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design brief

Acceptance Testing

Summary

The State of California's Title 24 Building Energy Efficiency Standards have long provided national leadership in improving building energy efficiency. First introduced in the 2005 Title 24 and expanded for 2008, Acceptance Testing is one of the core components of the Standards' ongoing effort to optimize energy use in modern construction. It's intent is to address the importance of proper system installation, as realized energy savings from advanced systems depend on them being installed and operating properly.

This design brief summarizes the purpose and structure of Acceptance Testing, outlining current requirements and terminology, highlighting benefits, and recommending strategies to optimize its effectiveness in a practical manner. This design brief is intended as a high-level overview of the Acceptance Testing process, and we strongly encourage readers to review the compliance manual and other documents referenced in this design guide for detailed test procedures.

CONTENTS

EDR ACCEPTANCE TESTING GUIDE FOR THE 2008 TITLE 24 STANDARDS

INTRODUCTION

Building energy consumption is influenced by several factors, including building design, construction materials and quality, controls system components and settings, and occupant operation. Energy codes have traditionally focused on measures related to building design and component specification. When systems are installed improperly, however, they fail to achieve the intended energy savings of the code they are designed to meet. Acceptance testing was developed and adopted into code in an attempt to address this discrepancy between intent and reality and ensure that systems operate as planned by the designer and code.

What Is Acceptance Testing?

Acceptance testing consists of two steps: construction inspection and equipment testing (known to the commissioning industry as "functional performance testing"). This process assures that the appropriate equipment is both installed and operating properly.

Construction inspection of mechanical and lighting systems and envelope components verifies their proper installation and configuration. In some cases, this phase includes checking calibration certificates of installed products. For example, a Heating, Ventilating, and Air Conditioning (HVAC) construction inspection may include verifying that a thermostat is located in the space it serves.

Equipment testing involves manipulating space conditions or control settings in order to determine whether a system operates as intended by the building efficiency Standards. A common equipment test involves lowering an air conditioner's thermostat setting to verify that the system responds by delivering cooled air.

Why Do We Need Acceptance Tests?

Unfortunately, building systems not operating as intended is a pervasive phenomenon. PIER[1] research on small commercial air conditioners found that economizers fail roughly 50% of the time, leading to reductions in energy savings potential[2]. Similarly, studies funded by the California Investor Owned Utilities

[1] The California Energy Commission's Public Interest Energy Research Program

[2] Architectural Energy Corporation, "Small HVAC Problems and Potential Savings Reports," October 2003, CEC Report P500-03-082-A-25

> Unlike simulated building energy savings, real world savings and efficiency result as much from attention to quality building system installation as to design and specification.

(IOUs) show that daylighting controls often do not perform as intended due to installation and programming errors.

Who Can Conduct An Acceptance Test?

Acceptance tests may be performed by one or more designated Field Technician under the responsible charge of a licensed contractor or design professional, designated the Responsible Person. Except for the air distribution system acceptance test, third party testing or review is not required. Most acceptance testing is performed by Field Technicians affiliated with the project's contractors installing mechanical, electrical, test and balance (TAB), and energy management control systems (EMCS), and/or their employees or agents. While Field Technicians perform and document the results of the acceptance tests and must sign Certificate of Acceptance certifying information they provide is true and correct, they are not required to be licensed building professionals, nor do they bear the ultimate responsibility for the tests.

The Certificate of Acceptance must also be signed by the Responsible Person, who by doing so accepts final responsibility for the accuracy and veracity of all acceptance testing work listed on the forms. The Responsible Person must be a California-licensed building professional (i.e., a registered architect, professional engineer, or licensed contractor), eligible under Division 3 of the Business and Professions code in the applicable classification, to take responsibility for complying with the Certificate of Acceptance. The Responsible Person may also fulfill the Field Technician role, performing the field testing and documentation work. In this case they must additionally sign the Field Technician's signature block on the Certificate of Acceptance.

It is often more cost-effective for equipment installers and/or controls contractor(s) to also act as the Field Technician and/or Responsible Person. If commissioning agents are engaged for the project, it may make sense for them to review test methods used and observe some of the analyses, even though they may not be designated as the Field Technician or Responsible Person.

Is Third Party Verification Required in Acceptance Testing?

Third party verification is generally not required. Only leakage testing of ducts in unconditioned space (MECH-4A Air Distribution Systems Acceptance) requires verification by a third party. Qualified persons, as previously described, can conduct and take responsibility for all other acceptance tests.

What Are the Consequences of a Fraudulent Acceptance Test?

Although enforcement agencies do not independently verify acceptance tests, alternative mechanisms do exist to discourage fraudulent compliance. Acceptance test documents must be provided to the building owner, creating a liability trail. Fraudulent acceptance test activities leave the Responsible Person open to a future lawsuit or disciplinary action, potentially affecting their professional license.

What Equipment Requires Testing?

Testing is required for the majority of nonresidential HVAC systems and components, including:

- Packaged single zone systems
- Packaged variable air volume (VAV) systems
- Outside air dampers
- Air-side economizers
- Hydronic systems
- Duct systems with more than 25% of their surface area outdoors or in an unconditioned space

Most indoor and outdoor automated lighting controls require testing, including:

- Occupancy sensors
- Switches controlling electric lighting in daylit areas
- Automatic time switch controls and their associated override switches
- Automatic daylighting controls
- Time clock, photosensor, and motion detector controls

Additionally, building envelope components can require testing, including:

- Thermal performance properties of installed fenestration

When Is Equipment Tested?

Acceptance tests must be conducted prior to a building's final inspection. Because they often involve verifying proper controls operation, acceptance tests are typically conducted during or shortly after the equipment or controls contractor sets up the necessary controls. Some tests, such as those involving air distribution, are best conducted before walls or ceilings are closed up so that duct system problems can be readily addressed. Similarly, mechanical and lighting controls should be tested while relevant wiring remains accessible.

Details regarding specific acceptance test prerequisite conditions can be found in the At A Glance descriptions of the 2008 Nonresidential Compliance Manual, Chapter 10.

What Documentation Is Required?

Acceptance testing forms must be filed with the enforcement agency, typically the building department with jurisdiction, prior to issuance of the *final* certificate of occupancy. Following the enforcement agency review, acceptance forms, along with operation and maintenance information, are given to the building owner.

Acceptance testing forms are found in the 2008 Nonresidential Compliance Manual Appendix A, which can be downloaded from the California Energy Commission's (CEC) website at http://www.energy.ca.gov/title24.

Chapter 10 of the 2008 Nonresidential Compliance Manual covers acceptance testing and contains further background information, conditions, and instructions for completing and documenting each test.

How Does Acceptance Testing Differ From Commissioning?

Acceptance testing is often confused with commissioning. While some similarities exist, the two are different in scope and implementation.

Though created to ensure the proper specification and installation of HVAC systems, commissioning has evolved into a collaborative and holistic quality assurance process. In an effort to best tune a building for optimal overall performance, it considers the interaction of envelope, lighting, and mechanical systems in conjunction with anticipated occupant use and schedules.

Acceptance testing, on the other hand, targets selected components or systems individually. While it addresses building system operations known to be problematic and integral to proper overall performance, it does so on a component level and is not a comprehensive evaluation of all factors affecting building performance. Acceptance testing is important, but not a substitute for a thorough commissioning process. It can be thought of as complementary to commissioning procedures concerning post-installation inspection and performance testing.

Recommended Sequence of Acceptance Testing Activities

Acceptance testing affects multiple building construction phases from design to construction to final inspection. This section outlines the recommended process as well as the parties involved and their specific roles and responsibilities.

Step 1: Designer Identifies Equipment to Be Tested On Compliance Forms

The intent of the Standards is that non-compliant equipment or systems fail acceptance tests. The designer's review and understanding of relevant Nonresidential Compliance Manual and Standards sections is therefore essential.

The designer or their agent responsible for compliance documentation is required to list on the compliance forms and permit plan-set each equipment requiring acceptance testing and the parties responsible for performing the tests. This information is included on the applicable ENV-1-C, MECH-1-C, or LTG-1-C compliance form.

Step 2: Building Department Verifies List of Equipment Requiring Testing

During plan check, the building department verifies that all applicable equipment is listed on the compliance forms and that a qualified person has been designated as Responsible Person. These designations need only indicate the roles of those performing the acceptance tests (i.e. contractor, controls specialist, design engineer, commissioning agent, etc.), and not the names of specific individuals.

Once the building department determines that the proposed work and plans meet all applicable requirements, including proper documentation of required acceptance testing, a building permit can be issued.

Step 3: Acceptance Testing Is Included In Bid Package

It is vital for bid set plans to clearly reflect project acceptance testing requirements. Acceptance tests take time, are often limited to specific construction schedule constraints, and can entail significant costs, especially on larger projects. The project's lighting and mechanical compliance forms must clearly note its acceptance testing requirements so that resources to comply with them are appropriately budgeted. Likewise, when reviewing bids, it is important to verify that all proposals have adequately considered acceptance testing requirements specific to the project.

Step 4: Responsible Person/Field Technicians Conduct Test

Attention to acceptance test scheduling is important and should be included in project planning phases. The best time to conduct tests is in conjunction with the relevant control installation or commissioning efforts. Acceptance test forms should be submitted only after the specific system or equipment passes. If a tested system fails, it should be repaired or adjusted as necessary until it successfully passes. The Responsible Person *and* Field Technician must then sign their respective signature blocks on the Certificate of Compliance.

Step 5: Inspector Receives Acceptance Forms

The building inspector is provided the signed acceptance forms at or prior to final inspection. The inspector should cross-reference the tests documented on the acceptance forms with those called out on the ENV-1C, MECH-1C and LTG-1C compliance forms. Any required tests not conducted or passed are cause for not issuing the final certificate of occupancy.

Step 6: Certificate of Occupancy Granted

The building department's Certificate of Occupancy is official confirmation that all applicable design, construction, and verification requirements have been met and that the building is ready for its permit-approved occupancy type. The addition of the acceptance testing component to the building approval process adds assurance to involved parties that the installation quality and performance of tested systems are consistent with the intent of the Standards.

Step 7: Acceptance Test Forms Transferred to Owner

Acceptance testing forms and documentation must be transferred to the building owner following inspector review. The potential for liability exists if fraudulent information is knowingly included in acceptance testing documentation. If passed equipment or systems function in a manner inconsistent with the Standards' intent, the owner may utilize acceptance testing documentation in requesting call-backs or in the pursuit of legal corrective action.

How are Designers Impacted by Acceptance Testing

Because acceptance testing offers assurance that designated building systems will be correctly installed and configured, thus performing per design intent, its benefits to designers can be significant. This can be especially important when energy efficiency measures are a customer priority and/or key component of a designer's marketed services. A building that functions well in terms of comfort from day one makes for satisfied occupants and repeat design business.

Designers (architects and engineers of record) play a very important role in the acceptance testing process. They document design intent and the physical and operational parameters for systems. They also designate the Responsible Persons who would conduct the acceptance tests.

Acceptance testing can often be simplified if the system designers specify system-integrated sensors and data monitoring stations, such as flow meters or pressure sensors. Doing so reduces time needed for post-installation system modification or addition of specialized equipment during acceptance testing.

A thorough design and specification documentation that accounts for acceptance testing can prevent costly additional work or system modifications later on. Some hydronic system tests, for example, require specific plumbing configurations to facilitate them. Design phase awareness of such requirements simplifies acceptance testing costs and time in the construction phase.

Careful attention to approving equipment substitutions or value-engineered modifications is likewise important. If this responsibility is neglected, acceptance testing requirements increase the likelihood that designs may be flagged for not meeting Title 24 requirements, causing delays during construction. Further, a change order may be necessary if an installed system cannot pass acceptance tests due to design or installation flaws.

Those reading this document are on the right track to taking efficient advantage of the acceptance testing process.

Integrated approach to project development and implementation

- Whenever feasible, increase contractor(s) awareness of and involvement in meeting acceptance testing requirements
- Have contractors certify that any substitutions they submit will meet Title 24 requirements, including those for applicable acceptance testing

Impact on Electrical and Lighting Plans

2008 Title 24 requires designers to identify specific daylit areas and their respective independently controlled circuits on the electrical and lighting plans. These include the type of daylighting controls, clear designation of the daylit zone, and identification of the light fixtures/circuits that are to be distinctly controlled for daylighting. To aid this process, Title 24 (Section 131) designates daylit zone extents as shown below:

Figure 1-1: Daylit Area Near Windows

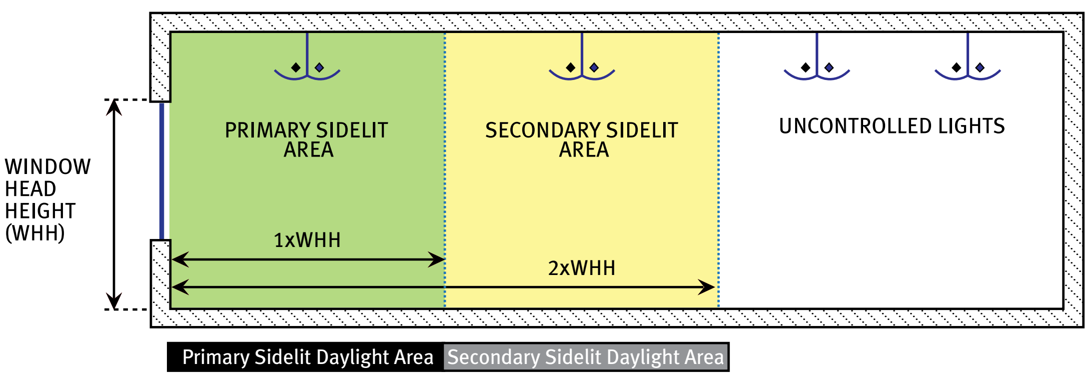
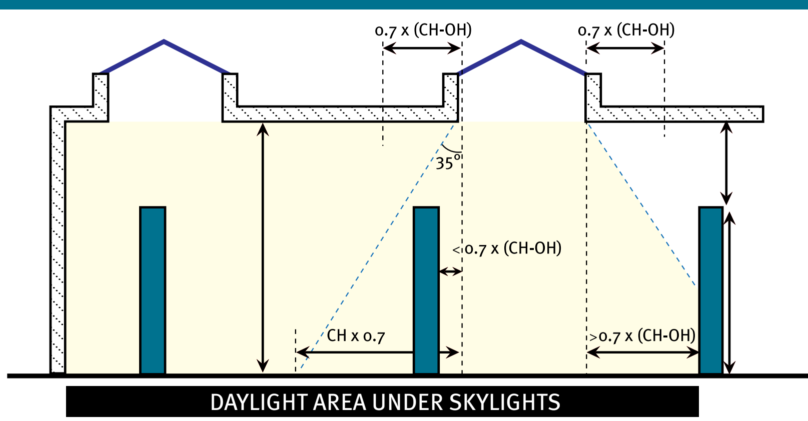


Figure 1-2: Daylit Area Under Skylights (With Interior Partitions)



Source: *2008 Title 24 Non-Residential Manual*

Attention to lighting control sensor installation and operation is vital to achieving intended system operation. Designers should carefully consider and specify sensor location and circuitry, as well as whether designated sensors have performance specifications appropriate to their intended purpose. All automatic daylighting control and occupancy sensor specifications should meet or exceed the requirements of 2008 Standards Section 119.

Improved awareness of energy code requirements

- Become familiar with the Title 24 Standards and its relevant sections: Lighting 119, 131, and 132; Mechanical 10-103, 121, 122, 125, and 144
- Develop a thorough understanding of acceptance testing rationale and procedures by reviewing the 2008 Nonresidential Compliance Manual

Impact on Mechanical Plans

Designers are required to list all systems to be tested on the appropriate compliance form and show location of controls and equipment on the mechanical plans. Similar to lighting design, attention to details through inclusion of necessary piping and instrumentation will enable expedient testing by the designated Responsible Person and the Field Technicians.

Coordination with contractors and acceptance test Responsible Persons during the design phase will inevitably save time during the construction phase. While such integration would likely benefit any construction project, acceptance testing requirements accentuate the benefits of doing so.

Increased systems design review

- Evaluate system designs in the context of applicable acceptance testing procedures to determine whether they enable feasible testing and performance that meets code requirements
- Consider having the designated Responsible Person(s) or commissioning agent review relevant plans to identify design issues in advance of construction

How are Contractors Impacted by Acceptance Testing

It is understandable that contractors may view acceptance testing as merely additional time and paperwork documenting what they were already doing. However, acceptance testing can positively affect those constructing quality building systems. Acceptance testing:

- Acknowledges the need to verify that systems are installed and operating as intended. This benefits contractors already installing systems in this manner but currently competing against those who do not.
- Provides repeatable, systematic methodology for verifying energy code-required performance and sets a minimum standard of reasonable care in building system implementation.
- Reduces the number of post-occupancy performance issues about which a building owner may contact the contractor to remedy. Such 'call-backs' are a drain on contractor time and reduce job profitability.

In addition to affecting bids and scheduling, acceptance tests add site time and planning requirements. A ballpark time estimate for each test is provided in Chapter 10 of the 2008 Nonresidential Compliance Manual. The actual time required for each test varies significantly depending on the size of the facility, the size and number of installed systems, and the Responsible Persons' familiarity with the system, components, and controls installed, among other variables. Acceptance testing consumes decreasing amounts of time as contractors gain experience and become familiar with the requirements and procedures. Additionally, conducting related acceptance tests in conjunction with each other can result in significant time savings not reflected in the given time estimates.

Acceptance forms require the signature of the licensed Responsible Person, and thus create some liability exposure. This liability should not detrimentally affect contractors that perform quality work and follow the acceptance testing requirements. In general, acceptance testing liability only applies to a system's initial implementation and its operation at the time of building hand-over. It does not apply to performance over time given future variability in post-occupancy adjustment, operation, and maintenance patterns.

ACCEPTANCE TESTING REQUIREMENTS IN 2008 TITLE 24

This section provides an overview of the acceptance tests as well as suggestions for meeting their requirements efficiently, but it is not intended to provide a comprehensive description of the tests. The authoritative acceptance testing information source is the 2008 Nonresidential Compliance Manual, Chapter 10. Further details and step-by-step test procedures can be referenced in the 2008 Standards Reference Appendix NA7.

Envelope Acceptance Test

This section provides an overview of the envelope acceptance tests, which were first introduced in the 2008 Title 24 Standards.

2008 Envelope Acceptance Test			
Notes	**Acceptance Test Description**	**Reference Appendix**	**Test Form**
NEW	Envelope Fenestration - NFRC or Energy commissions Label Certificate, including site-built fenestration.	NA7.5.1.1	ENV-2A

Revised *= 2008 Standards include additions and/or revisions to 2005 test requirements and/or procedures*
NEW *= new test in 2008 Standards*

This acceptance test ensures that the performance of installed fenestration is equal to or better than that approved for construction.

A fenestration product's performance specifications (U-value and Solar Heat Gain Coefficient, or SHGC) or changes in its installed orientation can significantly affect building energy use. Therefore, each installed fenestration product must be verified to match or exceed the performance characteristics listed on the approved permit plans/compliance documents.

Mechanical Acceptance Tests

This section provides an overview of the mechanical acceptance tests, highlighting changes and additions to the acceptance tests from the 2005 Standards, which were the first Title 24 Standards to incorporate mechanical acceptance testing requirements.

2008 Mechanical Acceptance Tests			
Notes	**Acceptance Test Description**	**Reference Appendix**	**Test Form**
Revised	Outdoor air ventilation for variable air volume systems	NA7.5.1.1	MECH-2A
Revised	Outdoor air ventilation for constant air volume systems	NA7.5.1.2	MECH-2A
Revised	Constant volume, single-zone, unitary air conditioner and heat pump systems temperature and scheduling controls	NA7.5.2	MECH-3A
Revised	Air distribution systems leakage of selected (depending on ductwork location) small, single-zone systems	NA7.5.3	MECH-4A
Revised	Air economizer controls for all economizers not factory installed and tested	NA7.5.4	MECH-5A
Revised	Demand-controlled ventilation (DCV) systems	NA7.5.5	MECH-6A
Revised	Supply fan variable flow controls	NA7.5.6	MECH-7A
Revised	Valve leakage test in hydronic variable flow systems and isolation valves on chillers and boilers	NA7.5.7	MECH-8A
Revised	Supply water temperature reset controls programmed into the building automation system for any water systems	NA7.5.8	MECH-9A
Revised	Hydronic variable flow controls on any water system where pumps are controlled by variable frequency drives	NA7.5.9	MECH-10A
NEW	Automatic demand shed control	NA7.5.10	MECH-11A
NEW	Fault detection and diagnostics for packaged DX units	NA7.5.11	MECH-12A
NEW	Automatic fault detection and diagnostics (AFDD) for air handling and zone terminal units	NA7.5.13	MECH-13A
NEW	Distributed energy storage DX AC systems	NA7.5.13	MECH-14A
NEW	Thermal energy storage (TES) systems	NA7.5.14	MECH-15A

Revised *= 2008 Standards include additions and/or revisions to 2005 test requirements and/or procedures*
NEW *= new test in 2008 Standards*

The following section summarizes new acceptance tests that were added in the 2008 Title 24 Standards. Included are brief discussions of the rationale and intent behind each. For further overview, procedures, and details, consult Chapter 10 of the 2008 Nonresidential Compliance Manual or Standards Reference Appendix NA7.

Automatic Demand Shed Control

This acceptance test ensures that the central demand shed controls have been properly programmed into the DDC system so that the demand savings potential can be realized.

Field studies show that increasing typical commercial building indoor temperature settings by 2-4°F during peak periods can reduce the electrical cooling demand by as much as 30%. To take advantage of this demand savings opportunity, the Standards require control systems with direct digital controls (DDC) at the zone level to enable centralized demand reduction, or 'shedding.'

Fault Detection and Diagnostics (FDD) for Packaged Direct Expansion (DX) Units

This acceptance test ensures that the packaged DX system's installed FDD system properly detects and reports designated common faults that affect performance and efficiency.

FDD systems help to maintain equipment efficiency closer to rated conditions over the life of the equipment. They ensure proper equipment operation by identifying and diagnosing common equipment problems such as improper refrigerant charge, low airflow or faulty economizer operation. FDD systems can receive a compliance credit using the performance approach.

Automatic Fault Detection and Diagnostic (AFDD) Systems

This acceptance test ensures that the air and zone terminal unit AFDD controls properly detect and report common faults and performance limiting issues such as sensor failure, failed dampers or actuators, improper operating modes, or other control tuning issues.

This acceptance test applies to FDD systems for air handling and zone terminal units. As with the equipment problems addressed by the previous test for packaged DX units, AFDD systems can detect common faults with equipment operation.

FDD systems for air handling units and zone terminal units require DDC controls to the zone level and can receive a compliance credit when using the performance approach.

Distributed Energy Storage (DES) DX AC Systems

This acceptance test ensures proper operation of DES DX AC systems with storage capacity less than 100 ton-hours. It verifies that the system is able to charge the storage tank during off-peak hours and discharge it during on-peak hours to reduce demand.

This acceptance test applies only to constant or variable volume direct expansion (DX) systems with distributed energy storage (DES DX AC). These acceptance requirements are in addition to those for other systems or equipment such as economizers, packaged equipment, etc.

DES DX AC systems reduce peak demand by storing cooling energy during off peak hours, usually in the form of ice. Ice is made during low-demand, off-peak hours and melted during peak demand cooling hours to avoid compressor operation and lower peak energy use. Since the DX air conditioner system typically operates more efficiently at night when ambient temperatures are lower, DES systems can also lessen required overall cooling energy in some climates.

Thermal Energy Storage (TES) Systems

This acceptance test ensures proper operation of TES systems. It verifies that the distributed energy storage system is able to charge the storage tank during off-peak hours and discharge the storage tank during on-peak hours to reduce demand.

While similar in purpose to the DES acceptance test described above, this test typically applies to larger capacity thermal energy storage (TES) systems used in conjunction with chiller-based AC.

Like DES DX AC, TES systems reduce peak demand by storing cooling energy during off peak hours, usually in the form of cooled liquid or ice. This stored energy is then extracted during peak demand cooling hours to lessen chiller operation and lower peak energy use. Since a chiller can operate more efficiently at night when ambient temperatures are lower, TES systems can also lessen required overall cooling energy in some climates.

Lighting Systems Acceptance Tests

This section provides an overview of the specific lighting control acceptance tests and sources for locating further information.

2008 Lighting Acceptance Tests			
Notes	**Acceptance Test Description**	**Reference Appendix**	**Test Form**
Revised	Automatic Daylighting Controls Acceptance	NA 7.6.1	LTG-3A
Revised	Occupancy Sensor Acceptance	NA 7.6.2	LTG-2A
Revised	Manual Daylight Controls Acceptance	NA 7.6.3	LTG-2A
Revised	Automatic Time Switch Control Acceptance	NA 7.6.4	LTG-2A
NEW	Outdoor Motion Sensor Acceptance	NA 7.7.1	OLTG-2A
NEW	Outdoor Lighting Shut-off Controls	NA 7.7.2	OLTG-2A

Revised *= 2008 Standards include additions and/or revisions to 2005 test requirements and/or procedures*
NEW *= new test in 2008 Standards*

Changes to 2008 Title 24 Requirements

The 2008 Standards incorporate significant changes to daylighting minimum levels, zone definitions, and lighting controls requirements (Sections 131, 143). The lighting acceptance testing process, detailed in the 2008 Nonresidential Compliance Manual, Chapter 10, reflects these modifications and likewise includes significant revisions and clarifications, especially to the functional test procedures. It is recommended that those involved in lighting controls design, installation, and acceptance testing review and become familiar with the revised Standards and their corresponding acceptance testing construction inspection and functional testing requirements.

New Tests in 2008 Title 24

Outdoor lighting acceptance testing is new to the 2008 Standards. The two new acceptance tests are as follows:

- **Outdoor Motion Sensor Acceptance (NA7.7.1):** Verifies that motion sensor specification, installation, and operation conform to the Standards

- **Outdoor Lighting Shut-off Controls Acceptance (NA7.7.2):** Verifies the specification, installation, and configuration of the required lighting control systems conform to the Standards

Outdoor lighting designated for testing includes those measures regulated by Standards Section 132(c), which covers most permanently installed outdoor lighting as well as building facades, parking lots, sales and non-sales canopies, outdoor sales areas, and student pick-up/drop off zones.

These acceptance tests ensure that automated controls turn off outdoor lighting during daylight hours and when not needed during nighttime hours to reduce site energy use.

Common Implementation Pitfalls

A failed acceptance test can add significant time and cost over-runs to a construction project. These failures can be minimized or eliminated through proper coordination of the planning, design, and project teams. Further, being aware of opportunities to facilitate tests, consolidate testing procedures, and avoid or minimize potential delays can expedite the process of acceptance testing.

Pitfall 1: Inaccurate Documentation

For energy code compliance demonstrated using the performance (calculated) method, it is permissible to meet the envelope acceptance requirements based on the area-weighted fenestration performance. In other words, the average installed fenestration performance value (U-factor/SHGC) per square foot, *for each orientation*, is compared to that provided on the approved plans/compliance documents. If the installed value is higher, the building must take the steps necessary to pass the acceptance test.

Because changing out windows is typically not feasible by the time acceptance tests are conducted, a failed fenestration acceptance test will likely require the building to re-comply using the performance specification values of the fenestration actually installed. Upon approval of revised compliance documents, the fenestration acceptance test would then be repeated.

Pitfall 2: Forgetting to Reset Internal Control Delays to Operational Conditions

Delays are programmed into many control sequences that require testing. Built-in lighting control delays are typically related to occupancy sensing, timed-out conditions triggered by occupancy, or pre-set daily timeclock lighting schedules. These exist to prevent systems from controlling with too much sensitivity and too rapidly, thus becoming unstable. With typical delays between five to thirty minutes, acceptance testing times can be prolonged considerably.

It is important that all parties involved in the process are aware of these inherent delays and allot acceptance testing time accordingly. With increased experience those conducting and documenting the acceptance tests will be able to coordinate and complete them more efficiently, as well as account for and estimate time required with improved precision.

For many test procedures, it may be reasonable to temporarily shorten control delays in order to expedite test performance. Coordinating or performing tests with the controls contractor may facilitate such adjustments. As with conducting all acceptance tests, the design or code-required control parameters (whichever are more stringent) should be recorded prior to any changes and the system returned to them upon test completion.

Pitfall 3: Poor Knowledge of Control Sequences

It is essential to know the exact control sequence programming *before testing begins*. The Responsible Person/Field Technician will otherwise be unable to customize the test to particular systems or verify that they function as intended. In many cases, the testing will be performed in conjunction with the controls contractor.

Sources for locating useful controls information include the following:

- Internal electronic controls: typically documented in the equipment O&M manual
- Pneumatic controls: review the control drawings to ascertain how the system is controlled
- DDC controls: it is best to review the control programming that is currently loaded in the controllers. Note that actual control logic often differs from that

in design plans and specifications for a number of reasons, including the following:

- Poorly written or incomplete design drawing sequences
- Standard practices by the installing EMCS contractor
- Issues arising in the field during control system start-up and commissioning

Functional testing based on incorrect control documentation or sequences will not necessarily yield valid results.

Pitfall 4: Affect Occupant Comfort

Performing many of the tests in cold weather conditions can cause occupant discomfort and risk damage to building systems components due to freezing. This is especially true for many of the mechanical tests, particularly those involving HVAC operations. If it is necessary to perform tests under low outdoor temperature conditions, first verify that necessary freeze protection and heating coil controls function properly.

Tips to Improve Speed and Accuracy of Acceptance Tests

Tip 1: Factory Calibration Saves Time

A number of acceptance test procedures require verifying sensor calibration. This requirement can be met by either a manufacturer's calibration certificate or through documentation of field calibration procedures. The former saves significant on-site time and effort compared to the latter, which directly impacts the time and cost of the acceptance testing.

Calibration verification is required of the following sensors:

- Pressure sensors used in variable flow applications (i.e. supply fan or pump VFD controlled to maintain a specific pressure setpoint).
- Temperature sensors used to control field-installed economizers and supply water temperature reset.
- Carbon dioxide sensors used to implement a demand-controlled ventilation control strategy.

Field calibration generally requires verifying an installed sensor's measured value against a calibrated instrument. Most sensor calibration can be verified at a single operating point if the expected measurement range does not vary significantly. If a sensor is not calibrated within designated tolerances, appropriate field adjustments must be made, or the sensor replaced, in order to meet acceptance requirements

A calibration certificate from the manufacturer verifies that a sensor has been tested per a traceable standard (typically National Institute of Standards and Technology) and confirmed to make accurate measurements. Factory-calibrated sensors require no further field testing and are recommended as a means to minimize field testing time. Ensure that proper calibration documents are supplied by the manufacturer and then stored in a safe, accessible location until required for submittal.

Tip 2: Factory Installed Economizers Save Time

Economizer acceptance testing is greatly facilitated by installation of units that are factory installed and certified operational by the manufacturer to Energy Commission economizer quality control requirements. In this case, field economizer functional test procedures are not required. However, the Construction Inspection section of the Air Economizer Control acceptance test (NA7.5.4) must still be completed.

The manufacturer of an HVAC unit with an Energy Commission-certified factory-installed economizer shall be responsible for documenting acceptance requirement compliance and providing the Certificate of Compliance to attach to form MECH-5A. The manufacturer is also responsible for verifying that the high-limit switch on the economizer is set in compliance with Table 144-C of the Standards. As with manufacturer-calibrated sensors, the Responsible Person should take care to ensure that the proper economizer documentation is supplied by the manufacturer and then stored in a safe, accessible location until required for submittal.

Tip 3: Integrated Sensors and System Monitors

The designer can reduce the amount of time spent on site for acceptance testing by designing sensors and data monitoring devices into the system. These will significantly minimize the need for, and time and effort associated with, installing data loggers and sensors after-the-fact during the acceptance tests.

Tip 4: System Overrides

Many acceptance tests, especially those related to the mechanical system, require override of the system controller programming, including forcing time settings to verify proper system response/operation. In some instances, adjusting the length of the override period will minimize required testing time. Always record system settings prior to testing and restore any altered settings to meet code requirements or the design conditions, whichever are more stringent, upon test completion.

Tip 5: Combining Test Procedures

Many acceptance tests have procedural overlaps. By identifying such instances for a specific project, field testing time and costs can be significantly reduced. In many instances, coordination with the controls contractor will likely facilitate these tests, since that person may be needed to manipulate the EMCS to simulate desired operating conditions. Additionally, test time may be reduced if two people perform the test - one manipulating the input and the other verifying operation. In addition to those noted below, many tests may also be performed in conjunction with equipment/system start-up procedures.

Acceptance Test Procedures That Can Be Combined	
Test Procedure Requirement(s) In Common	**Applicable Acceptance Tests**
Zone controls override	• NA7.5.1.1 Ventilation systems for Variable Air Volume Systems Acceptance • NA7.5.6 Supply Fan Variable Flow Controls Acceptance
Outdoor air damper override	• NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance or NA7.5.1.2 Constant Volume Systems Outdoor Air Acceptance • NA7.5.4 Air Economizer Controls Acceptance • NA7.5.5 Demand Controlled Ventilation Systems Acceptance
Equipment unit mode of operation changes	• NA7.5.2 Constant Volume, Single-zone, Unitary Air Conditioner and Heat Pumps Systems Acceptance • NA7.5.4 Air Economizer Controls Acceptance
Circulation pump zero flow ("deadheading") and control valve overrides	• NA7.5.7 Valve Leakage Tests • NA7.5.9 Hydronic System Variable Flow Controls Acceptance

Tip 6: Plan Review

Acceptance testing does not require a plan review to be performed by the construction team. However, it is wise to incorporate this step into the building process. The construction team should review the plans and specifications in the context of acceptance testing requirements and raise any issues that might affect meeting them.

Identified issues should be communicated to the design team so that necessary modifications can be made prior to equipment procurement and installation. It is better to review constructability and compliance with the acceptance test requirements prior to installation. Otherwise wiring may not pass the acceptance tests and require re-installation.

Tip 7: Circuiting

Design and installation teams should pay close attention to circuiting. A key component to meeting the lighting acceptance requirements includes designing and wiring lighting circuits that enable controls conforming to the Standards. Lamps, luminaires or rows of luminaires are assigned to different circuits so that light levels can be increased uniformly by switching. Lighting in the daylit zone has to be on separate circuits from other lighting and, in most cases, must also be wired for multi-level control.

The construction inspection component should occur while wiring is still being installed and the contractor responsible is still on-site. This will greatly facilitate making any necessary circuiting changes identified.

Tip 8: Documentation

Be aware that fenestration accepting testing, like the field performance of any window, is *orientation-specific*. Thus it is critical for the design specifications to be communicated clearly to the construction team so that the correct glazing is installed on the correct orientations.

Construction inspection will verify whether lighting control devices are properly located and calibrated, and their setpoints or schedules established per the Standards. It is important for equipment and design documentation to be readily available, enabling device and control settings to be easily inspected.

Tip 9: Sampling

Some lighting controls tests procedures include provisions for sampling, or testing a small sample system as a representative of all systems installed. If these sample systems pass the acceptance tests, testing is not required for the other systems. However, if the sample systems fail testing, then there is a need to fix and re-test the sample systems and conduct testing on additional systems. Thus, testing time in buildings with poorly designed and/or installed control systems can clearly expand rapidly.

Tip 10: Some Test-Specific Suggestions

In addition to specified procedures and best practices involved in conducting them, some constraints or cautions specific to individual acceptance tests are provided below.

- Outdoor Air Ventilation, Constant Volume Systems: NA7.5.1.2 (MECH-2A)

    This acceptance test verifies the outdoor airflow of the system after calibration and system set-up is complete. Testing costs can be reduced by conducting the acceptance test immediately after set-up is concluded and before setting the minimum damper position.

- Air Distribution Systems: NA7.5.3 (MECH-4A)

    Alterations to existing distribution systems, through changes to duct systems or HVAC equipment, can require demonstration of the system's improved relative duct leakage rather than an absolute leakage threshold. For this reason, be sure to test such system's leakage prior to making the specified alterations. Designers should also note this issue on the plans to ensure that it is not overlooked. Remember to return the distribution system to its initial conditions after completing acceptance testing, including removing all temporarily installed duct blockages, sealing holes drilled for the static pressure probes, etc.

    A certified California HERS rater must also verify duct leakage performance. Coordinating testing with the HERS rater will likely save testing time.

- Air Economizer Controls: NA7.5.4 (MECH-5A)

  Carefully monitor operation of the outdoor air damper interlocks during this test. If they fail and the outdoor air damper does not open before the return damper closes, the air handler will have no intake air source and its static pressure head will rise rapidly. Damage to the air handling unit or associated ductwork would likely result.

- Demand-Controlled Ventilation (DCV) Systems: NA7.5.5 (MECH-6A)

  Lock out the economizer control during the test in order to ensure representative test results. The outdoor air damper may not modulate correctly if the economizer control strategy is controlling damper operation.

- Valve Leakage: NA7.5.7 (MECH-8A)

  Pressure measurements necessary for this test involve running a pump in a 'deadhead' (no flow) condition, which, if lasting more than five minutes, can damage the pump seals or motor. Prepare the test so that the pump 'deadheads' for as little time as possible.

  The position of valves used to isolate three-way valves or pumps must be marked or noted prior to making adjustments. Return any such valves to their initial position upon test completion.

- Supply Water Temperature Reset Controls: NA7.5.8 (MECH-9A)

  Time required for this test can vary significantly depending on the heating load and the Field Technician's test sequencing. Under low heating load conditions, the low end reset (coolest hot water supply temperature) should be tested first. If the hottest supply water temperature is instead tested first, dissipating the hot water loop heat to reach the cooler setpoint can be difficult and time consuming.

- Fault Detection Diagnostics (FDD): NA7.5.11 (MECH-12A)

  The Field Technician should be aware of the potential for false alarms that may occur during this test. Compared to pressure sensors, temperature sensors can take longer to reach a steady-state condition. The FDD algorithms may therefore not function properly during transitional states, such as when the fan or compressor first turns on.

- Distributed Energy Storage (DES) DEC/DX AC Systems: NA7.5.13 (MECH-14A)

  Verify that the water tank is filled to the manufacturer's recommended level prior to beginning testing.

Resources for Designers and Contractors

- California Energy Commission Website: www.energy.ca.gov
- Business and Professions Act § 5537, 5538, and 6737.1
- 2008 Title 24 Nonresidential Compliance Manual
  1. Chapter 10
  2. Appendix
  3. Envelope, Mechanical and Lighting Acceptance Forms
- 2008 Title 24 Nonresidential Building Standards
  1. Mechanical Systems; Standards Sections 121, 122, 125, 144
  2. Lighting: Standards Sections 119, 131, 132

Acknowledgements

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