage power circuit breaker switchgear." Switchgear rated over 1000 V may be identified as "metal-enclosed switchgear" or "metal-clad switchgear." Switchgear is available in non–arc-resistant or arc-resistant constructions. [**70,** 2023]

N **A.3.3.61.1 Acceptance Tests.** Acceptance tests can be used to establish test benchmarks that can be used as reference during future tests, performed either at the factory, on-site, or after installation.

N **A.3.3.61.4 Enhanced Tests.** Examples of enhanced tests are cable fault-locating tests or tests performed on a circuit breaker that has interrupted a high level of fault current. Tests can be performed at the discretion of the EMP and provide additional diagnostic information about equipment.

N **A.3.3.63 Transients.** Transients were formerly referred to as surges, spikes, or impulses. Waveshapes of the excursions are usually unidirectional pulses or decaying amplitude, high-frequency oscillations. Durations range from fractions of a microsecond to milliseconds, and the maximum duration is in the order of one half-cycle of the power frequency. Instantaneous amplitudes of voltage transients can reach thousands of volts.

N **A.4.2.4.2** The person developing the EMP should verify if the local codes or ordinances include an electrical maintenance requirement. If an electrical maintenance requirement has been adopted into the local codes or ordinances, the person should verify that all requirements for this standard and the local codes or ordinances are satisfied in the EMP.

N **A.4.7.1** Rework, remanufacturing, or retrofitting of equipment typically involves replacement or refurbishing of major components of equipment or systems. Repairs or modifications not authorized by the original equipment manufacturer might void the equipment warranties and third-party certifications. Equipment can be reconditioned under rebuild programs provided the reconditioning follows established guidelines. The AHJ can assess the acceptability of reconditioned equipment to determine if a re-evaluation of the modified product by the organization that listed the equipment is necessary.

N **A.4.7.2** See also NFPA 791 and OSHA Safety & Health Information Bulletin (SHIB), "Certification of Workplace Products by Nationally Recognized Testing Laboratories."

N **A.4.8** When cleaning equipment, the method used should be determined by the type of contamination to be removed and whether the apparatus is to be returned to service immediately. Drying is necessary after using a solvent or water. Insulation should be tested to determine if it has been properly cleaned. Enclosure and substation room filters should be cleaned at regular intervals and replaced if they are damaged or clogged. Loose hardware, dust, and debris should be removed from equipment enclosures. When properly cleaned, new or unusual wear or loss of parts can be detected during subsequent maintenance operations.

Wiping off dirt with a clean, dry, lint-free cloth or soft brush is usually satisfactory if the apparatus is small, the surfaces to be cleaned are accessible, and only dry dirt is to be removed. Lint-free rags should be used so lint will not adhere to the insulation and act as a further dirt-collecting agent. Care should be used to avoid damage to delicate parts.

To remove loose dust, dirt, and particles, suction cleaning methods should be used.

Where dirt cannot be removed by wiping or vacuuming, compressed-air blowing might be necessary.

If compressed air is used, protection should be provided against injury to workers' faces and eyes from flying debris and to their lungs from dust inhalation. The use of compressed air should comply with OSHA regulations in 29 CFR 1910.242(b), "Hand and Portable Powered Tools and Equipment, General — Compressed Air Used for Cleaning," including limiting air pressure for such cleaning to less than a gauge pressure of 208.85 kPa (30 psi) and the provision of effective chip guarding and appropriate PPE.

Care should be exercised because compressed air can cause contaminants to become airborne, which can compromise the integrity of insulation surfaces or affect the mechanical operation of nearby equipment. Protection might also be needed

against contamination of other equipment if the insulation is cleaned in place with compressed air. Either equipment should be removed to a suitable location for cleaning or other equipment should be covered and guarded from cross contamination. Air should be dry and directed in a manner to avoid further blockage of ventilation ducts and recesses in insulation surfaces.

Accumulated dirt, oil, or grease might require a solvent to remove it. A lint-free cloth barely moistened (not wet) with a nonflammable solvent can be used for wiping. Solvents used for cleaning of electrical equipment should be selected carefully to ensure compatibility with the materials being cleaned. Liquid cleaners, including spray cleaners, are not recommended unless solvent compatibility is verified with the equipment manufacturer because residues could cause damage, interfere with electrical or mechanical functions, or compromise the integrity of insulation surfaces.

Some equipment could require cleaning by nonconductive abrasive blasting.

Shot blasting should not be used.

CAUTION: Cleaning with abrasives or abrasive blasting methods can create a hazard to personnel and equipment.

Abrasive blasting operations should comply with OSHA regulations in 29 CFR 1910.94(a), "Ventilation — Abrasive Blasting." Protection should be provided against injury to workers' faces and eyes from abrasives and flying debris and to their lungs from dust inhalation.

Airborne asbestos fibers can endanger health and are subject to government regulations. Knowledge of government regulations related to the handling of asbestos is required before handling asbestos and other such materials. (Copies of the Toxic Substances Control Act as defined in the US Code of Federal Regulations can be obtained from the US Environmental Protection Agency.)

If sweeping of an electrical equipment room is required, a sweeping compound should be used to limit the amount of dirt and dust becoming airborne. During mopping, the mop bucket should be kept as far as practical from the electrical equipment.

N **A.5.1.2** In addition to *NFPA 70E*, IEEE C2, *National Electrical Safety Code*; applicable legal requirements (e.g., 29 CFR 1926, "Occupational Safety and Health Standards," and 29 CFR 1910, "Safety and Health Regulations for Construction"); and *NFPA 70* are among the references that should be utilized for the development of programs and procedures associated with electrical maintenance activities and are necessary to be used in conjunction with this document.

Equipment should be placed in an electrically safe work condition for inspections, tests, repairs, and other servicing. Where electrical maintenance tasks must be performed when the equipment is energized, provisions are to be made to allow electrical maintenance to be performed safely.

N **A.6.1.1** Engineering studies generally cover the following areas:

(1) Short-circuit studies
(2) Coordination studies
(3) Load-flow studies
(4) Reliability studies
(5) Incident energy analysis (arc-flash hazard calculations)
(6) Maintenance-related design studies

In order to conduct short-circuit, coordination, and arc flash studies, specific data should be collected. Data that should be included on a single-line diagram are utility company points of contact and data records for equipment such as transformers, cables, overhead lines, fuses, medium-voltage breakers, reclosers, capacitor banks, low-voltage breakers, disconnects, generators, and motors. This information should be developed for each type of operating condition. Examples of data collection forms are included in Annex E.

Utility information should at least include the minimum and maximum short circuit megavolt-amperes (MVA) and the X/R ratio at the service point; point of contact name, address, and telephone number; and facility point of contact, address, and telephone number.

Transformer data records should include location, rated kilovolt-amperes (kVA), maximum kVA, primary voltage, secondary voltage, impedance in percent, type of primary and secondary connection, ground impedance, and, if appropriate, the voltage tap.

Cable data should include "to" and "from," rated volts, nominal volts, single-conductor or three-conductor cable, the number of conductors per phase, the neutral size, copper or aluminum, and length in feet.

Raceway material (i.e., magnetic or nonmagnetic) should be noted.

Overhead line information should include "to" and "from," connection configuration, nominal volts, number of lines, lines per phase, ground size, type of cable (material), and length in feet.

Medium-voltage breaker information should include location, manufacturer, type, rated volts, interrupting current, interrupting time (cycles), close/latch amps and for the associated relays the manufacturer/type, time delay range and existing tap, time dial, instantaneous range and existing tap, and CT ratio.

Recloser information should include location, CT ratio, nominal volts, manufacturer, type, BIL, continuous current rating, interrupting rating, minimum trip, operational sequence, reclosing times (if available), and tripping curves (if available).

Low-voltage information for the breaker should include location, manufacturer, type, rated volts, frame rating, and interrupting rating and for the trip device should include manufacturer, type, long time delay range and bands available, short time delay range and bands available, instantaneous range, and ground range and bands available.

Generator information should include location, type, kVA rating, generated volts, rated current, rpm, wiring connection (e.g., delta or wye), system ground, subtransient impedance, ground impedance, and power factor.

Motor information should include location, type, horsepower, rated volts, full load amps, rpm, code letter, locked rotor amps, power factor, and starter type.

Capacitor bank information should include location, kVAR rating, rated volts, and wiring connection (e.g., delta or wye).

Fuse information should include location, voltage rating, interruption rating, fuse type or class, manufacturer, and manufacturer's part number.

N A.6.3 Protecting electrical systems against damage during short-circuit faults is required in 110.9 and 110.10 of *NFPA 70*. Additional information on short-circuit currents can be found in ANSI/IEEE 242, *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book);* ANSI/IEEE 141, *Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book);* ANSI/IEEE 241, *Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book);* and ANSI/IEEE 399, *Recommended Practice for Industrial and Commercial Power Systems Analysis (IEEE Brown Book).*

IEEE is incorporating the information in the color book series into the IEEE 3000 Standards. The content will be organized into approximately 70 IEEE "dot" standards as follows:

(1) IEEE 3000 Standards: *Fundamentals*
(2) IEEE 3001 Standards: *Power Systems Design*
(3) IEEE 3002 Standards: *Power Systems Analysis*
(4) IEEE 3003 Standards: *Power Systems Grounding*
(5) IEEE 3004 Standards: *Protection & Coordination*
(6) IEEE 3005 Standards: *Energy & Standby Power Systems*
(7) IEEE 3006 Standards: *Power Systems Reliability*
(8) IEEE 3007 Standards: *Maintenance, Operations & Safety*

The user should refer to the IEEE website (www.ieee.org) for updated information regarding available standards.

Short circuits or fault currents represent a significant amount of destructive energy that can be released into electrical systems under abnormal conditions. During normal system operation, electrical energy is controlled and does useful work. However, under fault conditions, short-circuit currents can cause serious damage to electrical systems and equipment and create the potential for serious injury to personnel. Short-circuit currents can approach values as large as several hundred thousand amperes.

During short-circuit conditions, thermal energy and magnetic forces are released into the electrical system. The thermal energy can cause insulation and conductor melting as well as explosions contributing to major equipment burndowns. Magnetic forces can bend busbars and cause violent conductor whipping and distortion. These conditions have grim consequences on electrical systems, equipment, and personnel.

The following are some of the conditions that might require an update of the baseline short-circuit study:

(1) A change by the utility
(2) A change in the primary or secondary system configuration within the facility
(3) A change in the transformer size (kVA) or impedance (percent Z)
(4) A change in conductor lengths or sizes
(5) A change in the motors connected to the system

A comprehensive treatment of short-circuit currents is beyond the scope of this document. However, there is a simple method to determine the maximum available short-circuit current at the transformer secondary terminals. This value can be calculated by multiplying the transformer full load amperes by 100 and dividing the product by the percent impedance of the transformer.

Figure A.6.3 shows an example calculation: 500 kVA transformer, 3-phase, 480 volt primary, 208 Y/120 volt secondary, 2 percent Z.

There are several computer programs commercially available to conduct thorough short-circuit calculation studies.

N A.6.4 *NFPA 70* and various IEEE standards contain the requirements and suggested practices to coordinate electrical systems. The IEEE standards include ANSI/IEEE 242, *Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (IEEE Buff Book);* ANSI/IEEE 141, *Recommended Practice for Electric Power Distribution for Industrial Plants (IEEE Red Book);* ANSI/IEEE 241, *Recommended Practice for Electric Power Systems in Commercial Buildings (IEEE Gray Book);* and ANSI/IEEE 399, *Recommended Practice for Industrial and Commercial Power Systems Analysis (IEEE Brown Book). (See A.6.3.)*

Improper coordination can cause unnecessary power outages. For example, branch-circuit faults can open multiple upstream overcurrent devices. This process can escalate and cause major blackouts, resulting in the loss of production. Blackouts also affect personnel safety.

Changes affecting the coordination of overcurrent devices in the electrical system include the following:

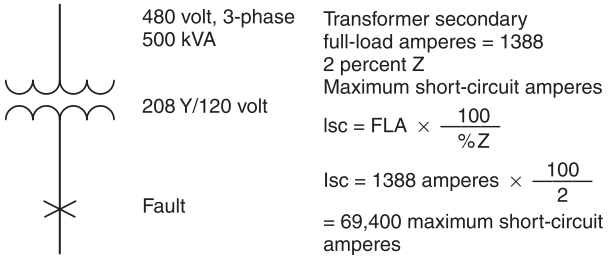
(1) A change in the available short-circuit current
(2) Replacing overcurrent devices with devices having different ratings or operating characteristics
(3) Adjusting the settings on circuit breakers or relays
(4) Changes in the electrical system configuration
(5) Inadequate maintenance, testing, and calibration

N A.6.5 Load-flow studies show the direction and amount of power flowing from available sources to every load. By means of such a study, the voltage, current, power, reactive power, and power factor at each point in the system can be determined.

This information is necessary before changes to the system can be planned and will assist in determining the operating configuration. This study also helps determine losses in the system. ANSI/IEEE 399, *Recommended Practice for Industrial and Commercial Power Systems Analysis (IEEE Brown Book)*, provides more detailed information.

Some of the events that result in load-flow changes include changing motors, motor horsepower, transformer size, or impedance; operating configurations not planned for in the existing study; adding or removing power-factor correction capacitors; and adding or removing loads.

It is important that the system single-line diagrams and operating configurations (both normal and emergency) be kept current along with the load-flow study.



N FIGURE A.6.3 Example Calculation of Maximum Available Short-Circuit Current at the Transformer Secondary Terminals.

Some signs that indicate a need to review a load-flow study include unbalanced voltages, voltage levels outside the equipment rating, inability of motors to accelerate to full load, motor starters dropping offline when other loads are energized, or other signs of voltage drop. Additional signs also include poor system power factor, transformer or circuit overloading during normal system operation, and unacceptable overloading when the system is operated in the emergency configuration.

N **A.6.6** The study methods are based on probability theory. The computed reliability of alternative system designs as well as the selection and maintenance of components can be made to determine the most economical system improvements. A complete study considering all the alternatives to improve system performance add technical credibility to budgetary requests for capital improvements.

An immediate benefit from this investigation is the listing of all system components with their failure modes, frequencies, and consequences. This allows weakness in component selection to be identified prior to calculation of risk indices.

A reliability study can be conducted when alternative systems, components, or technologies are being considered to improve reliability. Changes affecting the reliability of an electrical system or component can include one or more of the following:

(1) System design
(2) Reliability of the power source
(3) Equipment selection
(4) Quality of maintenance
(5) Age of equipment
(6) Equipment operating environment
(7) Availability of spare parts

Generally, the existing system design cannot be significantly altered; however, it is possible to meet with the utility and discuss methods for increasing the reliability of service. The selection of reliable equipment and the need for additional maintenance can be evaluated from an economic standpoint. The age of equipment and the environment in which it is operated affects the probability of equipment failure.

A reliability study begins with the system configuration documented by a single-line diagram. Reliability numerics are applied to a system model identifying system outages based on component downtime and system interactions. A failure modes and effect analysis (FMEA) is used to generate a list of events that can lead to system interruption and includes the probability of each event and its consequences. An example of an FMEA table for a facility's electrical equipment is shown in Table A.6.6. The frequency of failures per year can be obtained from ANSI/IEEE 493, *Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book)*.

The information in Table A.6.6 can be analyzed using event-tree analysis or by computing a system reliability index. The event tree is used to further break down each system or component failure into a series of possible scenarios, each with an assigned probability. The outcome is a range of consequences for each event tree.

A system reliability index assigns a number (usually expressed in hours down per year) for each system configuration. The calculations for alternative system configurations can be redone until an acceptable downtime per year is obtained.

ANSI/IEEE 399, *Recommended Practice for Industrial and Commercial Power Systems Analysis (IEEE Brown Book)*, Chapter 12, provides more detailed information. In addition, there are publications that deal with reliability calculations, including TM 5-698-1, *Reliability/Availability of Electrical and Mechanical Systems for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*; TM 5-698-2, *Reliability-Centered Maintenance (RCM) for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*; and TM 5-698-3, *Reliability Primer for Command, Control, Communications, Computer, Intelligence, Surveillance, and Reconnaissance (C4ISR) Facilities*.

N **A.6.7** Performing an incident energy analysis (arc-flash study) is an important aspect to risk assessment. A risk assessment is conducted on facility electrical systems to determine the following for each designated piece of electrical equipment:

(1) Incident energy exposure at working distance
(2) Arc-flash boundary

A risk assessment is an important consideration for electrical safe work practices. Refer to NFPA *70E* and IEEE 3007.3, *Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems*, for guidance on risk assessment and selection of PPE.

The available short-circuit current and the total clearing time at each designated piece of electrical equipment is needed to perform a risk assessment. NFPA *70E* and OSHA provide the requirements. IEEE 1584, *Guide for Performing Arc-Flash Hazards Calculations*, provides suggested calculation methods.

Where the result of the incident energy analysis at a designated piece of equipment is greater than what is appropriate for the available PPE, a means to reduce the hazard level should be implemented.

The risk assessment results are field marked by a label on the equipment. The documentation for the assessment should be retained for reference and use as needed.

The assessment should be repeated if there are changes that occur that affect the arc-flash hazard, such as changes in the available short-circuit current or in the overcurrent protective devices.

The benefit of a risk assessment is being able to provide the necessary information to a qualified electrical worker so that proper safe work practices can be followed if the worker has to work on or near electrical equipment not in an electrically safe work condition.

N **A.6.8** This study should use input that can include the electrical system design, the equipment maintenance instructions, and the company's historical maintenance data, as well as results of other available studies such as reliability and risk

N **Table A.6.6 Sample FMEA Table**

System/ Component	Failure Mode	Frequency per Year	Consequence ($1000)
Breaker B1	Internal fault	0.0036	150
Transformer T1	Winding failure	0.0062	260
Motor M1	Stator damage	0.0762	225

assessment studies. The study should evaluate design and operational concepts for electrical equipment and installations that impact the safety of maintenance practices and then make recommendations for improvement. Facilities management should use this study to make implementation decisions. Design considerations to enhance operations should include the entire life cycle cost of the building or system. The initial cost for efficient use of energy and for providing an efficient maintenance environment should be considered as valuable long-term investments that support daily operations. Workspaces and systems should be designed to allow safe maintenance or urgent repair while other operations continue. System-monitoring equipment can be used for planning predictive maintenance and help prevent unplanned outages.

A maintenance-related design study should include an evaluation of various maintenance-related design element options such as, but not limited to, the following:

(1) Sufficient clearances to remove and install drawout circuit breakers
(2) Remote operating controls and remote racking for circuit breakers
(3) Lift mechanisms to allow safe removal of drawout circuit breakers
(4) Motor control centers having the capability to rack individual buckets in or out remotely
(5) Permanently mounted absence-of-voltage testers
(6) Performance of an incident energy analysis in addition to short circuit and coordination studies
(7) Design redundancy into the electrical power system to facilitate personnel to perform maintenance on equipment in an electrically safe work condition and still power the loads
(8) Motor overload relays that can be reset without exposing the worker to energized conductors or circuit parts
(9) Infrared windows to allow for testing and inspection without exposing workers to energized parts
(10) Thermal sensors for critical terminations, ultrasonic sensors in medium-voltage equipment, and partial discharge monitoring of critical cables and equipment
(11) Automatic transfer switches having maintenance bypass switches

After the risk assessment study in Section 6.6 is complete, Annex O of NFPA *70E* should be referenced for additional items that could be evaluated in the maintenance-related design study.

N **A.8.3** The following considerations should be used in determining the use of the enhanced test classification (i.e., Category 1A or 2A):

(1) Are further diagnostics required?
(2) Does another Category 1 or Category 2 test provide similar information or analysis?
(3) Is the test complex without yielding additional meaningful analysis?
(4) Is the test costly compared with other standard tests that provide similar information?
(5) How commonplace is the test procedure?
(6) Does the electrical maintenance plan require enhanced testing?
(7) What is the application of the equipment?

N **A.8.5.3** The test equipment calibration should be traceable to recognized national standards. The National Institute of Standards and Technology (NIST) is an example of such in the United States of America.

N **A.8.7** An example of providing information on the condition of maintenance is a decal system. A color-coded decal (see Figure A.8.7) could be placed on the exterior enclosure or surface of the electrical equipment or device to communicate the condition of maintenance or calibration of the tested device, under the conditions of maintenance in 8.7.1.

White Decal: Serviceable. Equipment that passes all tests satisfactorily, is electrically and mechanically sound, and is acceptable for return to service could have a white "serviceable" decal attached to the electrical equipment or device. Issues considered acceptable for the "serviceable" decal are evidence of slight corrosion, incorrect circuit ID, and missing nameplate.

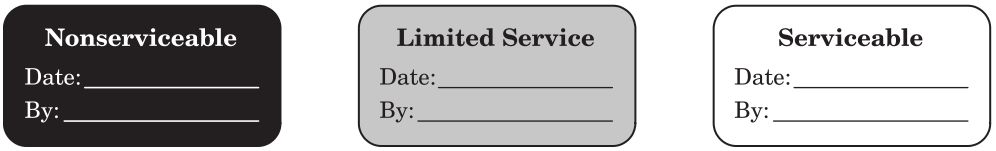
Yellow Decal: Limited Service. Equipment that has problems that are not detrimental to the protective operation or design characteristics of the equipment, such as trip targets that do not function properly, slightly lower than acceptable insulation resistance readings, and chipped arc chute, could have a yellow "limited service" decal attached to the electrical equipment or device.

Red Decal: Nonserviceable. Equipment that has a problem that is detrimental to the proper electrical or mechanical operation of the equipment, such as no trip on one or more phases, low insulation resistance readings, mechanical trip problems, and high contact resistance readings, could have a red "nonserviceable" decal attached to the electrical equipment or device.

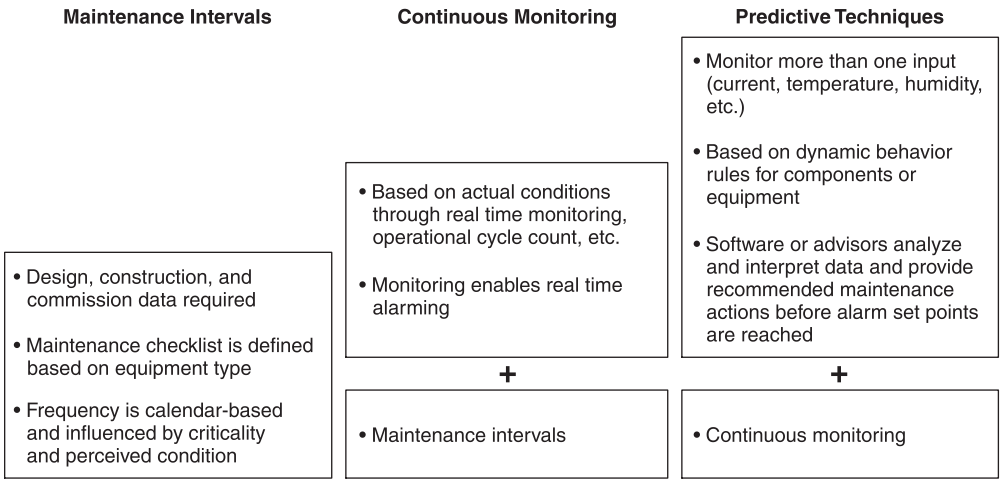
N **A.8.7.1.2** Examples of equipment that has problems that are not detrimental to the protective operation or design characteristics of the equipment are trip targets that do not function properly, slightly lower than acceptable insulation resistance readings, and chipped arc chute.

N **A.8.7.1.3** Examples of equipment that has a problem that is detrimental to the proper electrical or mechanical operation of the equipment are no trip on one or more phases, low insulation resistance readings, mechanical trip problems, and high contact resistance readings.

N **A.9.1.1** The objective of an equipment maintenance program is to maintain safe operation and production while reducing or eliminating system interruptions and equipment breakdowns. See Figure A.9.1.1 for methods that can be used to adjust maintenance intervals.



N **FIGURE A.8.7 Condition of Maintenance Test Decals.**



N FIGURE A.9.1.1 Maintenance Interval Adjustments.

N A.9.1.1.1 Maintenance intervals are used to plan inspections, testing, monitoring, analysis and service of equipment on a predetermined frequency. The interval frequency is commonly calendar-based but other possibilities, such as a frequency based on the number of switch operations, cycle count, or hours of operation can be used. The intervals can be modified based on the type, criticality, and perceived condition of the equipment.

N A.9.1.1.2 Continuous monitoring of specific equipment conditions can be performed using an uninterrupted method of data collection. Examples include the use of permanently mounted counters, sensors, or controllers to measure a condition or state inside the equipment. Multiple types of data can be continuously monitored, including voltage, current, temperature, humidity, cycle count, open/closed state, and others. The monitored data can be used to actively alert personnel to the existence of a condition that is either above or below a predetermined control limit. In many cases this data can obtained without removing covers or opening doors and without exposing workers to electrical hazards. The use of real-time data and actual performance of the equipment can be used to modify (shorten or lengthen) a predetermined maintenance interval.

Predictive techniques monitor multiple conditions in equipment using various sensors and analyze and interpret the data using analytical methods and algorithms. These proactive techniques identify trends or issues and notify personnel of recommended actions before the condition reaches an alarm point or alert them to urgent issues that are at or over a predetermined level. These technologies and methods often can detect minor items before they propagate into major issues or equipment failure.

N A.9.1.2.1.2 Statistics show that loss of production due to an emergency shutdown is almost always more expensive than loss of production due to a planned shutdown. Accordingly, the interval between inspections should be planned to avoid the diminishing returns of either too long or too short an interval.

N A.9.2.1 Manufacturer's service manuals and industry standards should have a recommended frequency of inspection. The frequency given is based on standard or usual operating conditions and environments.

N A.9.2.2 For more information on risk management, see ISO 31000, *Risk Management — Principles and Guidelines,* and Annex F of NFPA *70E*.

N A.9.3.2 A criticality assessment team should be comprised of personnel who are familiar with the electrical equipment, safety requirements, operational capabilities, potential impact of downtime, required maintenance activities, and business priorities. The team can include external expertise when needed. Some examples of the type of personnel to include in a criticality assessment include the following:

(1) The electrical foreman or superintendent
(2) Production personnel thoroughly familiar with the operation capabilities of the equipment and the effect its loss will have on quality and productivity
(3) The senior maintenance individual who is generally familiar with the maintenance and repair history of the equipment or process
(4) A technical individual knowledgeable in the theoretical fundamentals of the process and its hazards (e.g., in a chemical plant, a chemist; in a mine, a geologist)
(5) A safety engineer or the individual responsible for the overall security of the plant and its personnel against fire and accidents of all kinds

The team should review the entire plant or each of its operating segments in detail, considering each unit of equipment as related to the entire operation and the effect of its loss on safety and production. The purpose of the review is to identify failure modes and their cause and effect.

There should be objective criteria consistently used to evaluate all equipment to make a clear determination in establishing whether a system is critical and in having the proper amount of emphasis placed on its maintenance. The determination of critical parts should be the responsibility of the electrical foreman or superintendent on the team.

The entire team should consider each alarm in the system with the same thoroughness with which they have considered

the shutdown circuits. A critical alarm should be characterized by its separate sensing device, a separate readout device, and separate circuitry and power source. The maintenance department should thoroughly understand the critical level of each alarm. The critical alarms and their significance should be distinctly marked on drawings, in records, and on the operating unit. For an alarm to be critical does not necessarily mean that it is complex or related to complex action. A simple valve position indicator can be one of the most critical alarms in an operating unit.

N **A.9.3.2.1** The owner can also choose to assign criticality based on the threat to operational continuity. The criticality assessment should consider personnel exposure to electrical hazards. Electrical system criticality should be evaluated with consideration of the possible widespread effect of a fault in electrical equipment.

N **A.10.1** Hazardous location electrical equipment is used in areas that are recognized to commonly or infrequently contain ignitible vapors or dusts. Designs of hazardous location electrical equipment include, but are not limited to, explosionproof, dust-ignitionproof, dusttight, purged pressurized, intrinsically safe, nonincendive, oil immersion, and hermetically sealed. Maintenance of each type of equipment requires attention to specific items.

Explosionproof enclosures, dust-ignitionproof enclosures, dusttight enclosures, raceway seals, vents, barriers, and other protective features are required for electrical equipment in certain occupancies.

Intrinsically safe equipment and wiring is permitted in locations for which specific systems are approved. Such wiring is to be separate from the wiring of other circuits. Article 504 of *NFPA 70* describes control drawings, grounding, and other features involved in maintenance programs.

Purged and pressurized enclosures can be used in hazardous (classified) areas. NFPA 496 provides guidance useful to maintenance personnel.

N **A.10.1.2** In addition to any electrical safety assessments, classified locations require an additional analysis to determine the risk of igniting an explosive atmosphere.

To ensure that there are no ignition-capable sparks when performing maintenance, no equipment should be repaired or maintained in a hazardous location unless the equipment has been electrically isolated. If specific maintenance requires that the equipment be energized during maintenance, the work should be performed in a manner that verifies both initially and periodically that an explosive atmosphere is not present while the work is in progress or until the equipment has been reenergized and tested.

Where work is to be performed inside the classified space, the documented risk assessment should consider the safety of the tools and equipment being used to perform the maintenance activity.

N **A.10.2.2** Ignition sources can include high surface temperatures, stored electrical energy, and the buildup of static charges.

N **A.10.4.1** Other ignition sources can include static charges generated by clothing, cell phones and other electronic devices.

N **A.10.5.2.1** Special attention should be given to joints and other sealed openings in the enclosure that are intended to prevent propagation of flame. Foreign objects can prevent the proper closure of mating joints. Examples of foreign objects include the following:

(1) Caulking
(2) Sealants
(3) Unapproved gaskets
(4) Burrs
(5) Pinched gaskets
(6) Pieces of insulation
(7) Wiring

N **A.10.6.2** Damage to factory-installed seals within equipment can necessitate replacing the equipment.

N **A.10.8** Rough handling and the use of tools that pry, impact, or abrade components can dent, scratch, nick, or otherwise mar close-tolerance, precision-machined joints and make them unsafe.

N **A.10.9** When a product bearing a listing mark is modified or rebuilt after it leaves the factory where the listing mark was applied, it is unknown if the product continues to meet the applicable safety requirements unless the modification or rebuilding has been specifically investigated by the certification body. The only exception is when a listed product has specific markings for field-installed equipment or replacement components.

N **A.11.3.5** See Table A.11.3.5.

N **A.12.1.2** Some examples of related components that are not covered in this chapter include switches, circuit breakers, transformers, protective relays, batteries, and UPS.

N **A.12.3.1** *Insulators and Insulating Supports.* Insulators, insulating stand-offs, and insulating supports should be inspected for evidence of contaminated surfaces or physical damage, such as cracked or broken segments. Contaminated surfaces should be cleaned, and damaged components should be replaced. Where insulators and insulating stands-offs are not accessible, dielectric integrity tests should be used to determine the condition of dielectric properties.

Evidence of corona should be documented, and investigation of the root cause and potential for failure should be planned.

N **Table A.11.3.5 Reference Standards for the Electrical Tests Identified in Table 11.3.5**

Electrical Test	Reference Standard
Applied voltage test	IEEE C57.12.91
Sample insulating fluid and test for:	ASTM D923
Dielectric breakdown	ASTM D1816
Acid neutralization number	ASTM D974
Specific gravity	ASTM D1298
Interfacial tension	ASTM D971
Color	ASTM D1500
Visual condition	ASTM D1524
Water content	ASTM D1533
Power factor	ASTM D924
Dissolved gas analysis	IEEE C57.104
Furan analysis	ASTM D5837

All exposed conductors should be visually inspected for evidence of overheating at bolted joints and other connections, as well as for corrosion and evidence of any galvanic or chemical action that could deteriorate a connection. All bolts associated with connections that show evidence of overheating should be examined for integrity and tightness. Torque should be verified in accordance with Chapter 7. Manufacturer's instructions should be followed with respect to torque, method of termination, lubrication, and coatings.

Extreme overheating can discolor copper conductors, deteriorate the insulation, and could require additional maintenance. When the substation is de-energized, these bolted connections should be checked. There are infrared detectors that can be used on energized systems to check for overheating by scanning from a distance. Where aluminum-to-copper joints exist, they should be inspected carefully for evidence of corrosion, overheating, or looseness. In all cases, manufacturer's specifications should be followed.

Enclosures and Rooms. The security of fences and other enclosures and rooms should be checked to ensure against entry of animals or unauthorized personnel.

The gates and doors, especially where equipped with panic hardware, should be checked for security and proper operation.

The enclosed area should not be used for storage of anything other than spare parts or other assemblies needed for operations directly associated with the enclosed equipment. Such parts and assemblies should not be stored within the required working space, except where the room is large and an area has been designated for other equipment without negatively impacting working space or egress or impinging within the arc flash boundary.

Spare parts and operating assemblies stored within the area should be identified. Where applicable, the date of acquisition should be marked, any need for periodic evaluation or maintenance should be appropriately noted and planned, and the equipment should be stored per the manufacturer's recommendations.

Equipment Enclosures and Housings. All enclosures, especially arc-resistant enclosures, provide a degree of protection for nearby personnel. However, that protection is compromised if panel bolts, door latches, or any other type of fastening and cover system is not fully utilized and fully secure. This is especially true for arc-resistant equipment ratings that are used to determine the arc flash PPE requirements and the acceptable operating and maintenance practices.

Equipment enclosures should be inspected for any signs of deterioration, oxidation, impact from environmental factors, looseness or lack of fasteners, lack of proper grounding, or worn surfaces or coatings. Where noted, the as-found condition should be recorded, and proper corrective action should be taken or planned.

All equipment doors and access panels should be inspected to ensure that all hardware is in place and in good condition. Hinges, locks, and latches should be lubricated, if recommended by the manufacturer or as needed.

Screens covering ventilation openings should be determined to be in place to prevent entry of rodents or small animals.

On outdoor assemblies, roof or wall seams should be checked for evidence of leakage, and any leaking seams should be repaired. The base should be checked for openings that could permit water to drain into the interior, and any such openings should be repaired in an appropriate manner.

Moisture accumulation might occur on internal surfaces of enclosures even if they are weathertight. The source of this moisture could be condensation. Condensation is prevented by heat and air circulation.

All internal surfaces should be examined for signs of previous moisture such as the following:

(1) Droplet depressions or craters on dust-laden surfaces
(2) Excessive oxidation anywhere on the metal housing
(3) Deposits of salts from water or other liquid evaporation

Where ventilators are supplied on enclosures, including metal-enclosed bus enclosures, they should be checked to ensure that they are clear of obstructions and that the air filters are clean and in good condition. Base foundations should be examined to ensure that structural members have not blocked floor ventilation.

All enclosures and housings for circuit breakers (switchgear, switchboards, or other) should be inspected and checked for integrity of all fasteners annually or as indicated in the maintenance plan.

All ventilation openings should be checked for obstructions and proper operation of any flap or automatic cover intended to assist in arc-resistant ratings. (See ANSI/IEEE C37.20.7, *Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults.*)

Barriers, Insulation, and Insulators. Evidence of corona when the substation is energized should be documented, the root cause investigated, and the potential for failure planned.

Insulating or isolating barriers between compartments should be examined for signs of wear or looseness.

Grounded metal barriers around compartments and conductors should be examined for integrity and looseness. When barriers surround a power conductor, the barrier should be examined to ensure that the metal around the conductor is not continuous, creating eddy currents that can lead to losses and potential fire hazards.

The following specific areas in which insulation failure is more likely to occur should be inspected where they exist:

(1) Boundaries between two adjoining insulators
(2) Boundaries between an insulating member and the grounded metal structure
(3) Taped or compounded splices or junctions
(4) Bridging paths across insulating surfaces, either phase-to-phase or phase-to-ground
(5) Hidden surfaces such as the adjacent edges between the upper and lower members of split-type bus supports or the edges of a slot through which a busbar protrudes
(6) Edges of insulation surrounding mounting hardware either grounded to the metal structure or floating within the insulating member

Corona. Damage caused by dielectric stress could be evident on the surface of insulating members in the form of corona erosion or markings or tracking paths.

If corona occurs in switchgear assemblies, it is usually localized in thin air gaps that exist between a high-voltage busbar and its adjacent insulation or between two adjacent insulating members. It might form around bolt heads or other sharp projections that are not properly insulated or shielded.

Organic insulating materials, when exposed to corona discharge, initially develop white powdery deposits on their surface. These deposits can be wiped off with solvent. If the surface has not eroded, further maintenance is not required. Prolonged exposure to corona discharge will result in erosion of the surface of the insulating material. In some materials, corona deterioration has the appearance of worm-eaten wood. If the corrosion paths have not progressed to significant depths, surface repair probably can be accomplished. Manufacturer's recommendations should be followed for such repair.

Tracking. Tracking is an electrical discharge phenomenon caused by electrical stress on insulation. This stress can occur phase-to-phase or phase-to-ground. Tracking, when it occurs in switchgear assemblies, typically is found on insulation surfaces.

Tracking develops in the form of streamers or sputter arcs on the surface of insulation, usually adjacent to electrodes. One or more irregular carbon lines in the shape of tree branches are the most common sign of tracking.

Surface tracking can occur on the surfaces of organic insulation or on contaminated surfaces of inorganic insulation. The signs of tracking on organic materials are eroded surfaces with carbon lines. On track-resistant organic materials, these erosion patterns are essentially free of carbon.

Tracking can propagate from either the voltage terminals or the ground terminal. It does not necessarily progress in a regular pattern or by the shortest possible path.

Tracking conditions on surfaces of inorganic material can be completely removed by cleaning the surfaces, because no actual damage to the material occurs. In the case of organic material, the surface is damaged in varying degrees, depending on the intensity of the electric discharge and the duration of exposure. If the damage is not too severe, it can be repaired by sanding and application of track-resistant varnish in accordance with the manufacturer's instructions. Organic material that has been damaged should be replaced or repaired in accordance with manufacturer's instructions.

N **A.12.3.4** Temperatures over design levels for prolonged periods can reduce the electrical life of organic insulating materials. Prolonged exposure to higher than rated temperatures can also cause physical deterioration of the materials, resulting in lowered mechanical strength.

Localized heating (hot spots) can sometimes occur and can be masked because the overall temperature of the surroundings is not raised appreciably. Loosely bolted connections in a busbar splice or void spaces (dead air) in a taped assembly are examples of this problem.

Infrared thermography inspections can be used to detect potentially damaging heat. However, infrared inspection should not be utilized as the only method of inspection. External conditions that provide evidence of heat damage include the following:

(1) Discoloration, usually a darkening, of materials or finishes
(2) Crazing, cracking, and flaking of varnish coatings
(3) Embrittlement of tapes and cable insulation
(4) Delamination of materials or finishes
(5) Generalized carbonization of materials or finishes
(6) Melting, oozing, or exuding of substances from within an insulating assembly

Insulating materials that have been physically damaged should be replaced. Mild discoloration is permissible if the cause of overheating is corrected.

N **A.12.3.5** Online partial discharge (PD) surveys can be performed by permanently installed sensors and PD detection systems or with portable equipment. Refer to the manufacturer's instructions.

Verifying control power transformers, instrument transformers, and metering are operating correctly could require direct testing or could, in some cases, be accomplished by review of metering and other derived data.

N **A.12.3.6.1.1** Examples of dedicated maintenance or operational tools are rack-out devices, hoisting or handling apparatus, and ground and test devices.

N **A.13.1.1** Panelboards or switchboards are either fuse or circuit breaker type. Where critical circuits are involved, panelboards or switchboards should be appropriately identified by tags, labels, or color coding.

Seldom are panelboards or switchboards de-energized, and then only for circuit changes; it is for those times that electrical maintenance can be scheduled. There is always the possibility of an error or accidental tripping of a main circuit breaker causing an unscheduled shutdown. During operating periods, the panels can be checked only for hot spots or excessive heat. This electrical maintenance should be done at reasonable intervals in accordance with the importance of the circuit. A record should be made of areas that have given trouble; memory should not be relied on.

N **A.13.1.2** Examples of related components that are not covered in this chapter include switches and circuit breakers.

N **A.14.1** Additional resources and industry consensus standards that apply to busway include:

(1) UL 857, *Busways*, is a product standard that applies to busways and associated fittings rated at 600 volts or less.
(2) IEEE C37.23, *Standard for Metal-Enclosed Bus*, applies to metal-enclosed (ME) bus assemblies including nonsegregated-phase bus, segregated-phase bus, and isolated-phase bus. Rated maximum voltages of ac ME bus assemblies range from 0.635 kV through 38 kV with continuous current ratings above 600 amperes.
(3) NEMA BU1.1, *General Instructions for Handling, Installation, Operation, and Maintenance of Busway Rated 600 Volts or Less*, contains general instructions for handling, installation, operation, and maintenance of busway systems.
(4) ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*, Sections 7.4 and 7.21, contains inspection and test procedures that could be applicable to busway systems.

N **A.14.3.1** Inspect for moisture or signs of previous wetness or dripping onto the busway or onto connection boxes from leaky roofs, pipes, sprinklers, or other sources of moisture.

Seal off any cracks or openings that have allowed moisture to enter the busway or its connection boxes. Eliminate source of

any dripping onto the busway and any other source of moisture.

Where busways penetrate floors, a minimum 4-inch-high curb should be installed around the floor openings to prevent liquids from contacting the busway.

N A.14.3.2 Hydrocarbon spray propellants and hydrocarbon-based sprays or compounds can cause degradation of certain plastics and elastomers. Contact the busway manufacturer before using these products to clean, dry, or lubricate during installation or maintenance.

N A.14.3.2.1 Where combustible dust is involved, caution should be exercised to ensure that an ignition hazard is not created.

N A.14.3.3 Hydrocarbon spray propellants and hydrocarbon-based sprays or compounds can cause degradation of certain plastics and elastomers. Contact the busway manufacturer before using these products to clean, dry, or lubricate during installation or maintenance.

N A.14.3.5 *Insulation Resistance Testing for Busway Rated 600 Volts and Below.* Insulation resistance testing should be performed to ensure that the system is free from short circuits and grounds (phase-to-ground, phase-to-neutral, and phase-to-phase). Record and maintain records of the testing results.

Insulation resistance test readings vary inversely with the length of run and width or number of bars per phase. Readings will vary with humidity.

Dielectric Withstand (High-Potential) Testing for Metal-Enclosed Busway Rated over 600 Volts. Dielectric withstand (high-potential) tests in accordance with IEEE C37.23, *Standard for Metal-Enclosed Bus*, should be conducted at 75 percent of the rated insulation withstand levels shown in Table A.14.3.5. Because this might be above the corona starting voltage of some busways, frequent testing is undesirable.

N A.15.3.5 For additional information and guidance on testing molded case circuit breakers reference NEMA AB-4, *Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications.*

N A.16.3.1 Evidence of corrosion and wear can include excessive erosion of the inside of the fuse tube; physical damage to the outside of the fuse tube including cracksand cuts; discharge (tracking); dirt on the outside of the fuse tube; or improper assembly and could prevent proper fuse operation.

Fuses Rated 1000 V or Less. Early detection of overheating is possible using infrared examination. If evidence of overheating exists, the cause should be determined. Fuses showing signs of deterioration, such as discolored or damaged casings or loose terminals, should be replaced.

Fuseholders should be deenergized before installing or removing fuses. Where it is not feasible or would result in a greater hazard to deenergize the fuseholder, installation or removal of fuses should be performed only with the load removed and in accordance with appropriate safety-related work practices for the task.

Many different types of fuses are used in power distribution systems and utilization equipment. Fuses differ by performance, characteristics, and physical size. Fuses, whether new or replacement, should be verified as the proper type and rating. When fuses are replaced, fuseholders should never be altered or forced to accept fuses that do not readily fit. An adequate supply of spare fuses with proper ratings, especially those that are uncommon, minimizes replacement problems.

The most common fuse classes for 0 ampere through 600 ampere applications on power systems are Class H, Class K, Class R, Class J, Class T, Class G, Class CC, and Class L. Class H, Class K, and Class R are the same physical size and are interchangeable in standard nonrejection-style fuseholders. Class H and Class K fuses are not current limiting whereas Class R fuses are current limiting. Special rejection-style fuseholders accept only Class R fuses. Note that Class R fuses are manufactured in two types: Class RK1 and Class RK5. Class RK1 fuses are more current limiting than Class RK5 fuses and are generally recommended to upgrade older distribution systems. Class L fuses are available in the range of 601 amperes through 6000 amperes. Class J, Class T, Class G, Class CC, and Class L are size rejection fuses. One type of fuse should never arbitrarily be replaced with a different type simply because it fits into the fuseholder.

N A.16.3.5 Fuses can be tested with a continuity tester to verify that the fuse is not open. Resistance readings can be taken using a sensitive 4-wire instrument such as a Kelvin bridge or micro-ohmmeter. Fuse resistance values should be compared against values recommended by the manufacturer. Where the manufacturer's data is not readily available, resistance deviations of more than 15 percent for identical fuses in the same circuit should be investigated.

N A.17.3 For additional information and guidance on inspection and preventive maintenance of switches, reference NEMA KS-3, *Guidelines for Inspection and Preventive Maintenance of Switches Used in Commercial and Industrial Applications.*

N A.17.3.3 Where manufacturer's instructions are not available, electrically conductive lubrication should be of a synthetic oil-based solution and should not contain fillers or thickeners that are detrimental to contact action or resistance.

Where manufacturer's instructions are not available, electrical non-conductive lubrication should be a light viscosity, high-grade petroleum oil with formulated solvents to soften and remove contaminants and additives to displace moisture and prevent rust and corrosion.

N A.17.3.5 See NFPA 110 and NFPA 111 for further information on Line 11 of Table 17.3.5, performing functional tests for automatic transfer switches, bypass switches, and other transfer switch equipment.

N A.18.1 Electrical maintenance is the one of best ways to ensure continued reliable service from electrical cable installations. Visual inspection and electrical testing of the cable insu-

N Table A.14.3.5 Metal-Enclosed Bus Dielectric Withstand Test Voltages

Metal-Enclosed Bus Nominal Voltage (kV, rms)	Insulation Withstand Level (kV, rms)*	High-Potential Field Test (kV, rms)†
4.16	19	14
13.8	36	27
23.0	60	45
34.5	80	60

*Test duration is 1 minute.

†Field test voltage is 75 percent of insulation withstand level.

lation are the major maintenance procedures. However, it should be stressed that no amount of maintenance can correct improper application or physical damage done during installation.

N A.18.3.1 If, in addition to the visual inspection, cables are to be touched or moved, they should be in an electrically safe work condition.

Cables in vaults should be inspected for sharp bends, physical damage, excessive tension, oil leaks, pits, cable movement, insulation swelling, soft spots, cracked jackets in nonlead cables, damaged fireproofing, poor ground connections, deterioration of metallic sheath bonding, as well as corroded and weakened cable supports and the continuity of any main grounding system. Terminations and splices of nonlead cables should be inspected for tracking or signs of corona. The ground braid should be inspected for corrosion and tight connections. The bottom surface of the cable should be inspected for wear or scraping, due to movement, at the point of entrance into the vault and where it rests on the cable supports.

The vault should be inspected for deterioration of the concrete, both internal and above ground. In some instances, the vault can be equipped with drains that might require cleaning. In some instances, it might be necessary to pump water from the vault prior to entrance. A vault should not be entered unless a test for dangerous gas has been made and adequate ventilation is provided. The inspection crew should always consist of two or more persons with at least one remaining outside the vault, and the rules and regulations for confined space entry should be followed. [See OSHA requirements in 29 CFR 1910.146, "Permit-Required Confined Spaces," for practices and procedures to protect employees from the hazards of entry into permit-required confined spaces, and 29 CFR 1910.269(e), "Electric Power Generation, Transmission, and Distribution, Enclosed Spaces," for enclosed space entry.]

Potheads, a type of insulator with a bell or pot-like shape typically used to connect underground electrical cables to overhead lines, should be inspected for oil or compound leaks and cracked or chipped porcelain. The porcelain surfaces should be cleaned, and if the connections are exposed, their tightness should be checked.

Cable identification tags or markings should be checked.

Aerial Installations. Aerial cable installations should be inspected for mechanical damage due to vibration, deteriorating supports, or suspension systems. Special attention should be given to the dead-end supports to ensure that the cable insulation is not abraded, pinched, or bent too sharply. Aerial cable installations should be inspected for animal and bird infestation. Terminations should be inspected as covered in Chapter 7.

Raceway Installations. Because the raceway is the primary mechanical support for the cable, it should be inspected for signs of deterioration or mechanical damage or if the cable jacket is being abraded or mechanically damaged. In many installations, the raceway serves as a part of the ground-fault current circuit. Joints should be inspected for signs of looseness or corrosion that could result in a high resistance. Splices and terminations should be verified as covered in Chapter 7.

N A.18.3.5 A preferred testing method should be selected only after all circuit parameters have been analyzed.

Electrical Testing. When performing electrical testing of cables, there are many factors that need to be considered before applying a specific test methodology. The two most commonly used tests for cable insulation are insulation resistance testing and dc over-potential testing. Other tests are listed in ANSI/IEEE 400, *Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems Rated 5 kV and Above.* In many instances it can be desired to achieve a more comprehensive analysis of cable condition, doing so with techniques and methods other than insulation resistance.

Inspection and Testing Records. Because inspection intervals normally are 1 year or more, comprehensive records are an important part of any maintenance program. Comprehensive records should be arranged to facilitate comparison from year to year.

N A.20.3.1 Common mode noise voltages can develop when the equipment-grounding conductor and the grounded conductor are not effectively bonded. Common mode noise can be produced in wiring without an equipment-grounding conductor and without electrically continuous raceway. Ground loops can be undesirable because they create a path for noise currents to flow. Undesirable touch potentials can result from contacting metallic surfaces that are improperly grounded. Equipment misoperation due to unequal ground potentials results in improper data communication or improper readings of transducers. Shutdown or damage of electronic equipment can be due to electrostatic discharge (ESD). Nonoperation or malfunction of protective circuit devices or voltage sag can be due to high-impedance ground-fault paths. Damage, nonoperation, or misoperation of electronic components can be caused by poor connections in the grounding path. Damage or destruction of the neutral conductor or cable shields can result from improper sizing of a high-impedance neutral grounding device. Voltage can be present on de-energized circuits during testing of these conductors. Destruction of equipment and surge protection devices can follow a voltage transient, such as a lightning strike.

Grounding of surface-mounted equipment can be accomplished by securing the equipment to a properly grounded metal outlet box. Metal outlet boxes have a location to place a grounding screw. The bare copper equipment grounding conductor in the nonmetallic sheathed cable is usually terminated under this screw.

If the outlet box is nonmetallic, the equipment grounding conductor from the equipment is connected to the equipment grounding conductor in the outlet box. For example, with suspended ceiling luminaires, grounding of the luminaire can be accomplished by using metallic wire whips or nonmetallic sheathed cable with ground between the outlet box and the luminaire.

If the wiring method utilizes a metallic armored cable wiring method or nonmetallic-sheathed cable with ground, proper connection of the wiring provides an acceptable equipment ground.

For a more complete list of possible wiring methods or if there is no equipment grounding means found, refer to *NFPA 70* for proper grounding.

N A.20.3.5 An isolation transformer has separate primary and secondary windings. The bonding jumper between the equipment-grounding conductor and the secondary grounded

conductor provides protection from common mode electrical noise.

It is recommended that a shielded isolation transformer be used where grounding is inadequate for sensitive electronic equipment. It contains an electrostatic shield between the primary and secondary windings that is connected to the equipment-grounding terminal.

See J.7.4.1. See ANSI/IEEE 1100, *Recommended Practice for Powering and Grounding Electronic Equipment (IEEE Emerald Book).*

In Table 20.3.5, tests 4, 5, and 6 are diagnostic tests. These are performed when there is reason to suspect the ground system might have been compromised. Also consider the use of a power monitor that can be installed during a maintenance interval in lieu of discrete measurements.

One example of an industry practice for conducting Test No. 4 is the ground grid integrity test found in IEEE 80, *Guide for Safety in AC Substation Grounding.*

N **A.21.1** The term *ground-fault circuit interrupter (GFCI)* is applied to describe a family of devices intended for shock protection of personnel.

Ground-Fault Circuit Interrupter (GFCI). A Class A GFCI is listed to UL 943, *Ground-Fault Circuit-Interrupters*, and is designed to protect a person from electrocution when contact between a live part of the protected circuit and ground causes current through a person's body. A GFCI disconnects the circuit when a current equal to or higher than the calibration point (4 mA to 6 mA) flows through the protected circuit to ground. It does not eliminate the shock sensation since normal perception level is approximately 0.5 mA. Additional GFCI classes are available that offer protection under other conditions.

Special-Purpose GFCI (SPGFCI). A Class C, Class D, or Class E GFCI is listed to UL 943C, *Outline of Investigation for Special Purpose Ground-Fault Circuit-Interrupters*, and is designed to protect a person from electrocution when contact between a live part of the protected circuit and ground causes current through a person's body.

Ground-Fault Protection of Equipment. A system listed to UL 1053, *Ground-Fault Sensing and Relaying Equipment*, is intended to provide protection of equipment from damaging line-to-ground fault currents by causing a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device.

Circuit breakers with equipment ground-fault protection are a combination of a circuit breaker and ground-fault protective devices designed to serve the dual function of providing overcurrent protection and ground-fault protection for equipment. They are intended to be used in accordance with Articles 426 and 427 of *NFPA 70.*

Ground-fault sensing and relaying equipment is intended to provide ground-fault protection of equipment at services and feeders. They are rated for ground current pickup levels as high as 1200 amperes.

N **A.21.3.1** *Circuit-Breaker with an Integrated GFCI.* A circuit-breaker-type GFCI is designed in the form of a small circuit breaker and is completely self-contained within the unit housing. The circuit-breaker-type GFCI provides overload and short-circuit protection for the circuit conductors in addition to ground-fault protection for personnel. It is intended to be mounted in a panelboard or other enclosure.

Receptacles with an Integrated GFCI. A receptacle-type GFCI is designed in the form of a standard receptacle, is completely self-contained within the unit housing, and does not provide overload or short-circuit protection. It is intended for permanent installation in conventional-device outlet boxes or other suitable enclosures.

Portable Receptacles and Cords with Integrated GFCI. A portable-type GFCI is a unit intended to be easily transported and plugged into a receptacle outlet. Cords, tools, or other devices to be provided with ground-fault protection for personnel are then plugged into receptacles mounted in the unit.

Permanently Integrated, In-Equipment GFCI. A permanently mounted-type GFCI is a self-contained, enclosed unit designed to be wall- or pole-mounted and permanently wired into the circuit to be protected.

N **A.21.3.2** *Ground-Fault Sensing and Relaying Equipment.* Ground-fault sensing and relaying equipment is used to prevent damage to conductors and equipment. The protective equipment consists of three main components: (1) sensors, (2) relay or control unit, and (3) a tripping means for the disconnect device controlling the protected circuit.

Sensing Methods. Detection of ground-fault current is done by either of two basic methods. With one method, ground-fault current flow is detected by sensing current in the grounded conductor. With the other method, all phase conductor currents are monitored by either a single large sensor or several smaller ones.

Sensors. Sensors are generally a type of current transformer and are installed on the circuit conductors. The relay or control unit can be mounted remote from the sensors or can be integral with the sensor assembly.

N **A.22.3.3** OSHA 29 CFR 1926.56, "Illumination," and *The Lighting Library* (Illuminating Engineering Society of North America) provide guidance on acceptable illumination levels.

N **A.24.1** The use of wiring devices for the connection of equipment provides for rapid removal and replacement and facilitates relocation of electrical equipment.

Devices used in hazardous (classified) locations require some additional inspections. Flame paths should be inspected to ensure that safe gaps are not exceeded and that no scratches are on the ground joints. All screws holding the receptacle to the body should be installed and tight. Covers and threaded openings should be properly tightened. These devices should be checked to make sure that the plug and receptacle marking agree with the present classification of the area regarding class, group, and division.

The connection of equipment to supplies of incorrect electrical ratings of current, voltage, phase, or frequency can be dangerous or can cause damage to equipment. Therefore, attachment plugs, cord connectors, and equipment are provided with appropriate ratings and configurations to prevent interconnection that could create hazards. See ANSI/NEMA WD 6, *Wiring Devices — Dimensional Specifications*, for configurations.

Use of some of these devices to disconnect some equipment under load conditions, such as welders, and running or stalled motors can be hazardous. Other load-interrupting means intended for this purpose should be used prior to disconnecting the wiring device.

If there is abnormal heating of the receptacle, plug, or connector insulation, the device should be checked for loose terminations or insufficient pressure between contacts and terminations should be corrected or the device replaced. If there is arc tracking or evidence of burning of the insulation or other damage, the insulation should be replaced.

Plugs should fit firmly when inserted into the mating connector or receptacle. Insufficient mating force can result in contact erosion caused by arcing of the contacts or accidental disengagement. The connector or receptacle should be checked to ensure that adequate contact pressure is present. The complete interior should be replaced if there is discoloration of the housing or severe erosion of the contact.

Receptacle contacts should retain inserted plugs firmly. Corroded, deformed, or mechanically damaged contacts should be replaced.

All mounting and assembly screws must be present and checked to ensure that they are tight to ensure proper grounding, prevent the entrance of adverse environmental products, and provide cable retention.

Proper wire connections on receptacles and proper polarity of power connection, including the integrity of the equipment grounding conductor, should be confirmed.

The equipment grounding conductor (green insulation) of the cord must be attached to the grounding terminal of the device, thereby ensuring grounding continuity.

N A.25.1.1 There are two basic types of UPS systems: static and rotary. Some systems are hybrid versions that incorporate some features of both.

A static unit rectifies incoming ac power to dc and then inverts the dc into ac of the proper voltage and frequency as input power to the load. A battery bank connected between the rectifier and inverter sections ensures an uninterrupted supply of dc power to the inverter section.

A basic rotary system is essentially a motor-generator set that provides isolation between the incoming power supply and the load and stabilizes power supply aberrations by flywheel mechanical inertia effect.

In the UPS industry, the term *module* refers to a single self-contained enclosure containing the power and control elements needed to achieve uninterrupted operation. These components include transformers, rectifier, inverter, and protective devices.

UPS systems can comprise one or more UPS modules connected in parallel either to increase the capacity of the system power rating or to provide redundancy in the event of a module malfunction or failure. Figure A.25.1.1(a) illustrates a typical single-module static 3-phase UPS configuration. Note that in this configuration the solid-state switch (SSS) is internal to the UPS module.

Figure A.25.1.1(b) illustrates a typical multimodule static 3-phase UPS configuration. Note that in this configuration the SSS is in the stand-alone static transfer switch (STC) control cabinet.

Almost all UPS systems comprise these common elements: disconnecting means, bypass and transfer switches, protective devices and power switchgear, molded-case circuit breakers, and fuses. Depending on the type of UPS (static, rotary, or hybrid), the system might also include transformers, batteries, a battery charger, a rectifier/inverter unit (static system), and a motor-generator set (rotary system). The system might also be supported by a standby generating unit to permit operations to continue during sustained power outages.

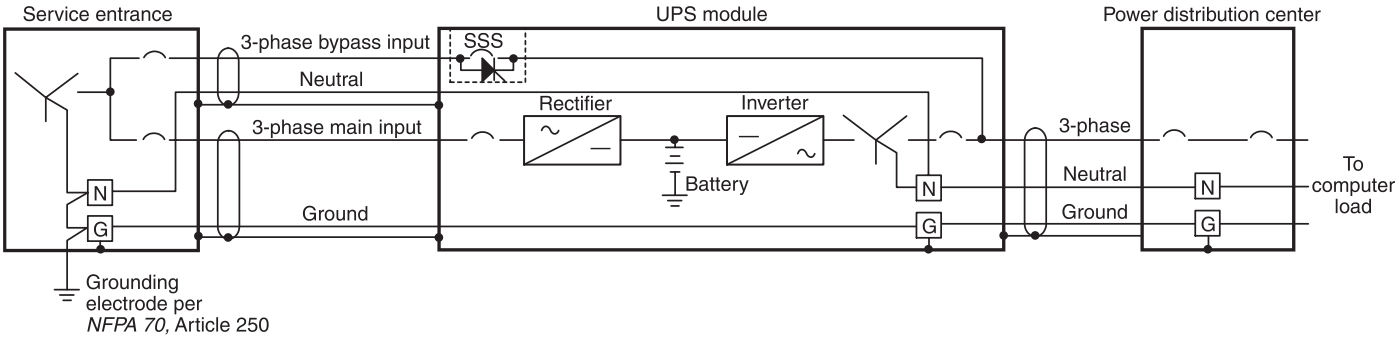
N A.25.4.2.2.1 Recommended load steps for determining UPS output stability are expressed as a percentage of the UPS system rating, as follows:

(1) 0 percent to 100 percent to 0 percent
(2) 25 percent to 75 percent to 25 percent
(3) 50 percent to 100 percent to 50 percent
(4) 0 percent to 100 percent to 0 percent

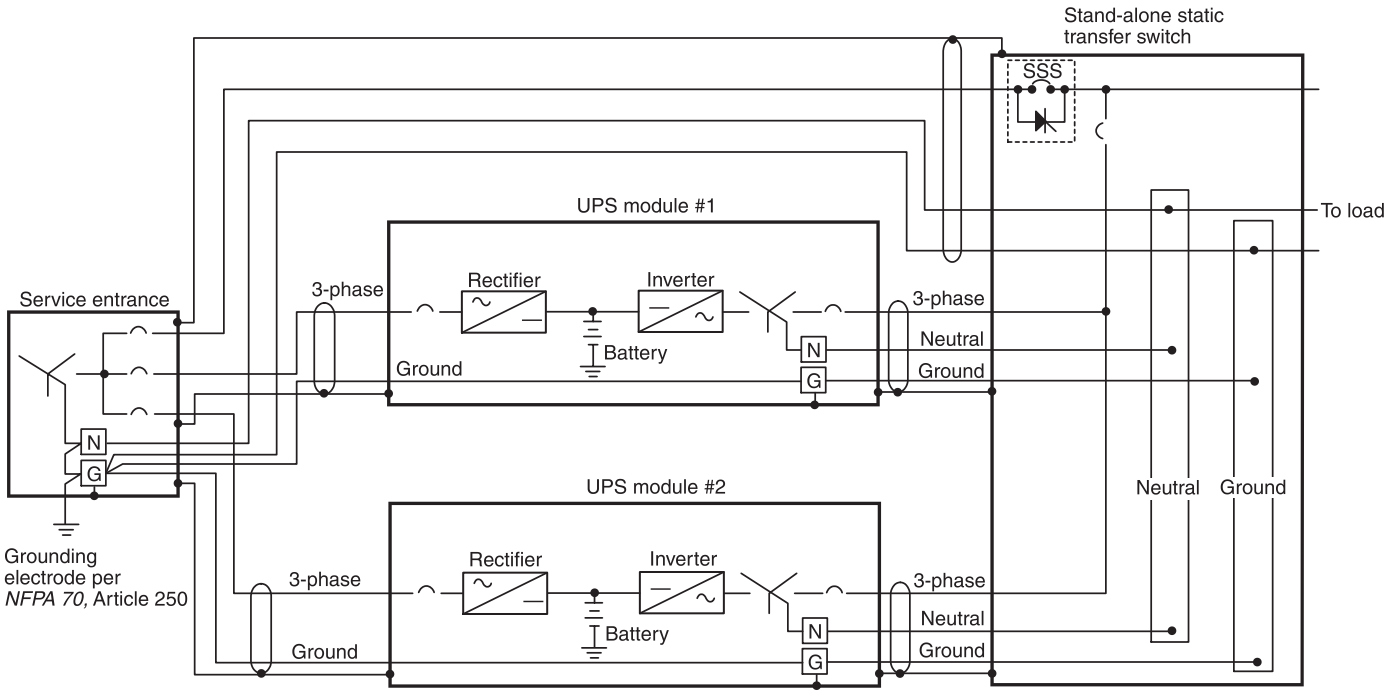
N A.27.1 Information on generator sets can be found in NFPA 110.

N A.27.3.1 In general, the machine should be observed while in operation, if safely possible, and any evidence of maloperation should be noted as an aid to future repairs.

If applicable, bearing oil level should be observed by means such as a sight glass or constant level oiler and oil added as needed (see A.27.3.3). If oil rings are used, free turning of the rings should be checked on starting a new machine, at each inspection period, and after maintenance work. The oil level should be such that a 90-degree segment of the oil ring on the inside diameter is immersed while the machine shaft is at rest,



N FIGURE A.25.1.1(a) Typical Single-Module Static 3-Phase UPS Configuration.



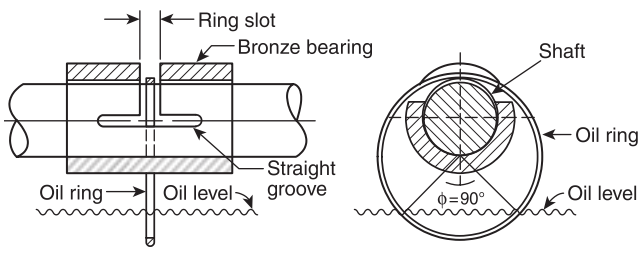
N FIGURE A.25.1.1(b) Typical Multimodule Static 3-Phase UPS Configuration.

as shown in Figure A.27.3.1. A sight glass, constant level oiler, or some other unit should be provided to mark and observe the oil level. Levels should be marked for the at-rest condition and the operating condition.

Large, vertical motors frequently have a surrounding oil bath for lubrication of either rolling-element bearings or plate-thrust bearings. Horizontal units equipped with ball and roller bearings might also have an oil bath. The proper oil level is determined by the manufacturer and depends on the bearing system. A sight glass or some other unit should be provided to mark and observe the oil level. This level can change depending on whether the motor is operating or at rest, and it should be marked for both situations.

For oil-mist lubrication systems the drain/discharge openings at each bearing should be checked to see that pressure can be discharged freely to the atmosphere and that the mist pressure–regulation equipment is functioning properly.

N A.27.3.2 Where rotating equipment is exposed to dirt, regular inspections should detect when cleaning is needed. The external surface of motors should be kept clean because a pileup of dirt restricts heat dissipation.



N FIGURE A.27.3.1 Ring Oiling.

Machines that have been clogged with mud from dust storms, floods, or other unusual conditions should be given a thorough water washing, usually with a hose with pressure not exceeding 1.72 kPa (25 psi). Initial cleaning should be made with hot nonsaline water plus detergent, followed by a rinse with hot nonsaline water (no detergent). The machine should be completely dismantled, terminal boxes opened, and all corroded parts identified for repair or replacement. All components that are to be reused should be washed in a tank of hot, fresh, nonsaline water for at least four hours. The winding insulation resistance should be measured with a megohmmeter every 2 hours until the insulation resistance has stabilized. Allow the insulation to cool in a dry environment to avoid moisture absorption. Sleeve bearings and housings should be cleaned and rolling element bearings should be replaced with the same type as originally supplied with the machine.

Drying Methods. The commonly used methods are external heat or internal heat. External heat is preferred because it is the safer application. Forced hot air can be heated electrically, by steam, or by a controlled gas burner. Electric space heaters or infrared lamps can also be used. They should be distributed so as not to overheat any machine components.

Coil insulation can be dried by circulating current through the winding. There is some hazard involved with this method because the heat generated in the inner parts is not readily dissipated. This method should be followed only under competent supervision.

N A.27.3.2.2 One reference for minimum insulation resistance levels is ANSI/IEEE 43, *Recommended Practice for Testing Insulation Resistance of Rotating Machinery.*

N A.27.3.3 Oils for lubricating rotating equipment should be high-quality circulating oils with rust and oxidation inhibitors.

The oil viscosity required for optimum operation is determined by the machine speed and operating temperature. The motor manufacturer's recommendations relative to oil viscosity should be followed. Oil mist lubrication systems normally have interlocked controls such that the source of mist pressure must be in operation to permit energization of the lubricated motor.

Machines with Sleeve Bearings. If the bearings can be relubricated, the oil should be drained, the bearings flushed, and new oil added.

Machines with Rolling Element (Ball or Roller) Bearings. Grease is the most common lubricant used for rotating equipment bearings. It provides a good seal against the entrance of dirt and moisture into the bearings, has good stability, is easy to apply, and is easy to contain without elaborate seals. Motors with sealed bearings should not be lubricated.

Grease should be selected based on the expected temperature range of service. A grease that is compatible with the grease already in the bearing should be used. Where special instructions regarding the type or quantity of lubricant are recommended by the manufacturer, they should be followed. For extended service intervals, an extremely stable grease is required. The motor manufacturer can provide advice on a specific grease to use.

The correct quantity of lubricant in a rolling element bearing should be used to assure proper operation.

Machines equipped with grease fittings and relief plugs should be lubricated by a low-pressure grease gun using the following procedure:

(1) The pressure-gun fitting and the regions around the motor grease fittings should be wiped clean.
(2) The relief plug should be removed, and the relief hole should be freed of any hardened grease.
(3) Grease should be added with the machine at standstill until new grease is expelled through the relief hole.
(4) The machine should be run for about 10 minutes with the relief plug removed to expel excess grease.
(5) The relief plug should be cleaned and replaced.

Observation at the time of greasing should determine whether the bearings are operating quietly and without undue heating.

N **A.27.3.4** Where possible, bearings, gears, and couplings should be uniformly preheated before installation to minimize damage. All rotating elements should be dynamically balanced to within standard tolerance.

All rotating equipment should be properly aligned at operating temperature when installed. Rim and face or reverse indicator methodology should be used. Dial indicators or laser alignment equipment should be used for alignment.

Machines with Brushes. If safely possible, the following should be performed offline:

(1) Check brushes in holders for fit and free play, and those that are worn down almost to the brush rivet should be replaced.
(2) Inspect brush faces for chipped toes or heels and for heat cracks; replace damaged brushes.
(3) Check the brush spring pressure and readjust in accordance with the manufacturer's instructions; constant tension springs with incorrect tension should be replaced.
(4) Check that brush shunts are properly secured to brushes and holders.

Machines with Collector (Slip) Rings. The ring surface should be smooth and concentric. If the rings are worn or eccentric, they should be machined to restore smoothness and concentricity.

Machines with Commutators. Commutator concentricity should be checked with a dial indicator if it is suspected that the commutator is out of round. If the commutator is out of round, it should be machined to concentricity. The commutator surface should be examined for high bars, grooving, evidence of scratches, roughness, and excessive filming. In light cases of surface roughness, several surface rounding brushes can be installed; for extreme roughness, turning the commutator in the lathe should be performed. If there is high mica between bars, the commutator should be turned and undercut. After servicing a commutator, it should be completely clean with traces of copper, carbon, or other dust removed. One reference for servicing commutators is ANSI/EASA AR100, *Recommended Practice for the Repair of Rotating Electrical Apparatus.*

Vibration analysis equipment is useful in isolating the source of vibration that might appear to be the result of other malfunctions within a machine. It is also useful for ensuring proper installation of critical production equipment. Today there are computerized data collecting analyzers that store vibration spectrums, using fast fourier transform (FFT) methodology. In addition to detecting vibration due to unbalance, FFT analysis of the instruments can identify faults in stator windings, rotor bars and end rings, and bearings.

A formal vibration analysis program can reduce costly machine failures. The program can range from the use of simple handheld analyzers to sophisticated multichannel recorders with permanently mounted sensors to provide data for comparison. Such a program makes it possible to keep track of the condition of rotating equipment, particularly high-speed types. Trend charts assist in establishing maintenance needs.

The most common methods of measuring vibration are in units of velocity. Velocity measurements are in millimeters per second or inches per second. Vibration is usually measured at the bearing housing.

Displacement is generally used as an indicator of vibration severity for both low-speed equipment operating at less than 1200 rpm and low-frequency vibration. When measured as displacement, the units are microns peak-to-peak or mils peak-to-peak. Velocity is independent of machine speed and therefore a better general indicator of overall vibration severity. Suggested vibration limits for machines are specified in Table A.27.3.4.

N **A.27.3.5** In addition to the electrical tests in Table 27.3.5, if applicable, a resistance check should be done to ensure that bearing insulation is not short-circuited by bearing temperature detectors or by lubricating-oil piping. This type of check might require uncoupling the machine or lifting the noninsulated end (after disassembling the bearing) of the shaft if both bearings are not insulated.

N **A.29.1.1** NFPA *70E* contains additional requirements on the use and maintenance of portable cord-and-plug connected electrical equipment.

N Table A.27.3.4 Vibration Severity Chart

Velocity rms					
mm/sec	in./sec	Class 1	Class 2	Class 3	Class 4
0.71	0.028	A	A	A	A
1.12	0.044	B	A	A	A
1.8	0.071	B	B	A	A
2.8	0.110	C	B	B	A
4.5	0.177	C	C	B	B
7.1	0.279	D	C	C	B
11.2	0.440	D	D	C	C
18.0	0.708	D	D	D	C
28.0	1.10	D	D	D	D

Notes:
(1) Class 1: up to 20 hp on fabricated steel foundation; Class 2: 25 hp–100 hp on fabricated steel foundation, 100 hp–400 hp on heavy solid foundation; Class 3: above 400 hp on heavy solid foundation; Class 4: above 100 hp on fabricated steel foundation.
(2) Grade A: good; Grade B: usable; Grade C: just acceptable; Grade D: not acceptable.

N A.29.3.1.1 Visual inspections are aimed at detecting signs of damage. This could also include the mechanical adjusting and tune-up of equipment and the detection and correction of small problems before they become major problems. Items requiring attention should be reported, removed from use, and tagged "Do Not Use."

N A.29.3.5 Tool and appliance testers are available to perform these tests quickly and easily.

N A.30.1 A solar photovoltaic (PV) electrical energy system is a renewable source of energy. The major electrical system components include the array circuit(s), inverter(s), and controller(s). The arrays are generally found mounted either on a building roof or on supports in a ground mounted array. Photovoltaic systems can be interactive with other electrical power production sources or standalone, with or without electrical energy storage such as batteries.

Photovoltaic systems typically generate voltages in the 48 Vdc to 1500 Vdc range. Only properly trained and qualified persons should perform maintenance on PV systems due to the unique hazards associated with the arrays. The array can produce hazardous electrical energy when exposed to sunlight and even artificial light.

Energy monitoring is a primary means of determining the "health" of the array performance. Short- or long-term reductions in output power can be associated with individual module failure, dirt accumulation, or deposits of debris on the array. Obtaining performance data and monitoring the array from the time of commissioning provides a baseline performance for ongoing system analysis.

N A.30.2.1 A maintenance program helps to ensure the greatest level of safety to the maintenance worker and that the highest level of efficiency and reliability can be obtained from the operation of the system. The system owner or maintenance personnel should consider performing maintenance during the nighttime, during periods of low moonlight and with minimal artificial light illuminating the array. This helps to reduce electrical hazards and lost production.

N A.30.2.2 Significant weather, such as hail, heavy snow, high winds, driving rain, or lightning, can adversely impact PV systems and their associated equipment. The priority is to render the site physically and electrically safe by tying down loose items and disconnecting exposed circuits and ground faults.

N A.30.3.1 Proper signage should be installed to identify the location of rooftop panels on the building prior to completion of installation. Marking on conduits and enclosures is needed to provide guidance for maintenance and emergency personnel to isolate the PV electrical system. This can facilitate identifying energized electrical lines that connect the solar modules to the inverter, which can be energized even when the inverter is offline. See also *NFPA 70*, Article 690.

N A.30.3.2 See *NFPA 70*, Article 690.

N A.30.4.1 See IEC 62446-2, *Photovoltaic (PV) systems — Requirements for testing, documentation and maintenance — Part 2: grid connected systems — Maintenance of PV systems.*

N A.30.4.2 PV systems and their associated equipment can be damaged when cleaned improperly. The following precautions should be considered:

(1) Cold water should never be applied to a hot PV array as thermal shock can damage the modules.
(2) Cleaning robots and systems should be validated with the system owner and designer as acceptable for the climate, environment, and module types.
(3) Water or cleaning solutions should not be applied to damaged or cracked modules.

N A.30.4.5 *Infrared thermography (IR):* This noncontact electrical test can be performed on photovoltaic modules, strings, systems, and/or associated wiring connections. The modules or systems must have current flowing to acquire useful data. These images can identify potential issues, including failed modules, high-resistance connections, cell hot spots, and interconnection issues.

IV curve trace — current and voltage (IV) tracing: This electrical testing is used to determine output and electrical parameters of photovoltaic modules, strings, and systems. Tests are conducted on electrically isolated photovoltaic devices. Electrical parameters are evaluated, including open circuit voltage, short-circuit current, maximum power, maximum power voltage, and maximum power current. This test can give an accurate snapshot of the health of the module, string, or system.

Electroluminescence imaging (EL): This noncontact electrical test is a useful tool to find and identify cracked cells in deployed crystalline or wafer-based photovoltaic modules. Depending on the equipment used, the modules or strings might need to be isolated to acquire useful images. Cracks in cells can contribute to power loss.

N A.31.3.1 See additional lightning protection requirements in NFPA 780 and applicable FAA requirements.

N A.32.1.2 All other chemistries and lead-acid and NiCd stored energy systems that do not fall under 36 are covered by Chapter 32.

N A.34.3.1 Any components found to be excessively corroded should be repaired or replaced. Leaks should be mitigated, or ventilation should be added or corrected as needed. Missing motor nameplates should be replaced. Electrically operated

pool pumps should be listed and labeled. Overhead conductor clearances should be in accordance with 680.9(A) of *NFPA 70*. Any components found to be excessively corroded should be repaired or replaced. Leaks should be mitigated, or ventilation shall be added or corrected as needed. Missing motor nameplates should be replaced. Electrically operated pool pumps should be listed and labeled. Overhead conductor clearances should be in accordance with 680.9(A) of *NFPA 70*.

N **A.34.3.2.2** Simple cord surface discoloration from pool chemicals is not considered physical damage.

N **A.34.3.2.3** The maximum resistance value permitted between the luminaire and niche is 0.0003 ohms.

N **A.36.1** See Chapter 32 for installations that do not meet the definition of stationary standby batteries or are comprised of cells other than lead-acid or NiCd. See Chapter 32 for installations that do not meet the definition of stationary standby batteries or are comprised of cells other than lead-acid or NiCd.

Battery Hazard Awareness. Personnel should be aware of the types of hazards associated with stationary batteries, such as flammable/explosive gas hazards, chemical hazards, electric shock hazards, and arc flash/thermal hazards. Not all stationary batteries have the same types or degrees of hazards. Personnel must understand the potential hazards and do a risk assessment prior to any work. Personnel should also follow the manufacturer's instructions. IEEE 1657, *Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries*, provides recommended curriculum for various skill levels.

Flammable Gas Hazard. Lead-acid and NiCd batteries will emit hydrogen gas, and if not vented the hydrogen concentration will reach a flammable level. Where lead-acid and NiCd batteries are charging, the following steps should be taken:

(1) Verify that the ventilation system in the room or compartment where the batteries are located is operating as required, including both the intake and exhaust systems.
(2) Prevent the use of open flames, sparks, and other ignition sources in the vicinity of storage batteries, gas ventilation paths, and places where flammable gas can accumulate.

AC and DC Voltage Hazard. Voltage is always present on battery systems, so the safety procedures in *NFPA 70E* and IEEE 3007.3, *Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems*, for energized equipment should be followed. Voltages present on large systems, including chargers, can cause injury or death. Personnel should determine the voltages that are present, use insulated tools, and use PPE as appropriate. Conductive objects should not be used near battery cells.

Chemical Hazard. Electrolyte can cause severe injury to the eyes and mucus linings and can cause rash or burns to skin if not treated promptly. Not all battery maintenance activities expose personnel to electrolyte, so the service person must understand the potential exposure as part of the risk assessment prior to doing any work on a battery system.

Arc Flash and Thermal Hazard. Prior to performing the task, personnel should perform a risk assessment and note the potential arc flash and thermal hazards, which should be already posted, and wear the appropriate level of PPE. Measures to avoid arc flash can include separating the battery into low-voltage segments and ensuring that positive and negative conductive paths are not exposed at the same time.

N **A.36.3.1** Measurements and inspections will vary from one type of battery to another. Two examples of battery records for one type of battery, VRLA, are shown in Figure E.21(a) and Figure E.21(b). The records should be modified to correspond to the user's maintenance program.

N **A.36.4** Applicable industry maintenance standards include the following:

(1) ANSI/NETA ATS, *Standard for Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems*
(2) ANSI/NETA MTS, *Standard for Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems*
(3) ANSI/IEEE 450, *Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*
(4) IEEE 1106, *Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Application*
(5) IEEE 1188, *Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*
(6) IEEE 1578, *Recommended Practice for Stationary Battery Electrolyte Spill Control and Management*
(7) IEEE 1657, *Recommended Practice for Personnel Qualifications for Installation and Maintenance of Stationary Batteries*

N **A.36.4.1** Battery chargers play a critical role in maintaining batteries because they supply normal dc requirements and maintain batteries at appropriate levels of charge.

A solution of water and bicarbonate of soda (baking soda) can be used to neutralize lead-acid battery spills, and a solution of boric acid and water can be used for Ni-Cad spills. The battery manufacturer's instructions should be consulted for proper proportions. Information on prevention of and response to electrolyte spills can be found in IEEE 1578, *Recommended Practice for Stationary Battery Electrolyte Spill Containment and Management.*

Excessive water consumption can be a sign of overcharging or cell damage. For lead-antimony batteries, including low-antimony designs such as lead-selenium, water consumption increases gradually with age. Distilled or deionized water needs to be used unless otherwise recommended by the battery manufacturer.

CAUTION: Never add anything but water to a battery unless recommended to do so by the manufacturer.

Local sources of heating and cooling can create cell temperature differentials that cause battery damage.

If deionized water is used, it is important to check for proper operation of the deionizer (or if deionizing filters need replacement).

Excess sedimentation and plate damage can be caused by any of the following:

(1) *Vibration caused by an external source.* Vibration reduces battery life. Excessive vibration can be detected by observing vibration of plates and sediment in the jar. If vibration is observed, then steps should be taken to reduce the vibration source, isolate the batteries from the vibration,

and/or plan for an earlier-than-normal scheduled battery replacement.

(2) *Incorrect charging regimes.* The charger settings should be set to the battery manufacturer's recommended voltage range. If not, they should be adjusted as appropriate.

(3) *Excessive cycling.* The cause of excessive discharge/recharge cycles should be determined and corrected, if possible. Otherwise, it might be necessary to plan for an earlier-than-normal battery replacement.

(4) *Aging.* The battery date codes should be noted, and it should be determined if the observed condition is within the predicted condition for a battery of that age.

(5) *Manufacturing defect.* If the battery is relatively new, or if the condition is only observed in one or a few cells within the same manufacturing "batch number," the manufacturer should be contacted for possible warranty replacement.

(6) *AC ripple current from charger or connected load.* Readings should be taken to determine if the amount of ripple current exceeds the manufacturer's recommended limit.

N **A.36.4.2** Lead-acid battery surfaces should be cleaned with a solution of water and sodium bicarbonate to avoid leakage currents caused by electrolyte on the battery. NiCd battery surfaces should be cleaned with a solution of boric acid and water. Cleaners, soaps, or solvents should not be used to clean battery containers and covers since damage can result. Consult the battery manufacturer for the proper solution and dilution.

N **A.36.4.5** Inspection results should be recorded to establish trends that can be used in predicting state of health for a battery or batteries.

For VRLA batteries, cell temperature should be obtained by measuring at the negative post of the unit.

For vented batteries in which electrolyte samples are being collected, electrolyte temperature could be determined at the same time.

Use of ohmic measurements should be in accordance with the manufacturer's instructions and with an EMP to set baselines, identify trends, and identify anomalies.

Connections should only be tightened when the need is indicated by resistance readings or infrared scan.

Where a connection resistance persists high, the connection should be cleaned and torqued in accordance with the manufacturer's procedures.

Where test sets to read intercell connection resistance are not available or cannot be used due to inaccessible posts, an infrared scan should be performed while under load to indicate which connections need to be corrected to the battery manufacturer's specified values and repaired.

For batteries that require periodic water additions, the electrolyte levels should be checked on a periodic basis. If the level is approaching the low-level line, distilled or other approved-quality water should be added.

Float current can be measured with a calibrated amp clamp at any point in a series connected battery string. The amp clamp needs to be accurate to currents below one amp. An alternate method could be using a calibrated voltmeter with a calibrated shunt installed in-line with the battery strings, which would be accurate for currents below one amp.

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Annex B Suggestions for Inclusion in a Walk-Through Inspection Checklist

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 General. The items suggested in this annex are directed toward minimizing day-to-day electrical hazards. The list is not complete, nor do the items necessarily appear in order of importance. It is presented as a guide for the preparation of a checklist that should be developed for each facility.

Δ **B.1.1 Flexible Cords (Including Those on Appliances).** An inspection should be made for badly worn or frayed spots, splices (not permitted), improper type, or current-carrying capacity that is too small.

Δ **B.1.2 Plugs and Connectors.** Plugs and connectors should be grounding type where required for specific appliances.

B.1.3 Extension Cords. Are extension cords used in place of permanent wiring, and are they of excessive length and of proper type? They should not pass through walls, partitions, or doors.

B.1.4 Multiple Current Taps. Are multiple current taps used because of too few receptacles? In particular, are they used in areas such as canteens, lunchrooms, and offices?

Δ **B.1.5 Appliances.** Grills, toasters, and similar equipment should be spaced from combustible material.

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B.1.6 Office Equipment. The condition of flexible cords, plugs, and connectors should be checked, and excessive use of extension cords and multiple current taps should be noted.

Δ **B.1.7 Receptacle Outlets.** Grounding-type receptacles are generally required. Are special receptacle configurations used for those supplying unusual voltages, frequencies, and so on? Are they well marked or identified? In particular, missing faceplates, receptacles showing signs of severe arcing, loose mounting, and so on should be noted.

Δ **B.1.8 Portable Equipment (Tools, Extension Lamps, and Extension Cords).** The condition of cords and plugs should be inspected, and any defective equipment should be removed from service. The condition of guards and shields on lamps should be checked.

Δ **B.1.9 Luminaires.** No luminaire should be located close to highly combustible material. The location of luminaires with burned out bulbs or tubes; luminaires that are heavily coated with dust, dirt, or other material; and reflectors that need cleaning should be noted.

B.1.10 Equipment Grounding. Broken or loose connections at boxes and fittings, flexible connections, and exposed ground straps should be identified. Multiple bonding of conduit and other metallic enclosures to interior water piping systems, including sprinkler systems, is sometimes used as a precaution where building vibration is severe, even though a separate equipment grounding conductor is run with the circuit conductors inside the raceway.

Δ **B.1.11 Yard Transformer Stations.** The condition of transformers, fence, gates, and locks should be noted. Yard and equipment should be free of storage of combustible material, weeds, grass, vines, nests, and so on. Localized overheating, indicated by conductor discoloration, should be watched for.

Indication of excessive transformer temperature, pressure, or oil leakage should be noted.

B.1.12 Services. The condition of weatherheads and weatherhoods should be visually checked to determine that they remain in good condition. Nests, such as rodent, insect, and bird nests, should be documented. At the same time, the apparent condition of lightning arresters, surge capacitors, grounding conductors, and grounds should be determined. Are switches safely and readily accessible?

B.1.13 Electrical Equipment Rooms and Motor Control Centers. Electrical equipment rooms and motor control centers should be clean, used for no other purpose, and free of storage of any kind, especially combustible material. Ventilation equipment should be in working condition and unobstructed. Any unusual noises or odors should be noticed and reported promptly. Metering equipment should be checked for high or low voltage and current and any indication of accidental grounding (ungrounded systems). Are switches, disconnects, and motor controllers properly identified as to function? Are fire extinguishers in place, of suitable type, and charged?

B.1.14 Grouped Electrical Control Equipment (Such as Might Be Mounted on Walls). Is grouped electrical control equipment protected from physical damage and readily accessible? Are any equipment enclosures damaged, or do any have missing or open covers? Are any live parts exposed? Any condition that prevents quick or ready access should be reported.

Δ **B.1.15 Enclosures of Electrical Parts (e.g., Motor Control Equipment, Junction Boxes, Switches).** All loose or missing covers and unused openings in enclosures should be documented.

B.1.16 Hazardous (Classified) Location Equipment. All cover bolts should be in place and tight. Permanent markings should not be obstructed by paint. Joints between cover and case should be examined for signs of having been pried open in the removal of the cover. This might have damaged the mating surfaces of the joints. Excessive accumulations of dust and dirt should be noted for removal from all enclosures, including motors, which also should be examined for obstructed ventilation. The use of nonexplosionproof electric equipment, including lighting that might have been installed in the hazardous (classified) location area, should be noted and reported.

B.1.17 Emergency Equipment.

B.1.17.1 All exit lights should be functioning properly.

B.1.17.2 Emergency lights should all be in working condition. Periodic tests are recommended to ensure that emergency lights function when normal lighting is lost.

B.1.17.3 Emergency power supplies, such as batteries and engine-driven generators, normally receive scheduled tests. Records of periodic tests should be checked. Are fuel and cooling supplies for engine drives adequate? Are fire extinguishers in place, of proper type, and charged?

B.1.17.4 Alarm systems, such as for fire, intrusion, smoke detection, sprinkler water flow, and fire pumps, also receive periodic tests. Records of these tests should be checked to ensure that all signals are properly transmitted and that equipment is in good working condition.

Annex C Symbols

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Figure C.1 contains some typical electrical symbols that are used on electrical power and control schematic drawings.

C.2 Figure C.2 contains some typical electrical symbols that are used on electrical control schematic drawings.

C.3 Figure C.3 contains some typical miscellaneous electrical symbols and tables that are used on electrical control schematics.

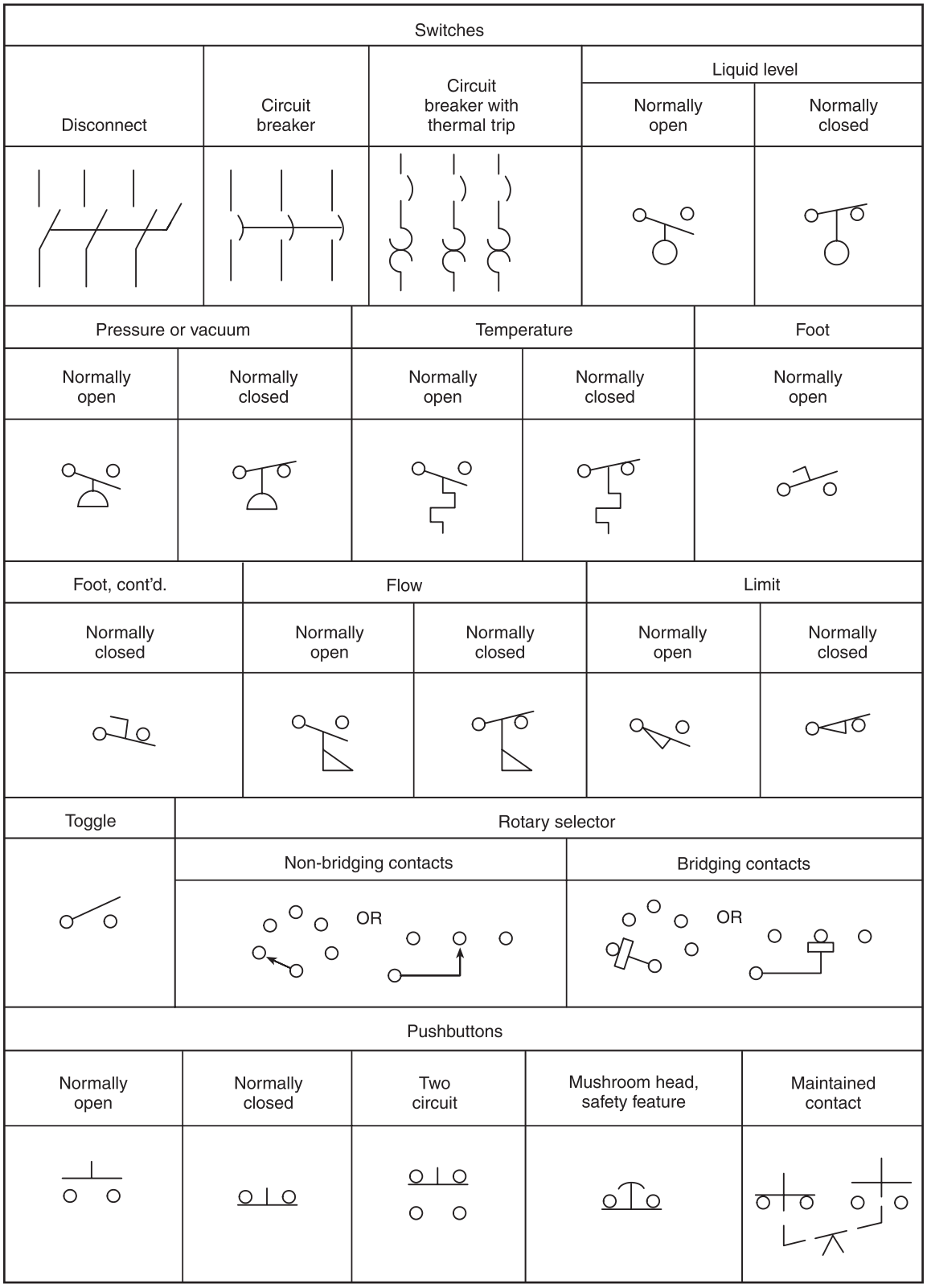


FIGURE C.1 Some Typical Electrical Symbols for Power and Control Schematics. (Courtesy of ANSI/IEEE 315, *Graphic Symbols for Electrical and Electronics Diagrams*.)

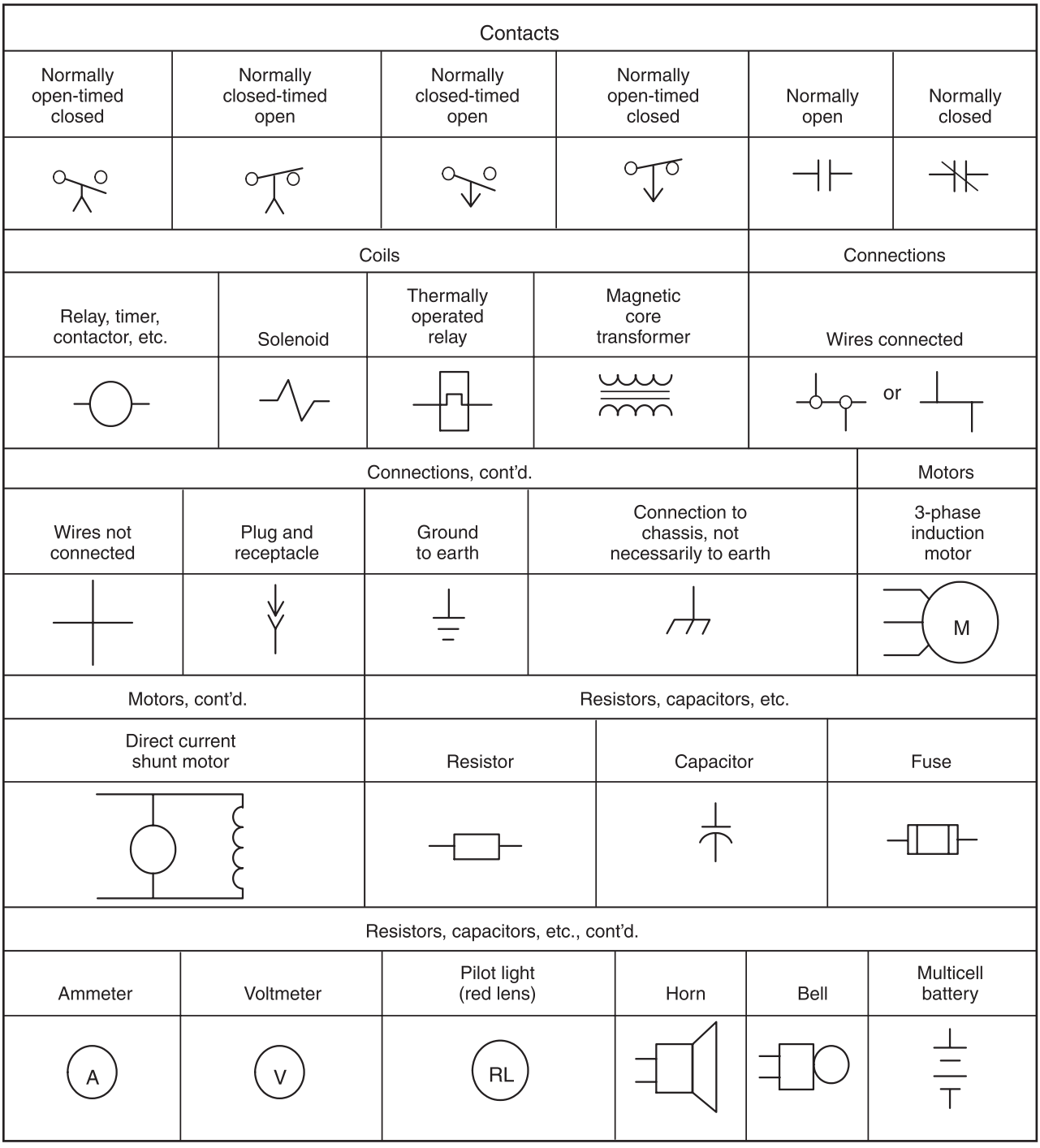
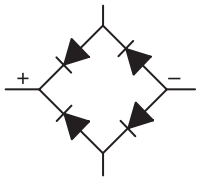
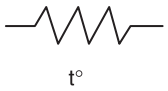


FIGURE C.2 Some Typical Electrical Symbols for Electrical Control Schematic Drawings.

Semiconductors			Miscellaneous
Rectifier diode	Rectifier bridge	Thermistor	Terminal block
			

Miscellaneous, cont'd.

Table of contact operation for control switch

Detached contacts shown elsewhere on diagram

Contact	Position		
	1	2	3
A	X		
B		X	
C			X

X — Indicates contact closed

Miscellaneous, cont'd.

Table of contact operation for drum switch (sliding contact type)

Detached contacts shown elsewhere on diagram

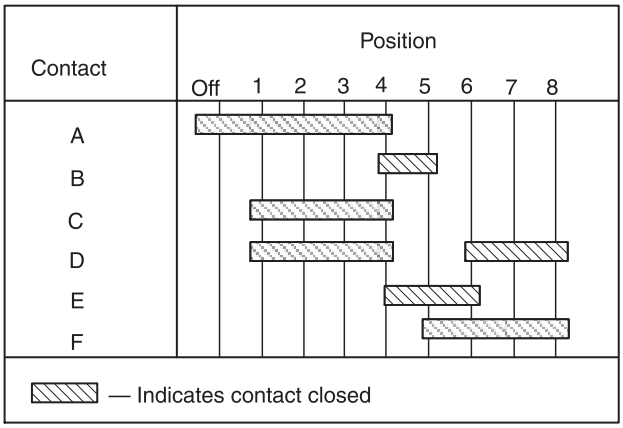


FIGURE C.3 Some Typical Miscellaneous Electrical Symbols.

Annex D Diagrams

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

D.1 Note that Annex D is presented to show use of symbols and should not be construed to indicate recommendations. Figure D.1 shows the use of some typical symbols in a single-line power distribution program.

D.2 Figure D.2 shows a wiring diagram for a reversing starter with control transformer.

D.3 Figure D.3 shows a power and control schematic for a reversing starter with low-voltage remote pushbuttons. Forward, reverse, and stop connections are shown.

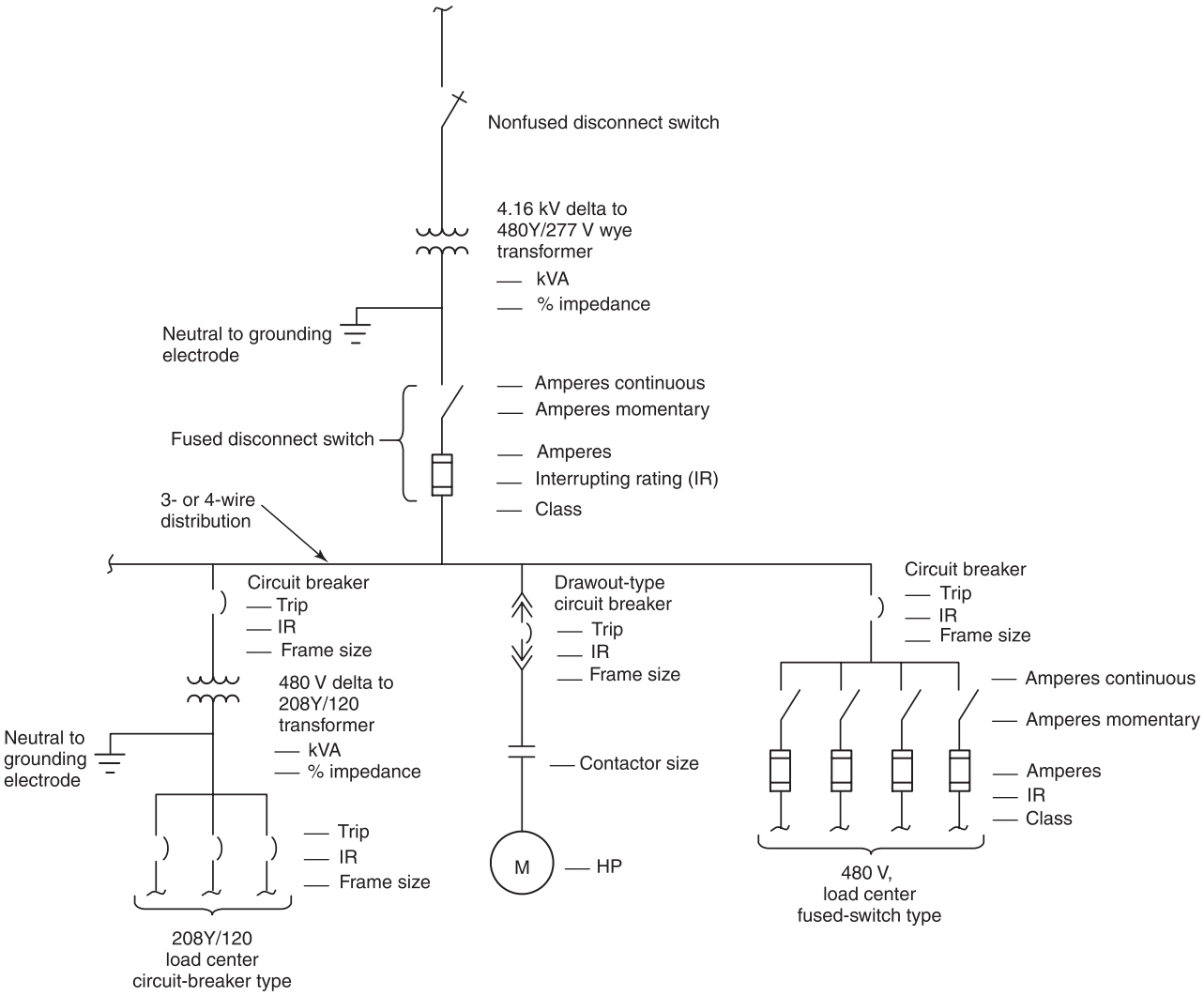


FIGURE D.1 Typical Use of Symbols in a Single-Line Power Distribution Program.

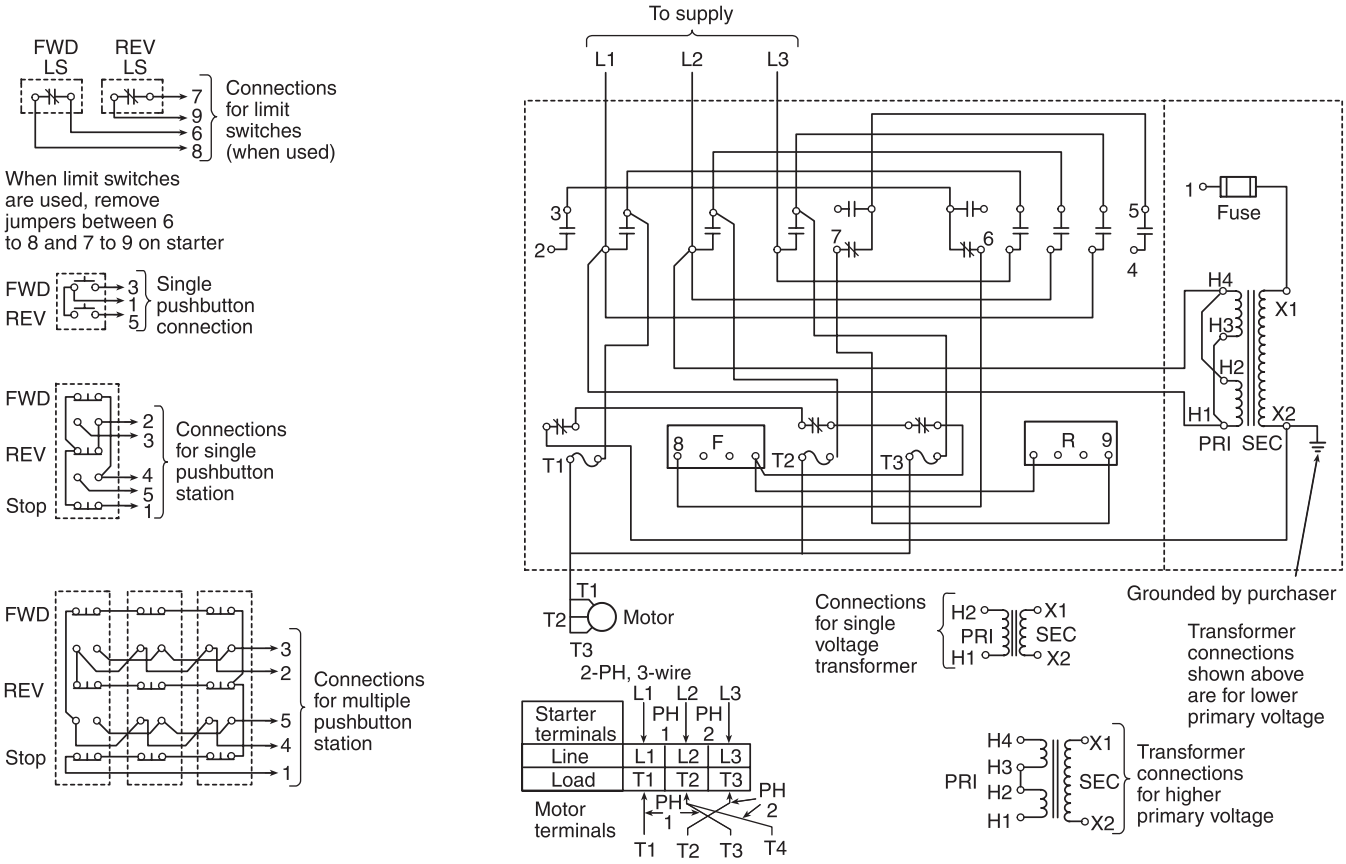
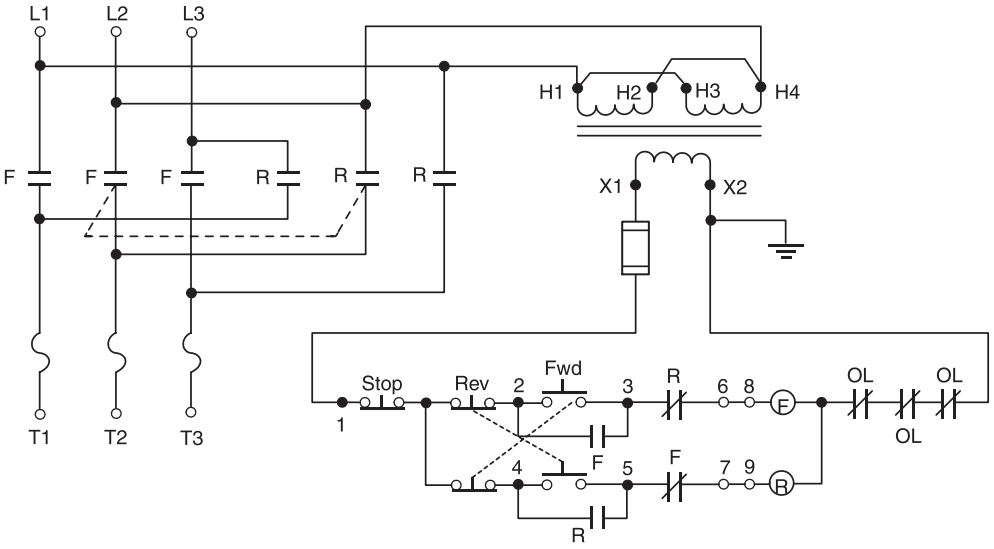


FIGURE D.2 Wiring Diagram for a Reversing Starter with Control Transformer.



Δ FIGURE D.3 Power and Control Schematic for Reversing Starter with Low-Voltage Remote Pushbuttons.

Annex E Forms

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

E.1 Figure E.1 shows a typical work order request form.

E.2 Figure E.2 shows a typical air circuit breaker inspection record.

E.3 Figure E.3 shows a typical air circuit breaker test and inspection report.

E.4 Figure E.4 shows a typical medium-voltage vacuum breaker form.

E.5 Figure E.5 shows a typical oil circuit breaker test report.

E.6 Figure E.6 shows a typical disconnect switch test report.

E.7 Figure E.7 shows a typical low-voltage circuit breaker 5-year tests form.

E.8 Figure E.8 shows a typical electrical switchgear–associated equipment inspection record.

E.9 Figure E.9 shows a typical current or potential transformer ratio test report.

E.10 Figure E.10 shows a typical overload relay test report.

E.11 Figure E.11 shows a typical ground-fault system test report.

E.12 Figure E.12 shows a typical instrument/meter calibration and test report.

E.13 Figure E.13 shows a typical watt-hour meter test sheet.

E.14 Figure E.14 shows a typical panelboard/circuit breaker test report.

E.15 Figure E.15 shows a typical transformer test and inspection report.

E.16 Figure E.16 shows a typical transformer (dry type) inspection record.

E.17 Figure E.17 shows a typical transformer (liquid filled) inspection record.

E.18 Figure E.18 shows a typical transformer oil sample report.

E.19 Figure E.19 shows a typical transformer oil trending report.

E.20 Figure E.20 shows a typical transformer insulation resistance record.

E.21 Figure E.21(a) shows an example of a VRLA battery inspection report. Figure E.21(b) shows an example of a VRLA maintenance work sheet.

E.22 Figure E.22 shows a typical engine generator set inspection checklist.

E.23 Figure E.23 shows a typical automatic transfer switch form.

E.24 Figure E.24 shows a typical uninterruptible power supply system inspection checklist.

E.25 Figure E.25 shows a typical back-up power system inspection checklist.

E.26 Figure E.26 shows a typical insulation resistance–dielectric absorption test sheet for power cable.

E.27 Figure E.27 shows a typical cable test sheet.

E.28 Figure E.28 shows a typical insulation resistance test record.

E.29 Figure E.29 shows a typical insulation resistance test record for rotating machinery.

E.30 Figure E.30 shows a typical motor test information form.

E.31 Figure E.31 shows a typical ground system resistance test report.

E.32 Figure E.32 shows a typical ground test inspection report for health care facilities.

E.33 Figure E.33 shows a typical line isolation monitor test data report for health care facilities.

E.34 Figure E.34 shows a typical torque value record.

E.35 Figure E.35 shows a typical main power energization checklist.

E.36 Figure E.36 shows instructions to contractor.

E.37 Figure E.37 shows project scope of work template.

E.38 Figure E.38 shows project scope of work form.

E.39 Figure E.39 shows project scope of work modification form.

E.40 Figure E.40 shows cover and contents.

E.41 Figure E.41 shows point of contact.

E.42 Figure E.42 shows power distribution unit (PDU) survey.

E.43 Figure E.43 shows generator set survey.

E.44 Figure E.44 shows electrical panel survey.

E.45 Figure E.45 shows inverter survey.

E.46 Figure E.46 shows building lightning protection survey.

E.47 Figure E.47 shows rectifier survey.

E.48 Figure E.48 shows electrical panel survey.

E.49 Figure E.49 shows transfer switches survey.

E.50 Figure E.50 shows power transformers survey.

E.51 Figure E.51 shows uninterruptible power system survey.

E.52 Figure E.52 shows low-voltage breaker data record.

E.53 Figure E.53 shows recloser data record.

E.54 Figure E.54 shows generator data record.

WORK ORDER REQUEST

Work Order No. — Craft

Plant Department

Directions to Requester: Complete Section I ONLY. Submit four copies to the Plant Department. Maintain last copy for your files. Prepare a separate request for each job. This request will be returned to you and becomes a work order only when approved and assigned a work order number by the Plant Department. Allow sufficient time for completion. Please TYPE your request.

I. To be completed by requester: Date ____ / ____ / ____

Summary of work request ____

Location of work: Room(s) ____ Building ____

Details of work request ____

Typical work order request form consists of five parts — includes copies for plant department (or plant engineer), data processing, receiving stores, requester, and requester's department. Work to be done is spelled out in detail.

Special time requirement: Date needed ____ / ____ / ____ Indicate reason ____

Department ____ Tel. ext. ____ ❑ Plan attached ❑ Info. attached

Authorized signature ____ Title ____ Approval if required ____

II. For plant department use only: Date Received ____ / ____ / ____

A. Your request has been ❑ Approved ❑ Disapproved ❑ Forwarded to ____ for action. Use the assigned work order number when referring to this request.

B. Instructions: ____

Job Estimates	Craft	Total Hours	Total Labor	Material	Grand Total
	Hours		$	$	$

Assigned to ____ Craft ____ ❑ Day ❑ Night

Foreman —

C. Completed per plant instructions? ❑ Yes ❑ No

Can recurrence be prevented? ❑ Yes ❑ No

If yes, indicate ____

Actual hours used	Tot. reg.	Tot. O/T	Tot. equiv. hrs.

Requester —

Completed per your request? ❑ Yes ❑ No

Plant and requester note variations ____

Date ____ Foreman's signature ____ Requester's signature ____

III. For data processing use only:

Dept.	Bldg.	Class	Category	Cause	Pay	O/T $

Total Labor $	+	Total Material $	=	Total $

Work description (alphabetic)

Plant Department

Work Order No. — Craft

 NFPA 70B

Δ FIGURE E.1 Typical Work Order Request Form.

AIR CIRCUIT BREAKER INSPECTION RECORD

Plant _____ Date _____
Location _____ Serial No. _____
Mfr. _____ Type or Model _____
Drawout ❑ Non-drawout ❑ Switchboard ❑ Metal clad ❑
Rating: Volts _____ Amperes _____ Interrupting Amperes _____
Operation: Manual ❑ Electrical ❑ Remote Control ❑
Volts close _____ ac ❑ dc ❑ Volts trip _____ ac ❑ dc ❑
Protective Devices: Induction Relays ❑ Direct Trips ❑ Direct Trips ❑
CL Fuses ❑ TD Setting _____ Inst. Setting _____

Annual Inspection

Date										
Inspector's Initials										
	Aux.	Main	Aux.	Main	Aux.	Main	Aux.	Main	Aux.	Main
Contact Condition										
Good — Surface Smooth										
Fair — Minor Burns										
Poor — Burned and Pitted										
Contact Check										
Pressure (Good, Weak, Bad)										
Drawout Contacts										
Pressure (Good, Weak, Bad)										
Alignment (Good, Bad)										
Lubricate (Must Do — Use a No-Oxide Lubricant by Mfr.)										
Arcing Assemblies										
Clean and Check the Arc-Splitting Plates Surface Conditions										
Bushings										
Clean and Check Surface Condition										

Date					
Inspector's Initials					
Operating Mechanisms					
Checks					
Positive Close and Trip					
Bushing and Pin Wear					
Set Screws and Keepers					
Protective Devices					
Lubricate Wear Points					
Clean Pots and Replace Oil with Equipment Mfrs. Recommended Oil					
Insulation Condition					
Loose Connections					
Discolored Areas					
Corona Tracking					
Clean Surfaces					
Insulation Tests					
Phase to Phase (Megohm)					
Phase to Ground (Megohm)					
Test Operation					
Close and Trip					
Counter Reading					
(No. of Ops.)					
Electrical Load					
Peak Indicated Amperes					

Remarks (record action taken when indicated by inspection or tests):

_____

_____

Other repairs recommended:

_____

_____

Δ **FIGURE E.2 Typical Air Circuit Breaker Inspection Record.**

AIR CIRCUIT BREAKER TEST AND INSPECTION REPORT

Customer _____ Date _____ Work Order No. _____
Address _____ Air Temp. _____ Rel. Humidity _____
Breaker Owner/User _____ Date Last Inspection _____
Address _____ Last Inspection Report No. _____
Equipment Location _____
Owner Identification _____

Breaker Data:

Manufacturer _____ Voltage _____ Type _____ Amperes _____ Int. Rating _____
Serial No. _____ Type Oper. Mech. _____ Age _____ Other N.P. Data _____

Test Data:	**Tank 1**	**Tank 2**	**Tank 3**
Ins. Res. _____ kV, Megohms			
Contact Resistance, Microhms			
Closing Speed/Opening Speed			
Reference, P.F. Test Sheet No.			
Adjustments:	**Mfr's. Rec.**	**As Found**	**As Left**
Arcing Contact Wipe			
Main Contact Gap			
Main Contact Wipe			
Latch Wipe			
Latch Clearance			
Contact Travel			
Prop Clearance			
Stop Clearance			

Inspection and Maintenance:	**Insp.**	**Dirty**	**Cleaned/ Lubed**	**See Remarks**
Overall Cleanliness				
Insulating Members				
Mech. Connections				
Structural Members				
Cubicle				
Pri. Contact Fingers				
Shutter Mech.				
Relays				
Auxiliary Devices				
Racking Device				
Arc Chutes				
Blow Out Coil				
Puffers				
Liner				
Arc Runners				
Main Contacts				
Cubicle Wiring				
Breaker Wiring				
Heaters				
Panel Lights				
Bearings				
Contact Sequence				
Ground Connection				
Counter Reading				

Remarks: _____

Inspections and Test by: _____ Equipment Used: _____ Sheet No.: _____

Δ FIGURE E.3 Typical Air Circuit Breaker Test and Inspection Report.

MEDIUM VOLTAGE VACUUM BREAKER

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT NO. _____
EQUIPMENT LOCATION _____
OWNER IDENTIFICATION _____

BREAKER DATA:

Manufacturer _____ Voltage _____ Type _____ Amps _____ Age _____
Serial No. _____ Type Oper Mech _____ Int. Rating _____ Other _____

TEST DATA:

Ins Res @ _____ kV

A to G	B to G	C to G

Results In

A to B	B to C	C to A

Gigaohms _____

A-L to L	B-L to L	C-L to L

Megohms _____

Contact Resistance

Microhms - As Found

Microhms - As Left

A-L to L	B-L to L	C-L to L

HiPot Test @ _____

ADJUSTMENTS:

	MFR'S. REC.	AS FOUND	AS LEFT
Erosion Indicator			
Main Contact Gap			
_____			
_____			
_____			
_____			
_____			
_____			
_____			
_____			
_____			
_____			
_____			
_____			
_____			

INSPECTION AND MAINTENANCE:

	INSP	NA	CLEAN LUBE	SEE REMARKS
Overall Cleanliness				
Insulating Members				
Mech. Connections				
Structural Members				
Cubicle				
Pri. Contact Fingers				
Shutter Mech.				
Relays				
Auxiliary Devices				
Racking Device				
Main Contacts				
Cubicle Wiring				
Breaker Wiring				
Heaters				
Panel Lights				
Bearings				
_____				
_____				
_____				
Contact Sequence				
Ground Connection				
Counter Reading				

Remarks _____

Equipment Used _____
Submitted By _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.4 Typical Medium-Voltage Vacuum Breaker Form.

OIL CIRCUIT BREAKER TEST

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT _____
EQUIPMENT LOCATION _____
OWNER IDENTIFICATION _____

BREAKER DATA:

Manufacturer _____ Voltage _____ Type _____ Amps _____ Age _____
Serial No. _____ Type Oper Mech _____ Int. Rating _____ Other _____
Bushing Data _____

TEST DATA:

Ins Res @ _____ kV

Results In
Gigaohms _____
Megohms _____

Contact Resistance
Microhms - As Found
Microhms - As Left
Reference PF Test Sheet

A to G	B to G	C to G
A to B	**B to C**	**C to A**
A-L to L	**B-L to L**	**C-L to L**

ADJUSTMENTS:

	MFR'S. REC.	AS FOUND	AS LEFT
Stop Clearance			
Contact Travel			
Overtravel			
Contact Wipe			
Trip Roller			
Latch Wipe			
Latch Clearance			
Prop Wipe			
Prop Clearance			
Cut-off Switch			
AA Switch			

INSPECTION AND MAINTENANCE:

	INSP	NA	CLEAN LUBE	SEE REMARKS
Tank Liners				
Insulating Members				
Oil Gauges				
Opening Spring				
Bushings				
Main Contacts				
Secondary Contacts				
Interrupters				
Linkage				
Dashpots				
Shutter Mechanism				
Elevating Mechanism				
Compressor Air Strainer				
Unload Valve				
Check Valve				
Compressor Belt				
Air Leaks				
Compressor Oil				
Gaskets				
Nuts, Bolts, Pins				
Closing Sequence				
Heater				
Oil Level				
Ground Connection				
Counter Reading As-Found				
Counter Reading As-Left				

Remarks _____

Equipment Used _____
Submitted By _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.5 Typical Oil Circuit Breaker Test Report.

DISCONNECT SWITCH TEST REPORT

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT NO. _____
EQUIPMENT LOCATION _____
OWNER IDENTIFICATION _____

Fused _____ Non-Fused _____

SWITCH DATA:

Manufacturer _____ Voltage _____ Type _____ Amps _____ Age _____
Serial No. _____ Type Oper Mech _____ Int. Rating _____ Other _____

TEST DATA:

Ins Res @ _____ kV

	A to G	B to G	C to G
Results In			
	A to B	B to C	C to A
Gigaohms _____			
Megohms _____			
Contact Resistance			
Microhms-As Found			
Microhms-As Left			
_____			
_____			

FUSE DATA:

	A	B	C
Manufacturer			
Size			
Catalog No.			
I.C. Rating			
Contact Resistance			
Microhms-As Found			
Microhms-As Left			
_____			
_____			
_____			
_____			
_____			
_____			
_____			
_____			

INSPECTION AND MAINTENANCE:

	INSP	NA	CLEAN LUBE	SEE REMARKS
Overall Cleanliness				
Insulating Members				
Mech. Connections				
Structural Members				
Cubicle				
Pri. Contact Fingers				
Main Contacts				
Arc Chutes				
Arc Runners				
Manual Operation				
Contact Lube				
Mechanical Lube				
Paint				
Door Interlock				
_____				
_____				
_____				
_____				
_____				
_____				
_____				
_____				
_____				
_____				
_____				
Ground Connection				

Remarks _____

Equipment Used _____
Test Technician _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.6 Typical Disconnect Switch Test Report.

LOW-VOLTAGE CIRCUIT BREAKER 5-YEAR TESTS FORM

Plant _____ Date _____

Substation _____ Feeder _____ Load Reading _____

Breaker Data

Mfr. _____ Type _____ Serial No. _____

Trip Coil Rating _____ Amperes Characteristic _____ Mfr's. Time Curve _____

Trip Devices: Long Time Delay ❑ Short Time Delay ❑ Instantaneous Trip ❑

Time Delay Type: Oil Sucker Dashpot ❑ Air Bellows ❑ Air Orifice ❑ Oil Orifice ❑ Other ❑

Settings:

LT Delay — Amperes _____ Adjustable Range _____ Time Adjustable? Yes ❑ No ❑

ST Delay — Amperes _____ Adjustable Range _____ Time Adjustable? Yes ❑ No ❑

Instantaneous Trip — Amperes _____ Adjustable? Yes ❑ No ❑

Test Data

Date of Test / Inspector's Initials		Left Pole	Center Pole	Right Pole	Time Range from Curve
As Found Test (Trip Time in Seconds) % Pickup _____ Amperes _____					
Time Delay	(As Found — Amperes)				
Minimum Pickup (Nullify Time Delay)	(Adjusted — Amperes)				
Time Delay Tests (Trip Time in Seconds) % Pickup Amperes					
Long Time _____ _____					
_____ _____					
Short Time _____ _____					
_____ _____					
Resettable Delay	(Satisfactory)				
(___ % for ___ sec)	(Tripped)				
Instantaneous Trip	(As Found — Amperes)				
	(Adjusted — Amperes)				

Remarks (record unusual conditions, corrections, needed repairs, etc.; use separate form to record annual breaker inspection details):

_____

_____

Δ FIGURE E.7 Typical Low-Voltage Circuit Breaker 5-Year Tests Form.

ELECTRICAL SWITCHGEAR–ASSOCIATED EQUIPMENT INSPECTION REPORT

Plant _____ Date _____
Location _____ Serial No. _____
Mfr. _____ Year Installed _____
Rating: Volts _____ Bus Capacity Amperes _____
Type: Switchboard ❑ Indoor Metal Clad ❑ Outdoor Metal Clad ❑

Annual Inspection (Disregard items that do not apply.)

Date							Date					
Inspector's Initials							Inspector's Initials					
Switchboards							Disconnect Switches					
Clean							Check Contact Surfaces					
Check Wiring							Check Insulation Condition					
Inspect Panel Insulation							Lubricate per Mfr's. Instructions					
Exposed Bus and Connections							Test Operate					
Clean and Check Porcelain							Fuses and Holders					
Check Insulators for Cracks or Chips							Check Contact Surfaces					
Check and Tighten Connections							Lubricate per Mfr's. Instructions					
Inspect Potheads for Leaks							Meters and Instruments					
Check for Environmental Hazards							Check Operation					
Test Insulation (Megohms)							Test Meters per Eng. Std.					
Metal Clad Enclosures							Test Relays per Mfr's. Instructions					
Clean							Interlocks and Safety					
Check for Openings That Permit Dirt, Moisture and Rodent Entrance — Repair							Check for Proper Operations					
Check Hardware for Rust or Corrosion							Check Lightning Arresters					
Paint Condition							Check Ground Detectors					
Check Heaters and Ventilators							Check Equipment Grounds					
Metal Clad Bus and Connections							Station Battery					
Clean Insulators and Supports							Periodic Routine					
Check and Tighten Connections							Maintenance is performed					
Check for Corona Tracking												
Inspect Potheads for Leaks												
Test Insulation (Megohms)												

Remarks (record action taken when indicated by inspection or tests):

_____

_____

Recommendations:

_____

_____

_____

Δ FIGURE E.8 Typical Electrical Switchgear–Associated Equipment Inspection Record.

CURRENT OR POTENTIAL TRANSFORMER RATIO TEST REPORT

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____

ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY (%) _____

OWNER/USER _____ DATE LAST INSPECTION _____

ADDRESS _____ LAST INSPECTION REPORT NO. _____

EQUIPMENT LOCATION _____

CIRCUIT IDENTIFICATION _____

LOCATION OF C.T. OR P.T. _____

C.T. OR P.T. IDENTIFICATION	C.T. OR P.T. SECONDARY TAPS	NAMEPLATE RATIO	APPLIED VOLTAGE OR CURRENT	MEASURED VOLTAGE OR CURRENT	PERCENT (%) ACCURACY	POLARITY PRIMARY	POLARITY SECONDARY
POLE #1 (A)	X1-X2						
BURDEN TEST							AMPS / VOLTS
SATURATION TEST							VOLTS / MA
MEGGER TEST							MEGOHMS
POLE #2 (B)	X1-X2						
BURDEN TEST							AMPS / VOLTS
SATURATION TEST							VOLTS / MA
MEGGER TEST							MEGOHMS
POLE #3 (C)	X1-X2						
BURDEN TEST							AMPS / VOLTS
SATURATION TEST							VOLTS / MA
MEGGER TEST							MEGOHMS

REMARKS _____

SUBMITTED BY _____

Courtesy of Northeast Electrical Testing NFPA 70B

Δ FIGURE E.9 Typical Current or Potential Transformer Ratio Test Report.

OVERLOAD RELAY TEST REPORT

SHEET NO. _____ OF _____
TEST REPORT NO. _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT _____
EQUIPMENT LOCATION _____
OWNER IDENTIFICATION _____

MOTOR PROTECTED _____
MOTOR FLA _____ MOTOR VOLTAGE _____

OVERLOAD INFORMATION

OVERLOAD MANUFACTURER _____ CATALOG NUMBER _____
OVERLOAD RELAY HEATER COIL _____ HEATER POSITION _____
MANUFACTURERS CURVE NO. _____ AMBIENT TEMP. _____
FULL LOAD CURRENT AMPERES _____ MIN. _____ MAX. _____

TEST RESULTS

PHASE	HEATER CURRENT	TEST CURRENT		TEST TIME
		PERCENTAGE	AMPS	SECONDS
PHASE 1				
PHASE 2				
PHASE 3				

STARTER INFORMATION

STARTER MANUFACTURER _____
STARTER SIZE _____ STARTER CATALOG NO. _____
STARTER _____ OTHER INFORMATION _____

CONDUCTOR _____ CONDUCTOR INSULATION _____

DATE _____

INSULATION RESISTANCE RESULTS:

Aø - GND _____ Aø - Bø _____
Bø - GND _____ Bø - Cø _____
Cø - GND _____ Cø - Aø _____

DATE _____

MEGGER MOTOR ø-GND: (1/2 MIN) _____ (1 MIN) _____

DATE _____

MEGGER MOTOR ø-GND W/CONDUCTOR INCLUDED: _____ (1 MIN) _____

REMARKS: _____

EQUIPMENT USED _____ SERIAL NUMBER _____
QUALITY CONTROL REP. _____ TITLE _____
SUBMITTED BY _____ TEST CREW _____

Courtesy of Northeast Electrical Testing

NFPA 70B

Δ **FIGURE E.10 Typical Overload Relay Test Report.**

GROUND FAULT SYSTEM TEST

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT NO. _____
EQUIPMENT LOCATION _____
CIRCUIT IDENTIFICATION _____

FIELD DATA

MAIN OVERCURRENT DEVICE:
☐ CIRCUIT ☐ FUSED SWITCH

MANUFACTURER _____
TYPE _____
MODEL/CAT. # _____
CURRENT RATING _____
SYSTEM VOLTAGE _____
VOLTAGE RATING _____

GROUND FAULT SYSTEM:
☐ NEUT-GND STRAP ☐ ZERO SEQUENCE

MANUFACTURER _____
MODEL _____
CAT. NO. _____
PICK-UP RANGE _____
TIME RANGE _____
SENSOR/ C.T. _____

INSPECTION

CORRECT	INCORRECT	INSPECTION POINT	SIZE - REMARKS
		NEUT.-GRD LOCATION	
		CONTROL POWER	
		MONITOR OR TEST PANEL OPERATION	
		OTHER _____	

ELECTRICAL TESTS

1. BREAKER/SWITCH REACTION TIME (RT) _____ ☐ SEC. ☐ CYC.
2. PICK UP CURRENT _____ AMPS
3. PICK UP CURRENT MINUS 10% (_____) A. ☐ TRIP ☐ NO TRIP
4. SHUNT TRIP COIL PICK-UP VOLTAGE _____ VOLTS
5. SYSTEM NEUTRAL INSULATION RESISTANCE TO GND _____ MEGOHMS
6. TIME-CURRENT CALIBRATION TESTS:

PRIMARY CURRENT AMPERE-TURNS	% PICKUP	TOTAL TIME	RT	RELAY TIME	MFG. TOLERANCE

REMARKS: _____

SUBMITTED BY: _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.11 Typical Ground-Fault System Test Report.

INSTRUMENT/METER CALIBRATION AND TEST REPORT

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT NO. _____
EQUIPMENT LOCATION _____
CIRCUIT IDENTIFICATION _____

LOCATION/FUNCTION OF INSTRUMENT/METER _____
TYPE _____ MANUFACTURER _____ MODEL _____
FULL SCALE _____ ACTUAL INPUT _____
P.T. RATIO _____ C.T. RATIO _____ CAL. WATTS _____

FULL SCALE CARDINAL POINTS							
BASIC RANGE CALCULATED VALUE							
STANDARD "AS FOUND"							
STANDARD "AS LEFT"							
"AS LEFT" ACCURACY (%)							

REMARKS _____

LOCATION/FUNCTION OF INSTRUMENT/METER _____
TYPE _____ MANUFACTURER _____ MODEL _____
FULL SCALE _____ ACTUAL INPUT _____
P.T. RATIO _____ C.T. RATIO _____ CAL. WATTS _____

FULL SCALE CARDINAL POINTS							
BASIC RANGE CALCULATED VALUE							
STANDARD "AS FOUND"							
STANDARD "AS LEFT"							
"AS LEFT" ACCURACY (%)							

REMARKS _____

SUBMITTED BY: _____ EQPT. USED: _____

Courtesy of Northeast Electrical Testing NFPA 70B

Δ **FIGURE E.12 Typical Instrument/Meter Calibration and Test Report.**

WATT-HOUR METER TEST SHEET

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT NO. _____
EQUIPMENT LOCATION _____
CIRCUIT IDENTIFICATION _____

TEST LOCATION _____ CIRCUIT METERED _____
METER MANUFACTURER _____ TYPE _____ SER. NO. _____
VOLTS _____ AMPS _____ _____ PHASE _____ WIRE INTERVAL _____
C.T. RATIO _____ P.T. RATIO _____ TEST K _____ PRI. TEST K _____

	AS FOUND	AS LEFT		AS FOUND	AS LEFT
KWH REGISTER READING			POTENTIAL IND LAMPS		
DEMAND REGISTER READING			CHECK AND VERIFY REGISTER RATIO		
DISC R.P.M.			SYNCHRONOUS MOTOR		
WORM WHEEL MESH			CHECK KW PTR AGAINST KWH PTR		
MAGNET CLEANLINESS			CREEP CHECK		
MAGNET TIGHTNESS			TIME INTERVAL		

	ACCURACY CHECK (% REG.)		COIL BALANCE CHECK					
			COIL NO. 1		COIL NO. 2		COIL NO. 3	
TEST FUNCTION	AS FOUND	AS LEFT	AS FOUND	AS LEFT	AS FOUND	AS LEFT	AS FOUND	AS LEFT
LIGHT LOAD								
FULL LOAD								
POWER FACTOR								

REMARKS: _____

CUSTOMER REPRESENTATIVE _____ TITLE _____
TEST EQUIPMENT USED _____ SERIAL # _____
SUBMITTED BY _____ TEST _____

Courtesy of Northeast Electrical Testing NFPA 70B

Δ FIGURE E.13 Typical Watt-Hour Meter Test Sheet.

PANELBOARD/CIRCUIT BREAKER TEST REPORT

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT _____
EQUIPMENT LOCATION _____
OWNER IDENTIFICATION _____

PANEL BUS INSULATION RESISTANCE IN MEGOHMS

A-G _____ B-G _____ C-G _____ A-B _____ B-C _____ A-C _____

PANEL BOARD RATINGS: AMPS: _____ VOLTAGE: _____

TEST VOLTAGE: _____ MODEL NO: _____ CATALOG _____

MFG. _____ CURVE NO. _____ CURVE RANGE: _____
MFG. _____ CURVE NO. _____ CURVE RANGE: _____
MFG. _____ CURVE NO. _____ CURVE RANGE: _____
MFG. _____ CURVE NO. _____ CURVE RANGE: _____

CIRCUIT #	CKT. BKR. SIZE	TEST AMPS	TRIP TIME	INST. TRIP	CONTACT RESIS.	CIRCUIT #	CKT. BKR. SIZE	TEST AMPS	TRIP TIME	INST. TRIP	CONTACT RESIS.

REMARKS: _____

CUSTOMER REPRESENTATIVE _____ TITLE _____
TEST EQUIPMENT _____ SERIAL # _____
SUBMITTED BY _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.14 Typical Panelboard/Circuit Breaker Test Report.

TRANSFORMER TEST AND INSPECTION REPORT

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY (%) _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT _____
EQUIPMENT LOCATION _____
OWNER IDENTIFICATION _____

NAMEPLATE INFORMATION:

MANUFACTURER _____ KVA _____ PHASE _____ CYCLE _____
SERIAL NO. _____ TYPE _____ CLASS _____
PRI. VOLTAGE _____ △ ☐ OR Y ☐ RATED CURRENT _____ AMPERES
SEC. VOLTAGE _____ △ ☐ OR Y ☐ RATED CURRENT _____ AMPERES
COOLANT ☐ OIL ☐ ASKAREL ☐ AIR ☐ NITROGEN ☐ OTHER _____
COOLANT CAPACITY _____ TEMP. RISE (°C) _____ IMPEDANCE (%) _____
NO LOAD TAP CHANGER VOLTAGES _____

GAUGES AND COUNTERS

TEMP. _____ TEMP. RANGE _____ RESET GAUGE _____
PRESSURE _____ OIL LEVEL _____ TAP SETTING _____

VISUAL INSPECTION

BUSHING _____ CONNECTIONS _____ PAINT _____ OTHER _____
LOAD TAP CHANGER _____ LEAKS _____
FANS & CONTROLS _____ GAS REGULATOR _____ GROUNDS _____

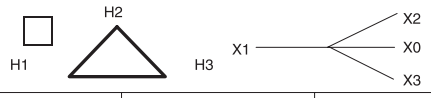
WINDING INSULATION RESISTANCE TEST (MEGOHMS)

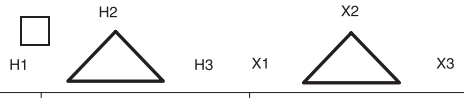
PRIMARY TO GROUND, SEC. GUARDED _____ KVDC
SECONDARY TO GROUND, PRI. GUARDED _____ KVDC
PRIMARY TO SECONDARY, GROUND GUARDED _____ KVDC

EQUIPMENT USED _____

30 SEC.	1 MIN.	10 MIN.	D.A.	P.I.

TURNS RATIO TEST





NAMEPLATE PRIMARY VOLTS	TAP POSITION	CONNECTION H____H____X____ X____	CONNECTION H____ H____ X____ X____	CONNECTION H____ H____ X____X____	CALCULATED RATIO
	A1				
	B2				
	C3				
	D4				
	E5				

REMARKS: _____

EQUIPMENT USED _____ SUBMITTED BY _____

Courtesy of Northeast Electrical Testing

NFPA 70B

△ **FIGURE E.15 Typical Transformer Test and Inspection Report.**

TRANSFORMER (DRY TYPE) INSPECTION RECORD

Plant _____ Date _____
Location _____ Serial No. _____
Year Purchased _____ Year Installed _____ Mfr. _____
kVA _____ Voltage _____ Impedance _____
Phase _____ Taps _____
Cooling System: Room Vent Fan ❑ Trans. Fan ❑ Gravity ❑

Annual Inspection

Date							Date					
Inspector's Initials							Inspector's Initials					
Electrical Load							Bushings					
							Cracks or Chips					
							Cleanliness					
Secondary Voltage												
No Load Volts							Equipment Ground					
Full Load Volts							Check Connections					
							Measured V					
Dust on Windings							Resistance					
Minor Collection												
Major Collection							Temperature Alarms and Indicators					
Cleaned							Operation					
							Accuracy					
Connections												
Checked							Case Exterior					
Tightened							Covers Intact					
							Paint Condition					
Cooling Systems												
Fan Operation							Lighting Arresters					
Filter Cleanliness							Check Connections					
System Adequate							Check Bushings					

Complete Internal Inspection

Report of Conditions Found:
Cooling System _____
Coil Insulation _____
Other _____

Description of Work Performed:
_____
_____

Other Repairs Recommended: _____
_____
_____

Shop or Contractor: _____ Cost: _____

Δ FIGURE E.16 Typical Transformer (Dry Type) Inspection Record.

TRANSFORMER (LIQUID FILLED) INSPECTION RECORD

Plant _____ Date _____
Location _____ Serial No. _____
Year Purchased _____ Year Installed _____ Mfr. _____
kVA _____ Voltage _____ Taps _____
Check type: Free Breathing ❑ Conservator ❑ Sealed ❑ Fan Cooled ❑
Phase _____ Weight _____ Impedance _____
Insulating Fluid: Type _____ Gallons _____

Annual Inspection

Date							Date						
Inspector's Initials							Inspector's Initials						
Tank — Liquid Level							Exposed Bushings						
Normal							Cracks or Chips						
Below							Cleanliness						
Added Fluid							Equipment Ground Connection						
Entrance Compartment Liquid Level							Good						
Normal							Questionable						
Below							Tested						
Added Fluid							Temperature Indicator						
Electrical Load							Highest Reading						
Peak Amperes							Reset Pointer						
Secondary Voltage							Pressure–Vacuum Indicator						
Full Load							Pressure						
No Load							Vacuum						
Gaskets and Case Exterior							Ventilators, Dryers, Gauges, Filters, and Other Auxiliaries						
Liquid Leaks							Operation OK						
Paint Condition							Maint. Req'd.						

Remarks (record action when inspection data or tests are out of limits, etc.):

_____

_____

Reports of Conditions Found: _____

_____

Description of Work Performed: _____

_____

Other Repairs Recommended: _____

_____

Shop or Contractor: _____ Cost: _____

Δ **FIGURE E.17 Transformer (Liquid Filled) Inspection Record.**

TRANSFORMER OIL SAMPLE REPORT

TOTAL NO. OF SAMPLES ______
CUSTOMER ______ PROJECT NO. ______
LOCATION ______ DATE ______

LOCATION ______ ☐ OIL ______ SAMPLE NO. ______
IDENTIFICATION ______ ☐ ASKAREL ______
MFG. ______ ☐ NO GAUGE ______ PAINT ______ ☐ GOOD
SERIAL NO. ______ KVA ______ ☐ PRESSURE ______ ☐ POOR
CLASS ______ TYPE ______ ☐ VACUUM ______
INSUL. CLASS ______ PHASE ______ ☐ INDOOR ______ GASKETS ______ ☐ OK
VOLTAGE ______ ☐ OUTDOOR ______ ☐ LEAK
INSTR. BOOK ______ ☐ TEMP. GA. ______
AVG. DIELECTRIC ______ KV ______ BUSHINGS ______ ☐ OK
ACIDITY NO. ______ KOH ______ ☐ LEAK
ASTM COLOR NO. ______ LIQUID CAPACITY ______
PARTICLES ☐ YES ☐ NO TEMP ______ ______ OIL LEVEL ______ ☐ OK
WEATHER ______ ☐ LOW
RECOMMENDATIONS ______

LOCATION ______ ☐ OIL ______ SAMPLE NO. ______
IDENTIFICATION ______ ☐ ASKAREL ______
MFG. ______ ☐ NO GAUGE ______ PAINT ______ ☐ GOOD
SERIAL NO. ______ KVA ______ ☐ PRESSURE ______ ☐ POOR
CLASS ______ TYPE ______ ☐ VACUUM ______
INSUL. CLASS ______ PHASE ______ ☐ INDOOR ______ GASKETS ______ ☐ OK
VOLTAGE ______ ☐ OUTDOOR ______ ☐ LEAK
INSTR. BOOK ______ ☐ TEMP. GA. ______
AVG. DIELECTRIC ______ KV ______ BUSHINGS ______ ☐ OK
ACIDITY NO. ______ KOH ______ ☐ LEAK
ASTM COLOR NO. ______ LIQUID CAPACITY ______
PARTICLES ☐ YES ☐ NO TEMP ______ ______ OIL LEVEL ______ ☐ OK
WEATHER ______ ☐ LOW
RECOMMENDATIONS ______

LOCATION ______ ☐ OIL ______ SAMPLE NO. ______
IDENTIFICATION ______ ☐ ASKAREL ______
MFG. ______ ☐ NO GAUGE ______ PAINT ______ ☐ GOOD
SERIAL NO. ______ KVA ______ ☐ PRESSURE ______ ☐ POOR
CLASS ______ TYPE ______ ☐ VACUUM ______
INSUL. CLASS ______ PHASE ______ ☐ INDOOR ______ GASKETS ______ ☐ OK
VOLTAGE ______ ☐ OUTDOOR ______ ☐ LEAK
INSTR. BOOK ______ ☐ TEMP. GA. ______
AVG. DIELECTRIC ______ KV ______ BUSHINGS ______ ☐ OK
ACIDITY NO. ______ KOH ______ ☐ LEAK
ASTM COLOR NO. ______ LIQUID CAPACITY ______
PARTICLES ☐ YES ☐ NO TEMP ______ ______ OIL LEVEL ______ ☐ OK
WEATHER ______ ☐ LOW
RECOMMENDATIONS ______

EQUIPMENT USED ______ SUBMITTED BY ______

Courtesy of Northeast Electrical Testing NFPA 70B

Δ FIGURE E.18 Typical Transformer Oil Sample Report.

TRANSFORMER OIL TRENDING REPORT

CUSTOMER _____ PROJECT NO. _____

LOCATION _____ DATE _____

LOCATION _____ ☐ OIL _____ SAMPLE NO. _____

IDENTIFICATION _____ ☐ ASKAREL _____

MFG. _____ ☐ GAUGE _____ PAINT _____ ☐ GOOD

SERIAL NO. _____ KVA _____ ☐ PRESSURE _____ ☐ POOR

CLASS _____ TYPE _____ ☐ VACUUM _____

INSUL. CLASS _____ PHASE _____ ☐ INDOOR _____ GASKETS _____ ☐ OK

VOLTAGE _____ ☐ OUTDOOR _____ ☐ LEAK

INSTR. BOOK _____ ☐ TEMP. GA. _____

DIELECTRIC FLUID ANALYSIS

YR - JOB#	DIELE. (KV)	ACIDITY (mgKOH/g)	IFT (dynes/cm2)	COLOR	VISUAL	SPECIFIC GRAVITY	WATER (PPM)	POWER FACTOR (%)	PCB (PPM)

ACCEPTABLE DIELECTRIC TEST VALUES:

DIELECTRIC (ASTM D877) 30KV MIN. NEW OIL / 26KV MIN. USED OIL / 30KV MIN. NEW SILICONE/ 25kV MIN. USED SILICONE

ACID (ASTM D974) 0.03 mgKOH/g MAX. NEW OIL / 0.20mgKOH/g MAX. USED OIL / 0.1mgKOH/g MAX. NEW SILICONE/ 0.2mgKOH USED SILICONE

IFT (ASTM D971) 35 dynes/cm2 MIN. NEW OIL / 24 dynes/cm2 MIN. USED OIL / 31 dynes/cm2 MIN. SILICONE

COLOR (ASTM D1500) 1 MAX. NEW OIL / 4 MAX. USED OIL / CLEAR FOR SILICONE

WATER (ASTM D1533B) 25PPM MAX. NEW OIL / 35PPM MAX. USED OIL / 50PPM MAX. NEW SILICONE/ 100PPM MAX. USED SILICONE

DISSOLVED GAS ANALYSIS

YEAR	HYDROGEN (H2) (<100PPM)	OXYGEN (O2)	NITROGEN (N2)	METHANE (CH4) (<120PPM)	CARBON MONOXIDE (CO) (<350PPM)	CARBON DIOXIDE (CO2) (<2500PPM)	ETHYLENE (C2H4) (<50PPM)	ETHANE (C2H6) (<65PPM)	ACETYLENE (C2H2) (<1PPM)	TOTAL GAS CONTENT (%)	TOTAL COMBUST. GAS

REMARKS: _____

SUBMITTED BY _____

Courtesy of Northeast Electrical Testing

NFPA 70B

FIGURE E.19 Typical Transformer Oil Trending Report.

TRANSFORMER INSULATION RESISTANCE RECORD

Plant _____ Date _____

Scope: Power transformers of 150 kVA and greater capacity with primary voltage of 2300 volts or higher. Direct reading — recorded and plotted.

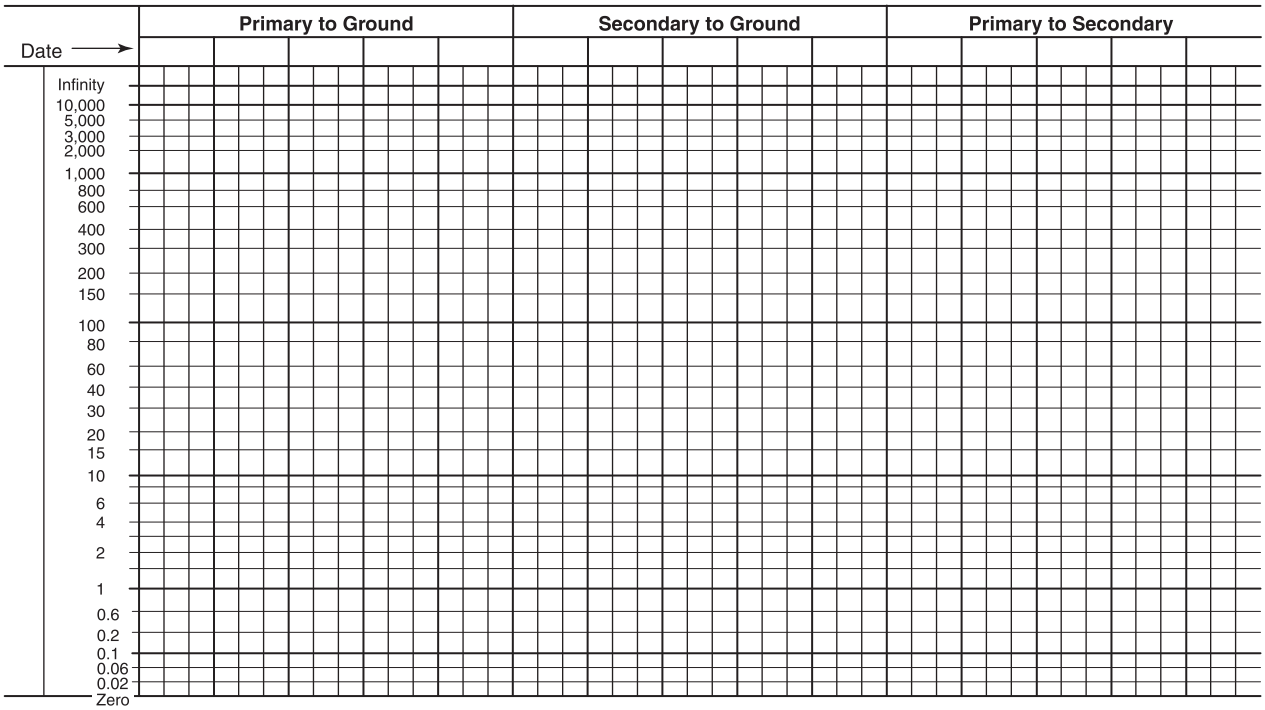
Transformer Serial No. _____ Phase _____

Location _____ Instrument Used _____

Equipment Included in Test _____

I I*	Date	Primary to Ground	Secondary to Ground	Primary to Secondary	Internal Temp.	Ambient Temp.

*Inspector's Initials



Remarks: _____

Δ FIGURE E.20 Typical Transformer Insulation Resistance Record.

VALVE-REGULATED LEAD-ACID (VRLA) STATIONARY BATTERIES AND CHARGERS INSPECTION REPORT

Inspected by: _____

Inspection date: _____

User's Name:	Authorized Site Contact:
Installation Location:	Phone No.:
	Other:
System OEM:	Installation by:

BATTERY AND CHARGER SYSTEM INFORMATION

VENDOR INSPECTION	USER INSPECTION
Order Number	Appearance of Following Battery Items
Ship Date	Positive Posts
Date Installed	Negative Posts
Battery Model	Cell Covers
Cells x Strings	Presence of Lubricant on Cells ❒ Yes ❒ No
Application	
Bus Voltage, Portable Meter	
Bus Voltage, Equipment, Final	
Charger Size, Type, Serial No. & Mfg.	
Ambient Room Temperature	
Last Discharge	
Peak Load Current Amp. or KW	
Typical Load Current/KW	
Cell Arrangement	

COMMENTS AND RECOMMENDATIONS

Δ **FIGURE E.21(a) VRLA Inspection Report.**

VALVE-REGULATED LEAD-ACID (VRLA) MAINTENANCE WORKSHEET

BATTERY CHARGE STATUS ❒ **OPEN CIRCUIT** ❒ **FLOAT** ❒ **EQUALIZE**

BATTERY BUS VOLTAGE _____ **Vdc** _____**Vdc** _____**Vdc**

Location: **Model:** **Date:**

Cell No.	Volts +2.000	Serial No.	Connection Resistance	Internal Cell Conductance /Impedance/ Resistance

Cell No.	Volts +2.000	Serial No.	Connection Resistance	Internal Cell Conductance /Impedance/ Resistance

Δ **FIGURE E.21(b) Example of a VRLA Maintenance Worksheet.**

ENGINE GENERATOR INSPECTION

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT _____
EQUIPMENT LOCATION _____
CIRCUIT IDENTIFICATION _____

ENGINE TYPE: ☐ GASOLINE ☐ DIESEL ☐ GAS TURBINE

MAKE _____ MODEL _____ SERIAL NO. _____ KS # _____
KVA _____ KW _____ VOLTAGE _____ F.L.A. _____
RPM _____ HZ _____ HP _____ TECH. BULL. #_____

1. ☐ Change oil and lube oil filters.
2. ☐ Remove unused oil from premises.
3. ☐ Change fuel oil elements.
4. ☐ Service crankcase breather.
5. ☐ Inspect air cleaner element, clean if required. If replacement is required, element(s) will be billed separately. Price of element(s) not included in contract price.
6. ☐ Check coolant level and maintain safe degree of protection. Engine mounted radiators only. (Remote radiators, cooling towers & heat exchangers serviced at user's request on a time and material basis.)
7. ☐ Check manifolds, brackets, mountings and flex connections.
8. ☐ Inspect fan belts, adjust if required.
9. ☐ Check pulley hub, bearings, lubricate if required.
10. ☐ Check operation of auxiliary water pump or fan motor.
11. ☐ Check operation of automatic louvers.
12. ☐ Repair minor fuel, coolant and lube oil leaks.
13. ☐ Check operation of jacket water heater(s).
14. ☐ Inspect generator, perform any routine maintenance as required.
    ☐ Megger
15. ☐ Inspect governor/actuator linkage.
16. ☐ Check battery electrolyte level and maintain to include:
    ☐ Temperature ☐ Specific Gravity ☐ Voltage
17. ☐ Check operation of charger and/or alternator.
18. ☐ Inspect fuel supply system for leaks or low level, inform owner of any discrepancies.
19. ☐ Drain condensation from day tank and check for any contamination. ONLY if day tank is equipped with a drain valve.
20. ☐ Check operation of transfer pump.
21. ☐ Check for correct generator output voltage & frequency, adjust if required.
22. ☐ Simulate & check operation of each safety shutdown and alarm device, relay type control panels only.
23. ☐ Check operation of generator control instrumentation; volts, amps, etc.
24. ☐ Test fault lamps & replace bulbs as required, panels with lamp test only.
25. ☐ Tank crankcase oil sample, owner to be notified of any discrepancies.
26. ☐ Submit report to owner
27. ☐ Auto start test.

REMARKS _____

SUBMITTED BY _____ EQUIPMENT USED _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.22 Typical Engine Generator Set Inspection Checklist.

AUTOMATIC TRANSFER SWITCH

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT NO. _____
EQUIPMENT LOCATION _____
OWNER IDENTIFICATION _____

Mfg. _____ Type: _____ Bul #: _____
Cat. # _____ Serial # _____ Voltage: _____
Amps: _____ Phase: _____ Op. Coil: _____
Inst. Bk: _____ Parts Bk. _____ Wire Diag: _____

Time Range "Transfer to Emergency" From _____ To _____
Time Range "Retransfer to Normal" From _____ To _____

TEST OPERATIONS

Transfer Time to Emergency As Found _____ As Left _____
Retransfer Time to Normal As Found _____ As Left _____

	NORMAL				EMERGENCY			
Contact Resistance in Microhms:	A _____	B _____	C _____		A _____	B _____	C _____	
Voltage Drop in Millivolts:	A _____	B _____	C _____		A _____	B _____	C _____	
Voltage Readings:	A-N _____	B-N _____	C-N _____		A-N _____	B-N _____	C-N _____	
	A-B _____	B-C _____	C-A _____		A-B _____	B-C _____	C-A _____	
Amperage Readings:	A _____	B _____	C _____		A _____	B _____	C _____	

Undervoltage Relay:

	1V	2V	3V
Pickup	_____	_____	_____
Dropout	_____	_____	_____

_____ Relay: Pickup _____ Dropout _____

_____ Relay: Voltage Pickup _____ Dropout _____
Frequency Pickup _____ Dropout _____

Arc Chutes: _____
Contacts: _____
Megger: _____
Cleaned: _____
Lubrication: _____

Circuit Properly Tagged: _____
Bolted Connections: _____
Mechanical Operation: _____
Unusual Conditions: _____

Remarks: _____

Test Crew: _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.23 Typical Automatic Transfer Switch Report.

UNINTERRUPTIBLE POWER SUPPLY (UPS) SYSTEM INSPECTION CHECKLIST

For use of this form see TM 5-694: the proponent agency is COE.

SECTION A – CUSTOMER DATA

1. PLANT/BUILDING	2. LOCATION	3. JOB NUMBER
4. EQUIPMENT	5. CIRCUIT DESIGNATION	6. DATE *(YYYYMMDD)*
7. TEST EQUIPMENT		8. TESTED BY

SECTION B – VISUAL AND ELECTRICAL/MECHANICAL INSPECTION

9. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
COMPONENT INSPECTION/TESTING			ENERGIZE AND TEST SYSTEM		
INSTALLATION INSPECTION/TESTING			UTILITY TRIP TEST		
WIRING VISUAL VERIFICATION			LOADED TRANSFER TEST (NORMAL, EMERGENCY & RETURN)		
GENERATOR CONTROL FUNCTIONS			TIGHTNESS OF BOLTED CONNECTIONS		
LOADING UPS TEST			BATTERY DISCHARGE TEST		
DISCONNECT RECTIFIERS & INVERTERS SEPARATELY. DOES SYSTEM OPERATE CORRECTLY?			TEST ALL UPS DIAGNOSTIC FAULT INDICATORS		

SECTION C – ELECTRICAL TESTS**

10.	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
UPS INPUT											
UPS OUTPUT	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
UPS SWITCHBOARD HARMONIC (THD)	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G

11. NOTES

* CONDITION: A = ACCEPTABLE; R = NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C = CORRECTED; NA = NOT APPLICABLE
** NOTE VALUE AND PHASING

NFPA 70B

FIGURE E.24 Typical Uninterruptible Power Supply System Inspection Checklist.

BACK-UP POWER SYSTEM INSPECTION CHECKLIST

For use of this form see TM 5-694: the proponent agency is COE.

SECTION A – CUSTOMER DATA

1. PLANT/BUILDING	2. LOCATION	3. JOB NUMBER
4. EQUIPMENT	5. CIRCUIT DESIGNATION	6. DATE *(YYYYMMDD)*
7. TEST EQUIPMENT AND CALIBRATION DATE		8. TESTED BY

SECTION B – EQUIPMENT DATA

9. MANUFACTURER	10. STYLES/S.O.	11. VOLTAGE RATING	12. CURRENT RATING
13. EQUIPMENT CLASSIFICATION	14. FREQUENCY	15. WET BULB TEMPERATURE	16. DRY BULB TEMPERATURE

SECTION C – VISUAL AND ELECTRICAL/MECHANICAL INSPECTION

17. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
COMPONENT INSPECTION/TESTING			WIRING VISUAL VERIFICATION		
ENERGIZE AND TEST SYSTEM			UTILITY TRIP/GENERATOR BUILDING LOAD TEST		
INSTALLATION INSPECTION/TESTING			TIGHTNESS OF BOLTED CONNECTIONS		
GENERATOR CONTROLS AND FUNCTIONS			CHECK FOR PROPER SIZE BREAKER		
WIRING CONTINUITY TESTING			REFERENCE DRAWINGS		
WORKING CLEARANCE			PROPER PHASING CONNECTIONS AND COLOR CODE		
SWITCHGEAR CONTROL FUNCTIONS					
PERFORM AUTOMATIC TRANSFER SYSTEM (ATS) FUNCTIONS UNDER THE ADJACENT CONTROLLER	A. OPERATE NORMAL POWER				
	B. ALL GENERATORS OPERATE				
	C. GENERATORS 1 AND 2 OPERATE				
	D. GENERATORS 2 AND 3 OPERATE				
	E. GENERATORS 1 AND 3 OPERATE				
	F. RETURN TO NORMAL POWER AFTER EACH OF THE ABOVE TESTS				
	G. PARALLEL WITH UTILITY UPON RETURN TO NORMAL POWER (ITEMS B THROUGH E)				

SECTION D – ELECTRICAL TESTS

18. MEASUREMENT DESCRIPTION	VOLTAGE AND CURRENT MEASUREMENTS										
	VOLTAGE**						CURRENT**				
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G

19. NOTES

1. CHECK FOR PROPER GROUNDING CONNECTIONS PRIOR TO ENERGIZING.

* CONDITION: A = ACCEPTABLE; R = NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C = CORRECTED; NA = NOT APPLICABLE
** NOTE VALUE AND PHASING

NFPA 70B

FIGURE E.25 Typical Back-Up Power System Inspection Checklist.

INSULATION RESISTANCE–DIELECTRIC ABSORPTION TEST SHEET FOR POWER CABLE

Test No. _____

_____ Company Date _____

_____ Location Time _____

Circuit			Circuit Length			Aerial	Duct	Burned
Number of Conductors	Conductor Size	AWG MCM (kcmil)			Belted	Shielded		
Insulating Material			Insulating Thickness		Voltage Rating		Age	
Pothead or Terminal Type					Location	Indoors	Outdoors	
Number and Type of Joints								
Recent Operating History								
						Mfr.		
State if Potheads or Terminals Were Guarded During Test								
List Associated Equipment Included in Test								
Misc. Information								

Test Data — Megohms

Part Tested					Test Made	Hours Days	After Shutdown
Grounding Time					Dry-Bulb Temp.		
Test Voltage					Wet-Bulb Temp.		
	To Line	To Line	To Line	To Line	Dew Point		
Test Connections	To Earth	To Earth	To Earth	To Earth	Relative Humidity		%
	To Guard	To Guard	To Guard	To Guard	Absolute Humidity		Gr./#
¼ minute					Equipment Temp.		
½ minute					How Obtained		
¾ minute							
1 minute							
2 minutes					"Megger" Inst.		
3 minutes					Serial No.		
4 minutes					Range		
5 minutes					Voltage		
6 minutes							
7 minutes							
8 minutes							
9 minutes							
10 minutes							
10:1 min. Ratio							

Remarks _____

Tested by:

Δ FIGURE E.26 Typical Insulation Resistance–Dielectric Absorption Test Sheet for Power Cable.

CABLE TEST SHEET

Company _____ Date _____ Job No. _____

Test Location _____ Circuit _____ Air Temp. _____ % Hum. _____

Test Type: Acceptance ❑ Periodic ❑ Special ❑ Date Last _____ Sheet No. _____ Weather _____

Cable Mfr.	
Rated kV	(Gnd., Ungnd.)
Oper. kV	(Gnd., Ungnd.)
Length	
Age	
No. Cond.	
No. Size	
Insul. Material	
Insul. Thickness	
Insul. Type	
Covering	
Installed in	
Factory Test kV	
% Factory Test kV	
Max. Test kV	
Voltmeter kV	

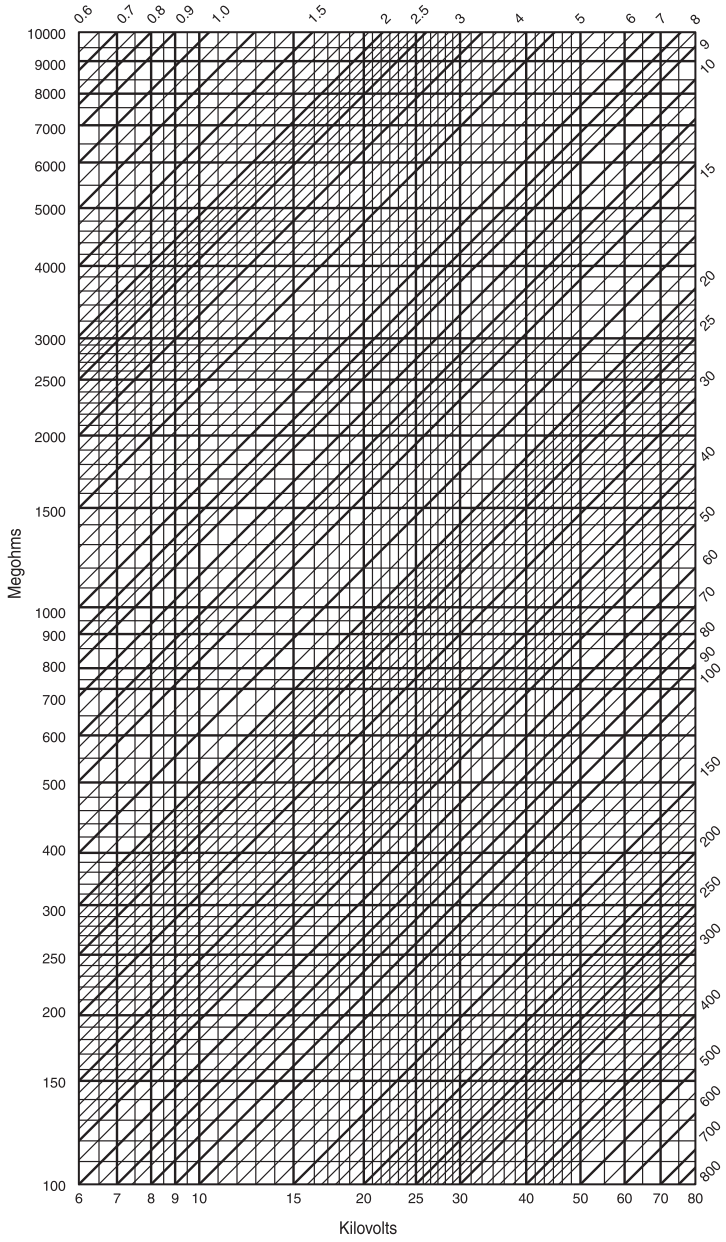
Time Min.	Volts kV	Leakage Current-Microamps Φ1 – ⊙	Φ2 – △	Φ3 – ⊡

Insulation Resistance Test 1 Minute @ 2.5 kV — 1000 Megohms			
Φ TO GND.			
Φ 1 TO Φ	—		
Φ 2 TO Φ	—	—	

Authorization of Max.
Test kV and Verifying Voltmeter kV

_____
Signature

Remarks: _____



Test Set No.: _____ Tested by: _____ Sheet No.: _____

Δ FIGURE E.27 Typical Cable Test Sheet.

INSULATION RESISTANCE TEST RECORD

Date _____

Scope: Dielectric Absorption Without Temperature Correction

Apparatus _____ Equipment Temp. _____ Ambient Temp. _____

Instrument Used _____ Polarization Index No. _____

Condition 10:1 Min. Ratio

Dangerous ---------- Less than 1

Poor ---------- Less than 1.5

Questionable ---------- 1.5 to 2

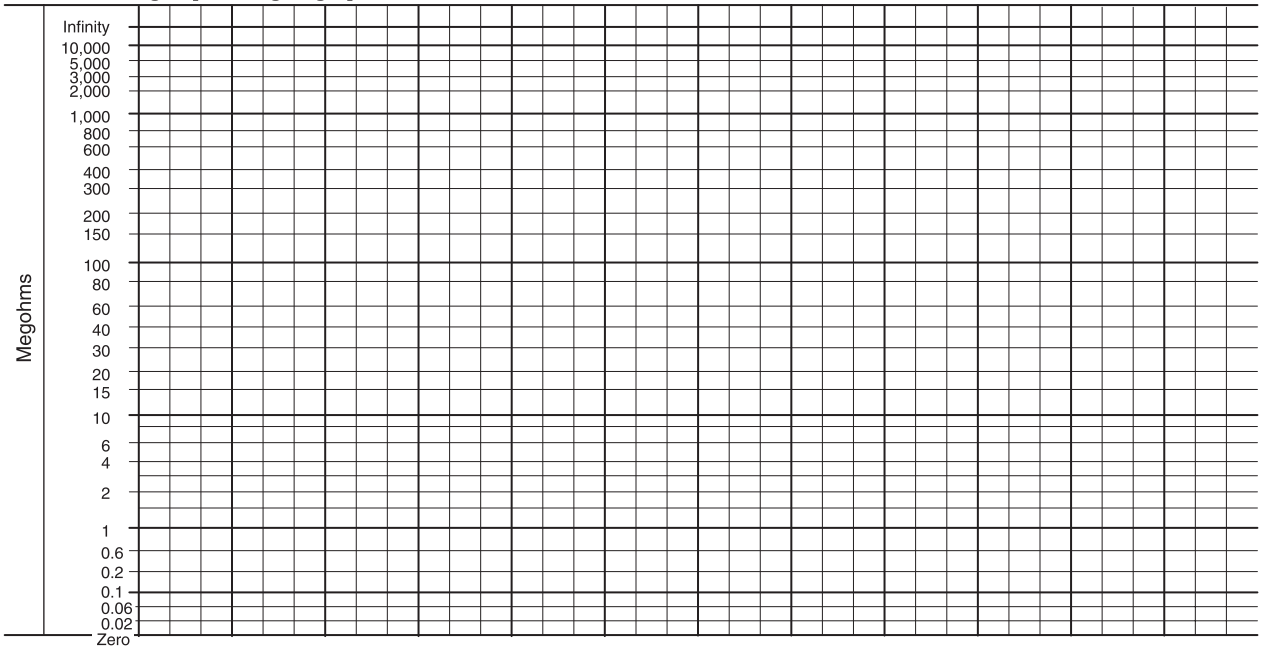
Fair ---------- 2 to 3

Good ---------- 3 to 4

Excellent ---------- Above 4

Time in Minutes		0.25	0.5	1	2	3	4	5	6	7	8	9	10
To Ground	Phase 1												
	Phase 2												
	Phase 3												
Between Phases	Phase 1–2												
	Phase 2–3												
	Phase 3–4												

Plot the lowest group reading on graph.



Tested by: _____

 NFPA 70B

Δ FIGURE E.28 Typical Insulation Resistance Test Record.

INSULATION RESISTANCE TEST RECORD FOR ROTATING MACHINERY

Reference: ANSI/IEEE 43, *Recommended Practice for Testing Insulation Resistance of Rotating Machinery*

Scope:

Dielectric Absorption — Temperature Corrected

ac machines 1000 kVA or more
dc machines 100 kW or more

Date _____

Apparatus _____ Voltage _____ Rating _____

Test Conditions:

List Associated Test Equipment Included in Test _____

Winding Grounding Time _____ Test Made _____ Hours After Shutdown

Ambient Temperature _____ Relative Humidity _____ % Weather _____

Equipment Temperature _____ How Obtained _____

Instrument _____ Range _____ Voltage _____

Test Data:

Minutes	0.25	0.5	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
Reading												
Correction												

Megohms: Infinity; 10,000; 5,000; 3,000; 2,000; 1,000; 800; 600; 400; 300; 200; 150; 100; 80; 60; 40; 30; 20; 15; 10; 6; 4; 2; 1; 0.6; 0.2; 0.1; 0.06; 0.02; Zero

Polarization No. (10:1 min. ratio) _____ Tested by _____

Remarks: _____

Δ FIGURE E.29 Typical Insulation Resistance Test Record for Rotating Machinery.

MOTOR TEST INFORMATION

SHEET NO. _____ OF _____
TEST REPORT NO. _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USER _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION _____
EQUIPMENT LOCATION _____
OWNER IDENTIFICATION _____

MOTOR TEST INFORMATION

INSULATION RESISTANCE TEST RESULTS AT _____ VDC IN MEGOHMS

30 SEC. _____
60 SEC. _____
10 MIN. _____
D.A. _____
P.I. _____

A. NAME & IDENTIFYING MARK OF MOTOR _____
B. MANUFACTURER _____
C. MODEL NUMBER _____
D. SERIAL NUMBER _____
E. RPM _____
F. FRAME SIZE _____
G. CODE LETTER _____
H. HORSEPOWER _____
I. NAMEPLATE VOLTAGE & PHASE _____
J. NAMEPLATE AMPS _____
K. ACTUAL VOLTAGE _____
L. ACTUAL AMPS _____
M. STARTER MANUFACTURER _____
N. STARTER SIZE _____
O. HEATER SIZE, CATALOG # & AMP _____
P. MANUFACTURER OF DUAL ELEMENT _____
Q. AMP RATING OF FUSE _____
R. POWER FACTOR _____
S. SERVICE FACTOR _____

REMARKS: _____

TEST EQUIPMENT USED _____ SERIAL # _____
SUBMITTED BY _____ TEST _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.30 Typical Motor Test Information Form.

GROUNDING SYSTEM RESISTANCE TEST

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____

ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____

OWNER/USER _____ DATE LAST INSPECTION _____

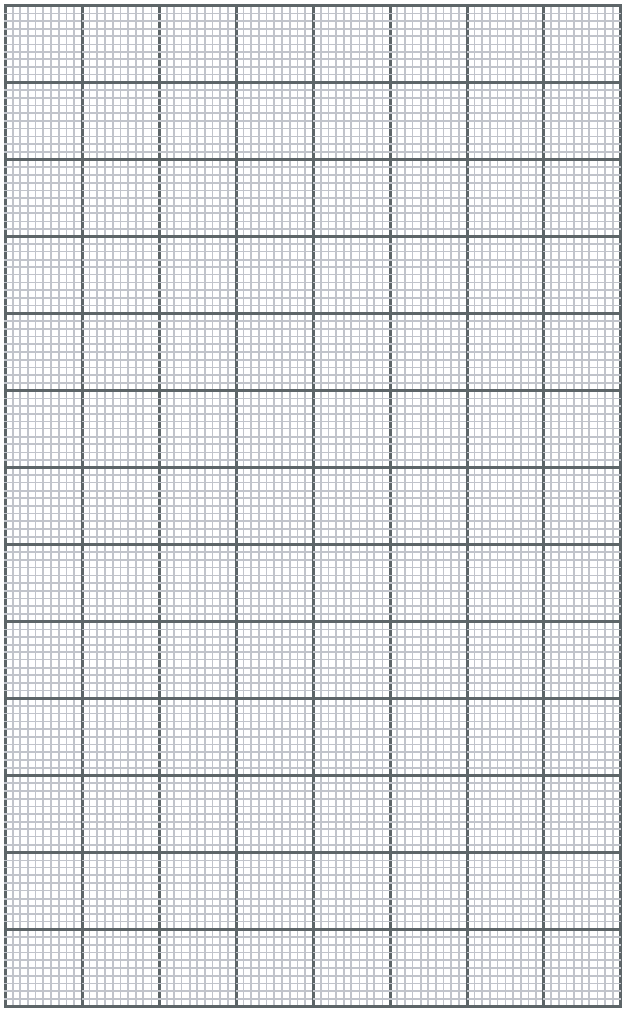
ADDRESS _____ LAST INSPECTION REPORT NO. _____

LOCATION _____

SEASON	
SOIL TYPE	
SOIL CONDITION	
SINGLE ROD DEPTH	
MULTIPLE RODS (Y/N)	
LONGEST DIMENSION	
BURIED WIRE/STRIPS (Y/N)	
LONGEST DIMENSION	
DIST. TO AUX. ELECTRODE	
OTHER	

AUXILIARY POTENTIAL ELECTRODE

DISTANCE (FEET)	RESISTANCE (OHMS)



REMARKS _____

SUBMITTED BY _____ EQUIPMENT USED _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.31 Typical Ground System Resistance Test Report.

GROUND TEST INSPECTION REPORT — HEALTH CARE FACILITIES

SHEET NO. _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____

ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____

OWNER/USER _____ DATE LAST INSPECTION _____

ADDRESS _____ LAST INSPECTION REPORT _____

EQUIPMENT LOCATION _____

OWNER IDENTIFICATION _____

MAXIMUM TEST INTERVALS:
GENERAL CARE: 12 MONTHS
CRITICAL CARE: 6 MONTHS
WET LOCATIONS: 12 MONTHS

*NOTE: MAXIMUM READINGS PERMITTED:
20mV NEW CONSTRUCTION
40mV CRITICAL EXISTING CONSTRUCTION
500mV GENERAL CARE EXISTING CONSTRUCTION
0.1 ohm NEW CONSTRUCTION
0.2 ohm QUIET GROUNDS AND EXISTING CONSTRUCTION

ROOM NO.	DESCRIPTION (C) CRITICAL (G) GENERAL	VOLTAGE MEASUREMENT			IMPEDANCE MEASUREMENT	
		NUMBER OF RECEPTABLES	NUMBER OF OTHER	MAX READING (MILLIVOLTS)	NUMBER OF RECEPTACLES	MAX READING (OHMS)

REMARKS _____

CUSTOMER REPRESENTATIVE _____ TITLE _____

TEST EQUIPMENT _____ SERIAL # _____

SUBMITTED BY _____

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.32 Typical Ground Test Inspection Report — Health Care Facilities.

LINE ISOLATION MONITOR TEST DATA — HEALTH CARE FACILITIES

SHEET _____ OF _____

CUSTOMER _____ DATE _____ PROJECT NO. _____
ADDRESS _____ AIR TEMP. _____ REL. HUMIDITY _____
OWNER/USE _____ DATE LAST INSPECTION _____
ADDRESS _____ LAST INSPECTION REPORT NO. _____
EQUIPMENT LOCATION _____
CIRCUIT _____

INSTRUMENT OR METER UNDER TEST

TYPE _____ MANUFACTURER _____ VOLTAGE _____
SERIAL NO. _____ MODEL NO. _____
CATALOG NO. _____ STYLE NO. _____

TEST OPERATIONS

CAUTION: NO TEST EQUIPMENT NEEDED FOR THIS SECTION. REMOVE ALL PLUGS FROM MONITOR DURING THESE TESTS. PATIENT MUST NOT BE SUBJECTED TO HARMFUL TEST VOLTAGES.

		AS FOUND		AS LEFT	
1. AUDIBLE AND VISUAL INDICATORS	SELF TEST				
	SILENCE (MUTE)				
2. CHECK APPROPRIATE BOX IF INDICATOR IS OPERATIONAL	RED				
	GREEN				
	YELLOW				
3. LIM	MANUFACTURER'S SPECIFIED ALARM POINT		MA		MA
	METER READING		MA		MA

TEST OPERATIONS USING TEST EQUIPMENT:
TEST SET _____

		AS FOUND	AS LEFT
4. LINE LEAKAGE TO GROUND	ONE mA		
	TWO mA		
	THREE mA		
	FOUR mA		
	FIVE mA		
5. ARE ALL BREAKERS OPERATIONAL AND CIRCUITS LABELED?			

REMARKS _____

CUSTOMER REPRESENTATIVE _____ TITLE _____
TEST EQUIPMENT _____ SERIAL # _____
SUBMITTED BY _____ TEST CREW _____

Courtesy of Northeast Electrical Testing NFPA 70B

Δ FIGURE E.33 Typical Line Isolation Monitor Test Data Report — Health Care Facilities.

TORQUE VALUE RECORD

SHEET NO. __________ OF _________

CUSTOMER ____________________ DATE ____________________ PROJECT NO. ____________________
ADDRESS ____________________ AIR TEMP. ____________________ REL. HUMIDITY ____________________
OWNER/USER ____________________ DATE LAST INSPECTION ____________________
ADDRESS ____________________ LAST INSPECTION REPORT NO. ____________________
EQUIPMENT LOCATION ____________________
OWNER IDENTIFICATION ____________________

GENERAL INFORMATION:

Equipment ID: ____________________ Performed By: ____________________
Location: ____________________ Torque Marked: ☐ Yes ☐ No Color: __________
Date Performed: ____________________ Verified By: ____________________
Torque Wrench Information: ☐ IN-LBS ☐ FT-LBS Verification Marked: ☐ Yes ☐ No Color: __________
Manufacturer: __________ Model: __________ Approved By: ____________________

TORQUE AND VERIFICATION

No.	No. of Items	Item Description/Location	Vendor Specification		NETA Specification		Torque		Note
			NO.	FT-LB / IN-LB	NO.	FT-LB / IN-LB	NO.	FT-LB / IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	
				FT-LB IN-LB		FT-LB IN-LB		FT-LB IN-LB	

REMARKS ____________________

CUSTOMER REPRESENTATIVE ____________________ TITLE ____________________
TEST EQUIPMENT ____________________ SERIAL # ____________________
SUBMITTED BY ____________________

Courtesy of Northeast Electrical Testing NFPA 70B

FIGURE E.34 Typical Torque Value Record.

MAIN POWER ENERGIZATION CHECKLIST

For use of this form see TM 5-694: the proponent agency is COE.

SECTION A – CUSTOMER DATA

1. PLANT/BUILDING	2. LOCATION	3. JOB NUMBER	
4. CIRCUIT DESIGNATION	5. CIRCUIT FED FROM	6. CIRCUIT FED TO	7. DATE *(YYYYMMDD)*
8. TEST EQUIPMENT TYPE/BRAND AND CALIBRATION DATE		9. TESTED BY	

SECTION B – VISUAL AND ELECTRICAL/MECHANICAL INSPECTION

10. CHECK POINT	COND*	NOTES	CHECK POINT	COND*	NOTES
COMPONENT INSPECTION/TESTING COMPLETED			VERIFY SWITCHGEAR CONTROL FUNCTIONS		
WIRING VISUAL VERIFICATION			CHECK FOR WORKING CLEARANCE		
VERIFY WIRING DIAGRAMS			ENERGIZE AND TEST SYSTEM		
VERIFY CIRCUIT SWITCHER CONTROL FUNCTIONS			TRANSFORMER TRANSFER CONTROL FUNCTIONS		
ENERGIZE AND TEST SYSTEM FOR ALL CONDITIONS			CHECK FOR UNUSUAL SOUNDS AFTER ENERGIZING		
CHECK BUSHING OR TERMINALS			CHECK ANCHORING OF TRANSFORMER SWITCHGEAR AND SWITCHES ENCLOSURE		
CHECK FOR REMOVAL OF PAINT OR HEAVY DENTS			CHECK FOR NORMAL/ABNORMAL SWITCHING OPERATION		

SECTION C – ELECTRICAL TESTS

11. MEASUREMENT DESCRIPTION	VOLTAGE AND CURRENT MEASUREMENTS										
	VOLTAGE**						CURRENT**				
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G
	A-N	B-N	C-N	A-B	B-C	C-A	A	B	C	N	G

12. NOTES

* CONDITION: A = ACCEPTABLE; R = NEEDS REPAIR, REPLACEMENT OR ADJUSTMENT; C = CORRECTED; NA = NOT APPLICABLE
** NOTE VALUE AND PHASING

FIGURE E.35 Typical Main Power Energization Checklist.

Facility Identification **Job No.**

INSTRUCTIONS TO CONTRACTOR

Date: _____

Contractor Name: _____

Address: _____

City, State, Zip Code: _____

Subject: Project Title: _____

Project No.: _____

Enclosed is one complete set of the following bid documents covering work for the subject project.

1. Project Scope of Work, Dated: _____
2. Proposal Forms for:
   General Maintenance of Electrical Power Equipment, and/or
   Infrared Surveying of Electrical Power Equipment, and/or
   Circuit Breaker Overhaul and Trip Unit Retrofit
3. Plant Electrical Power Equipment Documentation:
   - **Plant one line diagrams** **Dwg. Nos. _____ , Dated _____**
   - **Plant layout drawings** **Dwg. Nos. _____ , Dated _____**
   - **Plant equipment list** **Doc. No. _____ , Dated _____**
   - **Short circuit analyses and time-current coordination studies**
   - **Equipment manufacturers' requirements will be available at the plant for your use.**

We would appreciate receiving a quote from you for this work on the enclosed Project Scope of Work in strict accordance to the quote documents. Please respond in writing if you do not intend to submit a quote for this project.

One original and copy(s) of your quote will be due not later than _____ at _____ local time.

Fax and send one original of your proposal to: ***(Enter Project Engineer's Name, Address, and Fax No. here)***

We welcome suggestions regarding changes in specifications and/or modifications in design or production methods that will aid in reducing costs without impairing quality or that will improve the quality, safety, and/or performance of the product on which you are quoting. However, your base bid price must be submitted on the basis of the bid documents. All voluntary alternates are to be presented as a separate price from the base bid.

Pre-Quote Walk Through (if applicable)

You are invited to attend a pre-quote walk through meeting scheduled for:

Time: _____

Day: _____

Date: _____

Location: _____

If you desire further information addressing the technical specifications or site visitation, please contact ***(project engineer)*** at ***(phone no.).***

Sincerely,

(Enter Project Engineer's Name and Location here)

Δ **FIGURE E.36 Instructions to Contractor.**

Facility Identification **Job No.**

PROJECT SCOPE OF WORK

Introduction

This Scope of Work document will define the maintenance activities to be included in this project. The contractor shall provide all labor, materials, and equipment necessary to perform requested electrical power equipment maintenance. All maintenance activities will be performed in accordance with the applicable Technical Specification and other pertinent portions of facility's Electrical Power Equipment Maintenance Manual. *The costs of premium time, if required, shall be included in this quote.*

If electrical power equipment is found to be within the Manufacturer's specifications for continued service and the required maintenance is unnecessary, clean, adjust, and reassemble the electrical power equipment and perform all Manufacturer recommended procedures for continued service.

If the contractor discovers that the electrical power equipment cannot be brought into compliance with the Manufacturer's specifications for continued service, advise the Owner of the "as found" condition and await further direction. *Save all component parts for Owner inspection.*

General Task Description

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Schedule

Time to complete all tasks: _____

Time equipment is available: _____

Time/day to begin work: _____

Time/day to complete work: _____

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Δ **FIGURE E.37 Project Scope of Work Template.**

Facility Identification **Job No.**

PROJECT SCOPE OF WORK *(continued)*

Specific Task Description

Contractor will perform the specific tasks described in this section.

General Maintenance

The following maintenance activities will be performed in accordance with the Technical Specifications for General Maintenance or Electrical Power Equipment.

Circuit Breaker Overhaul and Trip Unit Retrofit

The following maintenance activities will be performed in accordance with the Technical Specifications for Circuit Breaker Overhaul and Trip Unit Retrofit.

Infrared Surveying

The following maintenance activities will be performed in accordance with the Technical Specifications for Infrared Surveying of Electrical Power Equipment.

Work Not Included (Listed Owner furnished services)

Exceptions to Specifications

Δ **FIGURE E.37** ***Continued***

PROJECT SCOPE OF WORK QUOTE FORM

Location: _____ Project No. _____ Purch. Req. No. _____

Contractor: _____ MBO No. _____

The Contractor shall perform the work in strict accordance with the facility's Electrical Power Equipment Maintenance Manual EMM-1 General Maintenance Technical Specification, the Circuit Breaker Overhaul and Trip Unit Retrofit Technical Specification, the plant equipment list, single line diagrams and drawings, and the Project Scope of Work. All alternates shall be fully described with exceptions listed by Item Number, and priced separately. When applicable, General Maintenance Technical Specification (GMTS) codes shall be used on this Proposal Form as they are used in the Project Scope of Work.

Item No.	Maintenance Activity Description and Location of Equipment	GMTS Code	Quantity	Item/Unit Price	Item Total Price
				Page Total	

Δ **FIGURE E.38 Project Scope of Work Form.**

PROJECT SCOPE OF WORK MODIFICATION QUOTE FORM

Location: _____ Project No. _____ Purch. Req. No. _____

Contractor: _____ MBO No. _____ Modification No. _____

All modifications shall be fully described with reference to the original Item Number, and priced separately. The Contractor shall perform the work in strict accordance with the facility's Electrical Power Equipment Maintenance Manual EMM-1 General Maintenance Technical Specification, the Circuit Breaker Overhaul and Trip Unit Retrofit Technical Specification, the plant equipment list, single line diagrams and drawings, and the Project Scope of Work. When applicable, General Maintenance Technical Specification (GMTS) codes shall be used on this Proposal Form as they are used in the Project Scope of Work. Contractor shall not begin work until approved by the plant.

Item No.	Maintenance Activity Description and Location of Equipment	GMTS Code	Qty.	Labor	Mat'l	Item Total Price
					Page Total	

Submitted by: _____ Date: _____

Approved by: _____ Date: _____

Δ **FIGURE E.39 Project Scope of Work Modification Form.**

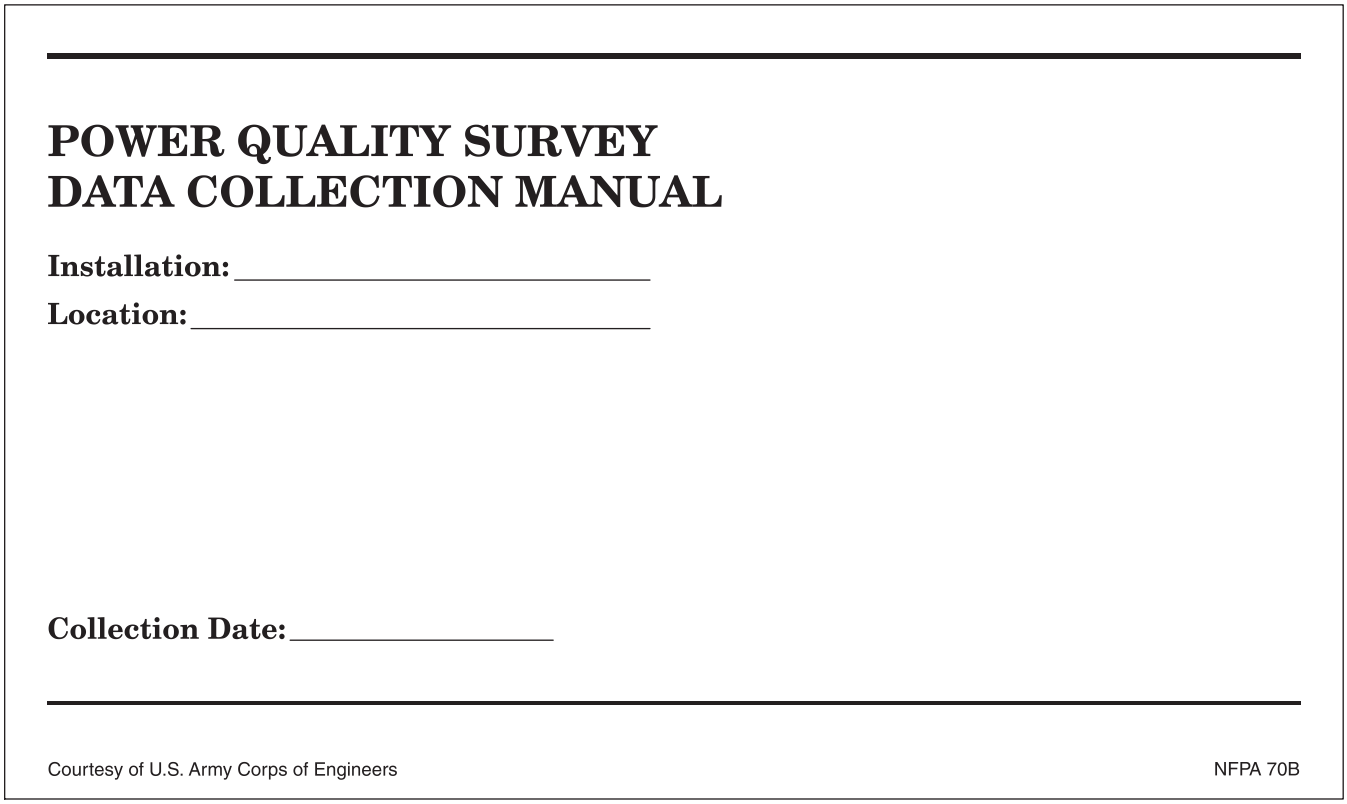


FIGURE E.40 Cover and Contents.

POINTS OF CONTACT

Installation: _____

Address: _____

_____

Names	Titles	Office Symbols	Phones

Contractor's Name: _____

Address: _____

_____

Names	Titles	Office Names	Phones

Utilities: _____

Address: _____

_____

Names	Titles	Office Names	Phones

Courtesy of U.S. Army Corps of Engineers NFPA 70B

FIGURE E.41 Points of Contact.

POWER DISTRIBUTION UNIT (PDU) SURVEY

Date: _____

Installation: _____ Location: _____

Power Distribution Unit (PDU) Identification: _____

Manufacturer: _____ Model/Serial #: _____

Size: _____ kVA 3-Phase: _____ Single-Phase: _____ Frequency: _____ Hz

Input Voltage Rating: _____ V Input Current Rating: _____ A Tap Changing Range: _____

Output Voltage Rating: _____ V Output Current Rating: _____ A

Measured Input Volts	$V_{(IN)A-B}$ = _____ V	$V_{(IN)B-C}$ = _____ V	$V_{(IN)C-A}$ = _____ V	
Input Voltage Harmonic Distortion	$V_{(IN)THD(A-B)}$ = ____ % 3rd = _____ __th = _____ __th = _____	$V_{(IN)THD(B-C)}$ = ____ % 3rd = _____ __th = _____ __th = _____	$V_{(IN)THD(A-C)}$ = ____ % 3rd = _____ __th = _____ __th = _____	
Measured Input Amps	$I_{(IN)A}$ = _____ A	$I_{(IN)B}$ = _____ A	$I_{(IN)C}$ = _____ A	
Input Current Harmonic Distortion	$I_{(IN)THD(A)}$ = _____ % 3rd = _____ __th = _____ __th = _____	$I_{(IN)THD(B)}$ = _____ % 3rd = _____ __th = _____ __th = _____	$I_{(IN)THD(C)}$ = _____ % 3rd = _____ __th = _____ __th = _____	
Measured Output Volts	$V_{(O)A-N}$ = _____ V $V_{(O)A-G}$ = _____ V	$V_{(O)B-N}$ = _____ V $V_{(O)B-G}$ = _____ V	$V_{(O)C-N}$ = _____ V $V_{(O)C-G}$ = _____ V	$V_{(O)N-G}$ = _____ V
Output Voltage Harmonic Distortion	$V_{(O)THD(A-N)}$ = ____ % 3rd = _____ __th = _____ __th = _____	$V_{(O)THD(B-N)}$ = ____ % 3rd = _____ __th = _____ __th = _____	$V_{(O)THD(C-N)}$ = ____ % 3rd = _____ __th = _____ __th = _____	$V_{(O)THD(N-G)}$ = ____ % 3rd = _____ __th = _____ __th = _____
Measured Output Amps	$I_{(O)A}$ = _____ A	$I_{(O)B}$ = _____ A	$I_{(O)C}$ = _____ A	$I_{(O)N}$ = _____ A
Output Current Harmonic Distortion	$I_{(O)THD(A)}$ = _____ % 3rd = _____ __th = _____ __th = _____	$I_{(O)THD(B)}$ = _____ % 3rd = _____ __th = _____ __th = _____	$I_{(O)THD(C)}$ = _____ % 3rd = _____ __th = _____ __th = _____	$I_{(O)THD(N)}$ = _____ % 3rd = _____ __th = _____ __th = _____
K Factor	Measured K Factor: _____		Nameplate K Factor: _____	
Ground System	Neutral bus of PDU is connected to ground? ❑ Yes ❑ No Ground bus of PDU is connected to upstream switchgear/switchboard/panel ground bus? _____ to building metal frame? _____ to raised floor frame? _____ Ground current measurement: _____ A Ground resistance measurement: _____ Ω			
Temperature	Transf winding temperature range: _____ Bus temperature range: _____ CBs having temperature higher than 32°C (90°F): _____			
Power Factor	PF: _____ Displacement Power Factor (DPF): _____			

Courtesy of U.S. Army Corps of Engineers NFPA 70B (p. 1 of 2)

Δ **FIGURE E.42 Power Distribution Unit (PDU) Survey.**

POWER DISTRIBUTION UNIT (PDU) SURVEY *(continued)*

Deficiencies found	
Problems in the past	
Customer's concerns	
Notes	

Courtesy of U.S. Army Corps of Engineers NFPA 70B (p. 2 of 2)

FIGURE E.42 ***Continued***

GENERATOR SET SURVEY

Date: _____

Installation: _____ Location: _____

Number of generator sets at this location: _____

Generator Set #1

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair ❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: _____

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: _____
- Model/Type: _____ Rated Voltage: _____
- Rated hp (or kW): _____ Rated Current: _____
- Power Factor: _____ Frequency: _____

Generator Data:

- Manufacturer: _____
- Model/Type: _____
- Generated Voltages: _____ V Generated Frequencies: _____ Hz
- Rated kVA: _____ Rated kW: _____
- Rated Currents: _____ A Efficiency Factor: _____
- Winding Connection (D/W/GW): _____ Power Factor: _____

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: _____
- Measured Voltages: _____ V Measured Temperatures: _____

Generator Set #2

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair ❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: _____

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: _____
- Model/Type: _____ Rated Voltage: _____
- Rated hp (or kW): _____ Rated Current: _____
- Power Factor: _____ Frequency: _____

Generator Data:

- Manufacturer: _____
- Model/Type: _____
- Generated Voltages: _____ V Generated Frequencies: _____ Hz
- Rated kVA: _____ Rated kW: _____
- Rated Currents: _____ A Efficiency Factor: _____
- Winding Connection (D/W/GW): _____ Power Factor: _____

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: _____
- Measured Voltages: _____ V Measured Temperatures: _____

Courtesy of U.S. Army Corps of Engineers NFPA 70B (p. 1 of 2)

Δ FIGURE E.43 Generator Set Survey.

GENERATOR SET SURVEY *(continued)*

Generator Set #3

Physical Conditions: ❑ Good condition ❑ Damage ❑ Not in use ❑ Need repair
❑ Old ❑ Corrosion ❑ Need maintenance ❑ Other: _____

- Designed for: ❑ Prime operation ❑ Standby operation ❑ Emergency operation

Engine Data:

- Manufacturer: _____
- Model/Type: _____ Rated Voltage: _____
- Rated hp (or kW): _____ Rated Current: _____
- Power Factor: _____ Frequency: _____

Generator Data:

- Manufacturer: _____
- Model/Type: _____
- Generated Voltages: _____ V Generated Frequencies: _____ Hz
- Rated kVA: _____ Rated kW: _____
- Rated Currents: _____ A Efficiency Factor: _____
- Winding Connection (D/W/GW): _____ Power Factor: _____

Batteries

- ❑ Good condition ❑ Leakage ❑ Need maintenance ❑ Dead ❑ Other: _____
- Measured Voltages: _____ V Measured Temperatures: _____

Generator Operation:

- Can these generators run in parallel with the utility power sources? ❑ Yes ❑ No
- The generators are being used as: ❑ Backup source ❑ Peak shaving ❑ Prime source
- Are the generators properly protected against overload? ❑ Yes ❑ No abnormal conditions? ❑ Yes ❑ No or reverse power flow (if generators can run in parallel with utility source)? ❑ Yes ❑ No
- Can the generators automatically start? ❑ Yes ❑ No and automatically shut off? ❑ Yes ❑ No
- How many times did generator fail to start or break down (with unknown reason) during the last few years? _____

Maintenance:

- Does the generator operation log book exist and is it up to date? ❑ Yes ❑ No
- How often does the generator run for maintenance? _____ times per week/month, ❑ with loads or ❑ without loads.
- How long did the generator run during each maintenance period? _____ minutes
- How often is the generator fuel system checked? _____ times per week/month

Generator Grounding System:

- ❑ Solidly grounded ❑ High resistance ❑ Low resistance ❑ Reactance
- Measured ground impedance in ohms: _____
- Is the generator's neutral bus connected to ground? ❑ Yes ❑ No
- Is the generator frame connected to ground? ❑ Yes ❑ No

Notes:

Courtesy of U.S. Army Corps of Engineers NFPA 70B (p. 2 of 2)

Δ **FIGURE E.43** *Continued*

ELECTRICAL PANEL SURVEY

Date: _____

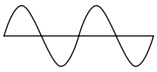
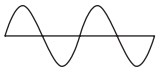
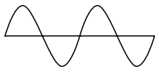
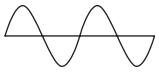
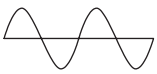
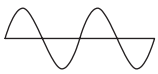
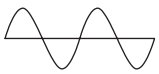
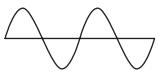
Installation: _____ Location: _____

Panel Identification: _____

Manufacturer Name: _____ Panel Type/Model: _____

Voltage Rating: _____ V Current Rating: _____ A Phases: _____ # of Wires: _____

Main Breaker: Type/Model: _____ Rating: _____ A Adjustable Setting Range: _____

Measured Voltages	V_{A-N} = _____ V V_{A-G} = _____ V	V_{B-N} = _____ V V_{B-G} = _____ V	V_{C-N} = _____ V V_{C-G} = _____ V	V_{N-G} = _____ V
Voltage Sine Waves	 V_{A-N}	 V_{B-N}	 V_{C-N}	 V_{N-G}
Harmonic Voltage Distortion	$V_{THD(A-N)}$ = ____ % 3rd = _____ % __th = _____ % __th = _____ %	$V_{THD(B-N)}$ = ____ % 3rd = _____ % __th = _____ % __th = _____ %	$V_{THD(C-N)}$ = ____ % 3rd = _____ % __th = _____ % __th = _____ %	$V_{THD(N-G)}$ = ____ % 3rd = _____ % __th = _____ % __th = _____ %
Measured Currents	I_A = _____ A	I_B = _____ A	I_C = _____ A	I_N = _____ A
Current Sine Waves	 I_A	 I_B	 I_C	 I_N
Harmonic Current Distortion	$I_{THD(A)}$ = _____ % 3rd = _____ % __th = _____ % __th = _____ %	$I_{THD(B)}$ = _____ % 3rd = _____ % __th = _____ % __th = _____ %	$I_{THD(C)}$ = _____ % 3rd = _____ % __th = _____ % __th = _____ %	$I_{THD(N)}$ = _____ % 3rd = _____ % __th = _____ % __th = _____ %
Power Factor	PF: _____ Displacement Power Factor (DPF): _____			
Grounding System	Ground bus isolated from frame? ____ or bonded to frame? ____ Ground by metal conduits? ____ or by ground conductors? ____ Ground bus bonded to neutral bus? ❑ Yes ❑ No Each branch circuit has separated neutral ❑ Yes ❑ No and ground conductor? ❑ Yes ❑ No Ground current measurement: _____ A Ground resistance measurement: _____ Ω Sketch the existing grounding system (on the back sheet) when it is necessary.			
Temperature	Bus temperature range: _____ Conductor temperature range: _____ CBs having temperature higher than 32°C (90°F): _____			
Entrance Conductor	Phases: _____ MCM Number of conductors per phase: _____			
Sizes	Neutral: _____ MCM Number of conductors per phase: _____ Ground: _____ MCM Number of conductors per phase: _____			
Lightning Protection	Manufacturer: _____ Type: _____ Voltage rating: _____			

Δ **FIGURE E.44 Electrical Panel Survey.**

ELECTRICAL PANEL SURVEY *(continued)*

Other Circuit Breakers in the Panel	Circuit breaker rating: _____ A 3 Ph or Single:_____ How many CB:_____ Circuit breaker rating: _____ A 3 Ph or Single:_____ How many CB:_____ Circuit breaker rating: _____ A 3 Ph or Single:_____ How many CB:_____ Circuit breaker rating: _____ A 3 Ph or Single:_____ How many CB:_____ Circuit breaker rating: _____ A 3 Ph or Single:_____ How many CB:_____ Circuit breaker rating: _____ A 3 Ph or Single:_____ How many CB:_____ Circuit breaker rating: _____ A 3 Ph or Single:_____ How many CB:_____ Circuit breaker rating: _____ A 3 Ph or Single:_____ How many CB:_____
Deficiencies Found	
Problems in the Past	
Customer's Concerns	
Notes	

Δ **FIGURE E.44** ***Continued***

INVERTER SURVEY

Date: ____________________

Installation: ____ Location: ____

Inverter Identification: ____________________________

Number of inverters at this location: ________ Do they all have the same size and characteristics? ❑ Yes ❑ No

Manufacturer: __________________________ Model: __________ Type: __________ Phases: _____ Wires: _____

Input Voltages	Rated: __________ Measured: __________
Input Currents	Rated: __________ Measured: __________
Output Voltages	Rated: __________ Measured: __________
Output Currents	Rated: __________ Measured: __________
kVA	Rated: __________ Measured input: _______ Measured output: _______ PF: _______
kW	Rated: __________ Measured input: _______ Measured output: _______ DPF: ______
Conductor Sizes	Phases: ( )________ Neutral: ( )________ Ground: ( )________
Measured Temperatures	Bus temperature range: __________ Conductor temperature range: __________
Grounding System	Terminal of inverter bonded to ground? ❑ Yes ❑ No Ground bus of inverter bonded to the frame? ❑ Yes ❑ No Ground current measurement: _______ A Ground resistance measurement: _______ Ω Sketch the existing grounding system (on the back sheet) when it is needed.
Batteries	Manufacturer: ______________________ Model: _____________ Type: ______________ Cell voltage: ________________________ Number of cells: ___________________________ Total battery voltages: __________ V Total battery currents: __________ A Conductor sizes: Phases: ( ) _______ Neutral: ( ) _______ Ground: ( ) _______ Physical conditions: ❑ Damage ❑ Corrosion ❑ Leakage Fluid fill level: __________ Proper mounting: __________ Proper clearance: __________ Battery rack condition: _______________ Battery rack grounded? ❑ Yes ❑ No Battery bank terminal grounded? ❑ Yes ❑ No Battery fluid specific gravity last checked: ___________________

Measured Cell Battery Voltages and Fluid Temperatures

All temperatures are in _°C _°F

Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____
Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____
Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____
Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____
Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____	Cell #_____ _____V _____

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Δ **FIGURE E.45 Inverter Survey.**

INVERTER SURVEY *(continued)*

Deficiencies Found	
Problems in the Past	
Notes	

Δ **FIGURE E.45** ***Continued***

BUILDING LIGHTNING PROTECTION SURVEY

Date: _____

Installation: _____ Building #: _____

Physical Conditions	❑ Good Condition ❑ Rust/Corrosion ❑ Damaged
Roof	Materials: ❑ Metal ❑ Non-metal Types: ❑ Flat ❑ Gable ❑ Hip ❑ Gambrel ❑ Intermediate Ridges ❑ Domed ❑ Shed
Air Terminals	Size (diameter): _____ inches Height: _____ feet _____ inches Material: ❑ Copper ❑ Copper Alloys ❑ Aluminum Approximate distance between two consecutive air terminals: _____ feet Air terminals securely mounted on appropriate bases? ❑ Yes ❑ No Air terminal bases are of the same material as the air terminals? ❑ Yes ❑ No Air terminal bases properly fastened/anchored to the roof? ❑ Yes ❑ No An air terminal at each corner of the roof? ❑ Yes ❑ No Two paths for currents to flow (to ground) at each air terminal? ❑ Yes ❑ No
Lightning Conductors	Sizes: _____ AWG Material: ❑ Copper ❑ Copper Alloys ❑ Aluminum Approximate distance between two consecutive lightning conductors: _____ feet Interconnected lightning conductors properly bonded together? ❑ Yes ❑ No Any sharp bend curves (less than 8 inch radius and 90° angle)? ❑ Yes ❑ No Lightning conductor securely fastened every 4 feet? ❑ Yes ❑ No
Down Conductors	Size: _____ AWG Material: ❑ Copper ❑ Copper Alloys ❑ Aluminum Are the conductors electrically continuous running down to the ground? ❑ Yes ❑ No Approximate distance between two consecutive down conductors: _____ feet At least 2 down conductors installed at opposite corners of the building? ❑ Yes ❑ No Total number of down conductors installed: _____ Average resistance measurement at down conductors: _____ Ω
Objects on the Roof	Metal object has a thickness less than 3/16 inch? ❑ Yes ❑ No Metal object is directly bonded to lightning conductors or through an air terminal to lightning conductors? ❑ Yes ❑ No The bonding surface has a contact area of not less than 3 sq-inches? ❑ Yes ❑ No Non-metal objects on the roof? ❑ Yes ❑ No Are they protected with air terminals? ❑ Yes ❑ No Does each air terminal provide a two-way path to the ground? ❑ Yes ❑ No For non-metal object, is the distance from the farthest corner of the object to the air terminal less than 2 feet? ❑ Yes ❑ No
Grounding System	Separate grounding loop for lightning protection system? ❑ Yes ❑ No Is the grounding loop for lightning protection system bonded to the electrical grounding system? ❑ Yes ❑ No Average ground resistance measurement (at the location where it is connected to electrical grounding system): _____ Ω

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Δ **FIGURE E.46 Building Lightning Protection Survey.**

BUILDING LIGHTNING PROTECTION SURVEY *(continued)*

Deficiencies Found	
Problems in the Past	
Sketch the roof floor plan and mark down the location of air terminals, cross-roof lightning conductors, down conductors, and distances between them.	

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Δ **FIGURE E.46** ***Continued***

RECTIFIER SURVEY

Date: ____________________

Installation: ____ Location: ____

Rectifier Identification: ____________________________

Number of units at this location: _________ Do they all have the same size and characteristics? ❑ Yes ❑ No

Manufacturer: __________________________ Model: __________ Type: __________ Phases: _____ Wires: _____

Input Voltages	Rated: __________ Measured: __________
Input Currents	Rated: __________ Measured: __________
Output Voltages	Rated: __________ Measured: __________
Output Currents	Rated: __________ Measured: __________
kVA	Rated: __________ Measured input: _______ Measured output: _______ PF: _______
kW	Rated: __________ Measured input: _______ Measured output: _______ DPF: ______
Conductor Sizes	Phases: ____________ Neutral: ____________ Ground: ____________ Number of conductors per phase: ____________
Measured Temperatures	Bus temperature range: __________ Conductor temperature range: __________
Grounding System	Terminal of rectifier bonded to ground? ❑ Yes ❑ No Ground bus of rectifier bonded to the frame? ❑ Yes ❑ No Ground current measurement: _______ A Ground resistance measurement: _______ Ω Sketch the existing grounding system (on the back sheet) when it is needed.
Batteries	Manufacturer: ______________________ Model: _____________ Type: ______________ Cell voltage: _________________________ Number of cells: ___________________________ Total battery voltages: __________ V Total battery currents: __________ A Conductor sizes: Phases: ( ) _______ Neutral: ( ) _______ Ground: ( ) _______ Physical conditions: ❑ Damage ❑ Corrosion ❑ Leakage Fluid fill level: __________ Proper mounting: __________ Proper clearance: __________ Battery rack condition: _______________ Battery rack grounded? ❑ Yes ❑ No Battery bank terminal grounded? ❑ Yes ❑ No Battery fluid specific gravity last checked: ___________________

Measured Battery Cell Voltages and Fluid Temperatures

All temperatures are in _°C _°F

Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____
Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____
Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____
Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____
Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____	Cell #_____ ______V _____

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Δ **FIGURE E.47 Rectifier Survey.**

RECTIFIER SURVEY *(continued)*

Deficiencies Found	
Problems in the Past	
Customer's Concerns	
Notes	

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Δ **FIGURE E.47** ***Continued***

ELECTRICAL PANEL SURVEY

Date: _____

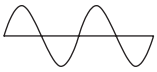
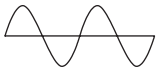
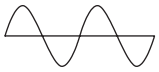
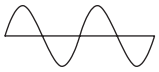
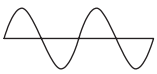
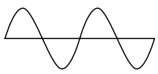
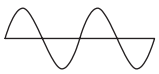
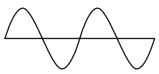
Installation: _____ Location: _____

Panel Identification: _____

Manufacturer Name: _____ Panel Type/Model: _____

Voltage Rating: _____ V Current Rating: _____ A Phases: _____ # of Wires: _____

Main Breaker: Type/Model: _____ Rating: _____ A Adjustable Setting Range: _____

Measured Voltages	V_{A-N} = _____ V V_{A-G} = _____ V	V_{B-N} = _____ V V_{B-G} = _____ V	V_{C-N} = _____ V V_{C-G} = _____ V	V_{N-G} = _____ V
Voltage Sine Waves	 V_{A-N}	 V_{B-N}	 V_{C-N}	 V_{N-G}
Harmonic Voltage Distortion	$V_{THD(A-N)}$ = ____ % 3rd = _____ % __th = _____ % __th = _____ %	$V_{THD(B-N)}$ = ____ % 3rd = _____ % __th = _____ % __th = _____ %	$V_{THD(C-N)}$ = ____ % 3rd = _____ % __th = _____ % __th = _____ %	$V_{THD(N-G)}$ = ____ % 3rd = _____ % __th = _____ % __th = _____ %
Measured Currents	I_A = _____ A	I_B = _____ A	I_C = _____ A	I_N = _____ A
Current Sine Waves	 I_A	 I_B	 I_C	 I_N
Harmonic Current Distortion	$I_{THD(A)}$ = _____ % 3rd = _____ % __th = _____ % __th = _____ %	$I_{THD(B)}$ = _____ % 3rd = _____ % __th = _____ % __th = _____ %	$I_{THD(C)}$ = _____ % 3rd = _____ % __th = _____ % __th = _____ %	$I_{THD(N)}$ = _____ % 3rd = _____ % __th = _____ % __th = _____ %
Power Factor	PF: _____ Displacement Power Factor (DPF): _____			
Grounding System	Ground bus isolated from frame? ____ or bonded to frame? ____ Ground by metal conduits? ____ or by ground conductors? ____ Ground bus bonded to neutral bus? ❑ Yes ❑ No Each branch circuit has separated neutral ❑ Yes ❑ No and ground conductor? ❑ Yes ❑ No Ground current measurement: _____ A Ground resistance measurement: _____ Ω Sketch the existing grounding system (on the back sheet) when it is necessary.			
Temperature	Bus temperature range: _____ Conductor temperature range: _____ CBs having temperature higher than 32°C (90°F): _____			
Entrance Conductor	Phases: _____ MCM Number of conductors per phase: _____			
Sizes	Neutral: _____ MCM Number of conductors per phase: _____ Ground: _____ MCM Number of conductors per phase: _____			
Lightning Protection	Manufacturer: _____ Type: _____ Voltage rating: _____			

Δ **FIGURE E.48 Electrical Panel Survey.**

ELECTRICAL PANEL SURVEY *(continued)*

Other Circuit Breakers in the Panel	CB rating: _____ A How many CB: _____ Conductor sizes: _____ CB rating: _____ A How many CB: _____ Conductor sizes: _____ CB rating: _____ A How many CB: _____ Conductor sizes: _____ CB rating: _____ A How many CB: _____ Conductor sizes: _____ CB rating: _____ A How many CB: _____ Conductor sizes: _____ CB rating: _____ A How many CB: _____ Conductor sizes: _____ CB rating: _____ A How many CB: _____ Conductor sizes: _____ CB rating: _____ A How many CB: _____ Conductor sizes: _____
Deficiencies Found	
Problems in the Past	
Customer's Concerns	
Notes	

Δ **FIGURE E.48** ***Continued***

TRANSFER SWITCHES SURVEY

Date: _____

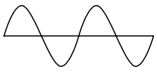
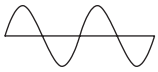
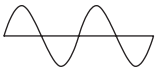
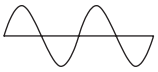
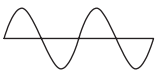
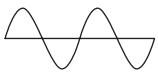
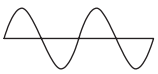
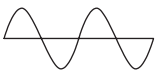
Installation: _____ Location: _____

Transfer Switch Identification: _____

Manufacturer Name: _____ Model/Type: _____ Serial #: _____

Voltage Rating: _____V Current Rating: _____A Fuse sizes: _____

Automatic or Manual: _____ Phases: _____ # of Poles: _____ # of Wires: _____

Measured Voltages	V_{A-G} = _____ V V_{A-N} = _____ V	V_{B-G} = _____ V V_{B-N} = _____ V	V_{C-G} = _____ V V_{C-N} = _____ V	V_{N-G} = _____ V
Voltage Sine Waves	 V_{A-G}	 V_{B-G}	 V_{C-G}	 V_{N-G}
Harmonic Voltage Distortion	$V_{THD(A-G)}$ = ____% 3rd = _____% 5th = _____% __th = _____%	$V_{THD(B-G)}$ = ____% 3rd = _____% 5th = _____% __th = _____%	$V_{THD(C-G)}$ = ____% 3rd = _____% 5th = _____% __th = _____%	$V_{THD(N-G)}$ = ____% 3rd = _____% 5th = _____% __th = _____%
Measured Currents	I_A = _____A	I_B = _____A	I_C = _____A	I_N = _____A
Current Sine Waves	 I_A	 I_B	 I_C	 I_N
Harmonic Current Distortion	$I_{THD(A)}$ = _____% 3rd = _____% 5th = _____% __th = _____%	$I_{THD(B)}$ = _____% 3rd = _____% 5th = _____% __th = _____%	$I_{THD(C)}$ = _____% 3rd = _____% 5th = _____% __th = _____%	$I_{THD(N)}$ = _____% 3rd = _____% 5th = _____% __th = _____%
Grounding System	Neutral bus exists? ❑ Yes ❑ No Ground bus exists? ❑ Yes ❑ No Neutral bus bonded to ground bus at the transfer switch? ❑ Yes ❑ No Neutral conductors just run through transfer switch? ❑ Yes ❑ No Ground bus bonded to the frame? ❑ Yes ❑ No Ground bus connected to upstream source ground? ❑ Yes ❑ No Ground bus connected to downstream load ground? ❑ Yes ❑ No Ground resistance measurement: _____ Ω Ground current measurement: _____A Sketch the existing grounding system (on the back sheet) when it is necessary.			
Temperatures	Bus temperatures: _____ Conductor temperatures: _____			
Power Factor	PF: _____ Displacement Power Factor (DPF): _____			
Conductor Sizes	Normal source: Phases: ( ) _____ Neutral: ( ) _____ Ground: ( ) _____ Emerg/Standby source: Phases: ( ) _____ Neutral: ( ) _____ Ground: ( ) _____ Load side: Phases: ( ) _____ Neutral: ( ) _____ Ground: ( ) _____			

Δ **FIGURE E.49 Transfer Switches Survey.**