Recommended Practice for Commissioning Building Electrical Systems

An American National Standard

Published by National Electrical Contractors Association

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Foreword

National Electrical Installation Standards™ (NEIS®) are designed 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:

All electrical systems shall be commissioned in accordance with NECA 90-2004, Standard for Commissioning Building Electrical Systems (ANSI).

Use of NEIS is voluntary, and the National Electrical Contractors Association (NECA) 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.

This publication is intended to comply with the edition of the National Electrical Code (NEC) in effect at the time of publication. Because they are quality standards, NEIS may in some instances go beyond the minimum safety requirements of the NEC. It is the responsibility of users of this publication to comply with state and local electrical codes when installing electrical products and systems.

Suggestions for revisions and improvements to this standard are welcome. They should be addressed to:

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1. Scope

This standard describes installation procedures for commissioning newly installed or retrofitted building electrical systems. It defines the process of commissioning building electrical systems and provides sample guidelines for attaining optimum system performances that conform to design, specification, and industry-accepted codes and standards.

1.1 Regulatory and Other Requirements

a) All information in this publication is intended to conform to the National Electrical Code (ANSI/NFPA 70). Installers should always follow the NEC, applicable state and local codes, manufacturer’s instructions, and contract documents when commissioning newly installed or retrofitted building electrical systems.

b) Only qualified persons familiar with the commissioning of building electrical systems should perform the work described in this publication.

c) General requirements for installing electrical products and systems are described in NECA 1, Standard Practices for Good Workmanship in Electrical Contracting (ANSI). 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

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Acceptable Performance</td>
<td>Performance of systems, subsystems and components that meets specified design performance perimeters under actual load, and responds to changing conditions and perimeters appropriately as expected and specified.</td>
</tr>
<tr>
<td>Basis of Design</td>
<td>A document that records the design criteria and assumptions upon which the design is based.</td>
</tr>
<tr>
<td>Design Intent</td>
<td>A narrative description of systems equipment and their intended modes and sequences of operation, as documented in the project drawings and specifications.</td>
</tr>
<tr>
<td>Commissioning</td>
<td>A systematic process for ensuring that in a building the electrical system performs in accordance with the design intent and the owner’s operational requirements.</td>
</tr>
<tr>
<td>Commissioning Authority</td>
<td>Individual or company responsible for developing and coordinating the execution of a commissioning plan, observing and documenting performance, and ensuring that building systems and equipment function in accordance with the design intent and the owner’s operational requirements.</td>
</tr>
<tr>
<td>Commissioning Plan</td>
<td>A document that outlines the organization, scheduling, and allocation of resources and documentation for the overall commissioning process.</td>
</tr>
<tr>
<td>Functional Performance Tests</td>
<td>A full range of checks and tests carried out to determine if all systems, subsystems, and components function in accordance with the design intent.</td>
</tr>
<tr>
<td>Verification</td>
<td>The full range of checks and tests carried out to determine if all components, subsystems, systems, and interfaces between systems operate in accordance with the contract documents. In this context, “operate” includes all modes and sequences of control operation, interlocks and conditional control responses, and specified responses to abnormal or emergency conditions.</td>
</tr>
</tbody>
</table>
Commissioning of building electrical systems is a systematic process of ensuring that all systems perform in accordance with the design intent and the owner’s operational needs. This is achieved by verifying that the performance meets or exceeds the designer’s intent as documented in the project drawings and specifications. The electrical commissioning process includes the traditionally separate functions of equipment startup, control system calibration, testing and balancing, functional performance testing, system documentation, and training.

3. Commissioning Process

3.1 Commissioning Intent

Electrical system commissioning should achieve the following objectives:

a) Ensure that all electrical equipment, subsystems, and systems are installed according to the final plans, specifications, and requirements; the contract documents; the manufacturer’s recommendations; and to industry accepted minimum standards. Ensure that all electrical equipment, subsystems, and systems, and that they receive adequate operational checkout, as well as detailed testing, calibration, and adjustment by the installing contractor.

b) Verify and document proper performance of all electrical equipment and systems.

c) Ensure that electrical system operations and maintenance (O&M) documentation, as required by the contract documents, is complete and left on site.

d) Ensure that the Owner’s operating personnel are adequately trained on all electrical equipment, as required by the contract documents.

3.2 Roles and Responsibilities of the Commissioning Authority

The Commissioning Authority (CA) is responsible for developing and coordinating the execution of a commissioning plan, observing and documenting performance, and ensuring that electrical systems are functioning in accordance with the documented design intent and contract documents. The CA does not have authority to approve materials, methods, and systems, but can recommend their approval to the owner, project manager, or contracting officer.

The CA should be the installing electrical contractor, the electrical design engineer, or a third party contracted to perform the commissioning process. In general, the CA is responsible for the following tasks:

a) Obtaining and reviewing design documents for overall design intent and the overall required system configurations.

b) Reviewing shop drawings and submittals for installation criteria and construction details as they support and define system features.

c) Coordinating and directing commissioning activities in a logical, sequential, and efficient manner, using standard forms and centralized documentation.

d) Providing all field technical services, tooling, equipment, instrumentation, and technical supervision to perform all tests and inspections.

e) Providing specific power requirements for test equipment.
f) Reviewing and approving O&M materials, control sequences and interlocks, contractor start-up procedures, and checkout procedures for completeness and accuracy.

g) Developing and distributing the required electrical pre-functional test forms.

h) Performing site visits, as necessary, to observe component and system installations.

i) Coordinating, witnessing, and approving functional performance tests performed by the installing contractor(s). Coordinating re-testing as necessary until satisfactory performance is achieved.

j) Notifying the owner’s representative and other concerned parties of the commissioning schedule, and of deficiencies and follow-up services undertaken to correct and re-test deficient items.

k) Providing a detailed, data-based report of all test records, testing, results, and recommendations.

3.3 Commissioning Authority Qualifications

The CA should have several years of experience in commissioning techniques and practices as they pertain to systems and equipment testing, adjusting, and balancing; sound and vibration measurement; performance documentation; performance versus design criteria; operation verification; and functional performance testing. The CA should have expertise in the following (for further guidance, refer to NETA standard ETT-2000):

a) All commissioning functions and the work each contractor is providing.

b) Operation and maintenance requirements of all building systems.

c) Construction management.

d) Building codes and standards, including those for each applicable construction industry (e.g., electrical, lighting, HVAC, plumbing, etc.).

e) Design specification and installation of building systems and equipment.

f) Writing functional performance test plans and directing building system tests, including working with testing instrumentation.

g) Developing and managing project documentation.

h) Planning and delivering O&M training.

i) Total quality for successful project performance.

3.4 Roles and Responsibilities of Other Parties

Proper commissioning of building electrical systems requires cooperation and coordination between all trades. In particular, the electrical contractor, mechanical contractor, and the electrical design engineers have key roles and responsibilities. The roles and responsibilities of the CA and all contractors should be included in the contract documents and Commissioning Plan. Failure to perform these duties in a timely manner should be considered a breach of contract.

3.4.1 Electrical Contractor

The electrical contractor provides and installs the electrical equipment and furnishes all tools needed to start up, check out, and conduct functional performance tests on the electrical systems and equipment installed.

3.4.2 Mechanical Contractor

The mechanical contractor installs all mechanical equipment in accordance with the contract documents, performs pre-functional and functional tests as defined in the Commissioning Plan, and coordinates work with other trades. Motors are generally installed on equipment by the mechanical contractor. For this reason, the mechanical contractor is responsible for functional tests involving vibration monitoring, balance, and adjustment. The controls contractor is responsible for functional testing of the mechanical control system.
3.4.3 **Electrical Design Engineer**

The electrical design engineer is responsible for developing the design concepts, establishing the design criteria, and ensuring compliance with codes. The electrical design engineer is also responsible for developing the design intent and the basis of design, construction scheduling, estimating cost, and for developing the technical project specifications.
4. Testing Requirements

Conduct tests of electrical equipment, subsystems, and systems using normal procedures and requirements to ensure safety. Disconnect sensitive electronic equipment, such as TVSS devices, before dielectric or megger tests. Also, items such as transformers and coils should have one side disconnected before such tests.

4.1 Test Equipment

Commissioning electrical equipment requires the use of proper test equipment. Many electrical systems require special tools and instruments for measurement of the equipment performance. All electrical testing equipment should be of sufficient quality and accuracy to test and/or measure the system performance with tolerance levels specified in the manufacturer’s specifications and design documents.

a) Calibration. It is essential that all test equipment used for performance verifications during the commissioning process has been calibrated within one year of its use for testing.

b) Data Logging. Use data logging instruments and software to measure the performance of electrical equipment and systems performance over a specified time, to ensure that they are functioning in accordance with the design intent and specifications. This may require energy management control system trending, stand-alone data log monitoring, or manual functional testing.

4.2 Verification and Pre-functional Performance Testing

The objective of verification and pre-functional performance tests is to ensure that the specified equipment, subsystem, or system is installed correctly, starts up, and is ready for functional performance tests. This includes all operating modes, interlocks, control responses, and specific responses to abnormal or emergency conditions.

These tests are often in checklist format. They are based on design intent documentation and equipment submittals. The verification checklists should at a minimum ensure:

a) All related equipment has been started up, with start-up reports and pre-functional checklists submitted and approved as ready for functional testing.

b) Testing, balancing, and calibration is complete and accepted by commissioning authority.

c) All control system functions and all interlocking systems are programmed and operable per contract documents, including final set points and schedules, with debugging, loop tuning and sensor calibrations completed.

d) All architectural/engineering (A/E) punchlist items for this equipment have been corrected.

e) Functional test procedures have been reviewed and approved by the installing contractor.

f) Safety, operating ranges, and functions have been reviewed by the commissioning authority.

g) Sufficient clearance around equipment is provided for servicing and maintenance.

h) A record has been made of all values for pre-test set points that were changed to accommodate testing. Check boxes can be used to verify that All pre-test set points (control parameters, limits, delays, lockouts,
schedules, etc.) have been returned to original values, as verified by a check box.

i) Other operational, safety, alarm checks, and start-up reports have been completed successfully.

4.3 Functional Performance and Condition Monitoring Tests

Pre-functional and functional performance tests determine if the electrical system is providing the required services in accordance with the finalized design intent. Each functional performance test should be performed under conditions that simulate actual operating conditions as closely as possible.

Upon satisfactory completion of all verified tests, the building electrical equipment and systems should be returned to the condition required by the contract documents as a complete and operational system. Deficiencies should be corrected by the installing contractor and the equipment, subsystems, or systems re-tested.

When performing any test, be sure to follow proper safety procedures and use personal protective equipment (PPE).

4.3.1 Medium and High Voltage Power Cables (above 600V)

a) Perform a visual and mechanical inspection of cable and connections.

b) Perform an insulation resistance test using a test voltage of 2500V DC or higher.

c) Perform a DC hi-pot test and a shield continuity test in accordance with NECA 600, NEMA/ICEA, NETA, and IEEE standards.

d) For additional information, see NECA 600.

4.3.2 Low Voltage Power Cable (below 600V)

a) Perform a visual and mechanical inspection of cable and connections.

b) Perform an insulation resistance test using a test voltage of 1000V DC.

c) Perform a continuity test to insure correct cable connection.

4.3.3 Electrical Feeders and Branch Circuits (600V or below)

a) Test each circuit for continuity to insure correct cable connection.

b) Physically examine the grounding installation to ensure that the equipment grounding conductor, grounding electrode conductor, and bonding ground jumpers are properly installed and firmly connected.

c) Perform a 500-volt megohm meter test on each circuit cable rated 300 volts and below, and a 1000-volt megohm meter test on each circuit cable rated 600 volts, between the conductor and ground. The insulation resistance shall not be less than 2 megohms for circuits under 115V, 6 megohms between conductor and ground on those 115-600V circuits (115V – 600V) with total single conductor length of 2500 feet and over, and not less than 8 megohms for 115-600V circuits with single conductor length of less than 2500 feet. If the conductor fails the test, have the installing contractor replace the conductor and replace wiring to correct the defect and retest.

d) Using a calibrated torque wrench, perform torque test for every conductor that is part of the tested circuit and terminated in an overcurrent device or bolted type connections. Torque all connections in accordance with the per manufacturer’s recommendations and record the results on a tabular form.

f) Verify conductor color coding with applicable specifications and the National Electrical Code.

4.3.4 Liquid-Filled Transformers

a) Perform visual and mechanical inspection of transformer and connections.
b) Perform an insulation resistance test on winding-to-winding and on each winding-to-ground as follows:

- For transformers rated 600V and below, use a minimum voltage of 1000V DC
- For transformers rated 601-5000V, use a minimum voltage of 2500V DC
- For transformers rated above 5000V, use a minimum voltage of 5000V DC

c) Perform a turns ratio test at all tap positions.

d) Perform liquid insulation tests for dielectric strength, acidity, interfacial tension, specific gravity, water content, power factor/dissipation factor, and color.

e) Perform an insulation power factor/dissipation factor test on each winding in accordance with transformer manufacturer’s published data or test equipment manufacturer’s published data.

f) Perform a power factor test on transformer bushings that are equipped with power factor taps, and perform hot color test on filled bushings that are not equipped with power factor taps.

4.3.5 **Dry-Type Transformers**

a) Perform an insulation resistance tests on winding-to-winding and winding-to-ground as follows:

- For transformers rated 600V and below, use a minimum voltage of 1000V DC
- For transformers rated 601-5000V, use a minimum voltage of 2500V DC
- For transformers rated above 5000V, use a minimum voltage of 5000V DC

b) Perform polarization index test.

c) Perform a turns ratio test at all tap positions.

d) Perform an overpotential test on all high and low voltage windings-to-ground.

e) Perform an insulation power factor/dissipation factor tests on each winding in accordance with transformer manufacturer’s published data or test equipment manufacturer’s published data.

f) For additional information, see *NECA 409*.

4.3.6 **Instrument Transformers**

a) Perform an insulation resistance test.

b) Perform a ration and polarity test.

4.3.7 **Switchgear and Switchboard Assemblies Rated 1200A or Greater**

a) Perform a visual inspection. Torque all bolted connections to manufacturer’s specified values using a calibrated torque wrench.

b) Perform an insulation resistance test on each bus section, phase-to-phase, and phase-to-ground, and on control wiring. Minimum test voltage and insulation resistance shall be as shown in Table 1.

c) Perform a power factor test. For switchgear rated 5 kV and above, power factor should not exceed the values shown in Table 2.

d) Perform a thermographic infrared scan under full load. Identify all hot spots and promptly mark and correct sources of heating problems.

e) For additional information, see *NECA 400*.

<table>
<thead>
<tr>
<th>Voltage Rating</th>
<th>Minimum Test Voltage</th>
<th>Minimum Insulation Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-250V</td>
<td>500V DC</td>
<td>25 ohms</td>
</tr>
<tr>
<td>250-600V</td>
<td>1000V DC</td>
<td>100 ohms</td>
</tr>
<tr>
<td>601-5000V</td>
<td>2500V DC</td>
<td>1000 ohms</td>
</tr>
<tr>
<td>5001-15,000V</td>
<td>2500V DC</td>
<td>5000 ohms</td>
</tr>
</tbody>
</table>
**4.3.8 Metal-Enclosed Bus Duct**

a) Measure insulation resistance of each bus phase-to-phase and phase-to-ground for one (1) minute.

b) Inspect all accessible bus joints and cable connections by infrared scanner while maintaining maximum load on the bus for at least one hour, or until temperature has stabilized, to detect loose or high-resistance connections and other circuit anomalies.

c) Perform an overpotential test on each busway phase-to-ground, with the phases not under test grounded, in accordance with manufacturer’s published data.

d) Perform a contact resistance test on each connection of non-insulated busway. On insulated busway, measure the resistance of assembled busway sections.

e) For additional information, see NECA 408.

**4.3.9 Motor Control Centers**

a) Test overload relay(s) by primary current injection and monitor the trip time of the overload relay. Compare against manufacturer’s published data and either replace or resize relays that do not conform.

b) Perform operational tests on each starter. Measure phase-to-phase and phase-to-ground insulation resistance phase-to-phase and phase-to-ground, with the starter contact closed and overload relays in the “open” position open.

c) Measure insulation resistance of the line bus phase-to-phase and phase-to-ground.

d) Perform thermographic infrared scan under load. Identify all hot spots and correct sources of heating problems promptly.

e) For additional information, see NECA 402.

**4.3.10 Medium-Voltage Circuit Breakers**

a) Perform a visual and mechanical inspection.

b) Perform an insulation resistance test. Measure insulation resistance phase-to-phase and phase-to-ground and across open poles, using a minimum voltage of 2500V DC.

c) Perform a power factor/dissipation test with breaker in open and closed positions.

d) Perform a contact resistance test of each phase and compare results.

e) Perform an overpotential test in accordance with manufacturer’s published data.

**4.3.11 Low-Voltage Air Circuit Breakers**

a) For all tests, use a low-resistance meter capable of measuring in micro-ohms.

b) Perform a contact resistance or millivolt drop test on each phase and compare results.

| Table 2  | Switchgear Power Factor Values |
|-----------------|-----------------|-----------------|
| **Voltage Rating (volts)** | **Test Voltage (volts)** | **Maximum Reading** |
| 5000 | 5000 | 2% |
| 7000 | 5000 | 2% |
| 15,000 | 10,000 | 2% |
| 35,000 | 10,000 | 2% |
c) Perform an insulation resistance test. Measure insulation resistance phase-to-phase and phase-to-ground and across open poles, using a minimum voltage of 1000V DC.

d) Perform a primary current injection test to determine minimum pickup current and long time delay, short-time pickup and time delay, instantaneous pickup current, and ground-fault pick up and time delay.

4.3.12 High and Medium-Voltage Air Switches

a) Perform a visual and mechanical inspection.

b) Perform an insulation resistance test on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute in accordance with manufacturer's published test data.

c) Perform a contact resistance test on each phase and compare results.

4.3.13 Protective Relays

a) Perform a visual and mechanical inspection to verify compliance with equipment specifications.

b) Perform an insulation resistance test (except on solid-state relays).

c) Perform a current/voltage pickup test.

d) Perform a timing test.

e) Perform phase angle and magnitude contribution tests, to vectorially prove polarity and connection of differential and directional relays.

f) Determine pickup and dropout of electromagnetic targets.

4.3.14 Molded-Case Circuit Breakers

a) For all tests, use a low-resistance meter capable of measuring in micro-ohms.

b) Measure contact resistance.

c) Perform time-current characteristic tests by passing three hundred percent (300%) of rated current through each pole separately. Determine and record trip time.

d) Determine instantaneous pickup current by run-up or pulse method. Clearing times should be within six (6) cycles or less. Record trip times.

e) Perform an insulation resistance test at 1000V DC from pole-to-pole and pole-to-ground with breaker closed and across open contacts of each phase for one minute.

f) Check trip unit reset operation.

g) For additional information, see NECA 407.

4.3.15 Service Ground

a) Perform three-point fall-of-potential tests on the main grounding electrode system. Maximum resistance to ground shall be less than 5 ohms. (Resistance values shall be no greater than those specified in the contract documents.) If this resistance cannot be obtained with the ground system shown, notify the General Contractor or Commissioning Authority immediately for further instructions.

b) Perform the two-point method test to determine the ground resistance between the main ground system and all major electrical equipment frames, system neutral, and/or derived neutral points. Resistance shall be no greater than 5 ohms. (Resistance values shall be no greater than those specified in the contract documents.)

c) Confirm that the neutral is grounded only at the service equipment by removing the service neutral grounding conductor and meaggering the neutral bus. Disconnect or remove all equipment that could be damaged by megger test before conducting this test.
4.3.16 Ground-Fault Protection Systems

a) Measure system neutral insulation resistance to insure no shunt ground paths exist. The neutral disconnect link shall be removed, neutral insulation resistance measured, the resistance recorded, and link replaced.

b) System neutral insulation resistance shall be two megohms or greater.

c) Determine the relay pickup current by current injection at the sensor and the circuit interrupting device operated. Relay pickup current shall be within ten percent (10%) of device dial or fixed setting.

d) Test the relay timing by injecting one hundred fifty percent (150%) and three hundred percent (300%) of pickup current into sensor. Electrically monitor and record total trip time. Relay timing shall be in accordance with manufacturer’s published time-current characteristics curves.

e) Test system operation at fifty-seven percent (57%) of rated voltage.

f) Test the zone interlock system by simultaneous sensor current injection and monitor the zone blocking function.

4.3.17 Panelboards

a) Check all panelboards for proper load balance between phase conductors and adjust the loads as necessary to bring unbalanced phases within 20% of average load.

b) Check torque and tighten all accessible connections to manufacturer’s specifications.

c) Perform a thermographic infrared scan after the panel has been operating with maximum load for at least one hour or until the temperature has stabilized. Mark all hot spots, and promptly correct sources of heating problems.

d) For additional information, see NECA 407.

4.3.18 Receptacles and Devices

a) Test every installed receptacle for open ground, reverse polarity, open hot, open neutral, hot and ground reversed, and neutral and hot open. Replace receptacles that do not pass these tests and retest.

b) Test each GFCI receptacle or each GFCI circuit breaker to ensure that the ground-fault circuit interrupter will not operate when subjected to a ground-fault current of less than 4 milliamperes, and will operate when subjected to a ground-fault current exceeding 6 milliamperes. Perform testing with an instrument specifically designed and manufactured for testing ground-fault circuit interrupters. Pushing the receptacle or circuit breaker “TEST” button operation is not acceptable as a substitute for this test. Replace GFCI receptacles or circuit breakers that do not shut off power at 5 milliamperes within 1/40th of a second. Test the replacement unit the same way.

c) Demonstrate the operation of each switch, circuit breaker, and other electrical control device with the systems fully energized and operating. Demonstrate each operation three times.

4.3.19 Engine Generators

a) Perform an insulation resistance and dielectric test (polarization index and dielectric absorption ratio) in accordance with IEEE standard 43.

b) Perform a phase rotation test.

c) Perform a vibration base line test.

d) Perform insulation power factor/dissipation factor tests.

e) Perform a resistive load bank test per NFPA 110.

f) Verify proper operation of all engine shut-down features.

g) Perform a high potential test on medium-voltage (those rated above 600 volt) generators in accordance with industry standards.
h) For additional information, see NECA/EGSA 404 and NECA 406.

4.3.20 Automatic Transfer Switches

a) Monitor and verify correct operation and timing of the following applicable items:

1. Normal voltage sensing relays
2. Emergency voltage sensing relays
3. Test switch
4. In-phase monitor
5. Time delay upon transfer
6. Alternate voltage sensing relay
7. Interlocks and limit switch function
8. Timing delay and re-transfer upon normal power restoration
9. Measure contact resistance across main contacts

b) Perform insulation resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed, and across each open pole for one minute in accordance with manufacturer’s published test voltage data. Perform test with the switch in both source positions.

c) Perform a contact resistance test.

d) Set adjustable parameters to match the settings provided.

f) Activate the various safety devices when possible, to ensure proper operation.

g) Record harmonic distortion at two levels of common coupling. Each level is to be at the next upstream feed.

h) After completion of air balancing, record final drive settings of the VFDs, hydraulic system, and hydronic system.

i) Check motor rotation, operating on the drive and on the bypass.

4.3.21 Variable Frequency Drives

a) Test and record the line volts and amps. Observe for balance within 10%.

b) Inspect for proper jumper or switch settings for given drive parameters, if so equipped.

c) Start and run the drive while observing the test metering or fault indicators, if so equipped.

d) Test and record output volts and amps while the drive is at 25%, 50%, and 100% of rated speed and attached load. Observe for balance and within manufacturer’s specifications.

e) Set adjustable parameters to match the settings provided.

f) Activate the various safety devices when possible, to ensure proper operation.

g) Record harmonic distortion at two levels of common coupling. Each level is to be at the next upstream feed.

h) After completion of air balancing, record final drive settings of the VFDs, hydraulic system, and hydronic system.

i) Check motor rotation, operating on the drive and on the bypass.

4.3.22 Rotating Machinery

a) Perform an insulation resistance and dielectric absorption test (polarization index and dielectric absorption ratio) in accordance with IEEE standard 43.

b) Perform and record an insulation resistance test (of pedestal).

c) Perform vibration monitoring on all rotating equipment greater than 7.5 HP (or smaller if highly critical to operations). This includes motors, pumps, turbines, compressors, engines, bearing, gearboxes, agitators, fans, blowers, shafts, etc. All tests should be conducted at normal operating speed at full load conditions. The motor shall meet the applicable vibration criteria as specified in Tables 3 and 4.

d) Perform laser alignment on all shaft coupled machines (see Figure 1). All shaft-to-shaft center line alignments should meet the requirements of Table 5 unless more precise tolerances are specified by the machine manufacturer. The tolerances specified in Table 5 are the maximum allowable deviations from Zero-Zero Specifications or alignment target specifications (i.e., an intention targeted offset and/or angularity). Figure 2 illustrates the concept of offset and angular motor alignment.
4.3.23 Battery System
Perform a battery impedance test and record the results.

4.3.24 Uninterruptible Power Supply (UPS) System
a) The UPS system and all integral components shall be tested together through actual power outages, with as many UPS loads operating as possible. Verify and record time to transfer, voltage and frequency, and sequence of operations.

b) Simulate critical malfunctions. Verify annunciation and protective device functions.

c) Perform a thermographic infrared scan under full load.

Figure 1. Coupled Shafts Alignment

Table 3  Motor Vibration Criteria

<table>
<thead>
<tr>
<th>Frequency (X RPM) Motor Component</th>
<th>Maximum Amplitude (in/sec Peak)</th>
<th>Maximum Amplitude (mm/sec Peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>0.10</td>
<td>2.5</td>
</tr>
<tr>
<td>0.4 – 0.5</td>
<td></td>
<td>Not detectable</td>
</tr>
<tr>
<td>1X</td>
<td></td>
<td>See Motor Balance Specifications</td>
</tr>
<tr>
<td>2X</td>
<td>0.02</td>
<td>0.5</td>
</tr>
<tr>
<td>Harmonics (NX)</td>
<td></td>
<td>Not detectable</td>
</tr>
<tr>
<td>Roller Element Bearings</td>
<td></td>
<td>Not detectable</td>
</tr>
<tr>
<td>Side Bands</td>
<td></td>
<td>Not detectable</td>
</tr>
<tr>
<td>Rotor Bar/Stator Slot</td>
<td></td>
<td>Not detectable</td>
</tr>
<tr>
<td>Line Frequency (60 Hz)</td>
<td></td>
<td>Not detectable</td>
</tr>
<tr>
<td>2X Line Frequency (120 Hz)</td>
<td>0.02</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 4  Motor Balance Specifications

<table>
<thead>
<tr>
<th>Motor Speed (RPM)</th>
<th>Special Application (in/sec Peak)</th>
<th>Standard Application (in/sec Peak)</th>
<th>Special Application (mm/sec Peak)</th>
<th>Standard Application (mm/sec Peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td>0.02</td>
<td>0.08</td>
<td>0.5</td>
<td>2.0</td>
</tr>
<tr>
<td>1200</td>
<td>0.026</td>
<td>0.08</td>
<td>0.66</td>
<td>2.0</td>
</tr>
<tr>
<td>1800</td>
<td>0.04</td>
<td>0.08</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>3600</td>
<td>0.04</td>
<td>0.08</td>
<td>1.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Mark all hot spots, and promptly correct sources of heating problems.  

4.3.25 Lighting

a) Measure lighting levels in all areas to assure they meet the requirements specified in the contract documents.

<table>
<thead>
<tr>
<th>Table 5 Coupled Shaft Alignment Tolerance Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>RPM</td>
</tr>
<tr>
<td>Soft Foot</td>
</tr>
<tr>
<td>&lt;0.002 inch (0.0508 mm) at each foot</td>
</tr>
<tr>
<td>Short Couplings</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>1200</td>
</tr>
<tr>
<td>1800</td>
</tr>
<tr>
<td>3600</td>
</tr>
<tr>
<td>7200</td>
</tr>
<tr>
<td>Couplings with Spacers</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>1200</td>
</tr>
<tr>
<td>1800</td>
</tr>
<tr>
<td>3600</td>
</tr>
<tr>
<td>7200</td>
</tr>
</tbody>
</table>

**Figure 2. Offset and Angular Motor Alignment**
b) Test the operation of lighting controls and integral components to ensure they respond appropriately to changing conditions and parameters, as specified.

c) For additional information, see NECA/IESNA 500, NECA/IESNA 501, and NECA/IESNA 502.

4.3.26 System Testing

In addition to the individual equipment tests described in this section, perform the following system testing:

a) Perform a complete test of the control system operation. Verify performance of the installed control system under real-life conditions.

b) Test interconnections of the electrical equipment with other systems (mechanical, security, fire alarm, etc.). If a building management system is installed, verify the overall system function, including the data points derived from or delivered to the electrical system.

c) Verify the electrical equipment and devices under load. Project schedules should allow for testing the electrical system while the mechanical system is running.

4.4 Deferred Testing

If any check or test cannot be completed due to the building structure, required occupancy condition, or other deficiency, execution of checklists and functional testing may be delayed upon approval of the project manager. These tests shall be conducted as soon as possible in the same manner as seasonal tests.

4.5 Seasonal Testing

During the warranty period, complete any specified seasonal testing (tests delayed until weather conditions are closer to the system’s design). Perform the specified tests, document the results, and correct any deficiencies. Make final adjustments to the O&M manuals and as-builts based on these seasonal testing results.
5. Recording and Documenting Performance

Documentation is an essential component of the commissioning process. All formal and informal communications should be recorded and collected. Document pre-functional and functional performance tests in an easily readable three-ring binder.

5.1 Documentation

Commissioning documentation includes, but is not limited to, the following:

a) Approved submittals, test, balance, and calibration reports for the equipment, subsystems, and systems being commissioned.

b) All accepted shop drawings of electrical equipment. Fold full-size sheets as required to fit in binders.

c) All pre-functional performance test checklists, signed by indicating personnel, organized by system and sub-system.

d) All verification and functional performance test checklists/results, signed by indicated personnel, organized by system and sub-system.

e) Completed as-built drawings signed by the contractor.

f) Copies of the operation and maintenance (O&M) manuals.

5.2 Non-conformance Forms

a) Record the results of functional tests on the standardized test forms.

b) Record any deficiencies or non-conformance issues on standardized non-conformance forms (correct minor deficiencies identified during testing).

c) The installing contractor should correct deficiencies in accordance with the contract documents and manufacturer’s instructions and recommendations.

d) When a non-conformance form has been submitted and deficiencies subsequently corrected, include a signed statement of correction at the bottom of the non-conformance form certifying that the equipment is ready to be re-tested.

f) The test should then be rescheduled and the test repeated.

g) Record each satisfactorily demonstrated functional performance test on the test forms.
Prior to the substantial completion of the electrical system commissioning, review the O&M manuals for systems that were commissioned to verify compliance with the specifications. Record any deficiencies found in the O&M manuals. If deficiencies are reported, the manuals should then be corrected and resubmitted, as necessary.

The Commissioning Authority (CA) should review the O&M manuals early in the commissioning process to become familiar with the equipment, sub-systems, and systems being tested. If possible, start the O&M manuals review process before pre-function testing starts.

Upon a successful review of the corrections, approval, and acceptance of the O&M manuals, the manuals shall be properly organized in three-ring binders for each major system. Equipment warranties shall also be reviewed to verify that all requirements are clearly stated to ensure warranties are kept valid.
7. Training

Conduct training for O&M personnel in the operation and maintenance of all commissioned systems and equipment. This training should meet any requirements listed in the contract documents, and should be videotaped as a record document for future training.

Interview the facility manager and lead engineer to determine any special needs, verify all areas in which training will be most valuable, and determine how rigorous training should be for each piece of commissioned equipment.

Vendors should be responsible for providing training on their own equipment. The vendor should submit a written training plan for review and approval by the owner’s representative and the Commissioning Authority (CA) prior to any training for the following elements:

- a) Equipment
- b) Intended audience
- c) Location of training
- d) Objectives
- e) Subjects covered
- f) Duration of training on each subject
- g) Qualifications of instructor
- h) Methods (classroom lecture, video, site walkthrough, actual operational demonstrations, written handouts, etc.).
Annex A: Test and Measurement Equipment

The following is a list of major test equipment that may not be commonly available. For additional test and measurement equipment, refer to NETA standards.

A.1 Vibration Monitoring
a) The vibration data collector shall have all of the following minimum requirements:
   - Minimum of 400 lines of resolution
   - Dynamic range greater than 70dB
   - Frequency response of 5Hz-10kHz (300 to 600,000 cpm)
   - Capability to perform ensemble averaging
   - Use of a Hanning window
   - Autoranging frequency
   - Minimum amplitude accuracy over the selected frequency range of + or – 20% or + or – 1.5 dB

b) The vibration data collector device shall use either a stud-mounted or a low mass rare earth magnet-mounted accelerometer. Hand-held accelerometers are not acceptable. The mass of the accelerometer and its mounting shall have minimal influence on the frequency response of the system over the selected measurement range.

c) Sound discs shall be a minimum of 1 inch in diameter, manufactured of a magnetic stainless steel, such as alloy 410 or 416, have a surface finish of 32 micro-inches rms, and be attached by tack weld, be stud mounted, or be epoxy glued. The contractor shall have the option of machining the equipment case in order to achieve a flat and smooth spot that meets the same tolerances as the sound disc if the equipment case is manufactured from a magnetic material.

A.2 Infrared Thermography (IRT)
The infrared imager shall be a short wave (for primarily indoor usage due to its sensitivity) or long wave (for primarily outdoor usage due to the impact of solar reflections) focal plane array camera with all of the following minimum requirements:
   - Self contained with a minimum of 2 hours of battery capacity
   - Temperature range of –20°C to 300°C
   - Sensitive to 0.2°C over all temperature ranges
   - Accurate to within + 3%
   - Must be capable of storing up to 12 images for later use
   - Have a video recorder interface

A.3 Insulation Power Factor
The power factor test set shall have the following minimum requirements:
   - Test voltage range of 500V to 12 kV
   - Ability to perform UST, GST, and GST-with-guard tests
   - Readings for power factor, dissipation factor, capacitance, and watts-loss
   - Power factor/dissipation factor range of 0 to 200%
   - Capacitance measuring range of 0 to 0.20 pico-farads
A.4  **Battery Impedance**  
The battery impedance test set shall have the following minimum requirements:

- Ability to test battery cells of up to 2500 amp-hour capacities
- Maximum battery test voltage of 25 Volts DC
- Impedance range of 0.0 to 100 milliohms
- Ability to test both lead-acid and nickel-cadmium batteries

A.5  **Breaker Timing**  
The breaker timing test set shall have the following minimum requirements:

- Perform contact timing during breaker close, open, open-close, close-open, and open-close-open.
- Have a minimum of three dry contact inputs
- Have a minimum of two wet-input channels to monitor breaker secondary contacts
- Have a minimum resolution of + 0.0001 seconds over a one-second duration
- Have travel transducers capable of linear and rotary motion
- Be capable of slow close contact point measurement

A.6  **Insulation Resistance**  
The insulation resistance test set shall have the following minimum requirements:

- Test voltage increments of 500V, 1000V, 2500V, and 5000V DC
- Resistance range of 0.0 to 500,000 megohms at 500,000V DC
- A short-circuit terminal current of at least 2.5 milliamps
- Test voltage stability of + 0.1%
- Resistance accuracy of + 5% at 1 megohm
Annex B: Reference Standards

This publication, when used in conjunction with the National Electrical Code and manufacturers’ literature, provides recommended guidelines for commissioning building electrical systems. The following publications may also provide useful information:

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02169-7471
(617) 770-3000 tel
(617) 770-3500 fax
www.nfpa.org

NFPA 70-2002, National Electrical Code (ANSI)

Institute of Electrical and Electronics Engineers
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331
(732) 981-0060 tel
(732) 981-9667 fax
www.ieee.org

IEEE 43-2001, Recommended Practice for Testing Insulation Resistance of Rotating Machinery

InterNational Electrical Testing Association
106 Stone St.
P.O. Box 687
Morrison, CO 80465
(303) 697-8441 tel
(303) 697-8431 fax
www.netaworld.org

NETA ETT-2000, Standard for the Certification of Electrical Testing Technicians

National Electrical Contractors Association
3 Bethesda Metro Center, Suite 1100
Bethesda, MD 20814
(301) 657-3110 tel
(301) 215-4500 fax
www.necanet.org
Current National Electrical Installation Standards™ published by NECA:

NECA 90-2004, Recommended Practice for Commissioning Building Electrical Systems (ANSI)
NECA 100-1999, Symbols for Electrical Construction Drawings (ANSI)
NECA 101-2001, Standard for Installing Steel Conduits (Rigid, IMC, EMT)
NECA 102-2004, Standard for Installing Aluminum Rigid Metal Conduit (ANSI)
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 111-2003, Standard for Installing Nonmetallic Raceways (RNC, ENT, LFNC) (ANSI)
NECA 200-2002, Recommended Practice for Installing and Maintaining Temporary Electrical Power at Construction Sites (ANSI)
NECA 202-2001, Recommended Practice for Installing and Maintaining Industrial Heat Tracing Systems (ANSI)
NECA 230-2003, Standard for Selecting, Installing and Maintaining Electric Motors and Motor Controllers (ANSI)
NECA/FOA 301-1998, Standard for Installing and Testing Fiber Optic Cables
NECA 400-1998, Recommended Practice for Installing and Maintaining Switchboards (ANSI)
NECA 402-2001, 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 406-2003, Standard for Installing Residential Generator Sets (ANSI)
NECA 407-2002, Recommended Practice for Installing and Maintaining Panelboards (ANSI)
NECA 408-2002, Recommended Practice for Installing and Maintaining Busways (ANSI)
NECA 409-2002, Recommended Practice for Installing and Maintaining Dry-Type Transformers (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)
NECA/MACSCB 600-2003, Recommended Practice for Installing and Maintaining Medium-Voltage Cable (ANSI)
Standards & Safety
Index: NECA 102
7K/8-04