

Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems



These specifications have been developed
by the
InterNational Electrical Testing Association

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 - 3.1 Testing Organization
 - 3.2 Testing Personnel
- 4. Division of Responsibility
 - 4.1 The Owner’s Representative
 - 4.2 The Testing Organization
- 5. General
 - 5.1 Safety and Precaution
 - 5.2 Suitability of Test Equipment
 - 5.3 Test Instrument Calibration
 - 5.4 Test Report

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PREFACE

It is recognized by the Association that the needs for acceptance testing of commercial, industrial, governmental, and other electrical power systems vary widely. Many criteria are used in determining what equipment is to be tested and to what extent.

To help the user better understand and navigate more efficiently through this document, we offer the following information:

The Document Structure

The document is divided into twelve separate and defined sections:

Section	Description
Section 1	General Scope
Section 2	Applicable References
Section 3	Qualifications of Testing Organization and Personnel
Section 4	Division of Responsibility
Section 5	General
Section 6	Power System Studies
Section 7	Inspection and Test Procedures
Section 8	System Function Test
Section 9	Thermographic Survey
Section 10	Electromagnetic Field Testing
Tables	Reference Tables
Appendices	Various Informational Documents

Section 7 Structure

Section 7 is the main body of the document with specific information on what to do relative to the inspection and acceptance testing of electrical power distribution equipment and systems. It is not intended that this document list how to test specific pieces of equipment or systems.

Expected Test Results

Section 7 consists of sections specific to each particular type of equipment. Within those sections there are, typically, three main bodies of information:

1. Visual and Mechanical Inspection
2. Electrical Tests
3. Test Values



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Results of Visual and Mechanical Inspections

Some, but not all, visual and mechanical inspections have an associated test value or result. Those items with an expected result are referenced under Section 3.1 Test Values – Visual and Mechanical. For example, Section 7.1 Switchgear and Switchboard Assemblies, item 7.1.1.7.2 calls for verifying tightness of connections using a calibrated torque wrench method. Under the Test Values – Visual and Mechanical Section 7.1.3. 1.2, the expected results for that particular task are listed within Section 3.1, with reference back to the original task description on item 7.1.1.7.2.

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean.
5. Verify that fuse and circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker's address for microprocessor-communication packages.
6. Verify that current and voltage transformer ratios correspond to drawings.
7. Inspect bolted electrical connections for high resistance using one of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
8. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
 1. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
 2. Make key exchange with devices operated in off-normal positions.
9. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
10. Inspect insulators for evidence of physical damage or contaminated surfaces.
11. Verify correct barrier and shutter installation and operation.
12. Exercise all active components.
13. Inspect mechanical indicating devices for correct operation.
14. Verify that filters are in place and vents are clear.
15. Perform visual and mechanical inspection of instrument transformers in accordance with Section 7.10.

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (continued)

4. Verify correct function of control transfer relays located in the switchgear with multiple control power sources.
9. Voltage Transformers
 1. Perform secondary wiring integrity test. Verify correct potential at all devices.
 2. Verify secondary voltages by energizing the primary winding with system voltage.
10. Perform current-injection tests on the entire current circuit in each section of switchgear.
 1. Perform current tests by secondary injection with magnitudes such that a minimum current of 1.0 ampere flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.
 - *2. Perform current tests by primary injection with magnitudes such that a minimum of 1.0 ampere flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.
11. Perform system function tests in accordance with Section 8.
12. Verify operation of cubicle switchgear/switchboard space heaters.
13. Perform phasing checks on double-ended or dual-source switchgear to insure correct bus phasing from each source.
3. Test Values
- 3.1 Test Values – Visual and Mechanical
 1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.1.1.7.1)
 2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.1.1.7.2)
 3. Results of the thermographic survey shall be in accordance with Section 9. (7.1.1.7.3)
- 3.2 Test Values – Electrical



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Results of Electrical Tests

Each electrical test has a corresponding expected result, and the test and the result have identical numbers. If the electrical test is item four, the expected result under the Test Values section is also item four. For example, under Section 7.15.1 Rotating Machinery, AC Induction Motors and Generators, item 7.15.1.2.2 (item 2 within the Electrical Tests section) calls for performing an insulation-resistance test in accordance with IEEE Standard 43. Under the Test Values – Electrical section, the expected results for that particular task are listed in the Test Values section under item 2.

7. INSPECTION AND TEST PROCEDURES 7.15.1 Rotating Machinery, AC Induction Motors and Generators 1. Visual and Mechanical Inspection 1. Compare equipment nameplate data with drawings and specifications. 2. Inspect physical and mechanical condition. 3. Inspect anchorage, alignment, and grounding. 4. Inspect air baffles, filter media, cooling fans, slip rings, brushes, and brush rigging. 5. Inspect bolted electrical connections for high resistance using one of the following methods: 1. Use of low-resistance ohmmeter in accordance with Section 7.15.1.2. 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. 3. Perform thermographic survey in accordance with Section 9. 6. Perform special tests such as air-gap spacing and machine alignment, if applicable. 7. Verify the application of appropriate lubrication and lubrication systems. 8. Verify that resistance temperature detector (RTD) circuits conform to drawings. 2. Electrical Tests – AC Induction 1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.15.1.1. 2. Perform insulation-resistance tests in accordance with ANSI/IEEE Standard 43. 1. Machines larger than 200 horsepower (150 kilowatts): Test duration shall be ten minutes. Calculate polarization index. 2. Machines 200 horsepower (150 kilowatts) and less: Test duration shall be one minute. Calculate dielectric-absorption ratio. 3. Perform dc dielectric withstand voltage tests on machines rated at 2300 volts and greater in accordance with ANSI/IEEE Standard 95. 4. Perform phase-to-phase stator resistance test on machines 2300 volts and greater. *5. Perform insulation power-factor or dissipation-factor tests.	7. INSPECTION AND TEST PROCEDURES 7.15.1 Rotating Machinery, AC Induction Motors and Generators (continued) 5. Air-gap spacing and machine alignment shall be in accordance with manufacturer's published data. (7.15.1.1.6). 3.2 Test Values – Electrical Tests 1. Compare bolted connection resistance values to values of similar connections. Investigate any values that deviate from similar bolted connections by more than 50 percent of the lowest value. 2. The dielectric absorption ratio or polarization index shall not be less than 1.0. The recommended minimum insulation resistance (IR_{1min}) test results in megohms shall be corrected to 40° C and read as follows: 1. $IR_{1min} = kV + 1$ for most windings made before 1970, all field windings, and others not described in 2.2 and 2.3. (kV is the rated machine terminal-to-terminal voltage in rms kV) 2. $IR_{1min} = 100$ megohms for most dc armature and ac windings built after 1970 (form-wound coils). 3. $IR_{1min} = 5$ megohms for most machines and random-wound stator coils and form-wound coils rated below 1 kV. NOTE: Dielectric withstand voltage and surge comparison tests shall not be performed on machines having values lower than those indicated above. 3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test. 4. Investigate phase-to-phase stator resistance values that deviate by more than 10 percent. 5. Power-factor or dissipation-factor values shall be compared to manufacturer's published data. In the absence of manufacturer's published data these values will be compared with previous values of similar machines. 6. Tip-up values shall indicate no significant increase in power factor. 7. If no evidence of distress, insulation failure, or lack of waveform nesting is observed by the end of the total time of voltage application during the surge comparison test, the test specimen is considered to have passed the test. 8. Bearing insulation-resistance measurements shall be within manufacturer's published tolerances. In the absence of manufacturer's published tolerances, the comparison shall be made to similar machines. * Optional
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Optional Tests

The purpose of these specifications is to assure that all tested electrical equipment and systems supplied by either contractor or owner are operational and within applicable standards and manufacturer's published tolerances and that equipment and systems are installed in accordance with design specifications.

Certain tests are assigned an optional classification. The following considerations are used in determining the use of the optional classification:

1. Does another listed test provide similar information?
2. How does the cost of the test compare to the cost of other tests providing similar information?
3. How commonplace is the test procedure? Is it new technology?

Manufacturer's Instruction Manuals

It is important to follow the recommendations contained in the manufacturer's published data. Many of the details of a complete and effective testing procedure can be obtained from this source.

Summary

The guidance of an experienced testing professional should be sought when making decisions concerning the extent of testing. It is necessary to make an informed judgment for each particular system regarding how extensive a procedure is justified. The approach taken in these specifications is to present a comprehensive series of tests applicable to most industrial and larger commercial systems. In smaller systems, some of the tests can be deleted. In other cases, a number of the tests indicated as optional should be performed.

Likewise, guidance of an experienced testing professional should also be sought when making decisions concerning the results of test data and their significance to the overall analysis of the device or system under test. Careful consideration of all aspects of test data, including manufacturer's published data and recommendations, must be included in the overall assessment of the device or system under test.

The Association encourages comment from users of this document. Please contact the NETA office or your local NETA Accredited Company.

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1. GENERAL SCOPE

1. These specifications cover the suggested field tests and inspections that are available to assess the suitability for initial energization of electrical power distribution equipment and systems.
2. The purpose of these specifications is to assure that tested electrical equipment and systems are operational and within applicable standards and manufacturer's tolerances and that the equipment and systems are installed in accordance with design specifications.
3. The work specified in these specifications may involve hazardous voltages, materials, operations, and equipment. These specifications do not purport to address all of the safety issues associated with their use. It is the responsibility of the user to review all applicable regulatory limitations prior to the use of these specifications



2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications

All inspections and field tests shall be in accordance with the latest edition of the following codes, standards, and specifications except as provided otherwise herein.

1. American National Standards Institute – ANSI

2. ASTM International - ASTM

ASTM D92	<i>Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester</i>
ASTM D445	<i>Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)</i>
ASTM D664	<i>Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration</i>
ASTM D877	<i>Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids using Disk Electrodes</i>
ASTM D923	<i>Standard Practices for Sampling Electrical Insulating Liquids</i>
ASTM D924	<i>Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids</i>
ASTM D971	<i>Standard Test Method for Interfacial Tension of Oil against Water by the Ring Method</i>
ASTM D974	<i>Standard Test Method for Acid and Base Number by Color-Indicator Titration</i>
ASTM D1298	<i>Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method</i>
ASTM D1500	<i>Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)</i>
ASTM D1524	<i>Standard Test Method for Visual Examination of Used Electrical Insulating Oils of Petroleum Origin in the Field</i>
ASTM D1533	<i>Standard Test Methods for Water in Insulating Liquids by Coulometric Karl Fischer Titration</i>
ASTM D1816	<i>Standard Test Method for Dielectric Breakdown Voltage of Insulating Oils of Petroleum Origin Using VDE Electrodes</i>



2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

ASTM D2029	<i>Standard Test Methods for Water Vapor Content of Electrical Insulating Gases by Measurement of Dew Point</i>
ASTM D2129	<i>Standard Test Method for Color of Clear Electrical Insulating Liquids (Platinum-Cobalt Scale)</i>
ASTM D2284	<i>Standard Test Method of Acidity of Sulfur Hexafluoride</i>
ASTM D2285	<i>Standard Test Method for Interfacial Tension of Electrical Insulating Oils of Petroleum Origin against Water by the Drop-Weight Method</i>
ASTM D2477	<i>Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Insulating Gases at Commercial Power Frequencies</i>
ASTM D2685	<i>Standard Test Method for Air and Carbon Tetrafluoride in Sulfur Hexafluoride by Gas Chromatography</i>
ASTM D2759	<i>Standard Practice for Sampling Gas from a Transformer under Positive Pressure</i>
ASTM D3284	<i>Standard Test Method for Combustible Gases in the Gas Space of Electrical Apparatus Using Portable Meters</i>
ASTM D3612	<i>Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography</i>
ASTM D3613	<i>Standard Practice for Sampling Electrical Insulating Oils for Gas Analysis and Determination of Water Content</i>

3. Association of Edison Illuminating Companies - AEIC

4. Canadian Standards Association - CSA

5. Electrical Apparatus Service Association - EASA

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



2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

6. Institute of Electrical and Electronic Engineers - IEEE

ANSI/IEEE C2	<i>National Electrical Safety Code</i>
ANSI/IEEE C37 Compilation	<i>Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses</i>
ANSI/IEEE C57 Compilation	<i>Distribution, Power, and Regulating Transformers</i>
ANSI/IEEE C62 Compilation	<i>Surge Protection</i>
ANSI/IEEE C93.1	<i>Requirements for Power-Line Carrier Coupling Capacitors and Coupling Capacitor Voltage Transformers (CCVT)</i>
ANSI/IEEE 43	<i>IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery</i>
ANSI/IEEE 48	<i>IEEE Standard Test Procedures and Requirements for Alternating- Current Cable Terminations 2.5 kV through 765 kV</i>
IEEE 81	<i>IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part I: Normal Measurements</i>
ANSI/IEEE 81.2	<i>IEEE Guide for Measurement of Impedance and Safety Characteristics of Large, Extended or Interconnected Grounding Systems</i>
ANSI/IEEE 95	<i>IEEE Recommended Practice for Insulation Testing of Large AC Rotating Machinery with High Direct Voltage</i>
IEEE 100	<i>The Authoritative Dictionary of IEEE Standards Terms</i>
IEEE 141	<i>IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants (IEEE Red Book)</i>
ANSI/IEEE 142	<i>IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)</i>
ANSI/IEEE 241	<i>IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book)</i>
ANSI/IEEE 242	<i>IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book)</i>

2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

IEEE 386	<i>IEEE Standard for Separable Insulated Connectors System for Power Distribution Systems above 600 V</i>
ANSI/IEEE 399	<i>IEEE Recommended Practice for Power Systems Analysis (Brown Book)</i>
ANSI/IEEE 400	<i>IEEE Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems</i>
ANSI/IEEE 400.2	<i>IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)</i>
ANSI/IEEE 421.3	<i>IEEE Standard for High-Potential-Test Requirements for Excitation Systems for Synchronous Machines</i>
ANSI/IEEE 446	<i>IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book)</i>
ANSI/IEEE 450	<i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications</i>
ANSI/IEEE 493	<i>IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book)</i>
ANSI/IEEE 519	<i>IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems</i>
ANSI/IEEE 602	<i>IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book)</i>
ANSI/IEEE 637	<i>IEEE Guide for the Reclamation of Insulating Oil and Criteria for Its Use</i>
IEEE 644	<i>Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines</i>
ANSI/IEEE 739	<i>IEEE Recommended Practice for Energy Management in Commercial and Industrial Facilities (Bronze Book)</i>
ANSI/IEEE 902	<i>IEEE Guide for Maintenance, Operation and Safety of Industrial and Commercial Power Systems (Yellow Book)</i>
IEEE 1015	<i>IEEE Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems (Blue Book)</i>
IEEE 1100	<i>IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book)</i>



2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

- | | |
|----------------|--|
| ANSI/IEEE 1106 | <i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Batteries for Stationary Applications</i> |
| ANSI/IEEE 1159 | <i>IEEE Recommended Practice on Monitoring Electrical Power Quality</i> |
| ANSI/IEEE 1188 | <i>IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve-Regulated Lead-Acid (VRLA) Batteries for Stationary Applications</i> |
| IEEE 1584 | <i>IEEE Guide for Arc-Flash Hazard Calculations</i> |
7. Insulated Cable Engineers Association – ICEA
- | | |
|-------------------------------------|---|
| ANSI/ICEA
S-93-639/NEMA
WC 74 | <i>5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy</i> |
| ANSI/ICEA
S-94-649 | <i>Standard for Concentric Neutral Cables Rated 5,000 - 46,000 Volts</i> |
| ANSI/ICEA
S-97-682 | <i>Standard for Utility Shielded Power Cables Rated 5,000 - 46,000 Volts</i> |
8. InterNational Electrical Testing Association - NETA
- | | |
|--------------------------|---|
| ANSI/NETA ETT | <i>Standard for Certification of Electrical Testing Technicians</i> |
| ANSI/NETA MTS
7.2.1.1 | <i>Standard for Electrical Maintenance Testing of Dry-Type Transformers</i> |
| ANSI/NETA MTS
7.2.1.2 | <i>Standard for Electrical Maintenance Testing of Liquid-Filled Transformers</i> |
| NETA MTS | <i>Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems</i> |
9. National Electrical Manufacturers Association - NEMA
- | | |
|----------------|--|
| NEMA AB4 | <i>Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications</i> |
| ANSI/NEMA 84.1 | <i>Electrical Power Systems and Equipment Voltage Ratings (60 Hz)</i> |
| NEMA MG1 | <i>Motors and Generators</i> |
10. National Fire Protection Association - NFPA

2. APPLICABLE REFERENCES

2.1 Codes, Standards, and Specifications (*continued*)

ANSI/NFPA 70	<i>National Electrical Code</i>
ANSI/NFPA 70B	<i>Recommended Practice for Electric Equipment Maintenance</i>
ANSI/NFPA 70E	<i>Electrical Safety Requirements for Employee Workplaces</i>
ANSI/NFPA 99	<i>Standard for Healthcare Facilities</i>
ANSI/NFPA 101	<i>Life Safety Code</i>
ANSI/NFPA 110	<i>Emergency and Standby Power Systems</i>
ANSI/NFPA 780	<i>Installation of Lightning Protection Systems</i>

11. Occupational Safety and Health Administration - OSHA
12. State and local codes and ordinances
13. Underwriters Laboratories, Inc. - UL



2. APPLICABLE REFERENCES

2.2 Other Publications

Manufacturer's instruction manuals for the equipment to be tested.

John C. Cadick, *Electrical Safety Handbook*, New York: McGraw Hill

Megger, *A Stitch in Time...The Complete Guide to Electrical Insulation Testing*

Paul Gill, *Electrical Power Equipment Maintenance and Testing*, New York: Marcel Dekker, Inc.

Kenneth G. Mastrullo, Ray A. Jones, Jane G. Jones, *The Electrical Safety Program Book*, NFPA

2.3 Contact Information

American National Standards Institute – ANSI

25 West 43rd Street 4th Fl.

New York, NY 10036

(212) 642-4900

www.ansi.org

ASTM International – ASTM

100 Barr Harbor Drive

W. Conshohocken, PA 19428

(610) 832-9585

www.astm.org

Association of Edison Illuminating Companies – AEIC

600 N. 18th Street; PO Box 2641

Birmingham, AL 35291

(205) 257-2530

www.aeic.org

Canadian Standards Association – CSA

178 Rexdale Boulevard

Toronto, ON M9W 1R3

(416) 747-4000

www.csa.ca

Electrical Apparatus Service Association – EASA

1331 Baur Boulevard

St. Louis, MO 63132

(314) 993-2220

www.easa.com

Institute of Electrical and Electronic Engineers – IEEE

PO Box 1331

Piscataway, NJ 08855

(732) 981-0060

www.ieee.org



2. APPLICABLE REFERENCES

2.3 Contact Information (*continued*)

Insulated Cable Engineers Association – ICEA
c/o Global Document Engineers
15 Inverness Way East
Englewood, CO 80112
(303) 397-7956
www.icea.net

International Electrotechnical Commission – IEC
Contact through American National Standards Institute

InterNational Electrical Testing Association – NETA
2700 W. Centre Avenue, Suite A
Portage, MI 49024
(269) 488-6382 or (888) 300-NETA (6382)
www.netaworld.org

Marcel Dekker, Inc.
PO Box 5005
Monticello, NY 12701
(800) 228-160
www.dekker.com

The McGraw-Hill Companies
P.O. Box 182604
Columbus, OH 43272
Phone: (877) 833-5524
www.mcgraw-hill.com

Megger
4271 Bronze Way
Dallas, TX 75237
(214) 723-2861
www.megger.com

National Electrical Manufacturers Association– NEMA
1300 N. 17th St. Suite 1847
Rosslyn, VA 22209
(703) 841-3200
www.nema.org

National Fire Prevention Association – NFPA
1 Battery March Park
PO Box 901
Quincy, MA 02269-9101
(617) 984-7247
www.nfpa.org



2. APPLICABLE REFERENCES

2.3 Contact Information (*continued*)

Occupational Safety and Health Administration – OSHA
U.S. Department of Labor
Occupational Safety and Health Administration
Office of Public Affairs - Room N3647
200 Constitution Avenue
Washington, D.C. 20210
(202) 693-1999
www.osha.gov

The Okonite Company
102 Hilltop Road
Ramsey, New Jersey 07446
(201) 825-0300 Fax 201-825-3524
www.okonite.com

Underwriters Laboratories, Inc. – UL
333 Pfingsten Road
Northbrook, IL 60062
(847) 272-8800
www.ul.com

3. QUALIFICATIONS OF TESTING ORGANIZATION AND PERSONNEL

3.1 Testing Organization

1. The testing organization shall be an independent, third party entity which can function as an unbiased testing authority, professionally independent of the manufacturers, suppliers, and installers of equipment or systems being evaluated.
2. The testing organization shall be regularly engaged in the testing of electrical equipment devices, installations, and systems.
3. The testing organization shall use technicians who are regularly employed for testing services.
4. An organization having a designation of “NETA Accredited Company” issued by the InterNational Electrical Testing Association meets the above criteria.
5. The testing organization shall submit appropriate documentation to demonstrate that it satisfactorily complies with these requirements.

3.2. Testing Personnel

1. Technicians performing these electrical tests and inspections shall be trained and experienced concerning the apparatus and systems being evaluated. These individuals shall be capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved. They must evaluate the test data and make a judgment on the serviceability of the specific equipment.
2. Technicians shall be certified in accordance with ANSI/NETA ETT-2000, *Standard for Certification of Electrical Testing Personnel*. Each on-site crew leader shall hold a current certification, Level III or higher, in electrical testing.



4. DIVISION OF RESPONSIBILITY

4.1 The Owner's Representative

The owner's representative shall provide the testing organization with the following:

1. A short-circuit analysis, a coordination study, and a protective device setting sheet as described in Section 6.
2. A complete set of electrical plans and specifications, including all change orders.
3. Drawings and instruction manuals applicable to the scope of work.
4. An itemized description of equipment to be inspected and tested.
5. A determination of who shall provide a suitable and stable source of electrical power to each test site.
6. A determination of who shall perform certain preliminary low-voltage insulation-resistance, continuity, and low-voltage motor rotation tests prior to and in addition to tests specified herein.
7. Notification of when equipment becomes available for acceptance tests. Work shall be coordinated to expedite project scheduling.
8. Site-specific hazard notification and safety training.

4.2 The Testing Organization

The testing organization shall provide the following:

1. All field technical services, tooling, equipment, instrumentation, and technical supervision to perform such tests and inspections.
2. Specific power requirements for test equipment.
3. Notification to the owner's representative prior to commencement of any testing.
4. A timely notification of any system, material, or workmanship that is found deficient based on the results of the acceptance tests.
5. A written record of all tests and a final report.

5. GENERAL

5.1 Safety and Precautions

All parties involved must be cognizant of industry-standard safety procedures. This document does not contain any procedures including specific safety procedures. It is recognized that an overwhelming majority of the tests and inspections recommended in these specifications are potentially hazardous. Individuals performing these tests shall be qualified and capable of conducting the tests in a safe manner and with complete knowledge of the hazards involved.

1. Safety practices shall include, but are not limited to, the following requirements:
 1. All applicable provisions of the Occupational Safety and Health Act, particularly OSHA 29 CFR Part 1910 and 29 CFR Part 1926.
 2. ANSI/NFPA 70E, *Standard for Electrical Safety in the Workplace*.
 3. *The Electrical Safety Program Book*, Kenneth G. Mastrullo, Ray A. Jones, Jane G. Jones, NFPA.
 4. Applicable state and local safety operating procedures.
 5. Owner's safety practices.
2. A safety lead person shall be identified prior to commencement of work.
3. A safety briefing shall be conducted prior to the commencement of work.
4. All tests shall be performed with the apparatus de-energized and grounded except where otherwise specifically required to be ungrounded or energized for certain tests.
5. The testing organization shall have a designated safety representative on the project to supervise operations with respect to safety. This individual may be the same person described in 5.1.2.

5.2 Suitability of Test Equipment

1. All test equipment shall meet the requirements in Section 5.3 and be in good mechanical and electrical condition.
2. Field test metering used to check power system meter calibration must be more accurate than the instrument being tested.
3. Accuracy of metering in test equipment shall be appropriate for the test being performed.
4. Waveshape and frequency of test equipment output waveforms shall be appropriate for the test to be performed and the equipment to be tested.



5. GENERAL

5.3 Test Instrument Calibration

1. The testing organization shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy for each test instrument calibrated.
2. The firm providing calibration service shall maintain up-to-date instrument calibration instructions and procedures for each test instrument calibrated.
3. The accuracy shall be directly traceable to the National Institute of Standards and Technology (NIST).
4. Instruments shall be calibrated in accordance with the following frequency schedule:
 1. Field instruments: Analog and Digital, 12 months maximum.
 2. Laboratory instruments: 12 months maximum.
 3. Leased specialty equipment: 12 months maximum.
5. Dated calibration labels shall be visible on all test equipment.
6. Records which show date and results of instruments calibrated or tested must be kept up to date.
7. Calibrating standard shall be of better accuracy than that of the instrument tested.

5. GENERAL

5.4 Test Report

1. The test report shall include the following:
 1. Summary of project.
 2. Description of equipment tested.
 3. Description of tests.
 4. Test data.
 5. Analysis and recommendations.
2. Test data records shall include the following minimum requirements:
 1. Identification of the testing organization.
 2. Equipment identification.
 3. Humidity, temperature, and other conditions that may affect the results of the tests and/or calibrations.
 4. Date of inspections, tests, maintenance, and/or calibrations.
 5. Identification of the testing technician.
 6. Indication of inspections, tests, maintenance, and/or calibrations to be performed and recorded.
 7. Indication of expected results when calibrations are to be performed.
 8. Indication of as-found and as-left results, as applicable.
 9. Sufficient spaces to allow all results and comments to be indicated.
3. The testing organization shall furnish a copy or copies of the complete report to the owner as specified in the acceptance testing contract.



6. POWER SYSTEM STUDIES

6.1 Short-Circuit Studies

1. Scope of Study

Determine the short-circuit current available at each component of the electrical system and the ability of the component to withstand and/or interrupt the current. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

2. Procedure

The short-circuit study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399 and the step-by-step procedures outlined in the short-circuit calculation chapters of IEEE 141 and ANSI/IEEE 242.

3. Study Report

Results of the short-circuit study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study.
2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and identification of the scenario used to evaluate equipment short-circuit ratings.
4. Tabulations of equipment short-circuit ratings versus available fault duties. The tabulation shall identify percentage of rated short circuit and clearly note equipment with insufficient ratings.
5. Conclusions and recommendations.



6. POWER SYSTEM STUDIES

6.2 Coordination Studies

1. Scope of Study

Determine protective device characteristics, settings, or sizes that provide a balance between equipment protection and selective device operation that is optimum for the electrical system. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

2. Procedure

The coordination study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399 and ANSI/IEEE 242. Protective device selection and settings shall comply with requirements of the NFPA 70 *National Electrical Code*.

3. Study Report

Results of the coordination study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study and a corresponding one-line diagram.
2. Time-current curves demonstrating the coordination of time-overcurrent protective devices.
3. Tabulations of protective devices identifying circuit location, manufacturer, type, range of adjustment, IEEE device number, current transformer ratios, recommended settings or device size, and referenced time-current curve.
4. Conclusions and recommendations.

4. Implementation

The owner shall engage an independent testing firm for the purpose of inspecting, setting, testing, and calibrating the protective relays, circuit breakers, fuses, and other applicable devices as outlined in this specification.



6. POWER SYSTEM STUDIES

6.3 Arc-Flash Hazard Analysis

Working on energized equipment with exposure to live parts is not an acceptable practice. OSHA 29 CFR Subpart S.1910.333 limits the situations in which work is performed near energized equipment or circuits:

Live parts to which an employee may be exposed shall be de-energized before the employee works on or near them unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations.

1. Scope of Study

The arc-flash study requires accurate short-circuit and coordination studies for the different modes in which the system may operate. After short-circuit and coordination studies have been performed, provide a detailed engineering analysis to determine worst case arc-flash hazards and associated incident energy conditions.

2. Procedure

Identify all locations and equipment to be included in the arc-flash hazard analysis.

1. Prepare a one-line diagram of the power system.
2. Perform a short-circuit study in accordance with Section 6.1.
3. Perform a coordination study in accordance with Section 6.2.
4. Identify the possible system operating modes including tie-breaker positions, and parallel generation.
5. Calculate the arcing fault current flowing through each branch for each fault location using empirical formula in accordance with NFPA, IEEE, or other standards.
6. Determine the time required to clear the arcing fault current using the protective device settings and associated trip curves.
7. Select the working distances based on system voltage and equipment class.
8. Calculate the incident energy at each fault location at the prescribed working distance.
9. Determine the hazard/risk category (HRC) for the estimated incident energy level.

6. POWER SYSTEM STUDIES

6.3 Arc-Flash Hazard Analysis (*continued*)

10. Calculate the flash protection boundary at each fault location.
11. Document the assessment in reports and one-line diagrams. Place appropriate labels on the equipment.

3. Study Report

Results of the arc-flash study shall be summarized in a final report containing the following items:

1. Basis, method of hazard assessment, description, purpose, scope, and date of the study.
2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and identification of the scenario used to evaluate equipment ratings.
4. Tabulations of equipment incident energies, hazard risk categories, and flash protection boundaries. The tabulation shall identify and clearly note equipment that exceeds allowable incident energy ratings.
5. Required arc-flash labeling and placement of labels.
6. Conclusions and recommendations.



6. POWER SYSTEM STUDIES

6.4 Load-Flow Studies

1. Scope of Study

Determine active and reactive power, voltage, current, and power factor throughout the electrical system. Provide an analysis of all possible operating scenarios.

2. Procedure

The load-flow study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399.

3. Study Report

Results of the load-flow study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study.
2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and the basis for each.
4. Tabulations of power and current flow versus equipment ratings. The tabulation shall identify percentage of rated load and the scenario for which the percentage is based. Overloaded equipment shall be clearly noted.
5. Tabulations of system voltages versus equipment ratings. The tabulation shall identify percentage of rated voltage and the scenario for which the percentage is based. Voltage levels outside the ranges recommended by equipment manufacturers, ANSI/IEEE C84.1, or other appropriate standards shall be clearly noted.
6. Tabulations of system real and reactive power losses with areas of concern clearly noted.
7. Conclusions and recommendations.



6. POWER SYSTEM STUDIES

6.5 Stability Studies

1. Scope of Study

Determine the ability of the electrical system's synchronous machines to remain in step with one another following a disturbance. Provide an analysis of disturbances for all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

2. Procedure

The stability study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399.

3. Study Report

Results of the stability study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study.
2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and tabulations or graphs showing the calculation results.
4. Conclusions and recommendations.



6. POWER SYSTEM STUDIES

6.6 Switching-Transients Studies

6.7 Motor-Starting Studies

— RESERVED —

6. POWER SYSTEM STUDIES

6.8 Harmonic-Analysis Studies

1. Scope of Study

Determine the impact of nonlinear loads and their associated harmonic contributions on the voltage and currents throughout the electrical system. Provide an analysis of all possible operating scenarios which will be or have been influenced by the proposed or completed additions or changes to the subject system.

2. Procedure

The harmonic analysis study shall be performed in accordance with the recommended practices and procedures set forth in ANSI/IEEE 399.

3. Study Report

Results of the harmonic analysis study shall be summarized in a final report containing the following items:

1. Basis, description, purpose, and scope of the study.
2. Tabulations of the data used to model the system components and a corresponding one-line diagram.
3. Descriptions of the scenarios evaluated and the basis for each.
4. Tabulations of rms voltages, peak voltages, rms currents, and total capacitor bank loading versus associated equipment ratings. Equipment with insufficient ratings shall be clearly identified for each of the scenarios evaluated.
5. Tabulations of calculated voltage-distortion factors, current-distortion factors, and individual harmonics versus the limits specified by ANSI/IEEE 519. Calculated values exceeding the limits specified in the standard shall be clearly noted.
6. Plots of impedance versus frequency showing resonant frequencies to be avoided.
7. Tabulations of the system transformer capabilities based on the calculated nonsinusoidal load current and the procedures set forth in ANSI/IEEE C57.110. Overloaded transformers shall be clearly noted.
8. Conclusions and recommendations.



6. POWER SYSTEM STUDIES

6.9 Ground-Mat Studies

6.10 Cable-Ampacity Studies

6.11 Reliability Studies

— RESERVED —

7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, grounding, and required area clearances.
4. Verify the unit is clean.
5. Verify that fuse and circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker's address for microprocessor-communication packages.
6. Verify that current and voltage transformer ratios correspond to drawings.
7. Inspect bolted electrical connections for high resistance using one of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
8. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
 1. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
 2. Make key exchange with devices operated in off-normal positions.
9. Verify appropriate lubrication on moving current-carrying parts and on moving and sliding surfaces.
10. Inspect insulators for evidence of physical damage or contaminated surfaces.
11. Verify correct barrier and shutter installation and operation.
12. Exercise all active components.
13. Inspect mechanical indicating devices for correct operation.
14. Verify that filters are in place and vents are clear.
15. Perform visual and mechanical inspection of instrument transformers in accordance with Section 7.10.



7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (*continued*)

16. Inspect control power transformers.

1. Inspect for physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
2. Verify that primary and secondary fuse or circuit breaker ratings match drawings.
3. Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.

2. Electrical Tests

1. Perform resistance measurements through bolted electrical connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.1.1.
2. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground, for one minute in accordance with Table 100.1.
3. Perform a dielectric withstand voltage test on each bus section, each phase-to-ground with phases not under test grounded, in accordance with manufacturer's published data. If manufacturer has no recommendation for this test, it shall be in accordance with Table 100.2. The test voltage shall be applied for one minute.
4. Perform insulation-resistance tests on control wiring with respect to ground. Applied potential shall be 500 volts dc for 300-volt rated cable and 1000 volts dc for 600-volt rated cable. Test duration shall be one minute. For units with solid-state components or control devices that can not tolerate the applied voltage, follow the manufacturer's recommendation.
5. Perform electrical tests on instrument transformers in accordance with Section 7.10.
6. Perform ground-resistance tests in accordance with Section 7.13.
7. Determine accuracy of all meters and calibrate watt-hour meters in accordance with Section 7.11. Verify multipliers.
8. Control Power Transformers
 1. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with Table 100.1 unless otherwise specified by the manufacturer.
 2. Perform secondary wiring integrity test. Disconnect transformer at secondary terminals and connect secondary wiring to a rated secondary voltage source. Verify correct potential at all devices.
 3. Verify correct secondary voltage by energizing the primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.



7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (*continued*)

4. Verify correct function of control transfer relays located in the switchgear with multiple control power sources.
9. Voltage Transformers
 1. Perform secondary wiring integrity test. Verify correct potential at all devices.
 2. Verify secondary voltages by energizing the primary winding with system voltage.
10. Perform current-injection tests on the entire current circuit in each section of switchgear.
 1. Perform current tests by secondary injection with magnitudes such that a minimum current of 1.0 ampere flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.
 - *2. Perform current tests by primary injection with magnitudes such that a minimum of 1.0 ampere flows in the secondary circuit. Verify correct magnitude of current at each device in the circuit.
11. Perform system function tests in accordance with Section 8.
12. Verify operation of cubicle switchgear/switchboard space heaters.
13. Perform phasing checks on double-ended or dual-source switchgear to insure correct bus phasing from each source.

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.1.1.7.1)
2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.1.1.7.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.1.1.7.3)

3.2 Test Values – Electrical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.



7. INSPECTION AND TEST PROCEDURES

7.1 Switchgear and Switchboard Assemblies (*continued*)

2. Insulation-resistance values of bus insulation shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.1. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.
3. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.
4. Minimum insulation-resistance values of control wiring shall not be less than two megohms.
5. Results of electrical tests on instrument transformers shall be in accordance with Section 7.10.
6. Results of ground-resistance tests shall be in accordance with Section 7.13.
7. Accuracy of meters shall be in accordance with Section 7.11.
8. Control Power Transformers
 1. Insulation-resistance values of control power transformers shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. Dielectric withstand voltage tests shall not proceed until insulation-resistance levels are raised above minimum values.
 2. Secondary wiring shall be in accordance with design drawings and specifications.
 3. Secondary voltage shall be in accordance with design specifications
 4. Control transfer relays shall perform as designed.
9. Voltage transformers
 1. Secondary wiring shall be in accordance with design drawings and specifications.
 2. Secondary voltage shall be in accordance with design specifications
10. Current-injection tests shall prove current wiring is in accordance with design specifications.
11. Results of system function tests shall be in accordance with Section 8.
12. Heaters shall be operational.
13. Phasing checks shall prove the switchgear or switchboard phasing is correct and in accordance with the system design.

7. INSPECTION AND TEST PROCEDURES

7.2.1.1 Transformers, Dry Type, Air-Cooled, Low-Voltage, Small

NOTE: This category consists of power transformers with windings rated 600 volts or less and sizes equal to or less than 167 kVA single-phase or 500 kVA three-phase.

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify that resilient mounts are free and that any shipping brackets have been removed.
5. Verify the unit is clean.
6. Inspect bolted electrical connections for high resistance using one of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.2.1.1.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
7. Verify that as-left tap connections are as specified.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.1.1.1.
2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer's published data or in the absence of manufacturer's published data, use Table 100.5.
3. Calculate the dielectric absorption ratio and polarization index in accordance with manufacturer's published data.
- *4. Perform turns-ratio tests at all tap positions.
5. Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.



7. INSPECTION AND TEST PROCEDURES

7.2.1.1 Transformers, Dry Type, Air-Cooled, Low-Voltage, Small (*continued*)

3. Test Values

3.1 Test Values – Visual and Mechanical

1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.2.1.1.1.6.1)
2. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.1.1.1.6.2)
3. Results of the thermographic survey shall be in accordance with Section 9. (7.2.1.1.1.6.3)
4. Tap connections are left as found unless otherwise specified. (7.2.1.1.7)

3.2 Test Values – Electrical

1. Compare bolted electrical connection resistances to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
2. Minimum insulation-resistance values of transformer insulation shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated.
3. The dielectric absorption ratio or polarization index shall not be less than 1.0.
4. Turns-ratio test results shall not deviate by more than one-half percent from either the adjacent coils or the calculated ratio.
5. Phase-to-phase and phase-to-neutral secondary voltages shall be in agreement with nameplate data.

7. INSPECTION AND TEST PROCEDURES

7.2.1.2 Transformers, Dry Type, Air-Cooled, Large

NOTE: This category consists of power transformers with windings rated higher than 600 volts and low-voltage transformers larger than 167 kVA single-phase or 500 kVA three-phase.

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect anchorage, alignment, and grounding.
4. Verify that resilient mounts are free and that any shipping brackets have been removed.
5. Verify the unit is clean.
- *6. Verify that control and alarm settings on temperature indicators are as specified.
7. Verify that cooling fans operate and that fan motors have correct overcurrent protection.
8. Inspect bolted electrical connections for high resistance using one of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.2.1.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
9. Perform specific inspections and mechanical tests as recommended by the manufacturer.
10. Verify that as-left tap connections are as specified.
11. Verify the presence of surge arresters.

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.1.2.1.
2. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Apply voltage in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.
3. Perform power-factor or dissipation-factor tests on all windings in accordance with the test equipment manufacturer's published data.
- *4. Perform a power-factor or dissipation-factor tip-up test on windings greater than 2.5 kV.
5. Perform turns-ratio tests at all tap positions.



7. INSPECTION AND TEST PROCEDURES

7.2.1.2 Transformers, Dry Type, Air-Cooled, Large (*continued*)

- *6. Perform an excitation-current test on each phase.
- *7. Measure the resistance of each winding at each tap connection.
- 8. Measure core insulation resistance at 500 volts dc if the core is insulated and the core ground strap is removable.
- *9. Perform an applied voltage test on all high- and low-voltage windings-to-ground. See ANSI/IEEE C57.12.91, Sections 10.2 and 10.9.
- 10. Verify correct secondary voltage, phase-to-phase and phase-to-neutral, after energization and prior to loading.
- 11. Test surge arresters in accordance with Section 7.19.

3. Test Values

3.1 Test Values – Visual and Mechanical

- 1. Control and alarm settings on temperature indicators shall operate within manufacturer's recommendations for specified settings. (7.2.1.2.1.6)
- 2. Cooling fans shall operate. (7.2.1.2.1.7)
- 3. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.2.1.2.1.8.1)
- 4. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.1.2.1.8.2)
- 5. Results of the thermographic survey shall be in accordance with Section 9. (7.2.1.2.1.8.3)
- 6. Tap connections shall be left as found unless otherwise specified. (7.2.1.2.1.10)

3.2 Test Values – Electrical

- 1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
- 2. Minimum insulation-resistance values of transformer insulation shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall not be less than 1.0.
- 3. C_H and C_L power-factor or dissipation-factor values will vary due to support insulators and bus work utilized on dry transformers. The following shall be expected on C_{HL} power factors:

7. INSPECTION AND TEST PROCEDURES

7.2.1.2 Transformers, Dry Type, Air-Cooled, Large (*continued*)

Power transformers: 2.0 percent or less

Distribution transformers: 5.0 percent or less

Consult transformer manufacturer's or test equipment manufacturer's data for additional information.

4. Power-factor or dissipation-factor tip-up exceeding 1.0 percent shall be investigated.
5. Turns-ratio test results shall not deviate more than one-half percent from either the adjacent coils or the calculated ratio.
6. The typical excitation current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.
7. Temperature-corrected winding-resistance values shall compare within one percent of previously-obtained results.
8. Core insulation-resistance values shall not be less than one megohm at 500 volts dc.
9. AC dielectric withstand test voltage shall not exceed 75 percent of factory test voltage for one minute duration. DC dielectric withstand test voltage shall not exceed 100 percent of the ac rms test voltage specified in ANSI C57.12.91, Section 10.2 for one minute duration. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.
10. Phase-to-phase and phase-to-neutral secondary voltages shall be in agreement with nameplate data.
11. Test results for surge arresters shall be in accordance with Section 7.19.



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled

1. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect impact recorder prior to unloading.
4. Test dew point of tank gases, if applicable.
5. Inspect anchorage, alignment, and grounding.
6. Verify the presence of PCB content labeling.
7. Verify removal of any shipping bracing after placement.
8. Verify the bushings are clean.
9. Verify that alarm, control, and trip settings on temperature and level indicators are as specified.
10. Verify operation of alarm, control, and trip circuits from temperature and level indicators, pressure relief device, gas accumulator, and fault pressure relay, if applicable.
11. Verify that cooling fans and pumps operate correctly and have appropriate overcurrent protection.
12. Inspect bolted electrical connections for high resistance using one of the following methods:
 1. Use of a low-resistance ohmmeter in accordance with Section 7.2.2.2.
 2. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data or Table 100.12.
 3. Perform thermographic survey in accordance with Section 9.
13. Verify correct liquid level in tanks and bushings.
14. Verify that positive pressure is maintained on gas-blanketed transformers.
15. Perform inspections and mechanical tests as recommended by the manufacturer.
16. Test load tap-changer in accordance with Section 7.12.
17. Verify presence of transformer surge arresters.
18. Verify de-energized tap-changer position is left as specified.



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (*continued*)

2. Electrical Tests

1. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with Section 7.2.2.1.
2. Perform insulation-resistance tests, winding-to-winding and each winding-to-ground. Apply in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Calculate polarization index.
3. Perform turns-ratio tests at all tap positions.
4. Perform insulation power-factor or dissipation-factor tests on all windings in accordance with test equipment manufacturer's published data.
5. Perform power-factor or dissipation-factor tests on each bushing equipped with a power-factor/ capacitance tap. In the absence of a power-factor/ capacitance tap, perform hot-collar tests. These tests shall be in accordance with the test equipment manufacturer's published data.
6. Perform excitation-current tests in accordance with test equipment manufacturer's published data.
7. Measure the resistance of each high-voltage winding in each no-load tap-changer position. Measure the resistance of each low-voltage winding in each load tap-changer position, if applicable.
- *8. If core ground strap is accessible, remove and measure core insulation resistance at 500 volts dc.
- *9. Measure the percentage of oxygen in the gas blanket, if applicable.
10. Remove a sample of insulating liquid in accordance with ASTM D 923. Sample shall be tested for the following.
 1. Dielectric breakdown voltage: ASTM D 877 and/or ASTM D 1816
 2. Acid neutralization number: ANSI/ASTM D 974
 - *3. Specific gravity: ANSI/ASTM D 1298
 4. Interfacial tension: ANSI/ASTM D 971 or ANSI/ASTM D 2285
 5. Color: ANSI/ASTM D 1500
 6. Visual Condition: ASTM D 1524
 - *7. Water in insulating liquids: ASTM D 1533. (Required on 25 kV or higher voltages and on all silicone-filled units.)



7. INSPECTION AND TEST PROCEDURES

7.2.2 Transformers, Liquid-Filled (*continued*)

- *8. Power factor or dissipation factor in accordance with ASTM D 924.
- 11. Remove a sample of insulating liquid in accordance with ASTM D 3613 and perform dissolved-gas analysis (DGA) in accordance with ANSI/IEEE C57.104 or ASTM D3612.
- 12. Test instrument transformers in accordance with Section 7.10.
- 13. Test surge arresters in accordance with Section 7.19, if applicable.
- 14. Test transformer neutral grounding impedance device, if applicable.

3. Test Values

3.1 Test Values – Visual and Mechanical

- 1. Alarm, control, and trip circuits from temperature and level indicators as well as pressure relief device and fault pressure relay shall operate within manufacturer's recommendations for their specified settings. (7.2.2.1.10)
- 2. Cooling fans and pumps shall operate. (7.2.2.1.11)
- 3. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value. (7.2.2.1.12.1)
- 4. Bolt-torque levels shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.12. (7.2.2.1.12.2)
- 5. Results of the thermographic survey shall be in accordance with Section 9. (7.2.2.1.12.3)
- 6. Liquid levels in the transformer tanks and bushings shall be within indicated tolerances. (7.2.2.1.13)
- 7. Positive pressure shall be indicated on pressure gauge for gas-blanketed transformers. (7.2.2.1.14)

3.2 Test Values – Electrical

- 1. Compare bolted connection resistance values to values of similar connections. Investigate values which deviate from those of similar bolted connections by more than 50 percent of the lowest value.
- 2. Minimum insulation-resistance values of transformer insulation shall be in accordance with manufacturer's published data. In the absence of manufacturer's published data, use Table 100.5. Values of insulation resistance less than this table or manufacturer's recommendations should be investigated. The polarization index shall be compared to previously obtained results and shall not be less than 1.0.