



Recommended Practice for
Installing and Maintaining

Dry-Type Transformers



Published by
National Electrical
Contractors Association



An American National Standard

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National Electrical Installation Standards™

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(This foreword is not a part of the standard)

Foreword

National Electrical Installation Standards™ are intended to improve communication among specifiers, purchasers, and suppliers of electrical construction services. They define a minimum baseline of quality and workmanship for installing electrical products and systems. *NEIS™* are intended to be referenced in contract documents for electrical construction projects. The following language is recommended:

Dry-type transformers shall be installed and maintained in accordance with NECA 409-2002, *Recommended Practice for Installing and Maintaining Dry-Type Transformers* (ANSI).

Use of *NEIS* is voluntary, and the National Electrical Contractors Association assumes no obligation or liability to users of this publication. Existence of a standard shall not preclude any member or non-member of NECA from specifying or using alternate construction methods permitted by applicable regulations.

Everything in this publication is intended to comply with the edition of the *National Electrical Code®* in effect at the time of publication. *NEIS* are not intended to duplicate *NEC®* requirements. It is the responsibility of users of this standard to comply with state and local electrical codes when installing electrical products and systems.

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1. Scope

1.1 Products and Applications Included

This recommended practice describes installation procedures for single- and three-phase distribution and power transformers and associated accessories rated 600 Volts AC or less, and 0.25 kVA or more, of the following types:

1. Ventilated, indoor and outdoor, self-cooled or forced air cooled.
2. Nonventilated, indoor and outdoor, self-cooled or forced air cooled.

This publication applies to general purpose, dry-type, two-winding transformers used for supplying power, heating and lighting loads for commercial, institutional, and industrial use in nonhazardous locations both indoors and outdoors.

It also covers periodic routine maintenance and troubleshooting procedures for transformers, and special procedures used after adverse operating conditions such as a short-circuit, ground-fault, or immersion in water.

1.2 Products and Applications Excluded

This publication does not apply to the following:

1. Transformers rated higher than 600 Volts,
2. Sealed dry-type transformers,
3. Specialty transformers such as control, industrial control, instrument, current, potential, meter-

ing, buck-boost transformers, or lighting and ballast transformers,

4. Autotransformers,
5. Cast coil transformers,
6. Arc furnace transformers,
7. Rectifier transformers,
8. Liquid-filled or oil-filled transformers,
9. Network transformers,
10. Unit substation transformers, or
11. Transformers with greater than two sets of windings.

1.3 Regulatory and Other Requirements

All information in this publication is intended to conform to the National Electrical Code® (ANSI/NFPA standard 70). Installers should always follow the NEC®, applicable state and local codes, and manufacturer's instructions when installing and maintaining transformers.

Only qualified persons familiar with the construction and operation of transformers should perform the work described in this publication.

Other *National Electrical Installation Standards* provide additional guidance for installing particular types of electrical products and systems. A complete list of *NEIS* is provided in Annex B.

2. Definitions

Dry-Type Transformer	A transformer in which the core and windings are cooled by a medium other than a liquid such as a gaseous or dry compound insulating medium.	Ventilated Transformer	A transformer constructed to provide ambient air circulation through its enclosure to cool the transformer core and windings.
Distribution Transformer	Any transformer rated 500 kVA and less, except for specialty transformers.	Weathershields	Transformer accessories that allow indoor transformers to be installed outdoors.
Indoor Transformer	A transformer which, because of its construction, must be protected from the weather.		
Non-Ventilated Transformer	A transformer constructed to provide no intentional circulation of external air through the transformer, and operating at zero gauge pressure.		
Outdoor Transformer	A transformer of weather-resistant construction suitable for service without additional protection from the weather.		
High Intensity Transformer	Any transformer rated over 500 kVA.		
Transformer	A static electrical device which, by electromagnetic induction, transforms energy from one circuit to another, usually with changed values of voltage and current.		

3. Receiving, Inspecting, Handling, and Storage

3.1 Receiving

- a) Upon delivery of transformers and prior to unloading, verify that readings from transportation shock recorders, if equipped, are within manufacturer's recommendations. If shock recorder readings are not within manufacturer's recommendations, notify the shipper and the manufacturer in writing immediately.
- b) Unload carefully, observing all packing label warnings.
- c) Compare the transformers and accessories received with the bill of materials to verify that the shipment is complete. If the shipment is not complete, notify the manufacturer in writing immediately.
- d) Upon delivery, carefully unpack transformers and accessories sufficiently to inspect for concealed damage resulting from shipping and handling. If damage has occurred, notify the shipper in writing immediately.
- e) Verify that the transformers and accessories received conform with the manufacturer's quotation and shop drawings. If they do not, notify the manufacturer in writing immediately.
- f) Remove accessible covers or panels and inspect internal components for damage or displacement of parts, loose or broken connections, cracked or chipped insulators, dirt or foreign material, and for the presence of water or moisture. Repair or replace damaged components in accordance with manufacturer recommendations.
- g) If transformers are to be stored prior to installation, restore original packing materials or cover ventilation openings with heavy plastic or canvas to protect

against exposure to moisture, dust, and contaminants. When conditions permit, leave the packing materials intact until transformers are ready for installation. (See 3.3 for more information on storage.)

3.2 Handling

- a) Handle transformers carefully, in accordance with manufacturer recommendations, to avoid damage to the enclosure, base, frame and internal components. Avoid subjecting transformers to impact, jolting, jarring, rough handling, etc.
- b) Use the manufacturer recommended points for lifting, jacking, and/or pulling transformers. Verify that the weight of transformers is within the rated capacity of the handling equipment to be used.
- c) Use care to balance and distribute weight when handling transformers with platform dollies, platform lifts, forklift trucks, skids, and rollers to prevent overturning. Use hand trucks or forklifts only when the blades or forks are long enough to pass completely under the transformer enclosure.
- d) Ensure that transformers are transported in the upright position. Avoid tilting or tipping transformers. Contact the manufacturer for acceptable tilt angles where a transformer is required to be tilted for movement through restricted passages.
- e) Use nylon straps to balance and distribute weight when handling transformers with a crane.
- f) Use spreaders to protect the enclosure when handling transformers with cables or chains to avoid damage to the finish or parts. Lifting cable pull angles should not be greater than 30 degrees from vertical.

g) Protect ventilated indoor transformers against the entrance of dust, rain, and snow when handling outdoors during inclement weather.

3.3 Storage

a) Store transformers in accordance with manufacturer recommendations. Protect transformers from dirt, water, moisture contamination, and physical damage during storage.

b) Only outdoor transformers may be stored outdoors without protective covering. Install electric heating to maintain a uniform temperature above ambient to prevent condensation. Consult transformer manufacturer for recommendations.

c) Store indoor transformers in a clean, dry, heated building having a uniform temperature and adequate air circulation to prevent condensation.

d) Where storage in a heated building is not possible, store indoor transformers indoors in a clean, dry shelter having provisions for maintaining a uniform temperature and adequate air circulation to prevent condensation.

e) Where it is not possible to store indoor transformers indoors, protect transformers from weather and contaminants. Install electric heating to maintain a uniform temperature above ambient to prevent condensation. Consult transformer manufacturer for recommendations.

3.4 Pre-Installation Checks

Complete the following checks prior to setting transformers in place. Contact the manufacturer if any test results are deficient.

a) Compare the manufacturer's shop drawings or wiring diagrams to ensure that the transformer and accessories are connected so that it will perform its intended function. Correct any discrepancies.

b) Perform an insulation resistance test to determine whether the transformer windings have absorbed moisture in accordance with 10.3. Consult the man-

ufacturer for acceptable test results. If test results indicate that the transformer has absorbed moisture, dry the transformer in accordance with Section 9.

c) Measure the turns ratio of all tap positions in accordance with 10.5.

d) Measure the transformer core resistance to ground in accordance with 10.8.

4. Installation

4.1 Environmental Conditions

- a) Unless specifically designed for such locations, do not locate transformers where they will be exposed to dust, vapors, abnormal vibration, shock or other such unusual operating conditions.
- b) Do not install ventilated transformers in environments containing contaminants including dust, excessive moisture, chemicals, corrosive gases, oils, or chemical vapors.
- c) Do not install transformers near heat-generating equipment or heat-sensitive equipment.
- d) Avoid opening transformers during inclement weather conditions, unless the opening is completely protected from weather.
- e) Install ventilated transformers indoors unless they are labeled as suitable for outdoor installation and are installed with appropriate environmental protection.
- f) Locate all transformers away from sources of water. When this is not possible, provide suitable protective shields to prevent water from entering transformer enclosures.
 - Install weathershields on indoor transformers exposed to liquids.
 - Protect indoor transformers from condensate where pipes pass directly above transformers. Insulate the piping or install transformer weathershields.

4.2 Coordination with Other Trades

- a) Locate and coordinate transformer installations in accordance with manufacturer recommendations. Provide sufficient clearances to permit opening hinged or removable doors, covers, and panels for routine inspection, maintenance, and testing.
- b) Verify transformer housing dimensions. Locate obstructions and combustible materials outside the required clearances and installation tolerances. Coordinate to insure that other trades do not use these required transformer clear areas.
- c) Locate transformers to provide sufficient spacings to permit free circulation of air. Install ventilated transformers such that ventilating openings are not blocked by walls or other obstructions.
- d) Coordinate installation of transformers with other trades to permit removal of the transformer without removal or major disassembly of other equipment.
- e) Coordinate installation of transformers with other equipment vendors to ensure power quality and minimize electromagnetic interference (EMI).

4.3 Supporting Transformers

- a) Use brackets, hangers, supports, anchors, etc., in accordance with manufacturer recommendations.
- b) Install mounting brackets, concrete pads, hangers, and/or supports prior to setting transformers in place.
- c) Evaluate structures prior to installation. Verify that structures are suitable for the hanger and weight of the transformer.

d) Provide support channels or concrete housekeeping pads for indoor floor-mounted transformers. Provide level concrete pads for outdoor transformers.

e) Use suitable anchors to attach floor-mounted and pad-mounted transformers to the mounting surface where required.

f) Verify anchors and bolts are suitable for conditions of installation.

4.3.1 Independent supports

a) Support transformers independently from supports for other building systems such as ceilings, piping, ductwork, conduits, etc.

b) Support conduits, raceways, cable trays, and busways attached to transformers independently from the transformers themselves.

4.3.2 Vibration and Sound Isolation

a) Install vibration isolators between the transformer enclosure and supports in accordance with manufacturer recommendations.

b) Provide supplemental seismic supports, restraints, and anchors where required by building code, approved plans, or project specifications.

4.4 General Installation Requirements

a) Install transformers in accordance with manufacturer recommendations, specific transformer markings, and installation instructions.

b) Install transformers level and plumb. Install shims under frames or bases to level transformers, if necessary.

c) After the transformer is placed in its permanent position, remove shipping braces, wedges, ties, and blocks, and loosen or remove shipping bolts, if present, per manufacturer recommendations. Adjust transformer core and coil mounting bolts, and ensure that all other transformer bolts, nuts, fasteners, etc., are made up tight.

d) Fasten removable panels and covers securely.

e) Install bollards, shields, fences, barriers, etc., as required to protect transformers and transformer accessories where exposed to physical damage.

f) Arrange rooms and spaces in which transformers are installed with fences, screens, partitions or walls, or other means to prevent entrance by unauthorized persons.

g) Display warning signs prominently at all entrances to rooms and spaces containing transformers. Use OSHA standard warning signs.

4.4.1 Outdoor installations

a) Provide weather-resistant transformers for installation outdoors.

b) Install factory baffles, grills, or barriers to protect all transformer ventilation openings from vandalism and rodents.

c) Verify adequate site drainage to prevent groundwater from entering transformers.

d) Install bollards, fences, barriers, etc., as required to protect transformers and transformer accessories from vehicular traffic.

4.5 Electrical Circuit Connections

a) Connect raceways and conductors to transformers at locations designated by the manufacturer.

b) Use flexible raceways, conduits, and connectors for attachment to transformer enclosures.

(b) Observe National Electrical Code wire bending space requirements within the transformer terminal enclosure.

(c) Bundle associated phase, neutral, and equipment grounding conductors together within the transformer enclosure.

- (d) Follow manufacturer recommendations for installing connecting lugs on transformer terminal pads.
- e) Use calibrated torque wrench to tighten electrical connectors and terminals according to manufacturer's published torque-tightening values.
- f) Seal connections with an electrical joint compound as recommended by the manufacturer for transformers installed outdoors or in a harsh environment.

4.6 Grounding and Bonding

- a) Connect transformer and related accessories and components to ground in accordance manufacturer recommendations and NEC 250.30.
- b) Ensure that factory-installed transformer grounding and bonding straps and conductors are properly connected.
- c) Terminate all grounding and bonding conductors on a common equipment grounding terminal on the transformer enclosure. Install supplemental terminal bars, lugs, and bonding jumpers as required to accommodate the number of conductors for termination and in accordance with manufacturer recommendations.
- d) Bond the transformer grounded conductor or neutral connection, if so equipped, to ground. Coordinate the neutral-to-ground bonding location with service entrance equipment, switchboards, panelboards, and on-site generation, if applicable.
- e) Bond exposed noncurrent-carrying metal parts of transformer installations, including fences, guards, etc., to the system ground per National Electrical Code requirements.
- f) Tighten grounding connectors and terminals, including screws and bolts, according to the manufacturer's published torque tightening values for equipment connectors.

4.7 Transformer Accessories

- a) Install manufacturer-supplied transformer accessories in accordance with manufacturer recommendations.
- b) Install air filters over ventilation openings in accordance with manufacturer recommendations.
- c) Connect branch circuits for transformer space heaters, thermostats, forced-air cooling fans, controls, etc.

5. Cleaning, Testing, and Commissioning

5.1 Cleaning

5.1.1 Preliminary safety procedures

NOTE: Use appropriate personal protective equipment (PPE) in accordance with established safety procedures when working on or near energized electrical equipment.

- a) Before performing any cleaning, testing, or maintenance procedure, electrically isolate the transformer in accordance with established procedures and 7.1.
- b) Remove trash, combustible material, and other debris from areas around transformer.
- c) Remove access covers, plates, and weathershields.

5.1.2 Transformer cleaning procedures

- a) Vacuum away as much dust as possible. Vacuum clean screens, louvers, or baffles covering ventilation openings.
- b) Clean supports, terminals, and other major insulating surfaces with lint-free rags or soft-bristled brushes. Do not use liquids, solvents or detergents.
- c) Remove any remaining dust accumulations by blowing with clean, dry compressed air or nitrogen with a dew point of -50°F or less and with a pressure at or below 25 psi.
- d) Maintain adequate ventilation during cleaning.

5.2 Visual and Mechanical Inspection

- a) Compare equipment nameplate with drawings and specifications. Verify the presence of transformer surge arresters if specified.

- b) Verify proper connection of taps in accordance with manufacturer's published literature.

- c) Check tightness and clearance of all electrical connections using calibrated torque wrench.

- d) Perform specific inspections and tests as recommended by the transformer manufacturer.

- e) Visually inspect transformer for physical damage. Repair physical damage, if practical, and provide suitable protective barriers to prevent future damage.

- f) Inspect accessible components for cleanliness, for mechanical and electrical integrity, and for damage or deterioration. Do not proceed with tests until deficiencies are corrected. Consult transformer manufacturer for recommendations.

- g) Visually check the core, frame, enclosure, conduits, raceways, and conductors for proper grounding and bonding (*see 4.6*).

- h) Verify that resilient mounts are free and that all shipping brackets have been removed.

- i) Check all accessories for proper installation and operation. Verify that control and alarm settings on temperature indicators are as specified. Verify that cooling fans operate and that fan motors have correct overcurrent protection where installed.

5.3 Acceptance Testing

Test transformers in accordance with manufacturer recommendations and maintain test results for future comparisons. At a minimum, perform the following tests on all transformers. Where test procedures are

not specified by the transformers manufacturer, follow the procedures described in Section 10.

- a) Contact resistance (*see 10.2*).
- b) Insulation resistance (*see 10.3*).
- c) Polarization index (*see 10.4*).
- d) Turns ratio (*see 10.5*).

5.3.1 Transformers rated 500 kVA and above

In addition, perform the following tests on transformers rated 500 kVA and above:

- a) Excitation current (*see 10.6*).
- b) Winding resistance (*see 10.7*).
- c) Core insulation resistance (*see 10.8*).

5.4 Energizing Transformers

NOTE: Consult transformer manufacturer and Annex A: Transformer Troubleshooting Guide, for any abnormal operating conditions encountered.

- a) Ensure that all temporary grounding devices are removed. Remove the warning sign from the transformer primary disconnect that indicates that the transformer terminals are grounded.
- b) Ensure that enclosure covers, baffles, weather-shields, etc., are installed and tightened.
- c) Ensure that ventilation openings are clear.
- d) Verify that all required transformer safety labels are installed.
- e) Ensure that all affected persons are notified that equipment will be energized.
- f) Ensure that all load isolation devices are open, padlocked, and tagged.
- g) Remove the tag and padlock from the transformer primary disconnect. Energize the transformer.

5.4.1 Transformer primary and secondary voltages and phase rotation

Measure primary and secondary phase-to-phase and phase-to-neutral voltages, along with the secondary phase-to-ground and neutral-to-ground voltages to verify that voltages are within specified tolerances after energizing the transformer and prior to loading. Check phase rotation using secondary phase rotation testers. On transformers equipped with taps, adjust them in accordance with manufacturer's recommendations and with the following:

- a) Do not change taps with transformer energized. Electrically isolate the transformer in accordance with established procedures and 7.1.
- b) Adjust transformer taps, if so equipped, to match actual primary and specified nominal secondary operating voltages, as required.
- c) Correct reversed phase rotation by disconnecting and swapping any two conductors at the transformer primary terminals. Use a calibrated torque wrench to tighten terminals to manufacturer's published torque values.
- d) Energize transformer in accordance with 5.4 and recheck no-load voltages and phase rotation.

5.4.2 Energize equipment supplied from the transformer

- a) Energize equipment supplied from the transformer starting at the source end of the transformer and working toward the load. Close main devices, feeder devices, and branch circuit devices in sequence.
- b) Energize lighting circuits, contactors, motors, and heaters after all main, feeder, and branch circuit devices have been closed. Verify proper rotation of three-phase motors.
- c) Inspect transformer for unusual or excessive noise. Investigate hardware that has not been tightened or metal parts that are not properly assembled as possible sources of extraneous noise.

d) Measure secondary phase-to-phase, phase-to-neutral, phase-to-ground, and neutral-to-ground voltages after loading transformer to ensure proper operating voltage under load and proper neutral-to-ground bonding. *NOTE: Consult transformer manufacturer prior to adjusting transformer taps to compensate for voltage drop under load.*

e) Measure primary and secondary phase and neutral current using a true RMS meter to ensure that transformer is not overloaded and that phases are properly balanced. Consult manufacturer for acceptable loading and imbalances. If required, reconfigure feeder and branch circuits supplied by transformers to closely balance loads in accordance with procedures outlined in NECA 407-2002, *Recommended Practice for Installing and Maintaining Panelboards* (ANSI).

f) Measure voltage and current harmonics on the transformer secondary, including secondary neutral current. Consult transformer manufacturer's specifications to ensure that readings are within acceptable limits.

g) Perform an infrared scan (*see 10.10*).

6. Site Cleanup

6.1 Restore Transformer Finish

Inspect exposed transformer finish. Remove burrs, dirt and construction debris, and repair damaged finishes including chips, scratches and abrasions to match original finish.

6.2 Test Data and Manuals

- a) Submit test results and data from all factory and field testing of transformers.
- b) Deliver transformer manufacturer's standard installation, operation, and maintenance manuals to the Owner or General Contractor in accordance with contract documents. In the absence of contractual requirements, deliver a minimum of one set of the transformer manufacturer's standard installation, operation, and maintenance manuals.

6.3 Training

- a) Provide training for the Owner's maintenance personnel, if required by contract documents.
- b) Discuss routine maintenance, operating procedures, cleaning, etc., using the manufacturer's standard installation, operation, and maintenance manuals as references.
- c) Notify the Owner or General Contractor a minimum of seven days in advance of training.

6.4 Spare Parts and Special Tools

Deliver spare parts and special tools to the Owner or General Contractor in accordance with contract documents. In the absence of contractual requirements, deliver the transformer manufacturer's supplied spare parts and special tools.

7. Inspections and Maintenance

7.1 Safety Procedures

NOTE: Before performing cleaning, inspection, testing, or maintenance, electrically isolate the transformer in accordance with established procedures. Consider all circuits live until they are confirmed to be de-energized and are locked out of operation. Consider the transformer enclosure energized until the case-ground connection is inspected and found to be adequate. Access panels, covers, weathershields, etc., should not be removed while the transformer is energized. Use appropriate personal protective equipment (PPE) in accordance with established safety procedures when working on or near energized electrical equipment. Failure to observe these precautions may result in severe personal injury or death.

- a) De-energize the transformer by opening the source switching device.
- b) Test transformer to confirm that it is de-energized.
- c) Padlock and tag source switching device in the open position.
- d) Short-circuit and ground each transformer winding for a minimum of one minute to drain static voltage.
- e) Attach grounding leads to the primary, secondary, and grounding terminals of the transformer.
- f) Provide a warning sign at the transformer primary disconnect indicating that the transformer terminals are grounded.

7.2 Frequency of Inspections and Maintenance

- a) Perform routine external transformer inspections monthly to determine detrimental physical conditions or changes in operating conditions.
- b) Perform periodic inspections, maintenance, and testing of transformers not less than once a year, but as often as the operating environment requires to keep transformers clean.
- c) Perform routine and periodic inspections, maintenance, and testing after any severe electrical short circuit or ground fault.
- d) Clean transformers before performing internal inspections, maintenance, and testing.
- e) Plan cleaning, inspections, maintenance, and testing to minimize transformer outages. Provide strip heaters to maintain transformer temperature above ambient to prevent condensation from forming in transformer windings during outages.

7.3 Routine Inspections

Perform external visual observations and record transformer operational data with transformers energized and in service.

- a) Remove any material or obstruction preventing free air circulation and access around transformers.
- b) Inspect transformer enclosures for evidence of localized heat damage to the paint. Eliminate external sources of heat to transformers. Investigate internal sources of damage to transformer enclosures in accordance with 7.5.

c) Inspect transformer enclosure ventilation openings, louvers, screens, and baffles, along with any visible portions of internal coil cooling ducts for accumulated dust or dirt. If accumulation is excessive, clean transformer and replace air filters in accordance with 7.4 and 7.5.

d) Note the level and characteristics of transformer vibration and sound, considering the contribution of forced-air cooling fan operation. Record and investigate any changes in vibration or sound level or characteristics. Consult the transformer manufacturer for recommendations, or see *Annex A: Transformer Troubleshooting Guide*.

e) Measure and record transformer primary and secondary operating voltages. Investigate and immediately correct causes of overvoltage or undervoltage conditions. If required, adjust transformer taps in accordance with 5.4.1.

f) Measure and record transformer load currents noting the date and time of day. Consult manufacturer for acceptable loading and imbalances. If required, reconfigure feeder and branch circuits supplied by transformers to closely balance loads in accordance with procedures outlined in NECA 407-2002, *Recommended Practice for Installing and Maintaining Panelboards* (ANSI).

g) Measure and record load levels noting the date and time of day. Provide comments regarding known causes of variations in loading, such as load additions or equipment maintenance outages to track transformer loading over time.

h) On transformers equipped with winding temperature indicators, record the values indicated and record the ambient temperature near the transformer enclosure. Note the date and time of day of these readings.

7.3.1 Transformer vaults or rooms

a) Measure and record the temperature of the vault or room where indoor transformers are installed.

b) Verify proper vault or room ventilation. Verify proper operation of power-driven ventilating fans, HVAC (heating, ventilating, and air-conditioning) units, and controls.

c) Inspect vault or room for evidence of water or moisture. Eliminate sources of water or moisture, or provide suitable protection for transformers from sources of water.

d) Inspect vault or room for any accumulation of dirt or dust. Remove any accumulations of dirt or dust. (NOTE: Use the rate of accumulation of dust and moisture on visible surfaces as a guide for scheduling inspections, maintenance, and testing.)

7.4 Periodic External Cleaning, Inspection, and Maintenance

NOTE: Consider the transformer enclosure energized until the case-ground connection is inspected and found to be adequate.

a) De-energize transformer in accordance with established safety procedures (see 7.1).

b) Clean transformer enclosure with a brush, vacuum cleaner, or clean, lint-free rags to remove any accumulation of dust, dirt, or other foreign matter.

c) Remove trash, combustible material, and other debris from areas around transformers.

d) Inspect ventilation openings for blockages.

e) Visually inspect transformer enclosure for physical damage. Repair physical damage, if practical, and provide suitable protective barriers to prevent future damage.

f) Inspect transformer enclosure for signs of overheating, rust, corrosion, or deteriorating paint. Repair painted surfaces.

g) Check for any equipment installed near the transformer that might cause damage from external heating. Eliminate external sources of heat to transformers.

- h) Inspect vibration isolators for deterioration.
- i) Check all accessible exterior hardware for tightness

7.4.1 Exposure to liquids

Visually check indoor transformer enclosures for evidence of exposure to liquids. Look for any recent changes in sprinklers or other plumbing that might now expose indoor transformers to a source of liquids. Eliminate sources or provide necessary protection, such as:

- a) Install weathershields on indoor transformers exposed to liquids.
- b) Protect indoor transformers from condensate where pipes pass directly above transformers. Insulate the piping or install transformer weathershields.
- c) Protect indoor transformers from leaking pipes or roofs by installing temporary sheet metal shields or other protective covers to prevent water from falling onto transformers until the pipes are repaired.
- d) Repair or replace transformers exposed to water in accordance with Section 8.

7.5 Periodic Internal Cleaning, Inspection, and Maintenance

NOTE: Maintain adequate ventilation during cleaning.

- a) Perform internal cleaning, inspection, and maintenance upon completion of external cleaning, inspection and maintenance.
- b) De-energize transformer in accordance with 7.1.
- c) Remove access covers, plates, weathershields, etc. Protect transformers from moisture and contaminants when removing access covers, plates, weathershields, etc.
- d) Vacuum away as much dust from transformer windings as possible. Vacuum clean screens, louvers, or baffles covering ventilation openings.

e) Clean supports, terminals, and other major insulating surfaces with lint-free rags or soft-bristled brush. Do not use liquids, solvents or detergents when cleaning internal transformer components.

f) Remove any remaining dust accumulations by blowing with clean, dry compressed air or nitrogen with a dew point of -50°F or less and with a pressure at or below 25 psi.

g) Inspect winding air ducts for the accumulation of dust and foreign substances. Blow out accumulation, if necessary. Replace dirty air filters. If not equipped with air filters, consult the transformer manufacturer for recommendations for installing air filter materials over the ventilation openings of transformer enclosures where dust or dirt has significantly accumulated within the enclosure or on the windings.

h) Clean forced-air cooling fans, heaters, or other auxiliary devices, if equipped, and check for proper operation. Consult transformer manufacturer for recommendations.

i) Inspect interior of transformer for moisture. Eliminate sources of moisture (*see 7.4.1 and Section 8*).

j) Use a calibrated torque wrench to check all bolts, nuts, washers, and pins for tightness. Tighten or replace parts as required.

k) Check insulators, clamps, and coil spacers for looseness. Tighten or replace parts as required.

7.5.1 Electrical, grounding, and bonding connections

a) Visually check transformer, cables, and raceways for proper bonding and grounding. Correct improper bonding and grounding.

b) Inspect all conductors and connections, including grounding connections, for tightness, erosion, corrosion, physical damage, etc. Use a calibrated torque wrench to check all wire connections according to manufacturer's instructions. Re-terminate loose or damaged conductors and connections.

c) Inspect interior of transformer for arc spatter, sooty deposits, and tracking. Inspect core laminations for signs of arcing or overheating. Investigate sources of arcing or overheating. Consult the transformer manufacturer for recommendations.

d) Inspect insulators, terminals, and terminal boards for signs of discoloration, heat damage, deterioration, carbonization, burns, cracks, chips, breaks, or partial discharge. Investigate sources of insulator damage. Consult the transformer manufacturer for recommendations.

e) Inspect transformer insulating materials for any indication that insulating material or sealing compound is deteriorated or melted. Consult the transformer manufacturer for recommendations.

f) Inspect terminals for alignment, tightness, pressure, burns, or corrosion. Investigate and correct cause of damage. Replace pitted or badly burned terminals. Minor pitting or burning may be repaired, provided the terminal plating is not damaged, using fine sandpaper to smooth down the surface. Follow manufacturer recommendations for repairing and replacing damaged terminals.

transformer is re-energized and has reached a stabilized operating temperature.

b) Investigate differences in temperature gradient in accordance with transformer and test instrument manufacturer recommendations.

7.6 Periodic Transformer Testing

Perform transformer testing in accordance with 5.3.

7.7 Re-energizing Transformers

Transformers that are de-energized for an extended period of time for cleaning, inspection, and testing, and that cool to ambient temperature may have condensed moisture in the windings. Perform insulation resistance testing in accordance with Section 10, and dry transformers in accordance with manufacturer recommendations and Section 9, if required, prior to re-energizing transformers. Re-energize transformer and loads in accordance with 5.4 and 5.4.2.

7.8 Final Infrared Scan

a) Perform a final infrared scan (*see 10.10*) after performing all of the above inspections, maintenance, testing, and making all necessary repairs, and after

8. Inspection and Re-energization After Adverse Operating Conditions

NOTE: Consult transformer manufacturer and Annex A: Transformer Troubleshooting Guide, for any abnormal operating conditions encountered.

8.1 Inspection and Testing Following a Short-Circuit or Ground-Fault

- a) Identify and remove the cause of the short-circuit or ground-fault.
- b) Clean, inspect, and test transformer in accordance with Section 7.
- c) Examine the transformer windings carefully. Look for any indication that windings have been physically displaced or damaged from magnetic forces. Consult the manufacturer for recommendations.
- d) Perform the following electrical testing in addition to those tests specified in 5.3. Consult the manufacturer for recommendations if any test results are deficient. Testing procedures are described in Section 10.
 - Perform a winding resistance test (*see 10.7*).
 - Perform a high potential test (*see 10.9*).

8.1.1 Re-energizing transformer

If test results are satisfactory, re-energize transformer in accordance with 7.7.

8.2 Transformer Soaked By or Submersed Under Water

Remove transformer from service and replace with a new unit.

8.3 Inspecting and Re-energizing Transformer Sprayed or Splashed with Clean Water

Consult the manufacturer for proper procedures for specific transformer components. In the absence of manufacturer recommendations, perform an insulation resistance test to determine the presence of water according to 10.3, and follow the procedure described in Section 9 for drying the transformer. Re-energize transformer and loads in accordance with 5.4 and 5.4.2.

9. Drying Transformers

NOTE: Provide supplemental barriers and safety precautions during transformer drying process to protect personnel from dangerous voltages and to prevent accidental contact with exposed energized components. De-energize transformer in accordance with 7.1.

9.1 General

- a) Supervise the transformer drying process constantly.
- b) Maintain access to a suitable fire extinguisher for use in an emergency.
- c) Wipe transformer windings with a clean, dry cloth to remove excess moisture from the windings. Use compressed air to further remove moisture from the windings.

9.2 Drying by Internal Heat

- a) Remove access covers, plates, weathershields, etc., and locate transformer to allow free circulation of air through the coils from the bottom to the top of the case.
- b) Short-circuit one winding with an adequately sized conductor and apply sufficient voltage at normal frequency to the other winding to circulate between 50 and 100 percent of nameplate current through the winding. Connect the voltage source across the full winding.
- c) Control the rate of temperature rise and limit the maximum winding temperature. Do not exceed the average winding temperature rise or 100°F, whichever is greater, as measured by resistance or by thermometers placed in the ducts between the windings. Place thermometers in physical contact with the winding insulation. Do not use mercury thermometers.

9.3 Drying by External Heat

Apply external heat to the transformer by one of the following three methods. With any method, protect the transformer core and coil assembly and any accessories from direct radiation from heating elements. Limit air temperature to 100°F.

- a) Place the transformer core and coil assembly in a suitably ventilated oven.
- b) Use resistance grids or space heaters located either inside the transformer enclosure or outside to direct heated air into the bottom air inlets of the transformer enclosure.
- c) Place the transformer core and coil assembly in a nonflammable enclosure with openings at the top and bottom through which heated air can be circulated.

9.4 Drying by Internal and External Heat

- a) Place the transformer core and coil assembly in a nonflammable enclosure or leave it in its enclosure.
- b) Circulate current through the windings as described in 9.2. and apply external heat as described in 9.3.

9.5 Determining Drying Time

- a) Perform insulation resistance testing for each winding to ground with all windings grounded except the one being tested at two-hour intervals during the drying process.
- (b) Short-circuit and ground the winding to be tested for a minimum of one minute to drain static voltage prior to performing insulation resistance tests.

- c) Measure insulation resistance one minute following the application of test voltage.
- d) Compare insulation resistance test results once the transformer temperature has stabilized.
- e) Plot insulation resistance values over time.
- f) Continue the drying process until insulation resistance values level off and remain relatively constant for three to four hours.

10. Transformer Testing

10.1 General

- a) De-energize and electrically isolate the transformer from the distribution system in accordance with established safety procedures and 7.1.
- b) Record and maintain all transformer test results for future comparison.

10.2 Contact Resistance Test

Inspect all bolted electrical connections for high resistance using one of the following methods:

- a) Use a low-resistance ohmmeter. Compare bolted connection resistance measurements to values of similar connections.
- b) Verify tightness of accessible bolted electrical connections using a calibrated torque wrench in accordance with manufacturer's published data.
- c) Perform infrared scan of transformer (*see 10.10*).

10.3 Insulation Resistance Test

Perform insulation-resistance tests from winding-to-winding and from each winding-to-ground in accordance with transformer and test instrument manufacturer recommendations.

- a) Short all terminals of each winding together.
- b) Ground windings not being tested.
- c) Connect megohm meter between each winding and ground (high voltage winding to ground and low voltage winding to ground) and between each set of windings (high voltage winding to low voltage winding).

d) Measure insulation resistance at one minute and ten minutes following the application of the test voltage.

e) Record the megohm values of each winding to ground and between each set of windings, along with the description of the instrument, voltage level, humidity and temperature at the time of the test.

f) Compare test results with previous test results and with the original factory test data corrected for temperature variations using manufacturer recommended correction factors. Consult transformer manufacturer's published data for acceptable test results. If published data is not available, investigate any values which deviate from previous test results under similar conditions by more than 50 percent of the lowest value.

g) If insulation resistance test results indicate the presence of moisture, dry the transformer in accordance with Section 9.

10.4 Polarization Index

a) Using the results from the insulation resistance test, calculate the polarization index by dividing the measured insulation resistance at ten minutes by the measured result at one minute.

b) Polarization index should be greater than 1.0. Consult transformer manufacturer for recommendations for any values of 1.0 or less.

10.5 Turns Ratio Test

a) Perform turns ratio tests in accordance with transformer and test instrument manufacturer recommendations.

b) For acceptance testing, measure the turns ratio for each tap and for the full winding of all phases. For

maintenance testing, measure the turns ratio for the full winding of all phases with the transformer tap connections as found prior to testing.

c) Measured turns ratios should not deviate more than 0.5 percent from the adjacent coils or from the transformer nameplate ratio. Investigate measured turns ratios outside this limit. Consult the transformer manufacturer for recommendations.

d) Verify that tap connections are reconnected as initially found. After transformer is re-energized, measure transformer primary and secondary voltage. Adjust tap connections as required to closely match transformer primary operating voltage in accordance with 5.4.1.

10.6 Excitation Current Test

a) Perform excitation current tests in accordance with transformer and test instrument manufacturer recommendations.

b) Measured results for individual windings should not deviate by more than 15 percent on any single excitation current test, with similar results for the two outer legs of the typical three-legged core transformer and lower results for the center leg.

c) Measured results for individual windings should not deviate by more than 5 percent when comparing with prior test results. Consult the transformer manufacturer for recommendations.

10.7 Winding Resistance Test

a) Perform winding resistance tests in accordance with transformer and test instrument manufacturer recommendations.

b) Measure and record the resistance of each transformer winding at each tap connection. Allow readings to stabilize for a minimum of 30 seconds before recording results.

c) Because winding resistance varies with temperature, record the winding temperature at the time of the test.

d) Compare results with prior test results, factory test results, and results from identical transformers.

e) Test results, after adjusting for temperature differences using manufacturer recommended correction factors, should compare within 1 percent of factory-obtained results and should be comparable between phases of multiphase transformers.

f) Investigate variations of more than 1 percent between phases or from historical data for the transformer. Consult the transformer manufacturer for recommendations.

10.8 Core Insulation Resistance Test

a) Perform core insulation resistance test in accordance with transformer and test instrument manufacturer recommendations and only where the core ground strap is accessible and removable.

b) Remove core grounding conductor.

c) Connect the megohm meter between the core grounding conductor and the core grounding lug. Measure and record the core insulation resistance.

d) Measured core insulation resistance values should be comparable to factory-obtained results, but not less than one megohm at 500 volts dc. Consult the transformer manufacturer for recommendations.

10.9 High Potential Test

NOTE: The high potential test can cause insulation failure and should be used with caution. Conduct the high potential test as a proof test when there has been an abnormal operating condition that makes the insulation integrity of a transformer suspect.

a) Complete all insulation resistance testing prior to high potential testing. Review insulation resistance test results to determine suitability of the transformer for high potential testing.

b) Perform high potential testing in accordance with transformer and test instrument manufacturer's recommendations.

- c) Connect all terminals of each individual winding together and apply a voltage between the windings and from each winding to ground in separate tests.
- d) Ground untested windings during each application of voltage.
- e) Limit AC acceptance high potential tests to 75 percent of factory AC test value for one minute.
- f) Limit AC maintenance high potential test voltages to 65 percent of factory AC test values for one minute.
- g) Limit DC high potential test voltages to 100 percent of factory AC test values for one minute.
- h) Transformer insulation should withstand the high potential test voltage applied. Consult the transformer manufacturer for recommendations.
- e) Prepare a certified report identifying the transformer tested and describing the results of the infrared scan. Include notation of deficiencies detected, remedial action taken, and results from retesting after remedial action.
- f) Maintain a permanent record of all infrared scan results to track electrical characteristics of transformers over time.
- g) Consult transformer manufacturer for repair or replacement recommendations if infrared scan results indicate overheating of components.
- h) De-energize transformer. Test transformer to confirm that it is de-energized. Reinstall accessible covers, plates, weathershields, etc. Re-energize transformer and loads in accordance with 5.4 and 5.4.2.

10.10 Infrared Scan

NOTE: Provide supplemental barriers and safety precautions during infrared scan to prevent accidental contact with exposed energized components.

- a) Perform infrared scanning in accordance with transformer and test equipment manufacturer recommendations.
- b) Perform an infrared scan of the transformer enclosure while transformer is energized and operating under maximum load conditions.
- c) De-energize transformer. Test transformer to confirm that it is de-energized. Remove accessible covers, plates, weathershields, etc. Re-energize transformer and loads in accordance with 5.4 and 5.4.2, and perform an infrared scan of all transformer electrical connections and terminals while transformer is energized and operating under maximum load conditions.
- d) Use an infrared scanning device designed to measure actual operating temperatures, or designed to detect significant deviations from surrounding conditions. Provide documentation of device calibration.

Annex A: Transformer Troubleshooting Guide

NOTE: Use this table as a guide in conjunction with the inspection, maintenance, and testing procedures described in this publication.

Table A-1. Transformer Troubleshooting Chart

Symptom	Possible Cause	Remedy
Elevated Transformer Operating Temperature	High ambient temperature	Improve ventilation, relocate transformer to cooler location, or reduce transformer loading.
	Blocked or restricted ventilation openings or ducts	Remove blockages. Clean ventilation openings and ducts.
	Cooling system failure	Ensure proper operation of supplemental forced-air cooling fans and controls.
	Voltage and/or current harmonics	Measure harmonic contribution to load profile. Consult transformer manufacturer for harmonic mitigating recommendations.
	Load current in excess of ratings	Reduce loading of transformer.
	Low power factor	Improve power factor.
	Improper electrical connections	Verify proper transformer connections.
	Improper operating voltage	Measure primary and secondary operating voltage and adjust transformer taps as required.
	Elevated transformer primary current	Test transformer for internal faults.
	Short-circuited core	Test for excitation current and no-load losses per manufacturer recommendations. Tighten core bolts and clamps. Check for welded core laminations. Repair or replace damaged transformers in accordance with manufacturer recommendations.

Symptom	Possible Cause	Remedy
Excessive Transformer Noise and Vibration	High input voltage	Measure primary operating voltage and change transformer taps as required.
	High input frequency	Measure operating frequency. Adjust frequency of generators. Consult transformer manufacturer for recommendations.
	Unbalanced loads	Adjust feeder and branch circuiting to closely balance loads.
	Transformer overload	Reduce load or improve power factor as required.
	Voltage and/or current harmonics	Measure harmonic contribution to load profile. Consult transformer manufacturer for harmonic mitigating recommendations.
	Loose transformer components	Check clamps, core, and connection parts for loose or broken connections, missing fasteners, bolts, nuts, etc. Tighten loose clamps, fasteners, bolts, and nuts. Replace missing components.
	Incipient fault in transformer core or coils	Test in accordance with Sections 7 and 8 to determine electrical condition of transformer.
	Transformer location and mounting surfaces	Check for surfaces that reflect sound. Check vibration isolators and sound dampeners. Check for flexible race way connections to transformer enclosure. Check proximity of transformer to each other for resonant conditions. Consult transformer manufacturer for recommendations.

Symptom	Possible Cause	Remedy
Low or Zero Voltage	Loose transformer connections	Tighten terminals, lugs, and connections in accordance with transformer manufacturer recommendations.
	Winding failure	Test transformer for internal faults. Repair or replace windings in accordance with transformer manufacturer recommendations.
	Open circuit conductors	Check continuity of conductors. Replace failed conductors. Correct open terminations.
	Improper operating voltage	Measure primary and secondary operating voltage and adjust transformer taps as required.
Elevated Secondary Voltage	Improper operating voltage	Measure primary and secondary operating voltage and adjust transformer taps as required.
Smoking Transformer	Excess varnish or encapsulation material	At time of initial energizing, no long term risk. Monitor for escalation.
	Winding fault	Test transformer for serviceability in accordance with Sections 7 and 8.
Core Thermal Damage <i>NOTE: Test transformer for serviceability in accordance with Sections 7 and 8.</i>	High operating voltage	Measure primary operating voltage and adjust transformer taps as required.
	High operating frequency	Measure operating frequency. Adjust frequency of generators. Consult transformer manufacturer for recommendations.
	High harmonic content	Measure harmonic contribution to load profile. Consult transformer manufacturer for harmonic mitigating recommendations.

Symptom	Possible Cause	Remedy
High Core Losses	High operating voltage	Measure primary operating voltage and adjust transformer taps as required.
	High operating frequency	Measure operating frequency. Adjust frequency of generators. Consult transformer manufacturer for recommendations.
Insulation Thermal Damage <i>NOTE: Test transformer for serviceability in accordance with Sections 7 and 8.</i>	Extended operating overload	Reduce load or improve power factor as required.
	Voltage and current harmonics	Measure harmonic contribution to load profile. Consult transformer manufacturer for harmonic mitigating recommendations.
	Overheating	Improve ventilation or relocate unit to cooler location. Remove blockages from ventilation openings. Clean ventilation openings and ducts.
	Lightning surge	Check lightning protection and grounding systems, arresters, connections, lugs, and conductors. Test transformer for winding damage.
	Utility switching or line disturbance	Check grounding system and surge suppression. Test transformer for winding damage.
	Damaged or broken terminals, lugs, or connectors	Check terminals, lugs, and connectors. Repair or replace in accordance with transformer manufacturer recommendations.
	Winding damage	Test transformer for winding damage.

Symptom	Possible Cause	Remedy
High Excitation Current	High input voltage	Measure primary operating voltage and adjust transformer taps as required.
	Low frequency	Measure operating frequency. Adjust frequency of generators. Consult transformer manufacturer for recommendations.
	Shorted turns	Perform turns ratio testing of transformer. Consult transformer manufacturer for recommendations.
	Core damage	Visually inspect transformer core for damage. Consult transformer manufacturer for recommendations.
High Conductor Losses	Overload	Reduce load or improve power factor as required.
	Mismatched tap positions	Ensure that identical tap positions are used for all windings.
	Turn-to-turn winding fault	Measure turns ratio. Consult transformer manufacturer for recommendations.
Excessive Conductor Heating	Loose connections	Tighten terminations, lugs, etc., and rework crimped connections in accordance with transformer manufacturer recommendations.
	Undersized conductors	Verify proper conductor sizing and application within temperature limitations of terminals and lugs. Correct deficiencies.

Symptom	Possible Cause	Remedy
Breaker or Fuse Operation	Overload	Reduce load or improve power factor as required.
	Voltage or current harmonics	Measure harmonic contribution to load profile. Consult transformer manufacturer for harmonic mitigating recommendations.
	Short circuit	Locate source of fault and remove from system.
	Winding failure	Test transformer for serviceability. Consult transformer manufacturer for recommendations.
Physical Winding Damage	Short circuit	Test transformer for serviceability in accordance with Sections 7 and 8. Consult transformer manufacturer for recommendations.
Rust and Paint Deterioration	Weather	Remove rust and deteriorated paint. Clean surfaces. Repaint with suitable paints and sufficient coatings.
	Corrosive environment	Remove rust and deteriorated paint. Clean surfaces. Repaint with suitable paint and sufficient coatings.
	Overload	Remove rust and deteriorated paint. Clean surfaces. Repaint with suitable paints and sufficient coatings. If discoloration reoccurs, check transformer sizing, input voltage, and loading amps.

Symptom	Possible Cause	Remedy
Overloaded Neutral Conductor	Overload	Reduce load or improve power factor as required.
	Undersized neutral conductor	Verify proper conductor sizing and application within temperature limitations of terminals and lugs. Correct deficiencies.
	Imbalance between phase conductors	Redistribute feeder and branch circuit loads to closely balance loads.
	Open Leg of wye-connected transformer bank	Check associated fuses. Isolate and remove cause of fuse operation and replace fuses. Check for open circuit in winding of transformer in bank.
	High harmonic content	Measure harmonic contribution to load profile. Consult transformer manufacturer for harmonic mitigating recommendations.
	Loose neutral connection	Tighten neutral connections.
Unbalanced Voltages	Open neutral or lost neutral-to-ground bond	Check neutral and ground connections.
	Improper operating voltages	Measure terminal voltages. Ensure that identical winding taps are used for all windings.
	Ground fault on ungrounded delta (perhaps with flashover of lightning arresters, terminations, etc.)	Isolate fault and remove from system. Test transformer for serviceability in accordance with Sections 7 and 8.
	Ground fault on corner-grounded delta	Isolate fault and remove from system. Test transformer for serviceability in accordance with Sections 7 and 8.
	Single-phasing of three-phase transformer or bank of single-phase transformers	Check availability of source voltages. Check associated fuses. Replace fuses.

(This annex is not part of the standard)

Annex B: Reference Standards

This publication, when used in conjunction with the National Electrical Code and transformer manufacturers' literature, provides sufficient information to install and maintain generator sets. The following publications may also provide useful information:

National Fire Protection Association
1 Batterymarch Park
P.O. Box 9101
Quincy, Massachusetts 02269-9101
(617) 770-3000 tel
(617) 770-3500 fax
www.nfpa.org

NFPA 70-2002, *National Electrical Code* (ANSI)

InterNATIONAL ELECTRICAL TESTING ASSOCIATION
106 Stone Street
P.O. Box 678
Morrison, CO 80465
(303) 697-8441 tel
(303) 697-8341 fax
www.netaworld.org

NETA MTS 7.2.1-2001, *Standard for Maintenance Testing of Dry-Type Transformers* (ANSI)

National Electrical Contractors Association
3 Bethesda Metro Center, Suite 1100
Bethesda, MD 20814
301-215-4504
301-215-4500 fax
www.neca-neis.org

Other *National Electrical Installation Standards*™ published by NECA:

NECA 1-2000, *Standard Practices for Good Workmanship in Electrical Contracting* (ANSI)

NECA 100-1999, *Symbols for Electrical Construction Drawings* (ANSI)

NECA 409 Recommended Practice for Installing Exterior Lighting Systems

NECA 101-2001, *Standard for Installing Steel Conduits (Rigid, IMC, EMT)*

NECA/AA 104-2000, *Recommended Practice for Installing Aluminum Building Wire and Cable* (ANSI)

NECA/NEMA 105-2002, *Recommended Practice for Installing Metal Cable Tray Systems* (ANSI)

NECA 202-2001, *Recommended Practice for Installing and Maintaining Industrial Heat Tracing Systems* (ANSI)

NECA/FOA 301-1997, *Standard for Installing and Testing Fiber Optic Cables*

NECA 305-2001, *Standard for Fire Alarm System Job Practices* (ANSI)

NECA 400-1998, *Recommended Practice for Installing and Maintaining Switchboards* (ANSI)

NECA 402-2000, *Recommended Practice for Installing and Maintaining Motor Control Centers* (ANSI)

NECA/EGSA 404-2000, *Recommended Practice for Installing Generator Sets* (ANSI)

NECA 405-2001, *Recommended Practice for Installing and Commissioning Interconnected Generation Systems* (ANSI)

NECA 407-2002, *Recommended Practice for Installing and Maintaining Panelboards* (ANSI)

NECA/IESNA 500-1998, *Recommended Practice for Installing Indoor Commercial Lighting Systems* (ANSI)

NECA/IESNA 501-2000, *Recommended Practice for Installing Exterior Lighting Systems* (ANSI)

NECA/IESNA 502-1999, *Recommended Practice for Installing Industrial Lighting Systems* (ANSI)

NECA/BICSI 568-2001, *Standard for Installing Commercial Building Telecommunications Cabling* (ANSI)



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Index: NECA 409
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