THE NEW NFPA 70B-2023 STANDARD FOR ELECTRICAL MAINTENANCE

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Abstract: NFPA 70B-2023 has made the transition from a recommended practice to the Standard for Electrical Equipment Maintenance. As a standard, the document prescribes the minimum requirements for maintenance of electrical equipment in industrial and various commercial installation of types when manufacturer instructions are not available. Electrical maintenance for safety of personnel and environment is the key focus of this standard. The standard identifies what is to be maintained, what maintenance is to be performed, and the expected intervals for performing electrical preventive maintenance. This paper supplies an explanation of the major points and foundations to help develop an understanding on how to use and apply the new standard.

Key terms: Maintenance, Electrical Safety, Reliability, Condition based maintenance, Reliability centered maintenance

I. INTRODUCTION

NFPA 70B [1], Standard for Electrical Equipment Maintenance, is one of the three core NFPA standards for the electrical power distribution and control industry within the commercial, industrial, and residential space. The other two are NFPA 70 [2], known as the National Electrical Code® (NEC®), an installation practices standard, addressing installation requirements in residential, commercial, and industrial occupancies for electrical infrastructure and NPFA 70E [3] the standard for electrical safety which addresses electrical safety for employees in all workplaces where there may be electrical hazards. NFPA 70B has, through this revision process, undergone an extensive revision as part of the process of being converted from a recommended practice to a standard to enhance its ability to promote good electrical maintenance practices in the electrical industry and thereby better support the shared safety goals for all three standards. This paper describes the contents of the new standard and its intent; however, it should not be construed as a replacement for reading, understanding, and following the new standard.

An important point about this document is that this is the first version of the document published as an NFPA standard Previous editions were published as a Recommended Practice. Refer to [4] for information concerning the NFPA document development process.

In a standard, it is a requirement that content only include minimum generally accepted practices that fulfill the scope and purpose of the document. Because of this, readers familiar with the previously published recommended practice may notice that some detailed practices described are no longer included in the prescriptive portions of the text. The technical committee may have agreed that this was useful content, however, the perception was that some of the content exceeded the minimum required practice all users needed to consider implementing. In some cases, some of this additional valuable content may be found in supporting annexes or found in other industry texts on electrical maintenance. As first edition of an important document, though created from a different previous document, in great part during the global pandemic of 2020 and 2021, it can be reasonably expected that it can greatly benefit from future public comments. Equipment users and electrical maintenance professionals and practitioners are encouraged to provide comments and input in future revision cycles so the document can be improved.

A. Organization

The document is divided into 38 chapters (numbered 1-38) and 13 Annexes (A-M). The annexes are not part of the requirements identified in the document and are provided for informational purposes. Below is the list of the titles of those chapters and annexes.

1) Administration
2) Referenced Publications
3) Definitions
4) General
5) Personnel Safety
6) Single-Line Diagrams and System Studies
7) Fundamental Tests
8) Field Testing and Test Methods
9) Maintenance Intervals
10) Hazardous (Classified) Location Electrical Equipment
11) Power and Distribution Transformers
12) Substations and Switchgear
13) Panelboards and Switchboards
14) Busways
15) Circuit Breakers, Low- and Medium-Voltage
16) Fuses
17) Switches
18) Power Cables and Conductors
19) Cable Tray
20) Grounding and Bonding
21) Ground-Fault Circuit Interrupters and Ground-Fault Protection of Equipment Systems
22) Lighting
23) Lighting Control Systems (Reserved)
24) Wiring Devices
25) Uninterruptible Power Supplies (UPS)
26) Electronic Equipment (Reserved)
27) Rotating Equipment

28) Motor Control Equipment
29) Portable Electrical Tools and Equipment
30) Photovoltaic Systems
31) Wind Power Electric Systems and Associated Equipment
32) Battery Energy Storage Systems
33) Electric Vehicle Power Transfer Systems and Associated Equipment
34) Public Pools, Fountains, and Similar Installations
35) Protective Relays
36) Stationary Standby Batteries
37) Instrument Transformers (Reserved)
38) Control Power Transformers (Reserved)
A) Explanatory Material
B) Suggestions for Inclusion in a Walk-Through Inspection Checklist
C) Symbols
D) Diagrams
E) Forms
F) NEMA Configurations
G) Primary Contact Matrix
H) Equipment Storage and Maintenance During Construction
I) Reliability Centered Maintenance
J) Power Quality
K) Electrical Disaster Recovery
L) Case Histories
M) Informational References

II. IT IS PRIMARILY ABOUT SAFETY

The productivity, return on investment, and good operations of any facility, commercial or industrial, is well known to depend on how well the equipment within that facility operates. Any equipment operator will understand this and attempt to implement optimal maintenance practices subject to budget, resources, time, and other constraints. Though this standard will help in determining what those good maintenance practices may be, the primary intent of the standard is to promote safety in the workplace and hence support the intent of the NEC and NFPA 70E. When reading the standard, the reader should realize that more can always be done to promote reliable operations and perhaps even safety. This standard establishes a minimum level of activity towards the goal of enhanced safety for workers and the public.

Improper maintenance can lead to arcing faults. Arcing faults can lead to dangerous arc-flash incidents [5]. Chapter 1 of NFPA 70E has requirements for considering condition of maintenance in work practices, including specifying that equipment must be properly maintained to be considered in normal operating condition (otherwise it shall be treated as exposed parts). Condition of maintenance is defined in 70E-2021 as "*The state of the electrical equipment considering the manufacturers' instructions, manufacturers' recommendations, and applicable industry codes, standards, and recommended practices*". NFPA 70E specifies further maintenance requirements in Chapter 2. However, the number of arc-flash incidents that continue to occur suggest that these requirements are, possibly, not enough, or the standard is not being properly or uniformly applied.

A. Scope and Purpose

The scope as written states *"… covers the preventive maintenance of electrical, electronic, and communications systems and equipment."* The primary intent is to prevent injury to personnel. Helping to prevent injury to personnel is accomplished by preventing unexpected failures and ensuring equipment performs as expected. Note that this does not necessarily mean preventing all failures. Some failures may be expected, not considered a hazard, and hence preventive maintenance is not required to be performed to prevent those failures. It may be part of the maintenance plan to operate that equipment to failure and simply repair or replace upon failure.

The purpose of the standard is stated as *"… 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."* The first stated goal is the safeguarding of persons, followed by property and processes with a caveat of practicality. Safety is most important and short cuts are not normal practice when to comes to safety, however practical safeguarding of property and process allows for more subjectivity and allows for thoughtful and well-reasoned business decisions to be made. Some equipment has low value and low impact on process and hence may not merit expensive maintenance investments, unless, of course, it may impact safety.

The various elements of electrical maintenance that such a maintenance plan may need are discussed in the standard, however exactly how these activities are to be carried out is not and is left for other industry documents to detail.

B. Application, other maintenance documents and the maintenance program

The document clarifies within its "application" section:

- Applies to electrical, electronic, and communications systems and equipment.
- Applies to systems and equipment typically installed in industrial plants, institutional and commercial buildings, and large multifamily residential complexes.
- Not intended to duplicate or replace instructions provided by manufacturers.
- Consumer appliances and equipment intended primarily for use in the home are not within scope.
- The standard is not intended to prevent equivalent or superior systems, methods, or devices with more quality, effectiveness, and safety than those in the standard.

The document does not apply to single family homes or small apartment buildings.

It is important to note that this document should not replace manufacturer maintenance. Manufacturer provided documents are expected to be the preferred source of maintenance information when provided and available. Other documents and accepted industry standards may provide detailed maintenance information and guidance for specific parts of the electrical infrastructure which may be applicable and provide better information on specific maintenance practices. While developing and documenting an Electrical Maintenance Program (EMP) the maintenance authority for a facility can vary from the prescriptions within the NFPA standard if the reason for that variation is well documented and supported by established or industry accepted practices that are applicable to the equipment and situation.

C. Roles of Calendar-based-, Reliability-centered-, Condition-based-maintenance and operations to failure

Maintenance of production equipment and electrical infrastructure may be a significant cost for any facility or business; however, it is also a mechanism to control risk for higher costs associated with safety related incidents and unplanned loss of production. Balancing the mostly known costs of planned maintenance versus risk of unknown and unplanned safety and production risk is an important business management problem. Each organizational entity may approach solving this problem differently. NPFA 70B exists to provide a base of knowledge and prescribed activity from which to start to create a plan to perform needed maintenance and control these risks, particularly and more importantly for safety, but also for reliability.

D. How extensive is the risk control?

The hierarchy of risk controls is key to all NFPA documents. The hierarchy of risk controls influences all documents promoting safety in the workplace or at home. Within NPFA 70E the hierarchy is identified as follows:

1. **Elimination:** Removing the hazard entirely
2. **Substitution:** Replacing a severe hazard with a less severe one
3. **Engineering Controls:** Replacing equipment or changing the work environment to separate workers from a hazard.
4. **Awareness:** Educating workers on the hazards and providing information on making safe decisions.
5. **Administrative Controls:** Developing formal procedures and processes for working safely under anticipated conditions.
6. **Personal Protective Equipment:** Equipping workers with clothing and equipment designed to reduce risk and limit the severity of injuries.

With elimination being the most effective and personal protective equipment considered the least effective, but not least important! Proper maintenance is implied in this hierarchy. Though proper maintenance will not remove a hazard, it can be thought of as substituting properly maintained equipment for improperly maintained equipment, a clearly beneficial substitution or as an engineered control since the maintenance more correctly can be thought of as impacting the risk associated with a hazard, not replacing the hazard itself. Engineered controls are of significantly less value if they are not able to perform as they were engineered to do if the equipment is improperly maintained. Awareness is dependent on understanding risk sources and risk control being what the training and signage indicates it is. Without proper maintenance the awareness of risk, risk controls and the actual risk may not align, more risk sources may exist, providing greater risk. Otherwise stated risk control may underperform its expectations. Administrative controls depend on those controls accomplishing what they are intended to accomplish. An Energy Reducing Maintenance Switch used as part of a procedure accomplishes nothing if the protection it alters is attempting to operate a circuit breaker immobile due to lack of maintenance, proper test before touch is not enough if conductors expected to be properly insulated have had their dielectric materials compromised or are unexpectedly loose due to lack of proper maintenance. PPE itself needs maintenance and the level of PPE selected per a carefully executed arc-flash study may not be enough if protective devices do not operate as expected when the need arises. The hierarchy of risk controls, within an electrical safety context, is very dependent on proper maintenance of electrical infrastructure.

III. KEY CHAPTERS AND CONTENT

A. Chapter 4, General

This chapter addresses general high-level requirements not specifically addressing any one product. It starts with the admonition that manufacturer instructions are to be followed, as well as applicable codes and standards. Industry consensus standards are identified as a replacement for manufacturer's instruction when those manufacturer instructions are not available. In current times, with the internet providing significant accessibility to documents, it may be easier to replace lost instruction documents than it may have been in years past. Not having a document in local files may not be sufficient reason to state that manufacturer's instructions are not available.

Section 4.2.1 states: *"The equipment owner shall implement and document an overall EMP that directs activity appropriate to the safety and operational risks."* This lays out the primary requirement, creation, documentation, and implementation of an EMP. That program shall be appropriate for the safety and operational risks for the facility. What amount of maintenance is appropriate is a management decision.

When it comes to safety, it's a more obvious decision with cost taking a more minor role. However, when it comes to being appropriate for operational risks, it's a business decision with cost and practicality of maintenance being a consideration that can be balanced with the potential product cost and repair cost of unplanned equipment failures. Regardless of the plan created, it needs to be documented and the authors would suggest the reasoning behind maintenance, or lack of maintenance, decisions should be part of that documentation. This could include how sensing data, operation data, event data, environmental data, or accumulated experience informs decisions to maintain or not maintain at any one point.

Specifically, sections 4.2.4.2 and 4.2.6 state the EMP should include elements that:

- Addresses the condition of maintenance.
- Identifies who must implement the program.
- Identifies electrical equipment and systems to determine maintenance requirements and priorities.
- Develops and document maintenance procedures.
- Includes a plan for inspecting, servicing, and testing
- Identifies a documentation and records-retention policy.
- Identifies a process to prescribe, implement, and document corrective measures based on collected data.
- Identifies how to incorporate design for maintainability in electrical installations.
- Identifies how to continuous improvement in the EMP.
- Identifies how to control, measure, and monitor the EMP.
- Utilizes relevant reports and feedback including:
  - Electrical safety incidents.
  - Equipment malfunctions.
  - Unintended operations or alarms.
  - Operation of protective devices.

NFPA 70B requires the EMP to be audited and reviewed at least once every five years and an EMP coordinator shall be identified. The document requires maintenance staff to be qualified and trained and for the employer to appropriately determine and document that qualification and training.

Chapter 4 also identifies survey and analysis requirements including planned inspections and retention of acceptance testing reports. Reports generated at the time of initial commissioning of equipment can be very useful as a be benchmark for future testing and maintenance.

Additions, rework and retrofitting of equipment is also specifically addressed in this chapter. The text identifies that safety certification for repair or rebuilt equipment shall be kept and that any such work should not impair the expected performance or safety for the equipment. The text also states that refurbished or remanufactured equipment shall be marked as such. Recent NEC editions also address this issue identifying what equipment may be refurbished and which may not, including how to handle markings. The reader is urged to review the latest edition of the NEC for this content.

B. Chapter 5, Personnel Safety

This chapter focuses on general safety requirements. This chapter requires qualified persons and adherence to electrical safety related work practices per applicable state and federal codes, standards, and laws. NFPA 70E is the primary national consensus electrical safety standard followed in the US.

C. Chapter 6, Single-Line Diagrams and System Studies

This chapter highlights the importance of obtaining, documenting, organizing, and storing electrical system knowledge. This knowledge includes single-line diagrams to systems studies such as short circuit, coordination, reliability, load flow studies and arc flash risk analysis among others. Many of these studies are impacted by changes to the system over time and hence need to be reviewed and updated periodically as needed. Single-line diagrams, coordination studies and arc-flash risk analysis are critical resources for good maintenance planning and execution.

Also mentioned in this chapter is "electrical maintenance related design", highlighting that maintenance is planned for a system since there may be ways that a power distribution system can be enhanced to facilitate future maintenance. Many system characteristics such as redundancy, embedded sensing, embedded instrumentation, embedded voltage sensing or absence of voltage sensing, remote controls, and HMI (Human machine interface) and other characteristics can facilitate lower cost, smarter and better maintenance while simultaneously reducing risk of injury to workers. Considering electrical maintenance related design as well as safety related design is part of a good PTD (Prevention Through Design) [6, 7] philosophy and should be implemented during original systems design. However, opportunities for improvement may also exist during the operating life of an existing installation.

D. Chapter 7, Fundamental Tests

This chapter identifies some testing and measurements familiar to all electrical maintenance practitioners. Primarily aimed at assessing the quality of electrical connections and insulation they describe millivolt, thermal and torque-based connection integrity assessment. Tables with reference values are provided. These values are not intended to supplant or override manufacturer provided data but can serve as a valuable reference if more specific manufacturer provided data is not available. The text does not preclude the use of permanently installed sensors, or instrumentation to gather this information in other acceptable ways that are useful to the execution of an EMP.

The standard does not specify how one shall perform such tests, but it is important to note that it is necessary to have a consistent methodology specified within the EMP to use the tests as predictive tools by detecting trends. These trends can only be meaningful when the methodology is consistent with calibrated test instruments.

For instance, instructions given to perform an insulation resistance test on 3-phase motors without any specific instructions on how to do this. Should resistance be measured with all 3 windings connected to each other, to ground for a single measure? Should each winding to ground be checked, and to each other for six total measures? Should each winding be checked to the other two windings grounded for a total of 3 measures? And should they check it for 1 and 10 minutes to obtain a polarization index? Are they taken on warm gear immediately after deenergizing? Do we record temperature and humidity?

These are important considerations even though the standard does not specify. However, Annex E provides many example forms that will suggest specific methods that can be used to help in the EMP. Furthermore, other accepted standards and documents exist that provide detailed information on how to do these tests under varying circumstances.

E. Chapter 8, Field Testing and Test Methods

This chapter starts by highlighting the need to assess the overall condition of electrical equipment and systems to ascertain the ability of tested devices to perform as designed, determine if corrective maintenance or replacement is necessary, document the condition of the equipment over its service life and provide an assessment of the overall condition of maintenance of the tested equipment and devices.

This is followed by highlighting the need for risk assessment to identify and control risk that may be associated with the maintenance practices. Content that readers will find new is an organization of maintenance practices into four types of activities:

(1) Category 1 — Online standard test; Testing while the equipment or device is connected to the source of supply. There may be potential for contact with energized conductors or uncontrolled release of energy. Shock, arc flash and other risks are possible.

(2) Category 1A — Online enhanced test; Same as Category 1 but that may not be typically performed as normal electrical maintenance activities. They provide additional diagnostic information that may be useful for good maintenance. These tests may be more optional and more rarely needed.

(3) Category 2 — Offline standard test; Includes testing performed with the equipment or device disconnected from the supply source or connected to an external test voltage source of supply. The potential for shock, arc flash or other risks are reduced relative to Category 1 activity.

(4) Category 2A — Offline enhanced test; Same as Category 2 but not typically performed in normal electrical maintenance activities but that provide

additional diagnostic information that may be useful for good maintenance.

Activity described as 1A or 2A later in subsequent chapters of this document should be considered based on the following considerations (Annex A.8.3):

1. Are further diagnostics, information, or analysis required over and above that achieved with a required category 1 or 2 activity?
2. Is the A type activity more complex or costly than its incremental value relative to less risky procedures?
3. How common is the test procedure?
4. Is the procedure part of the EMP?
5. Is the testing effort exceeding the equipment value, process reliability improvement or risk control obtained?

This chapter also mentions that personnel need to be qualified in both the operation of the equipment under test as well as the performance of the test procedures. The need for and importance of test record keeping is mentioned including details on some of the information that needs to be included in test records.

Condition of maintenance is mentioned throughout the document. Section 8.7.1 defines the condition of maintenance as one of three designations:

(1) *Serviceable*; Equipment that passes all tests and is electrically and mechanically sound.
(2) *Limited Service*; Equipment that has problems not detrimental to the protective operation or design characteristics.
(3) *Nonserviceable*; Equipment that has a problem detrimental to its electrical or mechanical operations.

In NFPA 70E there is a definition for the "condition of maintenance":

> *"The state of the electrical equipment considering the manufacturers' instructions, manufacturers' recommendations, and applicable industry codes, standards, and recommended practices." [NFPA 70E-2018, Article 100, Definitions]*

The NFPA 70E-2018 handbook [8] further states:

> *"The condition of maintenance for a piece of equipment plays a major role in the safety of not only the maintenance employee but also the person operating the equipment. Improperly maintained or damaged equipment cannot be assumed to function normally or to provide the protection for the operator that would be afforded by proper installation and maintenance."*

NFPA 70E uses this terminology and concept throughout the text associating it with risk assessment and need for risk control during operations and maintenance activity. The linkage is clear in both documents that a good (aka serviceable) condition of maintenance is required to provide optimal risk control with a minimum investment in additional risk controls needed to make up for a less than optimal condition of maintenance.

F. Chapter 9, Maintenance Intervals

This important chapter provides tables for the minimum requirements of preventive maintenance intervals. It is a much more detailed adaptation of the previous Annex L of the 70B-2019 recommended practice and previous section 6.4 for modifying guidance on interval adjustments. The new tables establish the intervals based on an equipment condition assessment that is a 3-dimension factor considering the physical condition, criticality, and operating environment of the equipment.

Clearly identified is that modern maintenance practices such as continuous monitoring can be relied upon to influence frequency of maintenance implemented. However, the method used to interpret the monitored values should be used on manufacturer's recommendations or accepted industry practice.

Section 9.1.2 states that once a maintenance frequency is first determined based on the suggested values in the document and other methods as appropriate, that frequency should be maintained for two maintenance cycles before it is modified based on new information unless unexpected failures occur. Any identified failures should be analyzed to determine how maintenance may be changed to avert similar future failures.

Inspections are a part of maintenance and when two or more planned inspections are determined to find no equipment problems it may be possible to extend periods between maintenance cycles.

A key principle described in the document is that where the manufacturer's recommendations are not available and failure, breakdown, or malfunction of the equipment will present an unacceptable risk for personnel or the environment, equipment maintenance shall be done at not greater than the intervals specified per the equipment condition assessment and this chapter. Note that the mentioned determinant for minimum maintenance frequency is safety, not plant reliability or production. Reliability or productivity considerations may influence maintenance activity to yield more frequent maintenance, however, determining that less frequent maintenance is appropriate needs to be done based on safety related risk control considerations.

The table that is used as a reference for the rest of the document to determine the base maintenance frequency is presented as a matrix classifying activity as (where X is the chapter number):

- X.3.1 Visual inspections
- X.3.2 Cleaning
- X.3.3 Lubrication
- X.3.4 Mechanical servicing
- X.3.5 Electrical testing
- X.3.6 Special

Not all six activity classifications are identified for all equipment in the table. The table is referenced by the subsequent equipment specific chapters in the rest of the document. It is further identified that the maintenance interval for equipment may be changed based on the potential risk to personnel or facility operations due to a failure of the equipment to operate as expected. Any changes from the maintenance intervals described in the maintenance interval table that extend the maintenance interval and the justification for the change shall be documented in the EMP.

IV. EQUIPMENT SPECIFIC CONTENT

Chapters 10 through 38 provide maintenance requirements for specific types of equipment. A consistent numbering scheme was adopted, attempting to provide consistency and clarity to the requirements. Certain aspects that may not currently appear applicable were kept as "Reserved" to respect the numbering scheme as well as to remain open to and encourage future inputs.

Many of the recommended practices from NFPA 70B-2019 were not carried over to the standard. One reason for that change is recommendations can be easily side stepped but mandatory requirements may be enforced by various authorities having jurisdiction (AHJs). Another compelling factor was that very few technical committee members had experience with nor witnessed facilities that were meeting all the recommended practices of NFPA 70B-2019. Most facilities that adopted the practices have struggled to fully execute all the practices.

Why facilities struggle to meet the NFPA 70B-2019 requirements usually comes down to these basic reasons:

- Lack of management support
- Lack of qualified resources and/or training of persons considered to be qualified
- Difficulty in scheduling required shutdowns (insufficient redundancy in design)

Thus, it is important to provide some detail on some of the specific equipment requirements to help address these issues. Our intent is not to repeat the standard in this paper but to provide an example of how the equipment types are covered. For this paper, chapter 15, Circuit Breakers, was selected as the chapter to provide most of the detail for that equipment category. Other chapters are included where points to highlight were selected.

A. Chapter 11, Power and Distribution Transformers

This chapter includes small dry-type transformers. Many facilities have a "run-to-failure" approach to these transformers. This is not a wrong operating philosophy provided that a failure will not expose persons to any hazards either through an arc-flash event or shock potential at the transformer or through the failure of the power supplied to operating equipment.

B. Chapter 15, Circuit Breakers, Low- and Medium-Voltage

Most facilities use circuit breakers. In the experience of the authors, very few maintain the circuit breakers properly. Few personnel understand the requirements to which the circuit breakers were built.

UL 489 [9] provides the requirements for molded-case circuit breakers. For molded-case circuit breakers rated up to 1600 amps, to obtain a Nationally Recognized Testing Laboratory mark (pass the tests) they must be able to make and break 50 overloads of current rated at 600% of their full load rating. However, the smaller AIC circuit breakers are only tested three times at rated interrupting ampacity while circuit breakers for high available fault current are only test once. They must also pass a calibration test at 200% overload to ensure they interrupt sufficiently fast (or "not too slow," since it is measured in minutes). Maintenance hopes to ensure this capability remains for the life of the device.

What the preventive maintenance required by the standard is attempting to achieve is that the circuit breaker is still capable of clearing a fault as expected to prevent downstream circuits from being exposed to fault current longer than expected and for selectivity to function as designed. It also impacts the arc-flash incident energy which is calculated based on a properly operating circuit breaker performing as per its protective settings. The required preventive maintenance includes evaluating the insulation of the circuit breaker to ensure it can manage the voltage related stresses of an interruption and does become, itself, a point of failure.

Although the other types of low- and medium-voltage power circuit breakers fall under other product standards, they have similar requirements for maintenance.

The scope of chapter 15, identified in section 15.1, is:

1. Molded-case circuit breakers (MCCBs) rated less than or equal to 1000 V ac (UL 489)
2. Insulated-case circuit breakers (ICCBs) rated less than or equal to 1000 V ac (UL 489)
3. Low-voltage power circuit breakers (LVPCBs) rated less than or equal to 1000 V ac (UL1066)
4. Medium-voltage power circuit breakers (MVPCBs) rated greater than 1000 V ac to less than or equal to 69 kV ac

Section 15.3 addresses the periodic maintenance procedures for all low-voltage circuit breakers. Tables are included within each sub-section with specific text for each. Here, again, the standard follows the same number sequence in each section:

Section 15.3.1, Visual Inspections, requires the following:

1. Verify ratings for proper system application.
2. Inspect insulating materials and frame for evidence of physical damage, cracks from stresses of operation, or contamination.
3. Inspect wiring, bus, cables, and connections for damaged insulation, broken leads, tightness of connections, proper crimping, and overall general condition, including corrosion.
4. Inspect visible current-carrying parts and control devices if applicable for signs of overheating or deterioration.
5. Inspect arc chutes for cracks or excessive erosion if applicable.
6. Check for cracks or lack of visual indication for all associated indicating status devices.
7. Check all markings on the circuit breaker are legible.
8. Inspect operating mechanism.
9. Check main contact over travel and arcing contact engagement.
10. Check condition of main and arcing contacts.
11. Check insulating links/push rods and interphase barriers for cracks and defects.

Each table item specifies a type 1 or 2 test or NA (not applicable) in columns related to the specific type of circuit breaker: MCCB, ICCB, or LVPCB. Note ICCB is not a type of circuit breaker defined by standard, it is a subtype of MCCB listed per UL 489, however, it tends to share operating characteristics with Low Voltage Power Circuit Breakers. The extent to which these characteristics are shared have varied over time with some modern ICCB (post 2000) being almost identical to LVPCB, but older ones being distinctly different devices.

Section 15.3.2, Cleaning, includes general instructions that are quite similar for all equipment as well as a specific table. Below is the 2-part requirement for cleaning.

- 15.3.2.1 Electrical equipment surfaces, enclosures, and insulating materials shall be kept in a clean and contaminant-free state.
- 15.3.2.2 If contamination is found, such as the

presence of dust, dirt, soot, grease, or moisture is found, cleaning shall be performed in accordance with Section 5.8 and Table 15.3.2.2.

The table for circuit breakers includes three specific items:

1. Clean insulating surfaces of the circuit breaker using a lint-free dry cloth, brush, or vacuum cleaner. Avoid (avoid blowing material into the circuit breaker or into surrounding equipment)
2. Clean contact surfaces
3. Clean circuit breaker interior frame

Again, each table item specifies a type 1 or 2 test or NA (not applicable). Section 15.3.3, Lubrication, contains three specific items for maintenance:

1. Apply a thin coating of conductive lubricant to exposed contacts as specified by the manufacturer
2. Apply nonconductive lubricant as needed to mechanism parts as specified by the manufacturer
3. Apply conductive lubricant to pivot points, as well as moving and sliding surfaces as specified by the manufacturer

Once again, each table item specifies a type 1 or 2 test or NA. Section15.3.4, Mechanical Servicing, has a table of five specific items.

1. Check all accessible electrical hardware connections for correct torque
2. Operate the circuit breaker three times
3. Verify operation and alignment of mechanical safety interlocks, where applicable
4. Verify correct operation of shutter assemblies on draw-out circuit breakers
5. Measure and record trip bar force

Section 15.3.5, Electrical Testing, has a table of 14 specific items. This table deviates from the previous table as MCCBs have a test type column for circuit breakers up to 250A frame sizes and a separate column for circuit breakers above 250A frame sizes.

1. Perform infrared thermography
2. Measure contact resistance of each switching pole
3. Perform insulation-resistance tests, phase-to-phase and phase-to-ground with circuit breaker closed and across each open pole
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
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
6. Perform inverse time trip test at 300% of rated continuous current of thermal magnetic circuit breakers
7. Perform inverse time trip test at 300% of rated continuous current of electronic trip circuit breakers
8. Perform the instantaneous overcurrent trip test for thermal-magnetic circuit breakers by “run-up” or “pulse” method
9. Perform the instantaneous overcurrent trip test for electronic trip breakers by “run-up” or “pulse” method
10. Perform rated hold-in test
11. Test current-limiter resistance
12. Check status of rating plug battery
13. Perform millivolt drop test
14. Test arc reduction technology in accordance with the manufacturer’s instructions

Section 15.4 begins a similar set of tables for specific maintenance instructions for medium-voltage circuit breakers. The above specific maintenance instructions for low-voltage circuit breakers coupled with the required intervals has been overwhelming to most facilities. Even some of the most basic test requirements are not applied. For instance, insulation resistance testing is often only used to troubleshoot a motor that has tripped overloads or circuit breakers repeatedly. Yet, a large percentage of failures and arc flash incidents are a result of insulation failure that could be detected and prevented with sufficiently frequent insulation resistance testing.

Similarly, contact resistance measurements (micro-ohm measurements) can detect wear or pitting on the contacts before they overheat and lead to a flashover event. Many persons considered by their employers as electrically qualified maintenance persons are completely unaware of many of these tests and the readily available test equipment for them.

C. Chapter 16 Fuses

This chapter may surprise persons who consider a fuse as a maintenance-free device that has a fail-safe manner of operation. It is, for example, important to ensure that fuses are correct and have not been changed without consideration for performance or documentation. This chapter addresses more than just the fuse itself as it deals with the fuse holder, clips, etc. all of which are potential failure points and have been associated with serious incidents.

D. Chapter 17 Switches

This scope includes common low-voltage disconnect switches, not just large switchgear, or high-voltage switches. The substantiation is the large number of accidents have occurred due to failures in disconnects that had sufficient available arc-flash energy to severely burn the individuals performing the switching or maintenance. Though switches are perceived as simple devices, they are as dangerous as any other device than carries high energy and in need of maintenance as any other electrical device with connections, moving parts, fulcrums, dielectric materials, etc.

E. Chapter 18 Power Cables and Conductors

This includes low-voltage cables (rated 1000 V or less) as well as higher-voltage cables (rated over 1000 V). The minimum electrical testing includes insulation resistance. The fact that cables are used in great abundance and often are out of sight, though very reliable, still makes them an important potential, and in the author’s experience, point of catastrophic failure.

F. Chapter 19 Cable Tray

This need is substantiated by the large number of faults that occur due to cables that fault in cable trays and fires that occur, often due to cable damage or overfill. To prevent these issues the maintenance requirements, include infrared thermography and equipment grounding impedance testing of the tray.

G. Chapter 20 Grounding and Bonding

Properly operating grounding and bonding is important for all parts of electrical systems, not just high-voltage substations, or appliance connections. It is an important risk control that is required regardless any other protection used.

H. Chapter 22 Lighting

This includes an assessment of the illuminance levels. This includes measuring the illumination and comparing to standard specified maintained illumination levels.

Illumination levels are often one of the root causes of accidents. Facilities relying on a subjective sense of "good enough" often fails to meet the minimum safe levels as specified in the ANSI/IES (Illumination Engineering Society) [10] standards.

I. Chapter 24 Wiring Devices

Electrical testing of wiring devices is another practice that is specified by the standard that has often been ignored by many facilities. Although it does not specify how to perform the tests, it does specify a test to confirm grounding and bonding for correct installation and secure connection. The second test is required to confirm proper polarity of contacts.

There are multiple instruments available that will provide an accurate equipment grounding conductor impedance on receptacles and other wiring devices.

J. Chapter 25 Uninterruptible Power Supplies (UPS)

This chapter addresses a common item that is an assembly of items listed elsewhere (and thus referred to by this chapter) as well as several instructions that are special procedures (25.4) that are specific to UPS and don't fit the standard maintenance categories. These special procedures are essentially functional tests of the UPS to ensure that it operates properly.

This is an important addition that addresses a common problem in the industry where facilities have UPS installed for critical loads and systems yet do not perform maintenance and functional tests to ensure they continue to operate properly when required. Most UPS, like many apparatuses that exists to work only under emergency conditions, are not required to function for long periods of time and when finally called upon in an emergency they fail to work properly. Following these procedures will provide a much higher probability of proper function when required.

These special procedures include:

1. Software upgrades
2. Load Transfer and Load Testing
3. System Test Conditions
4. Output Stability
5. Low Battery Voltage Shutdown

K. Chapter 29 Portable Electrical Tools and Equipment

A highlight of this chapter is, when the tools or equipment will not be used with a GFCI, the requirement to perform electrical tests of the portable tools and equipment for:

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

How these tests are done and what test equipment to use is not specified, and many persons considered qualified for electrical maintenance at their facilities are not aware of such test instruments. A facility will, probably, want to satisfy these tests with one of the portable appliance testers on the market. These units usually also provide a current leakage test that is a requirement of some product standards. Some provide bar code printing and reading to allow for comparison from previous intervals.

L. Chapter 30 Photovoltaic Systems

The standard has been updated with more current practices required to maintain these systems. This chapter is also one of the few that specify the required documentation and labeling in 30.3.1 to include the following:

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

This is an important inclusion that is not in many other sections. Though universally desirable it may be hard to fully comply with this requirement in many installations, especially with older equipment.

M. Chapter 31 Wind Power Electric Systems and Associated Equipment

With the growing proliferation of wind power systems, the committee chose to include minimum maintenance requirements on these systems. The mechanical servicing section is reserved. This is an area where more public input from industry experts is required.

N. Chapter 32 Battery Energy Storage Systems and Chapter 36 Stationary Standby Batteries

The fact that the new standard has two chapters to address batteries and battery systems demonstrates the technical committee's efforts to keep up with technology to address the variation in battery systems. These chapters also represent a significant addition to NFPA 70B as the 2019 edition only provided battery testing details without fully addressing the range of available battery systems. The new chapters attempt to cover battery system maintenance more broadly.

O. Chapter 33 Electric Vehicle Power Transfer Systems and Associated Equipment

This is another chapter that addresses new technology not previously covered by NFPA 70B. It is all visual inspection requirements at this point, but future public inputs are expected.

P. Chapter 34 Public Pools, Fountains, and Similar Installations

This chapter is another example of the standard broadening its scope. The chapter is substantiated by fatalities that occur in these areas and on related equipment due to a lack of maintenance. A lot of the maintenance is related to corrosion of electrical parts, enclosures, and fixtures that affect the condition of bonding and grounding around these wet areas. Public pool maintenance requirements exist at the state level in some parts of the USA, but not at the federal level. This is a way to give that important subject national visibility.

V. SUMMARY

The change of NFPA 70B from a Recommend Practice to a Standard has required that the entire document be rewritten with the understanding that new text would be short on details but long on the need for proper maintenance of important electrical infrastructure and the required planning and required documentation The scope has been expanded to include new classes of assets, some long used, like public pools, other newer such as PV facilities. Chapter 9 includes important preventive scheduling guidelines that may, at first, seem to differ from practices that may be used in some facilities. But the text also includes rational ways to deviate from the frequency detailed in the chapter if rational methods are used to vary maintenance frequency intelligently, and, always, considering safety of personnel operating and maintain the facility. This is, to a great extent, a new standard, regardless the fact it shares an identifying number with a respected industry document with a long and respected history. There is significant need for public comment to further improve this document and ensure it accomplishes its goal, stated in the standard as follows:

> *"…to provide for the practical safeguarding of persons, property, & processes from the risks associated with failure, breakdown, or malfunction & a means to establish a condition of maintenance of electrical equipment & systems for safety & reliability."*

The NFPA 70B committee is looking forward to much constructive public input and hopes you get involved.

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VII. VITAE

Mr. Cunningham is an IEEE senior member and has decades of experience leading electrical maintenance at global facilities for Alcoa through 2019. He is a member of the NFPA 70B technical committee and has played an instrumental role in the creation of the new standard. He is also a member of the 70E technical committee and CMP 12 of the NEC (NFPA 70). He has presented multiple papers on electrical maintenance at IEEE forums as well as provided courses on electrical maintenance at various facilities and IEEE conferences worldwide. He currently is a global consultant with ES Squared, Inc. providing safety and maintenance training as well as project consulting based out of Homosassa, FL.

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