



IEEE Guide for Induction Machinery Maintenance Testing and Failure Analysis

IEEE Power Engineering Society

Sponsored by the
Electric Machinery Committee

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IEEE Guide for Induction Machinery Maintenance Testing and Failure Analysis

Sponsor

**Electric Machinery Committee
of the
IEEE Power Engineering Society**

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Abstract: This guide provides maintenance testing and failure analysis guidance for form-wound, squirrel cage, induction machinery rated up to 15 kV. It addresses the following machine systems: Stator (Winding and Core) Rotor (Winding and Core) Vibration and Noise Bearings and Shafts Structure, Frame Ventilation Accessories. This guide is intended for use by personnel at the facility or corporate office responsible for the operation and maintenance of large induction machines. It is a guide to aid the thought processes and procedures necessary to determine root causes for failures.

Keywords: failure analysis, induction machinery, induction motor, maintenance tests, maintenance testing, root cause analysis

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Introduction

This introduction is not part of IEEE Std 1415, IEEE Guide for Induction Machinery Maintenance Testing and Failure Analysis.

This introduction provides some background on the rationale used to develop the guide. This information is meant to aid in the understanding and usage of this guide.

This guide describes maintenance testing and analysis techniques for failure investigation. It is intended for use by personnel at the facility or corporate office responsible for the operation and maintenance of large induction machines. It is a guide to aid the thought processes and procedures necessary to determine root cause for failures.

This guide is intended to satisfy the following objectives:

- To provide guidance concerning the appropriateness of various maintenance tests and in interpreting the results of those tests with respect to failure analysis and to routine predictive maintenance activities.
- To provide a methodology by which the most probable cause of any particular machine failure may be determined.
- To encourage the establishment of routine and uniform data collection so that valuable facts concerning the failure are not destroyed.
- To encourage cooperative efforts between users and manufacturers during failure analysis.

The future vision for this guide is to cover other rotating electric machinery types including the following:

- Synchronous machines
- DC machines
- Wound rotor machines
- Random wound induction machines

At the time when other machinery types are added, the word “Induction” will be removed from the guide title. But for now, it was considered misleading if “Induction” was omitted since the other types are not yet addressed.

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IEEE Guide to Induction Machinery Maintenance Testing and Failure Analysis

1. Overview

1.1 Scope

This guide provides maintenance testing and failure analysis guidance for form-wound, squirrel cage, induction machinery rated up to 15 kV. The guide addresses the following machine systems:

- Stator (winding and core)
- Rotor (winding and core)
- Vibration and noise
- Bearings and shafts
- Structure, frame
- Ventilation
- Accessories

1.2 Purpose

This document is intended for the following purposes:

- To provide guidance concerning the appropriateness of various maintenance tests and interpreting the results of those tests with respect to failure analysis and to routine predictive maintenance activities
- To provide a methodology by which the most probable cause of any particular machine failure may be determined
- To encourage the establishment of routine and uniform data collection so valuable facts of the failure are not destroyed
- To facilitate cooperative efforts by users and manufacturers during failure analysis

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI C50.41TM, American National Standard for Polyphase Induction Motors for Power Generating Stations.¹

ANSI/EASA AR100, Recommended Practice for the Repair of Rotating Electrical Apparatus.

ASTM E1444, Standard Practice for Magnetic Particle Testing.²

API Std 541, Form-Wound Squirrel-Cage Induction Motors—250 Horsepower and Larger.^{3, 4}

IEEE Std 43TM, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.⁵

IEEE Std 45TM, IEEE Recommended Practice for Electrical Installations on Shipboard.

IEEE Std 56TM, IEEE Guide for Insulation Maintenance of Large Alternating-Current Rotating Machinery 10 000 kVA and Larger.

IEEE Std 62.2TM, IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus—Electrical Machinery.

IEEE Std 95TM, IEEE Recommended Practice for Insulation Testing of AC Electric Machinery with High Direct Voltage.

IEEE Std 112TM, IEEE Standard Test Procedure for Polyphase Induction Motors and Generators.

IEEE Std 118TM, (withdrawn) IEEE Standard Test Code for Resistance Measurement.⁶

IEEE Std 120TM, IEEE Master Test Guide for Electrical Measurements in Power Circuits.

IEEE Std 286TM, IEEE Recommended Practice for Measurement of Power Factor Tip-up of Electric Machinery Stator Coil Insulation.

IEEE Std 388TM, IEEE Standard for Transformers and Inductors in Electronic Power Conversion Equipment.

IEEE Std 389TM, IEEE Recommended Practice for Testing Electronics Transformers and Inductors.

¹ ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

² ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

³ API historical materials can be obtained (for a fee) from the American Petroleum Institute Library, 1200 L Street NW, Washington, DC 20005, USA (<http://www.api.org/>).

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⁵ IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://standards.ieee.org/>).

⁶ IEEE Std 118 has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood, CO 80112-5704, USA, tel. (303) 792-2181 (<http://global.ihs.com/>).

IEEE Std 432TM, IEEE Guide for Insulation Maintenance for Rotating Electrical Machinery (5 hp to less than 10 000 hp).

IEEE Std 433TM, IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Voltage at Very Low Frequency.

IEEE Std 522TM, IEEE Guide for Testing Turn Insulation on Form-Wound Stator Coils for Alternating-Current Rotating Electric Machines.

IEEE Std 841TM, IEEE Standard for Petroleum and Chemical Industry-Severe Duty Totally Enclosed Fan Cooled (TEFC) Squirrel-Cage Induction Motors - Up to and Including 370 kW (500 hp).

IEEE Std 1434TM, IEEE Guide to Measurement of Partial Discharges in Rotating Machinery.

NEMA Std MG 1, Motors and Generators.⁷

NEMA Std MG 2, Safety Standards for Construction and Guide for Selection, Installation, and Use of Electric Motors and Generators.

NEMA Std MG 10, Energy Management Guide for Selection and Use of Polyphase Motors.

NFPA 70B Recommended Practice for Electrical Equipment Maintenance.⁸

UL 674, Hazardous Duty Motors Divisions 1 and 2.⁹

3. Definitions

For the purpose of this guide, the following term and definition apply. *The Authoritative Dictionary of IEEE Standards Terms*, [B14]¹⁰ should be referenced for terms not defined in this clause.

3.1 hard coil: Stator coils with insulation bonded with thermosetting resin and fully cured before installation in the stator.

4. Maintenance inspections and tests

4.1 Safety for inspections and tests

Before beginning maintenance or inspection of a machine, personnel safety is a primary concern. Machines can be extremely powerful and a common sense approach is essential. Safety issues are covered in detail by many organizations and documents, including OSHA, NEC, UL, NEMA (e.g., NEMA Std MG-2¹¹), NFPA (e.g., NFPA 70B), and IEEE. Most companies have their own safety procedures and require/provide detailed training.

⁷ NEMA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

⁸ NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA (<http://www.nfpa.org/>).

⁹ UL standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (<http://global.ihs.com/>).

¹⁰ The number in brackets corresponds to those of the bibliography in Annex A.

¹¹ Information on references can be found in Clause 2.

Safety also applies to the machine, which can indirectly result in a safety issue for the personnel. Some machine application issues to consider are as follows:

- Properly match the machine with the driven equipment
- Be aware of the operating environment of the machine, especially hazardous duty
- Select the proper frame enclosure
- Be aware of the variations in voltage and frequency in the power supply
- Evaluate the starting conditions
- Provide the necessary protection system to detect failures
- Review planned test procedures for safety issues

The following installation and disassembly issues are important to consider:

- Use only designed lifting lugs; do not lift the machine by the shaft. Refer to the manufacturer's outline and instruction manual for lifting instructions. Check machine for a lifting nameplate.
- The machine lifting lugs are designed for lifting the machine or part of the machine only, not the driven equipment or support.
- Ensure the electrical grounding is proper.
- Use qualified/trained personnel to make the electrical connections.
- Rotating parts (couplings, pulleys, and shaft extensions) should be protected by sturdy guards.
- Be aware of the operating parameters of the machine (temperature, amperes, vibration, noise, etc.).
- Ensure the mounting requirements are acceptable and bolts have adequate strength and depth of thread.

If a failure is suspected, use extra caution in all areas and always be aware of the status of the power source. Practice proper lock-out and tag-out procedures.

4.2 Maintenance inspections

The original equipment manufacturer's (OEM) instruction book is a good source of information and precautions on required maintenance, inspections, and testing. If an instruction book is not available, contact the local OEM sales person. Typically critical machines are opened (may include rotor removal) for inspection, cleaning, and general maintenance every three to seven years. More or less frequent inspections are needed as dictated by contamination and fouling, load cycle, or operating temperatures. For example, boiler feed pump machines may require a seven year cycle while most large fans (induced draft, forced draft, gas recirculation) may demand a five year cycle or less. Not all machines need time-based maintenance, but the service life of all machines will be increased if prudent repair and testing programs are followed. Annual inspection and cleaning may be required where abrasive contamination or coal dust buildup is significant, as with pulverizers and coal handling equipment. Annex B contains several checklists to consider for providing inspection support.

A balanced maintenance program is based on evaluation of test results and supplemented by visual inspection performed by qualified, knowledgeable, electric machinery personnel. There are no test programs available that can replace the need for visual inspection. A visual inspection program should concentrate on those areas most prone to damage or degradation. It is essential to detect damage caused by abrasive contaminate, loose parts, or foreign objects. Machines must be inspected for evidence of wear and deterioration. Moisture and dirt buildup can be observed directly. Unusual noise, leaking oil seals, or high vibration can often be detected. Oil level gages should be monitored. Operation personnel perform many of these checks during shift rounds.

In addition to operating machines, spare machines in storage require routine maintenance to ensure availability for service. Periodic inspection of stored machines is important.

4.2.1 External inspection

External inspections of the machine should be performed. These inspections should include, but not be limited to, the following:

- Verification of bearing oil level

- Check for signs of oil or water leakage
- Verification that air inlets are not plugged
- Check for abnormal sounds or smells
- Oil rings turning on sleeve bearings
- Check water and oil supply piping
- Check drain piping
- Condition of foundation, grout, bed plates, anchor bolts, shaft extensions, couplings, guards
- Check the surroundings (environment)

While the machine is out of service, it is desirable to observe the endwinding condition either directly or with a borescope. This inspection may reveal conditions of winding ties and evidence of loose coils, such as dusting or greasing at coil support points. Partial disassembly may be required. Also the presence of oil, water, or other contamination can be observed during these inspections.

Machines in storage should also have external inspections performed. Filling the oil reservoir with vapor barrier oil, the occasional rotation of the shaft, and verification of space heater operation are important items that should be included in maintenance storage procedures. Periodically evaluate the winding condition to ensure that deterioration has not occurred.

4.2.2 Disassembly and inspection of components

Dismantling a machine for visual inspection is an expensive and operationally disruptive decision. The decision to dismantle a non-critical machine should be carefully evaluated based on the analysis of trendable and pass/fail tests, any abnormal noise, vibration or odor, unexplained operation of protective relays, and industry experience with similar machines and applications. In addition to cost, a disadvantage of machine disassembly is the possibility of damage to components by mishandling and improper reassembly. A detailed visual inspection may be the only means of evaluating the physical condition of stator windings, rotor windings and the cores. A visual inspection may reveal the presence of dirt, oil or moisture, damage from foreign material, broken or cracked components, loose winding ties or abraded insulation. A simple visual inspection of the dismantled machine may reinforce findings of the tests given in Table 1 and also facilitate the root cause analysis.

4.2.2.1 Stator inspection

In general, while exercising appropriate safety precautions, examine everything that can be seen, and touch everything that can be reached. Contamination of coil surfaces will lower insulation strength and block heat transfer. The most common contaminants are oil, moisture, corrosive vapors, and airborne particles.

An examination of the stator winding should be made for insulating tape separation or cracks. Particular attention should be paid to the areas immediately adjacent to the core. Modern thermosetting coils do not usually exhibit tape separations, but may fail if cracks develop.

Deterioration of insulation can result from cumulative thermal aging. Examination of coils might reveal a general dark color, swelling into ventilation ducts, or a lack of firmness of the insulation; these conditions indicate a loss of bonding of the insulation layers.

Abrasion of stator wedges and coils by abrasive contaminants is occasionally encountered with machines. Boiler fans are particularly susceptible. The eroding effects of abrasive contaminants against the coil insulation surfaces are particularly damaging at air vents and on the coils at the core edge opposite the rotor fan.

The tightness of all coil bracing should be verified. Check the various components of the endwinding bracing system including surge rings. Visible cracks, especially those greater than 25–50 micrometers (0.001–0.002 inches) in the blocking and bracing system are signs of differential movement between components. If not corrected, these cracks will worsen and may eventually lead to winding failure. The endwinding bracing structure should be kept as tight as possible, with no movement noted when forced by hand or tapped.

The stator core should be examined in detail. The stator bore should be checked for looseness, burning of laminations, interlaminar short circuits, or damage by foreign objects. Wedges and vent ducts should be checked for looseness and blockage. Damaged core supports, loose bolts, or broken or cracked welds should all be corrected. The core vent ducts should be examined for blockage or abrasion of the stator winding.

Inspect carefully for evidence of damage due to the effects of partial discharge. This damage is more likely to occur in machines that operate at voltages above 4 kV. Partial discharge frequently manifests itself as a white fungus-like growth, discoloration, or deposit on the endwindings of the machine, at the vents, in the core, or at the core edge. The light color is caused by ozone bleaching of the surface paint. It is often confused with light colored dust that results from powdering of insulation materials due to loose conditions.

4.2.2.2 Rotor inspection

Cracks in the bars of fabricated rotors are common problems. Careful inspection for cracks should be conducted along the full bar length when visible and especially at the bar extensions and connections to the end ring. Visual inspection of the bars in the core area can be made through the cooling vent ducts and slot openings. All rotor laminations should be inspected for missing pieces or looseness of vent support spacers or looseness of fans or other parts. Welds on balance weights, on the spider, fan and shaft should be checked for cracks. The rotor bars should be centered in the iron core. Shifting of the squirrel cage or tilting of the shorting rings can cause breaks. Inspect the fingerplates and the rotor core laminations for cracks, breakage, or movement.

Inspect die-cast aluminum rotors carefully for signs of cracks or voids, which lead to distortion or overheating. The aluminum may have porosity or voids anywhere. Growler test (or single-phase rotor test if rotor is installed in stator) may be used to verify the condition of the squirrel cage for fabricated or die-cast cages (Table 1).

4.2.2.3 Lubrication inspection

When inspecting the lubrication of the bearings the following should be considered:

- Improper lubrication, oil of the wrong type, viscosity too heavy or too light
- Insufficient oil in bearing bracket to cover bottom of rings
- Dirty oil or old oil (should be replaced and/or tested)
- Oil rings turning (especially at low temperatures)
- Water or other contamination noted
- Feed oil connected to the correct ports

4.2.2.4 Bearing and seals inspection

When the bearing and seals are inspected the following should be considered:

- Excessive bearing clearance
- Seal clearance and condition
- Improper seating of shaft journal in bearing or a bent shaft
- Pitting of bearing and journal surfaces due to bearing currents
- Bearing insulation integrity
- Rough bearing surfaces due to corrosion or careless handling
- Excessive end thrust from the mechanical load
- Poor alignment
- Heat exchanger, if applicable, not working, reduced water flow or cooling fins covered with oil and dirt, fan blades broken
- Fractured bearing babbitt due to pounding by the bearing journal
- Bearing wear patterns for uniform loading

4.2.2.5 Miscellaneous inspections

In general, the following should receive an inspection, as appropriate:

- Frame
- Pedestals
- Coupling
- Accessories
- Foundation
- Bolts
- Conduit box
- Enclosure housing
- Gaskets
- Filters
- Terminations
- Connections
- Space heaters
- Temperature sensors
- End bells
- End brackets
- Water lines
- Water cooling tubes and headers
- Oil piping and pumps
- Ground connections, including to pedestal bearing supports

4.2.3 Alignment and end float

Verify that the shaft of the machine and the shaft of the driven equipment have correct alignment. Verify the endfloat of the machine shaft and the driven equipment shaft (off line and uncoupled). When energized, the machine should operate within its end float limits (see C.3). Special end float limits can exist on some applications. Refer to documentation of the machine and the driven load for specifics.

4.2.4 Driven equipment inspection

Inspect the driven equipment for solutions to machine problems. Many equipment problems may start as load related anomalies, which progress into machine problems. Troubleshooting and only repairing the machine problems does not offer a root cause analysis and solution. A variety of technologies identified in Table 1 may be used to identify the health of the driven equipment.

4.3 Maintenance tests

Table 1 contains a summary of various tests that are in widespread use in the industry. The tests are listed in alphabetical order for ease of locating a specific test. Information is provided to describe the test, its effectiveness, whether it is performed online or offline, and reference to the industry standard (e.g., IEEE Std 112) for performing the test. Two additional columns are included that give suggested test frequency and precautions. The entries in the first column provide the reference to the associated clause where additional information and discussion is provided concerning the specific test.

Table 1—Maintenance tests

Guide subclause number	Test	Description	Effectiveness	Online Offline	Typical test frequency (years)	Test precautions / considerations	Industry standard
4.3.1	AC high potential	Overvoltage test applied from conductor-to-ground.	Pass/Fail Test; not effective for trending	Offline	Factory test or as necessary	Potentially destructive.	IEEE Std 112 NEMA MG 1 IEEE Std 4 IEEE Std 95
4.3.2	Acceleration time	Measure acceleration time during starting.	May be effective for trending if conditions are maintained	Online	1—up to every start		
4.3.3	Bearing insulation	Insulation resistance shaft to ground.	Pass/Fail Test	Offline	1 to 2		IEEE Std 43 IEEE Std 112
4.3.4	Bearing temperature	Measurement of bearing metal, bearing housing, or bearing oil temperature. Applies to all bearings, oil lubricated and grease lubricated.	Effective for trending. Must account for ambient temperature	Online	0.5 to 1 continuously		
4.3.5	Capacitance	AC test to measure insulation capacitance line-to-ground.	Effective in manufacturing, possibly effective for trending.	Offline	Factory 1 to 2	Effective on single coils during manufacturing of medium voltage machines.	IEEE Std 286
4.3.6	Core Loss (Loop)	Test for shorted stator core laminations.	Pass/Fail Test; Not typically effective for trending, although under controlled conditions may be used for trending	Offline	Typically during a rewind process	Be prepared to stop test abruptly if core damage is suspected.	IEEE Std 62.2
4.3.7	Coupling insulation	Insulation resistance coupling to shaft.	Pass/Fail Test	Offline	1 to 1.5 after outage		
4.3.8	Current demodulation	Analysis of demodulated stator current frequency components.	Effective for trending	Online	1 to 2 continuously		
4.3.9	Current running	Measure stator current.	Rough estimate of overload	Online	1 to 2 continuously		IEEE Std 112 NEMA MG 1
4.3.10	Current signature analysis	Analysis of the frequency components of the stator current.	Effective for trending	Online	1 to 2 continuously	Better results on steady load over 30%.	

Table 1—Maintenance tests

Guide subclause number	Test	Description	Effectiveness	Online Offline	Typical test frequency (years)	Test precautions / considerations	Industry standard
4.3.11	Current starting	Measure stator current during acceleration time.	Effective for trending	Online	1—up to every start	Inrush current 4 to 10 times full load amperes.	IEEE Std 112
4.3.12	DC high potential	Overvoltage test applied line to ground test, measures leakage current plus charging current.	Effective for trending and as pass/fail	Offline	1 to 2 as necessary	DC high potential test should only be undertaken after passing the PI test.	IEEE Std 95 NEMA MG 1
4.3.13	Dielectric absorption	Ratio of the 60 second IR reading to the 30 second IR reading.	Effective for trending	Offline	1 to 2		IEEE Std 43 and IEEE Std 95 for IR test in general (PI variations)
4.3.14	Dissipation factor and power factor	AC test measuring dissipation—capacitance line-to-ground.	Effective on single coils during manufacturing of medium voltage machines. Possible effective for trending	Offline	Factory 1 to 2		IEEE Std 286
4.3.15	Grease analysis	Appearance, smell, grit, content of grease sample grease lubricated machine bearings.	Effective for trending	Offline	0.5 to 1		
4.3.16	Growler	Tests of rotor core and squirrel cage of disassembled machine by introducing an external magnetic field, and monitoring temperatures, magnetic patterns or current patterns of the rotor.	Pass/Fail Test; Not effective for trending	Offline	5 to 10 or as needed		
4.3.17	Insulation resistance	Measures resistance of insulation between conductor and ground.	Effective for trending	Offline	1 to 2	Temperature correction required for trending. Adequate scale range required.	IEEE Std 43 IEEE Std 56 IEEE Std 62.2 IEEE Std 432 IEEE Std 433
4.3.18	Oil Analysis	Analysis of oil for lubricant characteristics and foreign particles concentration for oil lubricated machine bearings.	Effective for trending	Offline analysis. sample can be taken online	0.5 to 1		

Table 1—Maintenance tests

Guide subclause number	Test	Description	Effectiveness	Online Offline	Typical test frequency (years)	Test precautions / considerations	Industry standard
4.3.19	Partial discharge	AC test that measures partial discharge (Corona) line-to-ground.	Requires experienced operator. With some technologies effective for trending	Online or Offline	0.5 to 5 continuously		IEEE Std 1434
4.3.20	Phase angle	Timed measurement of voltage and current angle in degrees.	Effective for trending	Offline	1 to 2		IEEE Std 388 ANSI/EASA AR100
4.3.21	Phase balance (Inductance and Impedance)	AC frequency test to measure stator line-to-line inductance or impedance balance.	Effective for trending	Offline	1 to 2	Correct for winding temperature and rotor position.	IEEE Std 388 IEEE Std 389 ANSI/EASA AR100
4.3.22	Polarization index	Ratio of ten-minute IR to one-minute IR.	Effective for trending	Offline	1 to 2	Should have adequate scale range NOTE— Form-wound coils only. ¹²	IEEE Std 43
4.3.23	Single-phase rotor test	Monitors the AC current level while the machine is single-phased at lower voltage level, while the shaft is rotated manually.	Pass/Fail	Offline	5 to 10 as needed	WARNING: Possible hazard to operator. Risk of single-phase start.	
4.3.24	Shaft grounding currents	Measure shaft current and waveform on oscilloscope shaft to ground.	Indicator of change trendable	Online	3 to 5 continuously		IEEE Std 112
4.3.25	Shaft testing	Non-destructive examination of shaft mechanical/structural problems.	Pass/Fail	Offline	5 to 10		

¹² Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

Table 1—Maintenance tests

Guide subclause number	Test	Description	Effectiveness	Online Offline	Typical test frequency (years)	Test precautions / considerations	Industry standard
4.3.26	Shaft voltage	Measure shaft voltage and waveform on oscilloscope shaft to ground.	Indicator of change trendable	Online	3 to 5 continuously	WARNING: Possible hazard to operator. Portable brush may catch on rotating equipment.	IEEE Std 112
4.3.27	Speed	Measure shaft speed.	Effective for trending	Online	1 to 2 continuously		IEEE Std 112 NEMA MG 1
4.3.28	Surge test	Impulse voltage.	Manufacturing and field test	Offline	Factory field as necessary	Potentially destructive should only be undertaken after integrity of insulation quality of groundwall has been verified. Use voltages according to industry standards or manufacturer's recommendations.	IEEE Std 522
4.3.29	Surge-PD	Seeks the lowest voltage at which the surge waveform shows high-frequency content.	Manufacturing and field. Pass/Fail and trending.	Offline	1 to 2	Should only be undertaken after integrity of insulation quality of groundwall has been verified. Use voltages according to industry standards or manufacturer's recommendations.	