

## CODES AND STANDARDS ENHANCEMENT INITIATIVE (CASE)

# Acceptance Requirements #1: Effectiveness and Compliance (Based on PIER Study)

## *2013 California Building Energy Efficiency Standards*

California Utilities Statewide Codes and Standards Team

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## **1. Introduction**

This report is a part of the California Investor-Owned Utilities (IOUs) Codes and Standards Enhancement (CASE) effort to develop technical and cost-effectiveness information for proposed regulations on building energy efficiency design practices and technologies.

This report investigates the potential for improvements or additions to current Title 24 nonresidential acceptance requirements. Acceptance requirements are targeted inspections and tests to determine whether specific building systems, controls, and/or equipment were installed properly and function as specified by the building plans and as required by Title 24 standards. Specifically, this measure directly references the findings from a recent draft PIER (Public Interest Energy Research) study, “Title 24 Acceptance Testing Requirements and Effectiveness”, that investigated barriers to the effectiveness of and compliance with the tests (Tyler, Farley, & Crowe, 2011). The purpose of the PIER Study was to evaluate existing acceptance requirements and enforcement procedures to understand the challenges, limitations, and opportunities for achieving the intended energy efficiency. The proposed code changes to current test requirements, which are presented in this CASE report, were informed by the PIER Study.

Specifically, based on this research we tentatively propose revisions to a number of the acceptance test forms and language (Chapter 10 of the Nonresidential Compliance Manual, At-A-Glance descriptions, nonresidential appendices NA7, and Certificates of Acceptance) to improve clarity, ease of use, and compliance.

Throughout 2010 and early 2011, the CASE Team (Team) evaluated costs and savings associated with each code change proposal. The Team engaged industry stakeholders to solicit feedback on the code change proposals, energy savings analyses, and cost estimates. The contents of this report were developed with feedback from building departments, contractors organizations, and other related industries and the California Energy Commission (CEC) into account.

The main approaches, assumptions and methods of analysis used in this proposal have been presented for review at three public stakeholder meetings hosted by the IOUs. At each meeting, the CASE Team asked for feedback on the proposed language and analysis. Following each meeting, the CASE Team sent participants a summary of what was discussed at the meeting and a summary of outstanding questions and issues. A record of the Stakeholder Meeting presentations, summaries and other supporting documents can be found at [www.calcodesgroup.com](http://www.calcodesgroup.com). Stakeholder meetings were held on the following dates and locations:

- ◆ First Stakeholder Meeting: May 20, 2010, Webinar
- ◆ Second Stakeholder Meeting: December 7, 2010, San Ramon Conference Center, San Ramon, CA
- ◆ Third Stakeholder Meeting: April 6, 2010, Webinar

## 2. Overview

### 2.1 Measure Title

Acceptance Requirements Topic #1: Revised Acceptance Requirements based on PIER Study Findings (Compliance and Effectiveness)

### 2.2 Description

This proposed code change would revise the standards, instructions and compliance forms for ten of the existing acceptance tests for the Energy Efficiency Standards for Nonresidential Buildings (Part 6, Title 24):

- ◆ NA7.5.1 Outdoor Air
- ◆ NA7.5.2 Constant Volume Single Zone Unitary Air Conditioner and Heat Pump Systems
- ◆ NA7.5.3 Air Distribution Systems
- ◆ NA7.5.4 Air Economizer Controls
- ◆ NA7.5.6 Supply Fan Variable Flow Controls
- ◆ NA7.5.8 Supply Water Temperature Reset Controls
- ◆ NA7.5.9 Hydronic System Variable Flow Controls
- ◆ NA7.6.1 Automatic Daylighting Control
- ◆ NA7.6.3 Manual Daylighting Control
- ◆ NA7.6.4 Automatic Time Switch Control

Acceptance requirements are targeted inspections and tests to determine whether specific building systems, controls, and/or equipment were installed properly and function as specified by the building plans and as required by the Title 24 standards. Currently, there are twenty-one unique acceptance tests that apply to major building systems including envelope, mechanical (HVAC), and indoor and outdoor lighting. Tests need to be conducted during new construction or if there is a significant retrofit that impacts the building system for which the tests apply. The acceptance test process generally includes conducting a visual inspection, reviewing certification requirements, and performing functional tests.

This measure relies upon the findings of a PIER Study on testing effectiveness and compliance, conducted by PECL. By interviewing various participants in the acceptance requirements process (building owners, building departments, contractors, and engineers), and viewing contractors performing a number of tests, common barriers to test compliance were identified.

### 2.3 Type of Change

The proposed code changes would be mandatory requirements. Acceptance tests are mandatory for any installed system that has an associated test, and the tests must be completed and documented via the acceptance forms before a building department can issue a Certificate of Occupancy.

More specifically, the changes would be made to the three sections of Title 24 that pertain to the acceptance requirements: Chapter 10 of the Nonresidential Compliance Manual (NRCM), Appendix

A of the NRCM, and Reference Nonresidential Appendix NA7. Chapter 10 contains general directions and rationale for the tests, Appendix A of the NRCM contains the acceptance forms, and Appendix NA7 contains specific instructions for performing the tests. The instructions, forms, and scope of compliance would be modified. Test procedures would also be revised.

This measure does not affect prescriptive or performance compliance, nor will it affect modeling performance calculations.

## 2.4 Energy Benefits

The proposed revisions to the acceptance tests will result in electricity, demand, and natural gas savings by improving compliance with existing code. Energy savings occur by ensuring that equipment is installed correctly and that it operates as designed and as specified by code.

All tests analyzed in the PIER Study were adopted in previous code change cycles, and therefore the energy benefits from these tests have been considered and accounted for previously. The proposed revisions will improve real-world compliance with the code, thereby ensuring the energy benefits that the state should already be realizing. Thus, the proposed changes do not create any “new” energy benefits.

There is little data on current and future compliance with the acceptance tests. To provide a scale of the potential savings, we provide an “upper bound” of potential statewide energy savings that may occur due to increased compliance with the acceptance tests. Section 4 discusses savings analysis considerations in more detail.

Statewide Power Savings (MW)	Statewide Electricity Savings (GWh)	Statewide Natural Gas Savings (Million Therms)
4.6	165	-1.0

## 2.5 Non-Energy Benefits

Non-energy benefits include improved operation and reduced need for maintenance for functioning systems. This will decrease maintenance costs, increase the building value, and improve comfort and indoor air quality (IAQ) due to properly functioning HVAC systems.

## 2.6 Environmental Impact

This proposed change does not have any anticipated adverse environmental impacts. There are no anticipated impacts to air or water quality, and there would be no increased use of or production of hazardous materials.

The reduction in energy use would result in reduced power generation thereby reducing air emissions associated with power generation. This includes reductions in CO<sub>2</sub>, CO, SO<sub>x</sub>, NO<sub>x</sub>, and PM<sub>10</sub> based on proposed energy savings. For these proposed acceptance test changes, we do not anticipate

significant savings on a per-test basis, so reduced air emissions will not be significant on a per-test basis.

## ***2.7 Technology Measures***

The proposed change does not require any new technology or equipment beyond that which is already commonly used for testing. The acceptance requirements currently require the use of a number of measurement tools, including:

- ◆ Airflow measurement probes / anemometer
- ◆ Fan flowmeter
- ◆ Digital manometer
- ◆ Reference CO<sub>2</sub> probe
- ◆ Differential pressure gauge
- ◆ Static pressure sensor
- ◆ Hydronic manometer
- ◆ Temperature probe
- ◆ Light meter (illuminance or foot-candle)
- ◆ Amperage meter / power meter

These tools are already in use and should be readily available to contractors and other test practitioners. Therefore no additional costs or concerns for availability are assigned to these tools in this analysis.

### **2.7.1 Useful Life, Persistence, and Maintenance:**

Acceptance requirements are meant to ensure compliance with the existing standards, and therefore increase the persistence of savings for measures.

For simplicity in analysis, it can be assumed that the persistence of savings will last for the entire life of the installed controls or equipment being tested. In practice, however, the energy savings for acceptance requirements depend on the manner in which the tests are carried out, how results are verified, and building maintenance practices. The effectiveness of the tests also depends greatly on whether they are performed correctly or at all; therefore, the key concerns related to persistence of savings are test effectiveness and compliance, as addressed in the findings of this report.

## ***2.8 Performance Verification of the Proposed Measure***

The Acceptance Requirements themselves verify proper installation and operation; they are a means of performance verification. However, as noted, the effectiveness of the acceptance tests varies greatly, and the accuracy of the tests impacts the performance of the energy related building features. If a test does not properly diagnose an issue with a building system, the system may not be adjusted and the energy consumption could be higher than it would be if the system were operating correctly. To verify compliance with the tests, building departments review the appropriate acceptance forms, which have been completed and signed by a "Responsible Person" (a licensed contractor or engineer). The building department must review the forms before issuing a Certificate of Occupancy.



The proposed code changes will improve the effectiveness of the acceptance tests. The proposed changes in this report will not apply to the process of verifying the tests have been conducted with pass results (i.e. the overall compliance process once the tests are completed and forms submitted to building departments). Additional outreach, a part of the aforementioned PIER study, will address the compliance process.

## ***2.9 Cost Effectiveness***

The proposed changes to the acceptance tests, forms, and code language are not expected to significantly increase the testing time or scope. Therefore, no additional costs are assumed for this measure proposal. In fact, the improvements to test clarity may decrease testing and review time, resulting in cost savings relative to current testing practice.

As mentioned previously, no new energy savings are assumed for these proposed changes, which will improve testing effectiveness and compliance and verify the energy savings from the tested equipment.

## ***2.10 Analysis Tools***

The current acceptance tests are mandatory for the applicable energy related building features. These proposed changes to the acceptance tests will not alter this; they will remain mandatory requirements and, therefore, would not be subject to whole building performance modeling or calculations.

Nonetheless, it will be necessary to ensure that building systems and equipment that undergo an acceptance test receive performance energy "credit", typically via building modeling software. The CASE team reviewed the relevant elements (i.e. elements pertain to all building elements that are covered by acceptance tests with proposed changes) of the Title 24 compliance software to ensure the current software is able to model the impacts of the tests and account for their energy benefits properly. However, there are instances of the compliance software specifying an incorrect or irrelevant test for the modeled system. These errors must be addressed by the software developers.

## ***2.11 Relationship to Other Measures***

This measure is being submitted in coordination with another measure related to acceptance testing: Acceptance Requirements #2: Based on Retro-commissioning (RCx) Failure Modes. Beginning in 2006, PECI developed and managed a number of retro-commissioning third-party utility programs across California to identify and correct building faults. The CASE team sorted and reviewed the dataset of 813 faults identified by PECI's RCx programs to determine which building failures could be addressed via new or revised acceptance requirements. The Acceptance Requirements #2 CASE report recommends new acceptance requirements for supply air temperature reset controls and condenser water supply temperature reset controls. It addresses technical building problems only, as opposed to problems with the testing and compliance process which are addressed in this (Acceptance Testing #1) CASE study.

The CASE Team that developed this report worked closely with the team that developed the Acceptance Requirements #2 CASE report to ensure consistency across the tests and in the associated code language.

### **3. Methodology**

This section summarizes the work done under the PIER study to identify key barriers to compliance with the acceptance requirements and to develop targeted recommendations for changes to the current acceptance requirements. Detailed information is available in the final PIER Study, submitted to the CEC in September 2011.

#### ***3.1 Identifying Code Change Options: PIER Study Tasks and Analysis***

The CASE Team relied directly on the PIER Study findings to identify potential code changes. Throughout the PIER study process, the CASE team communicated with the PIER Study team to monitor results and provide feedback. The specific code language recommendations and revised Certificates of Acceptance were provided by the PIER Study team to support the CASE effort. To provide key background information, the methodology from the PIER Study is summarized here.

Two specific tasks (6.2 and 6.3) in the PIER Study researched the effectiveness of current acceptance tests. The goal of Task 6.2 was to characterize and evaluate acceptance testing enforcement activities by seeking feedback from each of the major participant groups: building officials, contractors who conduct the tests, building owners, and design engineers. The goal of Task 6.3 was to investigate the effectiveness of the acceptance tests by observing contractors performing the tests. The following section details the key activities of these tasks.

##### **3.1.1 Review Existing Conditions**

Acceptance requirements have been a part of Title 24 since the 2005 code, originally supported by the CEC Nonresidential Building Quality Assurance Project. Sixteen tests were proposed at that time, which has since grown to twenty-one total tests under the 2008 code. However, the acceptance requirements are a complex process involving many participants, and there are many opportunities for the process to break down. Anecdotal evidence and research on code compliance indicates that the tests may be incompletely performed and enforced.

##### **3.1.2 Task 6.2: Evaluate Acceptance Testing Enforcement Activities**

Task 6.2 involved interviews with each participant group and visits to building departments. The objective was to obtain evidence of the ways the enforcement procedure breaks down, is misunderstood, or becomes onerous. As discussed in the results section of this report (Section 4), the PIER project team developed a multi-faceted view of the factors contributing to low compliance and low enforcement of acceptance testing.

##### ***Phone Interviews***

The PIER project team conducted 31 phone interviews. Individuals interviewed were identified through a combination of technical expert suggestions, contacts from retro-commissioning programs, participants in utility-sponsored training, professional organizations such as BOMA (Building Owners and Managers Association), and referrals. Interviewees included:

- ◆ 8 building officials
- ◆ 10 contractors

- ◆ 6 building owners
- ◆ 7 design engineers

### ***Building Department Visits***

After the phone interviews were completed, the PIER team conducted four building department visits in different jurisdictions to characterize common practice in reviewing test results and enforcing the acceptance requirements, and to identify buildings to recruit for testing in Task 6.3.

The PIER team met with building officials, inspectors, and building plans examiners for approximately 90 minutes at each of the four locations. The PIER team also reviewed a number of commercial building plans, compliance forms, and acceptance forms to understand each jurisdiction's method of processing incoming acceptance forms. Key observations from these visits can be seen in the Analysis and Results section of this report (Section 4).

### **3.1.3 Task 6.3: Investigate Effectiveness of Acceptance Tests**

#### ***Field Testing the Acceptance Tests***

The objective of the field study was to identify technical and non-technical barriers of completing the tests correctly. The PIER team identified and characterized key testing failures.

The PIER team secured 13 commercial high-rise and low-rise buildings for testing and organized acceptance tests at each site. Eight contractors performed ten different acceptance tests (with between one to five individual tests performed at each site, depending on the available building equipment). As discussed in the next section of this report, the PIER team interviewed each contractor to determine level of expertise, understanding of acceptance requirements in general, and familiarity with the tests procedures.

Originally eight tests were selected because they are believed to have the greatest impact on energy usage, as based on a 2005 study on the statewide savings impacts of acceptance tests (HMG, 2005). Two additional tests (NA7.5.8 and NA7.5.9, for hydronic systems) were included because the relevant mechanical systems were present at two of the ten sites. The ten acceptance tests are:

- ◆ LTG-2A Automatic Time Switch Control Acceptance (NA7.6.4)
- ◆ LTG-2A Manual Daylighting Controls Acceptance (NA7.6.3)
- ◆ LTG-3A Automatic Daylighting Controls Acceptance (NA7.6.1)
- ◆ MECH-2A Outdoor Air Acceptance (NA7.5.1)
- ◆ MECH-3A Constant Volume Single Zone Unitary Air Conditioner and Heat Pump Systems (NA7.5.2)
- ◆ MECH-4A Air Distribution Systems (NA7.5.3)
- ◆ MECH-5A Air Economizer Controls Acceptance (NA7.5.4)
- ◆ MECH-7A Supply Fan VFD Acceptance (NA7.5.6)
- ◆ MECH-9A Supply Water Temperature Reset Controls Acceptance (NA7.5.8)
- ◆ MECH-10A Hydronic System Variable Flow Control Acceptance (NA7.5.9)

Detailed information on the building systems tested and the tests performed at each site is presented in Table A1 of the Appendix.

### ***Contractor Interviews***

Eight contractors participated in the project. Contractors were interviewed before and after they performed the acceptance tests to gauge their understanding and familiarity with the test requirements. Summaries of the contractor interviews before and after the field tests are available in Tables A2 and A3 of the Appendix.

#### **3.1.4 Application of PIER Study Results to CASE**

Upon completion of the PIER Study activities, the PIER Study authors compiled detailed results of their interviews and observations, and summarized results in a comprehensive report. Based on their findings, the PIER Study authors modified the acceptance forms and associated code language. These results were given to the CASE team, to develop this CASE report.

## ***3.2 Per Measure Energy Savings Calculation Methodology***

The proposed changes to the acceptance forms and language are not expected to create additional energy savings on an individual test level beyond those already considered and accounted in past code cycles, as all of the tests considered in this report have existed for at least one code cycle already and represent measures that were implemented in previous code cycles. Therefore, TDV (Time Dependent Valuation) energy savings are assumed to be zero.<sup>1</sup> The goal of the proposed code changes is to increase compliance with existing code, and therefore realize energy savings that California should already be capturing.

## ***3.3 Costs Calculation Methodology***

The cost of acceptance tests consists mainly of the time for the technician to perform the test and for the Responsible Person, as defined in Section 2, to review and sign the forms. These are one-time costs accrued at the time of equipment installation and startup testing. Stakeholder feedback obtained during IOU sponsored stakeholder meetings, as well as feedback from contractor interviews, indicated that the installing contractor tends to perform the test and sign the forms as the Responsible Person.

New acceptance tests may require tools or equipment that are not easily accessible to the technicians, so technicians would incur a cost to purchase equipment. However, the tests under consideration for this code change are not new tests and no additional equipment purchases would be necessary.

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<sup>1</sup> Under typical CASE analysis, all yearly energy savings are multiplied against the 2011 TDV (Time Dependent Valuation) values to determine the monetary value of the energy savings over the entire measure life cycle. The TDV values weight peak savings more heavily than off-peak savings to account for the real cost of energy to society. For nonresidential non-envelope measures, the TDV period of analysis is 15 years at a 3% discount rate. This period of analysis is appropriate for HVAC controls, as HVAC equipment will operate to or beyond 15 years. The energy savings achieved by acceptance testing are assumed to be maintained by regular yearly incremental maintenance.

Since the proposed changes to the tests forms and instructions are not expected to significantly increase the testing time or the time required to fill out the forms, nor would they require any new equipment, there are no expected incremental costs associated with the code changes.

### ***3.4 Statewide Energy Savings Estimates Methodology***

Improving the acceptance tests will not produce significant savings on a per-test basis, but will create statewide savings due to increased compliance with the tests. There is little concrete data on current and future acceptance test compliance rates; therefore, we attempt to provide an upper bound of potential savings in this report.

A 2005 study of the existing acceptance tests calculated potential savings on a per-test and statewide basis based on energy modeling of typical failures identified by the acceptance tests, and estimates of the rate of equipment failure that would be identified and fixed by the tests (HMG 2005). Some tests produced a modeled energy penalty because the “failure case” described equipment that did not operate, and thus did not consume energy as compared to a properly operating unit. Multiplying these estimates against 2014 new construction rates, it is possible to place an upper bound of the potential savings due to improved compliance with acceptance tests. Details on the method and data source of the new construction forecast are presented in section 7.3.

## 4. Analysis and Results

### 4.1 Findings and General Recommendations

This section presents a summary of findings from the PIER Study as relevant to the Title 24 acceptance testing requirements. More detailed findings can be found in the final PIER report (Tyler, Farley, & Crowe 2011).

The PIER study findings are grouped into two areas:

- ♦ **Technical barriers to compliance:** problems in the test language or design, equipment deficiencies, availability of test equipment, or understanding and experience of technicians performing the tests
- ♦ **Non-technical barriers to compliance:** barriers due to lack of awareness or understanding about the test requirements, lack of enforcement

#### *Technical Barriers to Test Compliance*

The most significant technical barriers to completing the tests are:

- ♦ Poor test design
- ♦ Equipment deficiencies
- ♦ Insufficient contractor training, variations in technician expertise or interpretation
- ♦ Lack of thorough execution in the tests
- ♦ Test forms unclear or require interpretation, lacking clarifying reference information

Of the 48 tests conducted during the field examination, 19 tests passed, and 29 tests failed. This indicates that 60% of the tests were characterized as failures. The 29 failed tests generally fell under one of five identified failure modes: a design or installation issue, outside air percent out of range, sensor calibration, setpoint not set to meet code, or other error. These included problems with the building operation, and problems with the test itself. Detailed testing results (descriptions of failures, and frequency of failure events) can be seen in Table A4 and Figure A1 in the Appendix. We caution that all buildings evaluated in this study were occupied at the time of testing, and so the results may not be perfectly transferable to the typical practice of testing new buildings before occupancy.

These test failures were characterized as due to either a problem with the test itself; or a deficiency in the equipment, setpoint, or design. For example, during MECH-7A (Supply Fan Variable Flow Controls Acceptance), it was observed more than once that there was insufficient time allowed in the test for the system to meet the correct duct static pressure setpoint. In other cases, the system could not meet the duct static pressure setpoint at maximum flow due to system diversity. In these cases, it was unclear whether the test passed or failed; some contractors indicated the test as a “pass” and others as a “fail”. The test should be redesigned to match reasonable system operation in all potential conditions, and clarify confusing situations.

Contractor variation in training, interpretation, and familiarity is another barrier to compliance. Most contractors (7 of 10 interviewed) indicated they were aware of acceptance testing and had performed acceptance testing previously, particularly since 2010 when the 2008 code became effective. Despite having knowledge about the tests and having conducted tests, contractors did not always seem fully comfortable with performing the tests and were typically not aware of reference materials (Chapter 10

of the NRCM, “At-a-Glance” guides, etc.). Contractor expertise varied significantly; contractors who were most experienced with the tests had typically participated in Title 24 training or were test and balance (TAB) contractors who performed similar testing activities in their day-to-day work. Even those contractors who had participated in Title 24 training had not had hands-on training in the acceptance tests themselves. Four of eight building officials interviewed indicated that contractors were often unfamiliar with the forms, so that the forms have to be corrected.

The most frequent examples of poor test execution included verification of sensor calibration, and verification of code compliance (i.e. identification of the static pressure location, setpoint, and reset control to meet the requirements of the standards in MECH-7A). These tasks often required additional work not explicitly addressed in the test forms, such as reviewing design documents, reviewing code requirements, or obtaining factory calibration data. If this information was not readily available it was more likely to be bypassed, not checked, or marked as “N/A”.

The test form language presents a significant opportunity for improvement; in many cases the test language and sequence were unclear to the technician. In interviews, the majority of design engineers (5 of 7 interviewed) and building officials (6 of 8 interviewed) agreed that the form language is often confusing and requires interpretation. When observing tests, the PIER team found that technicians typically did not use reference materials as a tool to completing and clarifying the tests, or were not aware of those materials. In addition, technicians indicated that they only performed acceptance tests that have been identified as being required and are shown on the drawings and compliance forms.

Access to test equipment was not a significant barrier for most contractors observed. However, if a contractor does not have the necessary equipment, it could be cost prohibitive to perform acceptance testing.

### ***Non-technical Barriers to Test Compliance***

The most significant non-technical barriers to completing the tests are:

- ◆ Lack of enforcement by building departments, caused by lack of funding and training
- ◆ Lack of enforcement creating financial disincentives to include tests in contractor bid
- ◆ Lack of coordination or assigned responsibility for tests (“ownership”)
- ◆ Incorrect forms created by building energy software
- ◆ High number of forms, often requiring multiple tests for one system

Building department enforcement of acceptance tests was perhaps the primary barrier to completing and verifying the tests. All building departments interviewed indicated that their departments are underfunded and that, therefore, acceptance testing forms receive inadequate or no review, nor are they prioritized for training. Plans examination is often outsourced. Though enforcement may vary significantly among jurisdictions, even in areas where the acceptance requirements are enforced there is little indication that code officials provide feedback to technicians performing the tests.

The lack of enforcement creates a disincentive for contractors to include acceptance testing in their bid for equipment installation. Even if contractors are aware of the acceptance requirements, they may not include the tests in their pricing in order to remain competitive. On the other hand, contractors who are not as familiar with the acceptance requirements may not plan or budget at all for the tests and therefore may be forced to quickly perform the tests after installation, causing inaccuracy and confusion.

The value of acceptance testing is well-understood; testing is seen as a benefit to ensuring that systems work properly, and is an increased business opportunity for contractors. However, the lack of enforcement means that the tests will not be performed unless explicitly required and planned ahead.

Another barrier is the lack of specific responsibility for who should perform the tests (who “owns” the tests), and which tests should be performed. Contractors indicated that they only performed tests that were explicitly required and shown in the drawings. Review of compliance forms against building documents indicated that compliance software may not always produce the correct acceptance forms. If a test is not explicitly called for by the design engineer and/or software, it may not be performed.

Furthermore, there is often no clear specification of who should complete the tests; depending on the scope it can require a range of contractor specialties (controls, TAB, electrical, equipment representative etc.). The Responsible Person is not specified on the compliance forms (MECH-1C, LTG-1C, ENV-1C). If the Responsible Person is not clearly defined, then all parties may assume the tests are outside their scope of work, and not plan or budget accordingly. It is also difficult to coordinate testing activities among trades. For example, many tests require manipulating of the building DDC (direct digital control) system or other controls systems, requiring that the controls contractor be on site along with the contractor performing the test. It was observed that if the testing contractors could not make the necessary controls adjustments, they either modified the test procedure or marked “N/A” on the form.

Finally, building officials noted the large number of tests and forms is a barrier to ensuring compliance. One HVAC system may require that multiple tests be conducted and that multiple forms be filled out for each test. It may be possible to consolidate tests for similar systems, or recommend tests be performed jointly.

Building owner acceptance did not appear to be a barrier to acceptance testing; building owners interviewed were typically aware of and familiar with acceptance requirements.

### ***Proposed Edits to Acceptance Forms***

All of the acceptance tests that were evaluated have been edited with proposed changes. The intent is to address specific barriers to test interpretation, note supporting documentation and resources, improve clarity, and make tests easier and faster to complete. The revised Nonresidential Appendix testing language is included in the Appendix; the proposed revisions to the Nonresidential Compliance Manual, including revised Certificates of Acceptance and At-a-Glance Guides, will be finalized on a later schedule. Specific improvements to the individual test forms can be seen in the following table.

**Table 1: Specific Proposed Revisions to the Certificates of Acceptance**



Test Name	Revisions to Instructions	Notes
MECH-2A (NA7.5.1 Outdoor Air)	<ul style="list-style-type: none"> <li>▪ Changed the Responsible Person's Declaration Statement to only include Contractor</li> <li>▪ Clarified the intent statement and increased the font size</li> <li>▪ Indicated the test can be performed in conjunction with MECH-7A due to overlapping activities</li> <li>▪ Added reference to supporting documentation including At-A-Glance form</li> <li>▪ Specified sensor calibration should occur in the field either by person performing acceptance test or other</li> <li>▪ Added a notes section</li> <li>▪ Added space to document method used to measure airflow and equipment used.</li> <li>▪ Clarify if system is designed to dynamically control outside air.</li> <li>▪ Include VFD speed at full cooling.</li> <li>▪ Include VFD speed at minimum flow (full heating).</li> <li>▪ Add comment that intent of test is to ensure minimum outside airflow is achieved.</li> </ul>	<p><i>VAV systems with fixed OSA dampers will provide greater OSA air than necessary at full system flow. This scenario should be mentioned in the notes section as this is an energy savings opportunity for the building.</i></p>
MECH-3A (NA7.5.2 Constant Volume Single Zone Unitary Air Conditioner and Heat Pump Systems)	<ul style="list-style-type: none"> <li>▪ Changed Responsible Person's Declaration Statement to include Contractor only</li> <li>▪ Clarified the intent statement and increased the font size</li> <li>▪ Added reference to supporting documentation including At-A-Glance form</li> <li>▪ Added notes section</li> <li>▪ Add space to document method used to measure airflow and equipment used.</li> <li>▪ Add space to document heating/cooling setpoint and deadband.</li> <li>▪ Document pre-occupancy purge method used.</li> <li>▪ Modify sequence of functional testing steps 1-8 and edit table for clarity.</li> <li>▪ Eliminate redundancy in table.</li> </ul>	
MECH-4A (NA7.5.3 Air Distribution Systems)	<ul style="list-style-type: none"> <li>▪ Change mention of U-value to R-value</li> </ul>	
MECH-5A (NA7.5.4 Air Economizer Controls)	<ul style="list-style-type: none"> <li>▪ Changed Responsible Person's Declaration Statement to only include Contractor</li> <li>▪ Clarified the intent statement and increased the font size</li> <li>▪ Added reference to supporting documentation including At-A-Glance form</li> <li>▪ Add reference to 1.2 kOhm resistor under possible equipment needed.</li> <li>▪ Clarify reference to standards manual.</li> </ul>	

Test Name	Revisions to Instructions	Notes
<p>MECH-7A (NA7.5.6 Supply Fan VFD)</p>	<ul style="list-style-type: none"> <li>▪ Required that outside air sensor be field calibrated</li> <li>▪ Changed Responsible Person’s Declaration Statement to include Contractor only</li> <li>▪ Added reference to supporting documentation including At-A-Glance form</li> <li>▪ Add note that MECH-7A can be performed in conjunction with MECH-2A since activities overlap.</li> <li>▪ Additional instrumentation to perform test to include pitot tube and drill.</li> <li>▪ Provided clarification to static pressure sensor location, setpoint, and reset control.</li> <li>▪ Added static pressure design and setpoint value to be recorded and compliance verified.</li> <li>▪ Added static pressure reset sequence clarification.</li> <li>▪ Required field calibration of duct static pressure sensor</li> <li>▪ Added clarification about driving all VAV boxes to full open and included VFD speed.</li> <li>▪ Added comment about diversity in system resulting in static pressure setpoint not being met with all VAV boxes full open.</li> <li>▪ Added clarification to Step 2 regarding driving all VAV boxes to minimum flow (full heating) and added space for VFD speed at this condition.</li> </ul>	
<p>MECH-9A (NA7.5.8 Supply Water Temperature Reset Controls)</p>	<ul style="list-style-type: none"> <li>▪ Changed Responsible Person’s Declaration Statement to include Contractor only</li> <li>▪ Added reference to supporting documentation including At-A-Glance form</li> <li>▪ Clarified the intent statement and increased the font size</li> <li>▪ Added instrumentation to perform test and calibration date</li> <li>▪ Required supply water temperature sensor to be field calibrated</li> <li>▪ Added notes section</li> <li>▪ Revise Step 1 format for clarification.</li> <li>▪ Revise Step 3 title.</li> </ul>	

Test Name	Revisions to Instructions	Notes
<p>MECH-10A (NA7.5.9 Hydronic System Variable Flow Controls)</p>	<ul style="list-style-type: none"> <li>▪ Changed Responsible Person’s Declaration Statement to include Contractor only</li> <li>▪ Added reference to supporting documentation including At-A-Glance form</li> <li>▪ Clarified the intent statement and increased the font size</li> <li>▪ Added instrumentation to perform test and calibration date</li> <li>▪ Provide clarification to static pressure sensor location, setpoint, and reset control requirements.</li> <li>▪ Required supply water pressure sensor to be field calibrated</li> <li>▪ Added notes section</li> <li>▪ Revise Step 1 Minimum/Low Flow Test.</li> <li>▪ Added note for conversion from ft. w.c. to psig.</li> <li>▪ Revised Step 2 Maximum/Design Flow Test</li> </ul>	
<p>LTG-2A (NA7.6.3 Manual Daylighting Control, NA7.6.4 Automatic Time Switch Control)</p>	<ul style="list-style-type: none"> <li>▪ Changed Responsible Person’s Declaration Statement to include Contractor only</li> <li>▪ Improved visibility of Intent section</li> <li>▪ Added reference to supporting documentation including:                             <ul style="list-style-type: none"> <li>▪ As built and/or design documents</li> <li>▪ 2013 Building Energy Efficiency Standards Nonresidential Compliance Manual At-A-Glance</li> <li>▪ 2013 Building Energy Efficiency Standards Manual</li> </ul> </li> <li>▪ Included section to record automatic time switch settings. Provided reference to Certified Appliance and Control Devices database</li> <li>▪ Formatted test to clearly identify separate test procedures</li> <li>▪ Clarified the Manual Daylighting Control functional test: Identify lighting control device types as OS, MDC, and ATSC Identify 2013 Building Energy Efficiency Standards Manual where referenced</li> <li>▪ Added notes section after each functional test</li> <li>▪ Provided clarification for exempt lighting definition</li> </ul>	
<p>LTG-3A (NA7.6.1 Automatic Daylighting Control)</p>	<ul style="list-style-type: none"> <li>▪ Changed Responsible Person’s Declaration Statement to include Contractor only</li> <li>▪ Clarified the section that identifies which test(s) are included in the submittal</li> <li>▪ Edited Construction Inspection:                             <ul style="list-style-type: none"> <li>▪ Add reference to supporting documentation including:                                     <ul style="list-style-type: none"> <li>▪ As built and/or design documents</li> <li>▪ 2013 Building Energy Efficiency Standards Nonresidential Compliance Manual At-A-Glance</li> </ul> </li> </ul> </li> </ul>	<p><i>This test was edited in its entirety to be more understandable and easier to conduct the test.</i></p>

Test Name	Revisions to Instructions	Notes
	<ul style="list-style-type: none"> <li>▪ 2013 Building Energy Efficiency Standards Manual</li> <li>▪ Removed reference to type of control system</li> <li>▪ Changed Y/N responses to check boxes</li> <li>▪ Added definition of open loop and closed loop sensors</li> <li>▪ Added content for clarification</li> <li>▪ Added reference to 2013 Building Energy Efficiency Standards Manual</li> <li>▪ Added reference to CEC website</li> <li>▪ Reorganized test sequence by dimming controls type rather than measurement method used</li> <li>▪ Reformatted each test to be more consistent with other acceptance test forms</li> <li>▪ Provided definition of Illuminance and Distance Methods</li> <li>▪ Changed the test sequence and instructions to be more consistent with At-A-Glance document</li> <li>▪ Changed content of test procedures to allow testing to be completed as outlined in the At-A-Glance document</li> <li>▪ Simplified the test to make it more understandable and easier to follow</li> </ul>	

## 4.2 Energy and Cost Savings

The energy savings from these acceptance requirements are obtained by ensuring that equipment are installed and operate as designed and as specified by code, thereby improving compliance with the code. All tests analyzed in this PIER Study were implemented in previous code adoption cycles, and therefore the energy benefits from these tests have already been considered and accounted for. The revisions proposed as a part of this CASE report will improve compliance with the code, thereby ensuring the energy benefits. However, the energy savings from these acceptance requirements have already been accounted for in previous CASE analyses for prescriptive or performance energy requirements. Therefore, in this report we do not consider any new energy savings from the proposed revisions to the acceptance requirements.

The proposed changes to the acceptance requirements, forms, and code language are not expected to significantly increase the testing time or scope. Therefore, no additional costs are assumed for this measure proposal. In fact, the improvements to test clarity may decrease testing and review time, resulting in cost savings relative to current testing practice.

## 4.3 Cost Effectiveness

The cost-effectiveness of a measure depends on its ultimate life cycle cost. Costs and TDV cost value of life cycle energy savings are compared to determine whether the measure will have total negative life cycle cost (positive savings). Since per-test incremental costs and energy savings are both zero, life-cycle cost will effectively be zero as well.

#### 4.4 Recommended Modeling Approach

No new modeling rules or algorithms are proposed, and no new recommendations are made for the ACM (Alternate Compliance Method) Manual. All of the tests addressed in this proposal are currently implemented via the Nonresidential Compliance Manual, and the energy savings measures accounted for in the Nonresidential ACM.

Interviews indicated that the compliance software does not always generate the proper acceptance forms, leading to confusion about which forms are required and tests not being completed. The CASE Team recommends that the compliance software be evaluated against each acceptance test to determine whether it accurately predicts which tests will be necessary.

Furthermore, the compliance software does not require specification of the Responsible Person for the acceptance requirements on the compliance forms. The CASE Team reiterates the recommendation from the PIER Study that the compliance software require an input for the name of the Responsible Person before producing the compliance and acceptance forms, and that the name of the Responsible Person be printed on the compliance forms. With that in mind, we propose adding language to the Nonresidential Alternative Calculation Method (ACM) Approval Manual and Nonresidential Compliance Forms to ensure that the MECH-1-C, ENV-1-C, and LTG-1-C forms not only specify the required acceptance tests for each building system, but also the Responsible Person approving the test results.

#### 4.5 Statewide Savings Estimates

The total energy and energy cost savings potential for this measure are 0.0 kW/SF, 0.9 kWh/SF, and 0.0 therms/SF. (HMG 2005). Applying these unit estimates to the 2014 statewide estimate of new construction of 183.3 million square feet per year (HMG 2010) results in first year statewide energy savings of 4.6 MW, 165 GWh, and -1.0 MMtherms. Tables 2 and 3 show savings estimates.

Savings are higher than the 2005 estimates due to increased new construction forecasts from 157.4 million square feet in 2005 to 183.3 million square feet in 2014. See the new construction data in Table A5 in Appendix 7.1. Details on the method and data source of the new construction forecast are presented in section 7.3.

**Table 2: Per Square Foot Savings for Acceptance Tests**

Square Foot Savings		
kWh / SF	kW / SF	Therms / SF
0.90	0.03	-0.01

**Table 3: Statewide Savings for Acceptance Tests**

Test	% Fail Rate	2014 Yearly Statewide Savings		
		GWh	MW	MMTherms
NA7.5.1 Outdoor Air	13%	2	-2.3	-0.3
NA7.5.2 CAV Single Zone Unitary AC/HP	14%	8	-3.9	0.0

NA7.5.3 Air Distribution	15%	5	1.8	0.1
NA7.5.4 Economizer Controls	21%	41	0.7	0.0
NA7.5.6 SF Variable Flow	19%	4	1.0	0.0
NA7.5.8 Water Temperature Reset	27%	0	0.0	0.0
NA7.5.9 Hydronic Variable Flow	25%	1	0.1	0.0
NA7.6.1 Automatic Daylighting	11%	6	2.3	0.0
NA7.6.3 Manual Daylighting	16%	7	2.1	-0.1
NA7.6.4 Automatic Time Switch	26%	90	2.7	-0.7
<b>TOTAL</b>		<b>165</b>	<b>4.6</b>	<b>-1.0</b>

## **5. Recommended Language for the Standards Document, Compliance Manual, and the Reference Appendices**

Language recommendations apply to the Nonresidential Standards, the Nonresidential Compliance Manual, the Nonresidential Reference Appendices, and the Nonresidential Certificates of Acceptance.

### **5.1 Standards**

No changes proposed.

### **5.2 Compliance Manual**

Changes to the Compliance Manual and Compliance Forms are under development and will be updated on a later schedule

### **5.3 Reference Appendices**

Proposed changes to the Nonresidential Appendix 7 (NA7) are extensive and are therefore placed at the end of this document as an appendix.

### **5.4 Certificates of Acceptance (Forms)**

We propose changes to the Certificates of Acceptance for the following tests. Draft copies of proposed changes to the Certificates of Acceptance are extensive and attached to this document for review. The final Certificates of Acceptance will be provided on a later schedule consistent with updates to the Compliance Manual.

- ◆ MECH-2A Outdoor Air Acceptance (NA7.5.1)
- ◆ MECH-3A Constant Volume Single Zone Unitary Air Conditioner and Heat Pump Systems (NA7.5.2)
- ◆ MECH-4A Air Distribution Systems (NA7.5.3)
- ◆ MECH-5A Air Economizer Controls Acceptance (NA7.5.4)
- ◆ MECH-7A Supply Fan VFD Acceptance (NA7.5.6)
- ◆ MECH-9A Supply Water Temperature Reset Controls Acceptance (NA7.5.8)
- ◆ MECH-10A Hydronic System Variable Flow Control Acceptance (NA7.5.9)
- ◆ LTG-2A Automatic Time Switch Control Acceptance (NA7.6.4), Manual Daylighting Controls Acceptance (NA7.6.3)
- ◆ LTG-3A Automatic Daylighting Controls Acceptance (NA7.6.1)

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## 7. Appendices

### 7.1 Appendix A: Pier Study Results

**Table A1: PIER Study Participant Building Summary**

Source: Tyler, Farley, & Crowe, 2011

Building #	Climate Zone	Equipment	Acceptance Tests Performed	Did 2005 or 2008 Code Apply?	Were Acceptance Tests Performed Originally?
1	12	Constant Volume AHU Fan Coil Unit Automatic Lighting Controls	MECH-2A MECH-4A MECH-5A LTG-3A	Yes	Unsure. Building was commissioned as part of LEED. Documents were not available for review.
2	12	Constant Volume AHU VAV AHU Exterior lighting on timeclock	MECH-2A MECH-3A MECH-5A MECH-7A OLTG-2A	No	No
3	8	VAV AHU Occupancy sensors	MECH-2A MECH-7A LTG-2A	Yes	No
4	8	Constant Volume AHU	MECH-3A	Yes	No
5	8	VAV AHU	MECH-2A MECH-5A MECH-7A	Yes	No
6	8	VAV AHU	MECH-2A MECH-5A MECH-7A	Yes	No
7	8	VAV AHU	MECH-2A MECH-5A MECH-7A	Yes	Compliance Certificate 1-C shows MECH-2A, 3A, 4A, 5A, 6A, and 8A were completed but no documentation was available for review.
8	8	Central Plant with VAV on each floor Hot water reheat via gas boiler Pneumatic T-stats DDC NOT to zone level	MECH-2A MECH-7A MECH-9A MECH-10A	Yes	Yes
9	8	Central Plant with VAV on	MECH-2A	No	No

		each floor Hot water reheat via gas boiler Pneumatic T-stats DDC NOT to zone level	MECH-7A MECH-9A MECH-10A		
10	12	Automatic Lighting Controls	LTG-3A	No	No
11	12	Central Plant with VAV	Yes	Yes	11

**Table A2: PIER Pre-Site Visit Interview Questions and Responses**

Source: Tyler, Farley, & Crowe, 2011

Question	Aggregate Contractor Responses
<p>Are you familiar with the acceptance requirements in the energy code for certain HVAC and lighting equipment? (Nonresidential Appendix NA7 in Title 24).</p>	<p>Generally the contractors indicated they had heard of the requirements, although there was uncertainty as to when the tests were required. One contractor indicated it would be nice if there was a reference manual to assist with the tests. He was obviously unfamiliar with the 2008 Nonresidential Compliance Manual. The general understanding was that the tests weren't required or at least enforced until recently. One contractor who had been aware of the acceptance tests since 2005 was an exception. He serves on a committee for the CEC and provided input to the development of the acceptance testing forms.</p>
<p>Are you aware of the new tests that were required when the 2008 standards became effective on January 1 this year? If yes, how did you first learn about these new tests?</p>	<p>Most of the contractors were familiar with acceptance testing requirements beginning in January 2010 but were unaware that they had been required since the 2005 code became effective. Some indicated they had learned of the testing requirements through school or classes they were taking through the union. One TAB contractor who knew of the requirements since 2008 was an exception since he had been involved with the CEC and provided input to acceptance testing requirements. He was the only contractors who was aware of any specific differences between 2005 and 2008 versions of acceptance testing requirements.</p>
<p>What is your experience with conducting acceptance tests?</p>	<p>One of the contractors interviewed had significant knowledge about acceptance testing requirements and had conducted several of the tests since they became required. A majority of the other contractors indicated they had some exposure to the tests, either through a class or actually performing the tests, but this usually consisted of only a few of the tests. One contractor was completely unfamiliar with the tests.</p>
<p>Do you find the acceptance requirements clear and easy to understand? If not, what is not clear?</p>	<p>The answer to this question was typically yes, but it was clear after performing the tests that the contractor was not clear about when the tests need to be performed. Contractors rely on the design documents to determine what tests and forms are necessary. If the drawings don't show that the forms are necessary they don't get performed. It was understood that identifying the specific tests to perform is the responsibility of the engineer.</p>
<p>Do you find the acceptance</p>	<p>Most contractors answered yes to this question. But it was clear after</p>

<p>testing forms clear and easy to follow? If not, what is not clear.</p>	<p>performing the tests that there were many examples of the tests not being clear and resulting in confusion by the contractor. It appeared that the contractor prepared for the field survey by reviewing the forms and felt they were pretty clear.</p>
<p>How often do you perform acceptance testing?</p>	<p>Most indicated they have been performing the tests more often recently, primarily since early 2010. One contractor indicated they perform them on most jobs and he has become quite familiar with the tests. A majority of the other contractors indicated they perform a few tests per month and have since early 2010. One contractor had never performed the tests.</p>
<p>Which of the following tests have you done?</p>	<p>The only tests that contractors indicated they perform are MECH-2A, MECH-3A, MECH-5A, MECH-7A, and LTG-2A.</p>
<p>In general, how often do the tests fail the first time?</p>	<p>Most of the contractors indicated the tests don't fail and they typically pass. In addition, they suggested it was easy to get them to pass when they otherwise may fail. For example, by marking "NA" on a question they technically pass. There is room for interpretation by the technician on the test. One contractor indicated the tests pass the first time 20% of the time, but it appeared they would resolve the issues before submitting the forms to the building department. This is of course the preferred course of action; otherwise the building is not allowed to receive the Certificate of Occupancy.</p>
<p>What are the most common problems (why the test fails)?</p>	<p>Tests sometimes fail because equipment wasn't set up properly. Jobs are being priced so competitively that the quality of installation and startup is poor. Other common failure modes were indicated as problems with controls, controls sequences, and lack of commissioning. Limitations of the equipment was indicated as a cause for failure, such as outside air not being able to vary with supply air of a VAV system.</p>
<p>Do you have the test equipment required to perform the tests? If not, what do you need?</p>	<p>Most of the contractors said they had all or almost all of the required equipment. One of the service contractors said he had limited equipment and purchased a calibrated pressure gauge the day before the test. The TAB contractors typically had the most equipment. Only contractors that performed duct leakage testing or HERS testing had a duct leakage tester. It was indicated that the equipment is expensive and therefore cost prohibitive for some of the contractors.</p>
<p>How much time is required to perform the tests?</p>	<p>The answers varied from six hours to complete all of the tests to 25% of the total time on a job. One contractor suggested the time it takes to complete the tests is however long it takes to fill them out and sign them. This particular technician conducted the test quickly and missed significant content in the tests.</p>
<p>Do the building departments require completed acceptance testing documentation before issuing a certificate of occupancy?</p>	<p>The contractors indicated that building departments in certain jurisdictions request completed acceptance tests. The two cities that required the forms are Sacramento and Irvine. Contractors indicated there was low or no enforcement in the other cities where they performed work.</p>
<p>After you submit the acceptance</p>	<p>Contractors answered no. One contractor indicated if a form is</p>

documents to the building departments, do they ever contact you again needing anything else	incomplete the city kicked it back but generally the answer to this question was overwhelmingly no.
If you would use an alternate procedure, describe why. For example, it is faster, easier, requires no specialized test equipment, and/or results in a more effective test.	Equipment start-up documentation was mentioned as an alternative to performing acceptance tests. Contractors typically have standardized start-up documentation based on equipment type that they use to functionally test equipment. NEBB and TABB forms are used by TAB contractors. In general the techs liked the acceptance forms and thought they were a combination of TAB and equipment startup documentation
Do you typically include performing acceptance tests in your scope when preparing a bid?	Three contractors indicated they include performing acceptance testing into their bid. It was mentioned that to remain competitive in the bidding process acceptance testing would only be included if it was required or other contractors were including it. Unless it was indicated on the design documents that acceptance testing was required it typically isn't included in the bid. Including it in the bid is more common now. One of the more experienced techs suggested that the cover sheet of the form that states "I certify under penalty of perjury" is effective at ensuring the tests are included in the scope of work and filled out properly.
Is the additional cost of performing acceptance tests significant in your opinion?	Most of the contractors felt it was significant. For one reason in order to comply with the tests some jobs may incur an expense in order to comply with the tests. They added credibility to meeting code requirements. Most felt it was significant mainly because of the time involved in performing the tests. One felt the only additional time was literally filling out the forms and signing them. Any additional cost can be significant in a competitive bidding process. It could affect winning a job or not.
In your opinion what percent of contractors are currently including acceptance testing in their bids and performing the tests?	This depends on the jurisdiction. In high compliance rate districts, 80% or more are including acceptance tests in their bids. In other jurisdictions it is 0%. All but one contractor felt it was very low.
In your opinion what percent of contractors are currently performing acceptance testing as an afterthought, i.e. not included in bid but scrambling to comply with Title 24?	Not all contractors answered this question, but one who did suggested all contractors are currently performing acceptance testing as an afterthought.
Do the inspectors verify any of the acceptance testing results onsite?	Most felt they never verify results on site. One answered yes and indicated it was to verify an airflow requirement.
What is your or your company's	All companies were supportive of the tests. They felt it leads to more

<p>attitude about the acceptance requirements? (not beneficial to owner, relatively beneficial, highly beneficial, leads to more work/money, indifferent).</p>	<p>work and adds credibility to their work. The general feeling was there is benefit to performing the tests, but unless they're enforced and everyone does them, they may not perform them in order to remain competitive in bidding.</p>
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**Table A3: PIER Post-Site Visit Interview Questions and Responses**

Source: Tyler, Farley, & Crowe, 2011

Question	Aggregate Contractor Responses
<p>Were there any problems completing the acceptance tests? If so, what was the problem and how was it resolved?</p>	<p>Problems found during the tests included broken equipment, sequences not functioning properly, and sensors out of calibration.</p> <p>Problems conducting the tests included lack of proper documentation (i.e. design documents, standards manual, compliance manual), confusing test language, building occupancy that prevented tests in certain areas from being performed, and difficulties accurately measuring outside air.</p> <p>A problem identified by multiple contractors was found while performing MECH-7A, Supply Fan VFD Acceptance. The test required driving all VAV boxes to design airflow. If this was interpreted as max airflow, the static pressure setpoint could not be achieved because the system wasn't designed to provide maximum airflow at any one time. System diversity must be considered in order to achieve design static pressure setpoint.</p> <p>Coordination with the controls contractor and other trades was also a significant hurdle.</p>
<p>Describe any issues with the systems being tested that were not addressed by the acceptance test documents.</p>	<p>MECH-5A requires heating to be disabled while in economizer mode. This did not occur in systems with hot water heating. Therefore this question in NA. Heating can operate simultaneously since it's not controlled by the air handler. The test is intended for a packaged AHU with integrated heating, not a boiler loop.</p> <p>MECH-2A doesn't consider variation in outside airflow resulting from a fixed outside air damper position in a VAV system. This will cause the test to fail every time (false negative).</p> <p>MECH-7A describes putting the VAV system into design airflow and verifying the static pressure setpoint is met. It is difficult to attain design airflow, and proved to be much easier to put the system into full cooling to achieve the desired results. But doing so resulted in the static pressure setpoint not being met. This will always be the case in a VAV system due to system diversity, which is the design consideration that the whole building will never be in a full cooling condition.</p>
<p>How did they affect the completion of the tests?</p>	<p>The result would be either the test would pass when it should have failed (false positive) or it would fail when it should have passed (false negative).</p>
<p>Which of the following documents would you most</p>	<p>The technician most familiar with the tests indicated he would use all of</p>

Question	Aggregate Contractor Responses
<p>likely use to complete the tests? Certificate of Acceptance Forms (Nonresidential Compliance Manual, Chapter 10.9 and Appendix A) At-a-glance (Nonresidential Compliance Manual, chapters 10.7-10.8). Sample test procedure (Nonresidential Compliance Manual, Chapters 10.7-10.8).</p>	<p>Chapter 10 in the compliance manual. Most of the contractors were not familiar with these documents. They didn't have them during the test. Two of seven had the documents on hand.</p>
<p>What sections (if any) of these documents did you find confusing?</p>	<p>One contractor indicated that the forms are a big improvement over the 2005 forms. They are clearer now. Some discrepancies were noted between the tests and the At-A-Glance forms.</p>
<p>What are some barriers to effectively completing the acceptance tests and forms?</p>	<p>Not having access to the proper building documentation including design documents, or as-builts. Not having reference documents on hand such as the compliance manual and standards manual. Not having building staff available. Not having DDC contractor available. Also, sections within each test that didn't apply to the specific system being tested resulted in NA being answered on the test but resulted in lost credibility in the test. It's easy to write NA in a specific section since there is some subjectivity to some of the questions.</p>
<p>Is there anything extra on the acceptance testing forms that is not needed to assure the test is completed correctly?</p>	<p>MECH-3A has a redundancy in the checklist where it refers to no heating, no cooling, and no heating or cooling. The headings of each test have redundant project information. It's not necessary to write this information on every page.</p>
<p>Is there anything missing from the acceptance testing forms that is needed to assure the test is completed correctly?</p>	<p>Full reference to the standards manual rather than just a section number is needed. It's confusing to only reference a section out of the standards manual or compliance manual. Most of the technicians interviewed were not familiar with these documents. MECH-7A needs a location to record the drive speed. In general there should be a location to record specific system parameters on all forms for future reference. It provides a good baseline of system performance. These documents could be useful if they could be referenced later for this performance baseline information. Calibration date of equipment should also be added to all forms. It was recommended that MECH-2A be more specific about the method used to calibrate the outside airflow. There is large variation between contractors on how they measure airflow and there needs to be better accountability of the method used.</p>
<p>How could the procedures be improved?</p>	<p>Improve the Intent Section of each test to make it stand out more. References to other documents is vague and confusing. One of the techs commented that the reference to the At-A-Glance forms was confusing and he didn't know what it was. Be more specific on questions to document system performance. For example, MECH-5A should require documenting actual damper</p>

Question	Aggregate Contractor Responses
	<p>position rather than just referring to 'minimum position'. On MECH-2A document damper position and static pressure.</p> <p>Organize test procedures in a more effective manor. The tests jump around a lot and are confusing. For example MECH-3A part A. Re-organize sequence of activities to prevent having to go from occupied to unoccupied repeatedly. Errors and misprints on the forms also make them confusing.</p>
<p>If you (contractor) had previously attended training by utilities or SMACNA, did the training prepare you adequately for performing the test?</p>	<p>Training was indicated to have been provided by SMACNA and NEBB. One contractor indicated he had received general Title 24 training but it didn't cover acceptance testing specifically.</p> <p>Five of nine contractors indicated they haven't received any training and of those that did receive training only one said it was relevant to acceptance tests.</p>
<p>Would you prefer in-person training or print/online materials?</p>	<p>Of those who answered this question, three preferred in person training and two preferred on line training. It was suggested that on line training is better suited to technicians with some experience performing the tests. In person training was indicated as being more effective.</p>
<p>What improvements would you suggest for training?</p>	<p>Training should include hands on training and should be specific to acceptance testing. Classes geared specifically for technicians and focused on HVAC units was mentioned. One of the contractors recommended there be a certification process for performing acceptance tests. Access to a technical resource to bounce questions off would be helpful. Also access to literature that provided support for performing testing would be desirable.</p>
<p>Do you have any further comments about the tests?</p>	<p>Add references to supporting material to the tests. The tests should provide reference to the CEC website. The testing was thought of as a good thing. It keeps contractors honest, saves energy, and ensures customers get what they pay for. One technician commented that after performing the tests he could perform future tests much easier and quicker.</p>



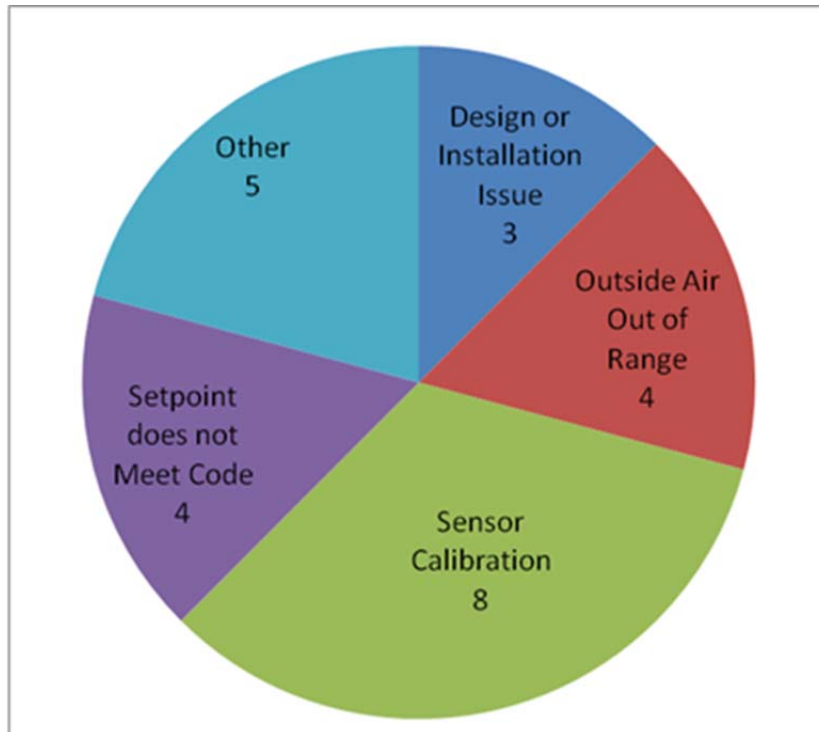
**Table A4: Description of Failure Modes**

Source: Tyler, Farley, &amp; Crowe, 2011

Failure Mode	Acceptance Test(s)	Examples of Failure Root Cause(s)	Correct Diagnosis ?
<b>Design/Installation Issue</b>	<b>LTG-3A</b>	Photocell sensors installed outside the controlled zone	Yes
		Controlled light fixtures outside of the daylit zone	Yes
<b>Outside Air Out of Range</b>	<b>MECH-2A</b>	Broken damper linkage.	Yes
		Incorrect measurement due to quality of equipment or technician experience. For example, the mechanical start-up technician utilized a less expensive airflow measuring device than the TAB contractor. This device was less accurate, and the technique they used allowed for a significant variation in their measurements.	No
		Equipment unable to achieve the test condition	No
<b>Sensor Calibration</b>	<b>MECH-7A</b>	Duct static pressure sensors used to control supply fan speed out of calibration	Yes
	<b>LTG-3A</b>	Photocell dimming sensors used to dim lighting in daylit zones out of calibration. Sensors were approximately 5 years old and it was indicated they had never worked properly.	Yes
<b>Setpoint Not Meeting Code</b>	<b>MECH-3A</b>	Economizer lockout temperature and enthalpy do not meet code based on climate zone	Yes
	<b>MECH-5A</b>	Supply fan operation was found to not be continuous as required by code	Yes
<b>Other</b>	<b>MECH-7A</b>	Static pressure setpoint not met at design airflow. This was commonly tested by driving all VAV boxes to full cooling. Doing this always resulted in the fan being unable to maintain the static pressure setpoint so the test will always fail.	No
	<b>MECH-7A, MECH-10A</b>	Stabilization time to reach setpoint exceeded 5 minutes with DDC controls. This time is dependent on the DDC programming and not always achievable.	No

**Figure A1: Failures of Acceptance Tests Identified by their Root Cause**

Source: Tyler, Farley, & Crowe, 2011



**Table A5: Statewide New Construction Estimates, All Building Types, 2014**

Source: NonRes Construction Forecast by BCZ v7, HMG 2010

New Construction	
CZ	MSF
1	0.44
2	4.03
3	15.95
4	10.00
5	1.94
6	14.99
7	19.63
8	18.12
9	36.15
10	10.47
11	5.31
12	27.52
13	12.38

14	2.40
15	0.99
16	2.99
<b>TOTAL</b>	<b>183.33</b>

## 7.2 Appendix B: Proposed Changes to Appendix NA7 – Acceptance Requirements for Nonresidential Buildings

Proposed additions are underlined.

Proposed deletions are ~~struck out~~.

### **Nonresidential Appendix NA7**

## Appendix NA7 – Acceptance Requirements for Nonresidential Buildings

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### **NA7.1 Purpose and Scope**

This appendix defines acceptance procedures that must be completed on certain controls and equipment before the installation is deemed to be in compliance with the Standards. These requirements apply to all newly installed equipment for which there are acceptance requirements in new and existing buildings. The procedures apply to nonresidential, high-rise residential and hotel/motel buildings as defined by the California Energy Commission's Energy Efficiency Standards for Nonresidential Buildings (Standards).

The purpose of the acceptance tests is to assure:

1. The presence of equipment or building components according to the specifications in the compliance documents.
2. Installation quality and proper functioning of the controls and equipment to meet the intent of the design and the Standards.

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### **NA7.2 Introduction**

Acceptance requirements are defined as implementation of targeted inspection checks and functional and performance testing to determine whether specific building components, equipment, systems, and interfaces between systems conform to the criteria set forth in the Standards and to related construction documents (plans or specifications). Acceptance requirements improve code compliance effectiveness and help meet the expected level of performance.

Prior to signing a Certificate of Acceptance, the installing contractor, ~~engineer of record or owner's agent~~ shall be responsible for reviewing the plans and specifications to assure they conform to the acceptance requirements. Persons eligible to sign the Certificate of Acceptance are those who are (1) responsible for its preparation and (2) licensed in the State of California as a civil engineer, mechanical engineer, licensed architect or a licensed contractor performing the applicable work or a person managing work on a structure or type of work described pursuant to Business and Professions Code sections 5537, 5538, and 6737.1.

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### **NA7.3 Responsible Party**

The installing responsible party shall certify compliance with the acceptance requirements. They shall be responsible for performing data analysis, calculation of performance indices, and crosschecking results with the requirements of the Standards. They shall be responsible for issuing a Certificate of Acceptance as well as copies of all measurement and monitoring results for individual test procedures to the enforcement agency. The

enforcement agency shall not release a final Certificate of Occupancy until a Certificate of Acceptance, and all applicable acceptance requirements for code compliance forms, are approved and submitted by the responsible party. A responsible party ~~who is licensed~~ shall record their State of California contractor's license number ~~or their State of California professional registration license number~~ on each Certificate of Acceptance that they issue.

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## **NA7.4 Building Envelope Acceptance Tests**

### NA7.4.1 Fenestration

Each fenestration product shall have either an NFRC Label Certificate or the Commission's Fenestration Certificate, FC-1 or FC-2, to identify the thermal performance (e.g. U-factor, SHGC) of each fenestration product being installed. The labels shall be located at the job site for verification by the enforcement agency. In addition, the responsible party shall fill out the Fenestration Acceptance Certificate. The responsible party shall verify the thermal performance of each specified fenestration product being installed and shall ensure that it matches the label certificate, energy compliance documentation and building plans. A copy of the certificate shall be given to the building owner and the enforcement agency for their records.

#### **NA7.4.1.1 Elements Requiring Verification:**

The responsible party shall verify the following:

1. The thermal performance for each fenestration product matches the building plans, energy compliance documentation, and the label certificate,
2. The delivery receipt or purchase order matches the delivered fenestration product(s).
3. Verify the NFRC Label Certificate is filled out and includes an NFRC's Certified Product Directory (CPD) number or that the FC-1 or FC-2 matches the purchase order or detailed receipt.
4. The Certificate of Acceptance form is completed and signed.

#### **NA7.4.1.2 Required Documentation**

- NFRC Product Label Certificate:
  - The label can list a single or multiple fenestration products, each with its own CPD number. The CPD number for each fenestration product" can be verified for authenticity by accessing [www.NFRC.org](http://www.NFRC.org), Certified Product Database; or
- Commission's Fenestration Label Certificate:
  - The FC-1 and FC-2 are used to document products not certified by NFRC by using the Commission's Default Table values in §116 or the Alternate Default Fenestration Thermal Performance method as described in Appendix NA6.
    - FC-1 is used for vertical fenestration 10,000 ft<sup>2</sup> or greater and is only limited to the Energy Commission's Default Values found in Standards Table 116-A and Table 116-B or;
    - FC-2 is used for vertical fenestration less than 10,000 ft<sup>2</sup> and may use either the Energy Commission's Default Table Values found in Standards Table 116-A and Table 116-B or may use the Alternate Default Fenestration Thermal Performance procedures described in Appendix NA6.
- Purchase Order or Receipt:
  - A copy of the purchase order or a detailed payment receipt shall be used to cross reference with the NFRC Product Label Certificate CPD number or the FC-1 or FC-2 values; and
  - The purchase order or a detailed payment receipt should match the energy compliance documentation and the building plans.
- Fenestration Building Plans:

- The building plans shall list in a schedule each fenestration product to be installed in the building.
- Certificate of Acceptance Form:
  - The acceptance form must be filled out by the responsible party and signed.
  - The signed Certificate of Acceptance shall be submitted to enforcement agency or field inspector.
  - A copy of the Certificate of Acceptance shall be given to the building owner.

### **NA7.5 Mechanical Systems Acceptance Tests**

#### NA7.5.1 Outdoor Air (Certificate of Acceptance Form MECH-2A)

##### **NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance**

###### **NA7.5.1.1.1 Construction Inspection**

Prior to functional testing, verify and document the following:

- ~~System controlling outside airflow was calibrated either in the field or factory.~~ Sensor used to control outdoor air flow is either factory calibrated or field calibrated.
- Attach calibration certification or results.
- Dynamic damper control is being used to control outside air.
- Specify the type of dynamic control being utilized to control outside air.
- Specify the method of delivering outside air to the unit.
- Pre-occupancy purge has been programmed for the 1-hour period immediately before the building is normally occupied.

###### **NA7.5.1.1.2 Functional Testing**

Step 1: If the system has an outdoor air economizer, force the economizer high limit to disable economizer control (e.g. for a fixed drybulb high limit, lower the setpoint below the current outdoor air temperature)

Step 2: ~~Adjust supply air to either the sum of the minimum zone airflows or 30 percent of the total design airflow~~ achieve design airflow or maximum airflow at full cooling. Verify and document the following:

- Measured outside airflow reading is within 10 percent of the total ventilation air called for in the Certificate of Compliance.
- ~~OSA~~ Outside air damper position controls stabilizes within 5 minutes.

Step 3: ~~Adjust supply airflow to achieve design airflow either the sum of the minimum zone airflows, full heating, or 30 percent of the total design airflow.~~ Verify and document the following:

- Measured outside airflow reading is within 10 percent of the total ventilation air called for in the Certificate of Compliance.
- ~~OSA~~ Outside air damper position controls stabilizes within 5 minutes.

Step 4: Restore system to "as-found" operating conditions

##### **NA7.5.1.2 Constant Volume System Outdoor Air Acceptance (Certificate of Acceptance Form MECH-2A)**

###### **NA7.5.1.2.1 Construction Inspection**

Prior to Functional Testing, verify and document the following:

- System is designed to provide a fixed minimum OSA when the unit is on.
- Specify the method of delivering outside air to the unit.
- Pre-occupancy purge has been programmed for the 1-hour period immediately before the building is normally occupied.
- Minimum position is marked on the outside air damper.
- The system has means of maintaining the minimum outdoor air damper position.

#### **NA7.5.1.2.2 Functional Testing**

Step 1: If the system has an outdoor air economizer, force the economizer to the minimum position and stop outside air damper modulation (e.g. for a fixed drybulb high limit, lower the setpoint below the current outdoor air temperature).

- Measured outside airflow reading is within 10 percent of the total ventilation air called for in the Certificate of Compliance.

#### **NA7.5.2 Constant-Volume, Single-Zone, Unitary Air Conditioners and Heat Pumps (Certificate of Acceptance Form MECH-3A)**

##### **NA7.5.2.1 Construction Inspection**

Prior to Functional Testing, verify and document the following:

- Thermostat is located within the space-conditioning zone that is served by the HVAC system.
- Thermostat meets the temperature adjustment and dead band requirements of Standards §122(b).
- Occupied, unoccupied, and holiday schedules have been programmed per the facility's schedule.
- Pre-occupancy purge has been programmed to meet the requirements of Standards §121(c)2.

##### **NA7.5.2.2 Functional Testing**

Step 1: Disable economizer and demand control ventilation systems (if applicable).

Step 2: Simulate a heating demand during the occupied condition. Verify and document the following:

- Supply fan operates continually.
- The unit provides heating.
- No cooling is provided by the unit.
- Outside air damper is at minimum position.

Step 3: Simulate operation in the dead band during occupied condition. Verify and document the following:

- Supply fan operates continually.
- Neither heating nor cooling is provided by the unit.
- Outside air damper is at minimum position.

Step 4: Simulate cooling demand during occupied condition. Lock out economizer (if applicable). Verify and document the following:

- Supply fan operates continually.
- The unit provides cooling.
- No heating is provided by the unit.

- Outside air damper is at minimum position.

Step 5: Simulate operation in the dead band during unoccupied mode. Verify and document the following:

- Supply fan is off.
- Outside air damper is fully closed.
- Neither heating nor cooling is provided by the unit.

Step 6: Simulate heating demand during unoccupied conditions. Verify and document the following:

- Supply fan is on (either continuously or cycling).
- Heating is provided by the unit.
- No cooling is provided by the unit.
- Outside air damper is either closed or at minimum position.

Step 7: Simulate cooling demand during unoccupied condition. Lock out economizer (if applicable). Verify and document the following:

- Supply fan is on (either continuously or cycling).
- Cooling is provided by the unit.
- No heating is provided by the unit.
- Outside air damper is either closed or at minimum position.

Step 8: Simulate manual override during unoccupied condition. Verify and document the following:

- System operates in “occupied” mode.
- System reverts to “unoccupied” mode when manual override time period expires.

Step 9: Restore economizer and demand control ventilation systems (if applicable), and remove all system overrides initiated during the test.

### NA7.5.3. Air Distribution Systems (Certificate of Acceptance Form MECH-4A)

#### **NA7.5.3.1 Construction Inspection**

Prior to Functional Testing on new duct systems, verify and document the following:

- Duct connections meet the requirements of §124
- Specify choice of drawbands.
- Flexible ducts are not ~~compressed~~ constricted in any way.
- ~~Ducts are fully accessible for testing~~
- Duct leakage tests to be performed before access to ductwork and connections are blocked.
- Joints and seams are properly sealed according to the requirements of §124.
- Joints and seams are not sealed with cloth back rubber adhesive tape unless used in combination with Mastic and drawbands. Cloth backed tape may be used if tape has been approved by the CEC. Ducts are fully accessible for testing.
- ~~Insulation R-Values meet the minimum requirements of §124(a).~~
- Duct R-values are verified R-8 in non-conditioned spaces
- Insulation is protected from damage and suitable for outdoor service if applicable per §124(f)



- A sticker has been affixed to the exterior surface of the air handler access door.

Prior to Functional Testing on all new and existing duct systems, visually inspect to verify that the following locations have been sealed:

- Connections to plenums and other connections to the forced air unit
- Refrigerant line and other penetrations into the forced air unit
- Air handler door panel (do not use permanent sealing material, metal tape is acceptable)
- Register boots sealed to surrounding material
- Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes

Prior to Functional Testing on all new and existing duct systems, visually inspect to verify that portions of the duct system that are excessively damaged have been replaced. Ducts that are considered to be excessively damaged are:

- Flex ducts with the vapor barrier split or cracked with a total linear split or crack length greater than 12 inches
- Crushed ducts where cross-sectional area is reduced by 30 percent or more
- Metal ducts with rust or corrosion resulting in leaks greater than 2 inches in any dimension
- Ducts that have been subject to animal infestation resulting in leaks greater than 2 inches in any dimension

#### **NA7.5.3.2 Functional Testing**

Step 1: Perform duct leakage test per Reference Nonresidential Appendix NA2. Certify the following:

- Duct leakage conforms to the requirements of §144(k) and §149(b)1D.

Step 2: Obtain HERS Rater field verification as required by Reference Nonresidential Appendix NA1.

#### NA7.5.4 Air Economizer Controls (Certificate of Acceptance Form MECH-5A)

##### **NA7.5.4.1 Construction Inspection**

Prior to Functional Testing, verify and document the following:

- Economizer lockout setpoint complies with Table 144-C of Standards §144(e)3.
- Economizer lockout control sensor is located to prevent false readings.
- Unitary systems with an economizer have control systems, including two-stage or electronic thermostats, that cycle compressors off when economizers can provide partial cooling
- Economizer reliability features are present per Standards Section 144(e)4.
- System is designed to provide up to 100 percent outside air without over-pressurizing the building.
- For systems with DDC controls lockout sensor(s) are either factory calibrated or field calibrated.
- For systems with non-DDC controls, manufacturer's startup and testing procedures have been applied

##### **NA7.5.4.2 Functional Testing**

Step 1: Disable demand control ventilation systems (if applicable).

Step 2: Enable the economizer and simulate a cooling demand large enough to drive the economizer fully open. Verify and document the following:

- Economizer damper is 100 percent open.

- Return air damper is 100 percent closed.
- For systems that meet the criteria of Standards §144(e)1, verify that the economizer remains 100 percent open with the use of mechanical cooling. This occurs when the cooling demand can no longer be met by the economizer alone.
- All applicable fans and dampers operate as intended to maintain building pressure.
- The unit heating is disabled (if applicable).

Step 3: Disable the economizer and simulate a cooling demand. Verify and document the following:

- Economizer damper closes to its minimum position.
- All applicable fans and dampers operate as intended to maintain building pressure.
- The unit heating is disabled (if applicable).

Step 4: If the unit is equipped with heating, simulate a heating demand and set the economizer so that it is capable of operating (i.e. actual outdoor air conditions are below lockout setpoint). Verify the following:

- The economizer is at minimum position

Step 5: Restore demand control ventilation systems (if applicable) and remove all system overrides initiated during the test.

#### NA7.5.5 Demand Control Ventilation (DCV) Systems (Certificate of Acceptance Form MECH-6A)

##### **NA7.5.5.1 Construction Inspection**

Prior to Functional Testing, verify and document the following:

- Carbon dioxide control sensor is factory calibrated or field-calibrated per §121(c)4.
- The sensor is located in the high density space between 3ft and 6 ft above the floor or at the anticipated level of the occupants' heads.
- DCV control setpoint is at or below the CO<sub>2</sub> concentration permitted by §121(c)4C.

##### **NA7.5.5.2 Functional Testing**

Step 1: Disable economizer controls

Step 2: Simulate a signal at or slightly above the CO<sub>2</sub> concentration setpoint required by §121(c)4C. Verify and document the following:

- For single zone units, outdoor air damper modulates open to satisfy the total ventilation air called for in the Certificate of Compliance.
- For multiple zone units, either outdoor air damper or zone damper modulate open to satisfy the zone ventilation requirements.

Step 3: Simulate signal well below the CO<sub>2</sub> setpoint. Verify and document the following:

- For single zone units, outdoor air damper modulates to the design minimum value.
- For multiple zone units, either outdoor air damper or zone damper modulate to satisfy the reduced zone ventilation requirements.

Step 4: Restore economizer controls and remove all system overrides initiated during the test.

Step 5: With all controls restored, apply CO<sub>2</sub> calibration gas at a concentration slightly above the setpoint to the sensor. Verify that the outdoor air damper modulates open to satisfy the total ventilation air called for in the Certificate of Compliance.

NA7.5.6 Supply Fan Variable Flow Controls (Certificate of Acceptance Form MECH-7A)

**NA7.5.6.1 Construction Inspection**

Prior to Functional Testing, verify and document the following:

- Discharge static pressure sensors are either factory calibrated or field-calibrated.
- The static pressure location, setpoint, and reset control meets the requirements of §144(c)2C and §144(c)2D.

**NA7.5.6.2 Functional Testing**

Step 1: Simulate demand for full design airflow. Verify and document the following:

- Supply fan controls modulate to increase capacity.
- Supply fan maintains discharge static pressure within +/-10 percent of the current operating set point.
- Supply fan controls stabilize within a 5 minute period.

Step 2: Simulate demand for reduced or minimum airflow. Verify and document the following:

- Supply fan controls modulate to decrease capacity.
- Current operating setpoint has decreased (for systems with DDC to the zone level).
- Supply fan maintains discharge static pressure within +/-10 percent of the current operating setpoint.
- Supply fan controls stabilize within a 5 minute period.

Step 3: Restore system to correct operating conditions

NA7.5.7 Valve Leakage Test (Certificate of Acceptance Form MECH-8A)

**NA7.5.7.1 Construction Inspection**

Prior to Functional Testing, verify and document the following:

- Valve and piping arrangements were installed per the design drawings.

**NA7.5.7.2 Functional Testing**

Step 1: For each of the pumps serving the distribution system, dead head the pumps using the discharge isolation valves at the pumps. Document the following:

- Record the differential pressure across the pumps
- Verify that this is within 5 percent of the submittal data for the pump

Step 2: Reopen the pump discharge isolation valves. Automatically close all valves on the systems being tested. If 3-way valves are present, close off the bypass line. Verify and document the following:

- The valves automatically close.
- Record the pressure differential across the pump
- Verify that the pressure differential is within 5 percent of the reading from Step 1 for the pump that is operating during the valve test.

Step 3: Restore system to correct operating conditions.

### NA7.5.8 Supply Water Temperature Reset Controls (Certificate of Acceptance Form MECH-9A)

#### **NA7.5.8.1 Construction Inspection**

Prior to Functional Testing, verify and document the following:

- Supply water temperature sensors have been either factory or field calibrated.

#### **NA7.5.8.2 Functional Testing**

Step 1: Change reset control variable to its maximum value. Verify and document the following:

- Chilled or hot water temperature setpoint is reset to appropriate value.
- Verify that actual temperature changes to within 2 percent of the new setpoint.

Step 2: Change reset control variable to its minimum value. Verify and document the following:

- Chilled or hot water temperature setpoint is reset to appropriate value.
- Verify that actual system temperature changes to within 2 percent of the new setpoint.

Step 3: Restore reset control variable to automatic control. Verify and document the following:

- Chilled or hot water temperature set-point is reset to appropriate value.
- Actual supply temperature changes to meet setpoint.
- Actual supply temperature changes to within 2 percent of the new setpoint.

### NA7.5.9 Hydronic System Variable Flow Controls (Certificate of Acceptance Form MECH-10A)

#### **NA7.5.9.1 Construction Inspection**

Prior to Functional Testing, verify and document the following:

- The static pressure location, setpoint, and reset control meets the requirements of the Standards Section 144.2C.
- Pressure sensors are field calibrated.

#### **NA7.5.9.2 Functional Testing**

Step 1: Modulate coil control valves to reduce water flow to a maximum of 50 percent of the design flow. Verify and document the following:

- Pump operating speed decreases (for systems with DDC to the zone level).
- Current operating setpoint has not increased (for all other systems that are not DDC).
- System pressure is within 5 percent of current operating setpoint.
- System operation stabilizes within 5 minutes after test procedures are initiated.

Step 2: Open control valves to increase water flow to a minimum of 90 percent design flow. Verify and document the following:

- Pump speed increases.
- Pumps are operating at 100 percent speed.
- System pressure is greater than the setpoint in Step 1.
- System pressure is within  $\pm 5$  percent of current operating setpoint.

- System operation stabilizes within 5 minutes after test procedures are initiated.

Step 3: Restore system to correct operating conditions.

NA7.5.10 Automatic Demand Shed Control Acceptance (Certificate of Acceptance Form MECH-11A)

**NA7.5.10.1 Construction Inspection**

Prior to Acceptance Testing, verify and document the following:

- That the EMCS interface enables activation of the central demand shed controls.

**NA7.5.10.2 Functional Testing**

Step 1: Engage the global demand shed system. Verify and document the following:

- That the cooling setpoint in non-critical spaces increases by the proper amount.
- That the cooling setpoint in critical spaces do not change.

Step 2: Disengage the global demand shed system. Verify and document the following:

- That the cooling setpoint in non-critical spaces return to their original values.
- That the cooling setpoint in critical spaces do not change.

NA7.5.11 Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion Units (Certificate of Acceptance Form MECH-12A)

**NA7.5.11.1 Construction Inspection**

Verify FDD hardware is installed on equipment by the manufacturer and that equipment make and model include factory-installed FDD hardware that match the information indicated on copies of the manufacturer's cut sheets and on the plans and specifications.

Eligibility Criteria

A fault detection and diagnostics (FDD) system for direct-expansion packaged units shall contain the following features to be eligible for credit in the performance calculation method:

1. The unit shall include a factory-installed economizer and shall limit the economizer deadband to no more than 2°F.
2. The unit shall include direct-drive actuators on outside air and return air dampers.
3. The unit shall include an integrated economizer with either differential dry-bulb or differential enthalpy control.
4. The unit shall include a low temperature lockout on the compressor to prevent coil freeze-up or comfort problems.
5. Outside air and return air dampers shall have maximum leakage rates conforming to ASHRAE 90.1-2004.
6. The unit shall have an adjustable expansion control device such as a thermostatic expansion valve (TXV).
7. To improve the ability to troubleshoot charge and compressor operation, a high-pressure refrigerant port will be located on the liquid line. A low-pressure refrigerant port will be located on the suction line.
8. The following sensors should be permanently installed to monitor system operation and the controller should have the capability of displaying the value of each parameter:
  - Refrigerant suction pressure
  - Refrigerant suction temperature

- Liquid line pressure
- Liquid line temperature
- Outside air temperature
- Outside air relative humidity• Return air temperature
- Return air relative humidity
- Supply air temperature
- Supply air relative humidity.

The controller will provide system status by indicating the following conditions:

- Compressor enabled
- Economizer enabled
- Free cooling available
- Mixed air low limit cycle active
- Heating enabled.

The unit controller shall have the capability to manually initiate each operating mode so that the operation of compressors, economizers, fans, and heating system can be independently tested and verified.

#### **NA7.5.11.2 Functional Testing**

1. Test low airflow condition by replacing the existing filter with a dirty filter or appropriate obstruction.
2. Verify that the fault detection and diagnostics system reports the fault.
3. Verify that the system is able to verify the correct refrigerant charge.
4. Calibrate outside air, return air, and supply air temperature sensors.

NA7.5.12 Automatic Fault Detection and Diagnostics (FDD) for Air Handling Units and Zone Terminal Units (Certificate of Acceptance Form MECH-13A)

#### **NA7.5.12.1 Functional Testing for Air Handling Units**

Testing of each AHU with FDD controls shall include the following tests.

##### 1. Sensor drift/failure:

Step 1: Disconnect outside air temperature sensor from unit controller.

Step 2: Verify that the FDD system reports a fault.

Step 3: Connect OAT sensor to the unit controller.

Step 4: Verify that FDD indicates normal system operation.

##### 2. Damper/actuator fault:

Step 1: From the control system workstation, command the mixing box dampers to full open (100 percent outdoor air).

Step 2: Disconnect power to the actuator and verify that a fault is reported at the control workstation.

Step 3: Reconnect power to the actuator and command the mixing box dampers to full open.

Step 4: Verify that the control system does not report a fault.

Step 5: From the control system workstation, command the mixing box dampers to a full-closed position (0 percent outdoor air),

Step 6: Disconnect power to the actuator and verify that a fault is reported at the control workstation.

Step 7: Reconnect power to the actuator and command the dampers closed.

Step 8: Verify that the control system does not report a fault during normal operation.

3. Valve/actuator fault:

Step 1: From the control system workstation, command the heating and cooling coil valves to full open or closed, then disconnect power to the actuator and verify that a fault is reported at the control workstation.

4. Inappropriate simultaneous heating, mechanical cooling, and/or economizing:

Step 1: From the control system workstation, override the heating coil valve and verify that a fault is reported at the control workstation.

Step 2: From the control system workstation, override the cooling coil valve and verify that a fault is reported at the control workstation.

Step 3: From the control system workstation, override the mixing box dampers and verify that a fault is reported at the control workstation.

**NA7.5.12.2 Functional Testing for Zone Terminal Units**

Testing shall be performed on one of each type of terminal unit (VAV box) in the project. A minimum of 5 percent of the terminal boxes shall be tested.

1. Sensor drift/failure:

Step 1: Disconnect the tubing to the differential pressure sensor of the VAV box.

Step 2: Verify that control system detects and reports the fault.

Step 3: Reconnect the sensor and verify proper sensor operation.

Step 4: Verify that the control system does not report a fault.

2. Damper/actuator fault:

(a) Damper stuck open.

Step 1: Command the damper to be fully open (room temperature above setpoint).

Step 2: Disconnect the actuator to the damper.

Step 3: Adjust the cooling setpoint so that the room temperature is below the cooling setpoint to command the damper to the minimum position. Verify that the control system reports a fault.

Step 4: Reconnect the actuator and restore to normal operation.

(b) Damper stuck closed.

Step 1: Set the damper to the minimum position.

Step 2: Disconnect the actuator to the damper.

Step 3: Set the cooling setpoint below the room temperature to simulate a call for cooling. Verify that the control system reports a fault.

Step 4: Reconnect the actuator and restore to normal operation.

3. Valve/actuator fault (For systems with hydronic reheat):

Step 1: Command the reheat coil valve to (full) open.

Step 2: Disconnect power to the actuator. Set the heating setpoint temperature to be lower than the current space temperature, to command the valve closed. Verify that the fault is reported at the control workstation.

Step 3: Reconnect the actuator and restore normal operation.

4. Feedback loop tuning fault (unstable airflow):

Step 1: Set the integral coefficient of the box controller to a value 50 times the current value.

Step 2: The damper cycles continuously and airflow is unstable. Verify that the control system detects and reports the fault.

Step 3: Reset the integral coefficient of the controller to the original value to restore normal operation.

5. Disconnected inlet duct:

Step 1: From the control system workstation, commands the damper to full closed, then disconnect power to the actuator and verify that a fault is reported at the control workstation.

#### NA7.5.13 Distributed Energy Storage DX AC Systems (Certificate of Acceptance form MECH-14A)

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

##### **NA7.5.13.1 Construction Inspection**

Prior to Performance Testing, verify and document the following:

- The water tank is filled to the proper level.
- The water tank is sitting on a foundation with adequate structural strength.
- The water tank is insulated and the top cover is in place.
- The DES/DXAC is installed correctly (refrigerant piping, etc.).
- Verify that the correct model number is installed and configured.

##### **NA7.5.13.2 Equipment Testing**

Step 1: Simulate cooling load during daytime period (e.g. by setting time schedule to include actual time and placing thermostat cooling set-point below actual temperature). Verify and document the following:

- Supply fan operates continually.
- If the DES/DXAC has cooling capacity, DES/DXAC runs to meet the cooling demand (in ice melt mode).
- If the DES/DXAC has no ice and there is a call for cooling, the DES/DXAC runs in direct cooling mode.

Step 2: Simulate no cooling load during daytime condition. Verify and document the following:

- Supply fan operates as per the facility thermostat or control system.
- The DES/DXAC and the condensing unit do not run.

Step 3: Simulate no cooling load during morning shoulder time period. Verify and document the following:

- The DES/DXAC is idle.

Step 4: Simulate a cooling load during morning shoulder time period. Verify and document the following:

- The DES/DXAC runs in direct cooling mode.



**NA7.5.13.3 Calibrating Controls**

Set the proper time and date, as per manufacturer's installation manual for approved installers.

**NA7.5.14 Thermal Energy Storage (TES) Systems (Certificate of Acceptance Form MECH-15A)**

The following acceptance tests apply to thermal energy storage systems that are used in conjunction with chilled water air conditioning systems.

**NA7.5.14.1 Eligibility Criteria**

The following types of TES systems are eligible for compliance credit:

- Chilled Water Storage
- Ice-on-Coil
- Ice Harvester
- Brine
- Ice-Slurry
- Eutectic Salt
- Clathrate Hydrate Slurry (CHS)

The following Certificate of Compliance information for both the chiller and the storage tank shall be provided on the plans to document the key TES System parameters and allow plan check comparison to the inputs used in the DOE-2 simulation. DOE-2 keywords are shown in ALL CAPITALS in parentheses.

Chiller:

- Brand and Model
- Type (Centrifugal, Reciprocating, Other)
- Capacity (tons) (SIZE)
- Starting Efficiency (kW/ton) at beginning of ice production (COMP - KW/TON - START)
- Ending Efficiency (kW/ton) at end of ice production (COMP - KW/TON/END)
- Capacity Reduction (% / o F) (PER – COMP - REDUCT/F)

Storage Tank:

- Storage Type (TES-TYPE)
- Number of Tanks (SIZE)
- Storage Capacity per Tank (ton-hours) (SIZE)
- Storage Rate (tons) (COOL – STORE - RATE)
- Discharge Rate (tons) (COOL – SUPPLY - RATE)
- Auxiliary Power (watts) (PUMPS + AUX - KW)
- Tank Area (CTANK – LOSS - COEFF)
- Tank Insulation (R - Value) (CTANK – LOSS - COEFF)

### **NA7.5.14.2 Functional Testing**

Acceptance testing also shall be conducted and documented on the Certificate of Acceptance in two parts:

In the TES System Design Verification part, the installing contractor shall certify the following information, which verifies proper installation of the TES System consistent with system design expectations:

- The TES system is one of the above eligible systems.
  - Initial charge rate of the storage tanks (tons).
  - Final charge rate of the storage tank (tons).
  - Initial discharge rate of the storage tanks (tons).
  - Final discharge rate of the storage tank (tons).
  - Charge test time (hrs).
  - Discharge test time (hrs).
  - Tank storage capacity after charge (ton-hrs).
  - Tank storage capacity after discharge (ton-hrs).
  - Tank standby storage losses (UA).
  - Initial chiller efficiency (kW/ton) during charging.
  - Final chiller efficiency (kW/ton) during charging.

In the TES System Controls and Operation Verification part, the installing contractor also shall complete the following acceptance testing to ensure the TES System is controlled and operates consistent with the compliance simulation. The installing contractor shall convey the results of the testing to the enforcement agency using the Certificate of Acceptance.

1. Verify that the TES system and the chilled water plant is controlled and monitored by an energy management system (EMS).
2. Force the time to be between 9:00 p.m. and 9:00 a.m. and simulate a partial or no charge of the tank and simulate no cooling load by setting the indoor temperature set point higher than the ambient temperature. Verify that the TES system starts charging (storing energy).
3. Force the time to be between 6:00 p.m. and 9:00 p.m. and simulate a partial charge on the tank and simulate a cooling load by setting the indoor temperature set point lower than the ambient temperature. Verify that the TES system starts discharging.
4. Force the time to be between noon and 6:00 p.m. and simulate a cooling load by lowering the indoor air temperature set point below the ambient temperature. Verify that the tank starts discharging and the compressor is off.
5. Force the time to be between 9:00 a.m. to noon, and simulate a cooling load by lowering the indoor air temperature set point below the ambient temperature. Verify that the tank does not discharge and the cooling load is met by the compressor only.
6. Force the time to be between 9:00 p.m. and 9:00 a.m. and simulate a full tank charge by changing the sensor that indicates tank capacity to the Energy Management System so that it indicates a full tank capacity. Verify that the tank charging is stopped.
7. Force the time to be between noon and 6:00 p.m. and simulate no cooling load by setting the indoor temperature set point above the ambient temperature. Verify that the tank does not discharge and the compressor is off.

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## **NA7.6 Indoor Lighting Control Systems**

Lighting control testing is performed on:

- Manual daylighting controls.
- Automatic daylighting controls.
- Occupancy sensors.
- Automatic time-switch control.

NA7.6.1 Automatic Daylighting Controls Acceptance (Certificate of Acceptance Form LTG-3A)

### **NA7.6.1.1 Construction Inspection**

Prior to Functional testing, verify and document the following:

- All control devices (photocontrols) have been properly located, field-calibrated and set for appropriate setpoints and threshold light levels.
- The location where calibration adjustments are made is readily accessible by authorized personnel.
- Installer has provided documentation of setpoints, setting and programming for each device.
- Luminaires located in primary or secondary sidelit zone(s) or in skylit area(s) are controlled separately from non-daylit areas. Compare location of daylighting controlled luminaires against description of sidelit and skylit zones on the building plans.
- Luminaires located in primary or secondary sidelit zone(s) are controlled separately from skylit area(s).
- Daylighting control devices have been certified in accordance with Standards Section 119.
- Model numbers of all daylighting controls are listed on the Energy Commission database as "Certified Appliances & Control Devices."

### **NA7.6.1.2 Functional testing**

All photocontrols serving more than 5,000 ft<sup>2</sup> of daylit area shall undergo functional testing. Photocontrols that are serving smaller spaces may be sampled as follows:

For buildings with up to five (5) photocontrols, all photocontrols shall be tested. For buildings with more than five (5) photocontrols, sampling may be done on spaces with similar sensors and cardinal orientations of glazing. If the first photocontrol in the sample group passes the functional test, the remaining building spaces in the sample group also pass. If the first photocontrol in the sample group fails the functional test, the rest of the photocontrols in the group shall be tested. If any tested photocontrol fails the functional test, it shall be repaired, replaced or adjusted until it passes the test.

For each photocontrol to be tested do the following:

Continuous Dimming Control Systems-Power Estimation Using Amp Meter or Watt Meter Measurement

This requirement is for systems that have more than 10 levels of controlled light output in a given zone.

Step 1: Identify the minimum daylighting location in the controlled zone (Reference Location). This can be identified using either the illuminance method or the distance method.

*Illuminance Method*

- Turn OFF controlled lighting and measure daylight illuminance within zones illuminated by controlled luminaires.
- Identify the Reference Location; this is the task location with lowest daylight illuminance in the zone illuminated by controlled luminaires. This location will be used for illuminance measurements in subsequent tests.
- Turn controlled lights back ON.

*Distance Method*

- Identify the task location within the zone illuminated by controlled luminaires that is farthest away from daylight sources. This is the Reference Location and will be used for illuminance measurements in subsequent tests.

Step 2: No daylight test. Simulate or provide conditions without daylight. Verify and document the following:

- Automatic daylight control system provides appropriate control so that electric lighting system is providing full light output unless otherwise specified by design documents.
- Document the reference illuminance, which is the electric lighting illuminance level at the reference location identified in Step 1.
- Measure that the light output is either within 70 percent of the full load light output or within 80% of the design light output.

Step 3: Full daylight test. Simulate or provide bright conditions. Verify and document the following:

- Lighting power reduction is at least 65 percent under fully dimmed conditions.
- Only luminaires in daylit zones are affected by daylight control.
- Light output is stable with no perceptible visual flicker.

Step 4: Partial daylight test. Simulate or provide bright conditions where illuminance (fc) from daylight only at the Reference Location is between 60 and 95 percent of Reference Illuminance (fc) documented in Step 2. Verify and document the following:

- Measure that the combined illuminance of daylight and controlled electric lighting (fc) at the reference location is no less than the electric lighting illuminance (fc) at this location during the no daylight test documented in Step 2.
- Measure that the combined illuminance of daylight and controlled electric lighting (fc) at the Reference Location is no greater than 150 percent of the reference illuminance (fc) documented in Step 2.

Continuous Dimming Control Systems-Power Estimation Using Light Meter Measurement

Perform an estimation of rated power output using the default fraction of rated power to fraction of light output or the manufacturer's cut sheet ratio of power to light.

Step 1: Identify the minimum daylighting location in the controlled zone (Reference Location). This can be identified using either the illuminance method or the distance method.

Illuminance Method

- Turn OFF controlled lighting and measure daylight illuminance within zones illuminated by controlled luminaires.

- Identify the Reference Location; this is the task location with lowest daylight illuminance in the zone illuminated by controlled luminaires. This location will be used for illuminance measurements in subsequent tests.
- Turn controlled lights back ON.

Distance Method

- Identify the task location within the zone illuminated by controlled luminaires that is farthest away from daylight sources. This is the Reference Location and will be used for illuminance measurements in subsequent tests.

Step 2: No daylight test. Simulate or provide conditions without daylight. Verify and document the following:

- Measure the light level at the reference location at night time or at daytime covering the photocell.
- Turn lights OFF and measure the daylight illuminance at the reference location.
- Document the reference illuminance, which is the electric lighting illuminance level at the reference location identified in Step 1.
- Measure that the light output is either within 70 percent of the full load light output or within 80% of the design light output.

Step 3: Full daylight test. Simulate or provide bright conditions. Verify and document the following:

- Lighting power reduction is at least 65 percent under fully dimmed conditions.
- Only luminaires in daylit zones are affected by daylight control.
- Light output is stable with no perceptible visual flicker.

Step 4: Partial daylight test. Simulate or provide bright conditions where illuminance (fc) from daylight only at the Reference Location is between 60 and 95 percent of Reference Illuminance (fc) documented in Step 2. Verify and document the following:

- Measure that the combined illuminance of daylight and controlled electric lighting (fc) at the reference location is no less than the electric lighting illuminance (fc) at this location during the no daylight test documented in Step 2.
- Measure that the combined illuminance of daylight and controlled electric lighting (fc) at the Reference Location is no greater than 150 percent of the reference illuminance (fc) documented in Step 2.

Stepped Switching or Stepped Dimming Control Systems – Power Estimation Using Amp Meter or Watt Meter Measurement

This requirement is for systems that have no more than 10 discrete steps of control of light output.

If the control has 3 steps of control or less, conduct the following tests for all steps of control. If the control has more than 3 steps of control, testing 3 steps of control is sufficient for showing compliance.

Step 1: Identify the minimum daylighting location(s) in the controlled zone.

If lighting controls are staged so that one stage is closer to the daylight source, identify a minimum daylighting location for each stage of control. If all stages of control are equally close to the daylight source, select a single minimum daylighting location representing all stages of the control. This minimum daylighting location for each stage of control is designated as the reference location for that stage of control and will be used for illuminance measurements in subsequent tests. The reference location can be identified using either the illuminance method or the distance method.

#### *Illuminance Method*

- Turn OFF controlled lighting and measure daylight illuminances within a zone illuminated by controlled luminaires.
- Identify the reference location; this is the task location with lowest daylight illuminance in the zone illuminated by controlled luminaires. This location will be used for illuminance measurements in subsequent tests.
- Turn controlled lights back ON.

#### *Distance Method*

- Identify the task location within the zone illuminated by controlled luminaires that is farthest away from daylight sources. This is the reference location and will be used for illuminance measurements in subsequent tests.

Step 2: No daylight test. Simulate or provide conditions without daylight for a stepped switching or stepped dimming control system. Verify and document the following:

- If the control is manually adjusted (not self commissioning), make note of the time delay and override time delay or set time delay to minimum setting. This condition shall be in effect through step 4.
- Automatic daylight control system turns ON all stages of controlled lights
- Document the reference illuminance which is the electric lighting illuminance level measured at the reference location identified in Step 1.
- Measured light output is within either 70 percent of the full load light output or 80percent of the design light output.

Step 3: Full daylight test. Simulate or provide bright conditions. Verify and document the following:

- Lighting power reduction of controlled luminaires is at least 65 percent (for non-switching systems).
- At least two-thirds of luminaires are turned off for switching systems.
- Dimmed lamps have stable output with no perceptible visual flicker.

Step 4: Partial daylight test. For each control stage that is tested in this step, the control stages with lower setpoints than the stage tested are left ON and those stages of control with higher setpoints are dimmed or controlled off. Simulate or provide conditions so that each control stage turns on and off or dims. Lights should be dimmed through at least three stages. Verify and document the following for each control stage:

- The measured illuminance contribution from the control stage tested at its corresponding reference location.
- The total daylight and electric lighting illuminance level measured at its reference location just after the stage of control dims or shuts off a stage of lighting:
  1. The total measured illumination shall be no greater than 150 percent of the reference illuminance.
  2. The System Power Reduction of one of the partially dimmed stages is between 30 and 50 percent of the system rated power line.

- The control stage shall not cycle on and off or cycle between dim and undimmed while daylight illuminance remains constant.
- Only luminaires in daylit zones (toplit zone, primary sidelit zone, and secondary sidelit zone) are affected by daylight control.

Confirm that there is a time delay of at least 3 minutes between the time when illuminance exceeds the setpoint for a given dimming stage and when the control dims or switches off the controlled lights.

#### Stepped Switching or Stepped Dimming Control Systems – Power Estimation Using Light Meter Measurement

This requirement is for systems that have no more than 10 discrete steps of control of light output.

If the control has 3 steps of control or less, conduct the following tests for all steps of control. If the control has more than 3 steps of control, testing 3 steps of control is sufficient for showing compliance.

Perform an estimation of power by counting lamps that are switched off (stepped switching), using the manufacturer's cut sheet, or by using the default fraction of rated power to fraction of light output.

#### Step 1: Identify the minimum daylighting location(s) in the controlled zone.

If lighting controls are staged so that one stage is closer to the daylight source, identify a minimum daylighting location for each stage of control. If all stages of control are equally close to the daylight source, select a single minimum daylighting location representing all stages of the control. This minimum daylighting location for each stage of control is designated as the reference location for that stage of control and will be used for illuminance measurements in subsequent tests. The reference location can be identified using either the illuminance method or the distance method.

##### Illuminance Method

- Turn OFF controlled lighting and measure daylight illuminances within a zone illuminated by controlled luminaires.
- Identify the reference location; this is the task location with lowest daylight illuminance in the zone illuminated by controlled luminaires. This location will be used for illuminance measurements in subsequent tests.
- Turn controlled lights back ON.

##### Distance Method

- Identify the task location within the zone illuminated by controlled luminaires that is farthest away from daylight sources. This is the reference location and will be used for illuminance measurements in subsequent tests.

Step 2: No daylight test. Simulate or provide conditions without daylight for a stepped switching or stepped dimming control system. Verify and document the following:

- If the control is manually adjusted (not self commissioning), make note of the time delay and override time delay or set time delay to minimum setting. This condition shall be in effect through step 4.
- Automatic daylight control system turns ON all stages of controlled lights
- Document the reference illuminance which is the electric lighting illuminance level measured at the reference location identified in Step 1.
- Measured light output is within either 70 percent of the full load light output or 80percent of the design light output.

Step 3: Full daylight test. Simulate or provide bright conditions. Verify and document the following:

- Lighting power reduction of controlled luminaires is at least 65 percent (for non-switching systems).
- At least two-thirds of luminaires are turned off for switching systems.
- No lamps are dimmed outside of daylit area.
- Dimmed lamps have stable output with no perceptible visual flicker.

Step 4: Partial daylight test. For each control stage that is tested in this step, the control stages with lower setpoints than the stage tested are left ON and those stages of control with higher setpoints are dimmed or controlled off. Simulate or provide conditions so that each control stage turns on and off or dims. Lights should be dimmed through at least three stages. Verify and document the following for each control stage:

- The measured illuminance contribution from the control stage tested at its corresponding reference location.
- The total daylight and electric lighting illuminance level measured at its reference location just after the stage of control dims or shuts off a stage of lighting.
  1. The total measured illumination shall be no greater than 150 percent of the reference illuminance.
  2. The System Power Reduction of one of the partially dimmed stages is between 30 and 50 percent of the system rated power line.
- The control stage shall not cycle on and off or cycle between dim and undimmed while daylight illuminance remains constant.
- Only luminaires in daylit zones (toplit zone, primary sidelit zone, and secondary sidelit zone) are affected by daylight control.
- Confirm that there is a time delay of at least 3 minutes between the time when illuminance exceeds the setpoint for a given dimming stage and when the control dims or switches off the controlled lights.

NA7.6.2 Occupancy Sensor Acceptance (Certificate of Acceptance Form LTG-2A)

#### **NA7.6.2.1 Construction Inspection**

Prior to Functional testing, verify and document the following:

- Occupancy sensor has been located to minimize false signals:
  - No closer than four (4) feet from a HVAC diffuser.
  - PIR sensor pattern does not enter into adjacent zones.
- Occupancy sensors do not encounter any obstructions that could adversely affect desired performance.
- Ultrasonic occupancy sensors do not emit audible sound above the limits found in the 2013 Building Energy Efficiency Standards Table 119-A within five feet from source.
- Occupancy sensors have been certified to the Energy Commission in accordance with the applicable provision in 2013 Building energy Efficiency Standards section 119, and model numbers for all controls are listed on the Commission database as Certified Appliance and Control Devices.

#### **NA7.6.2.2 Functional testing**

For buildings with up to seven (7) occupancy sensors, all occupancy sensors shall be tested. For buildings with more than seven (7) occupancy sensors, sampling may be done on spaces with similar sensors and space



geometries. If the first occupancy sensor in the sample group passes the acceptance test, the remaining building spaces in the sample group also pass. If the first occupancy sensor in the sample group fails the acceptance test the rest of the occupancy sensors in that group must be tested. If any tested occupancy sensor fails it shall be repaired, replaced or adjusted until it passes the test.

For each sensor to be tested do the following:

Step 1: Simulate an unoccupied condition. Verify and document the following:

- Lights controlled by occupancy sensors turn off within a maximum of 30 minutes from the start of an unoccupied condition per 2013 Building Energy Efficiency Standard section 119(d).
- The occupant sensor does not trigger a false “on” from movement in an area adjacent to the space containing the controlled luminaires or from HVAC operation.
- Signal sensitivity is adequate to achieve desired control.

Step 2: Simulate an occupied condition. Verify and document the following:

- Status indicator or annunciator operates correctly.
- Lights controlled by occupancy sensors turn on immediately upon an occupied condition, *OR* sensor indicates space is “occupied” and lights are turned on manually (automatic OFF and manual ON control strategy).

Step 3: System has been returned to initial operating conditions.

Step 4: If the sensor to be tested is also a multi-level occupant sensor used to qualify for a Power Adjustment Factor as defined in the 2013 Building Energy Efficiency Standards section 146(a)2D, verify and document the following:

- The first stage activates between 30 to 70 percent of the lighting, either manually or automatically.
- Dimming of all lamps or luminaires, or switching alternate lamps in luminaires, alternate luminaires, or alternate rows of luminaires, achieves a reasonably uniform level of illuminance.
- After the first stage occurs, manual switches have been provided to activate the alternate set of lights, activate 100 percent of the lighting power, and manually deactivate all of the lights.

NA7.6.3 Manual Daylighting Controls Acceptance (Certificate of Acceptance Form LTG-2A)

#### **NA7.6.3.1 Construction Inspection**

Prior to Functional testing, verify and document the following:

- If dimming ballasts are specified for light fixtures within the daylit area, make sure they meet all the Standards requirements, including “reduced flicker operation” for manual dimming control systems.

#### **NA7.6.3.2 Functional testing**

Step 1: Perform manual switching control. Verify and document the following:

- Manual switching or dimming achieves a lighting power reduction of at least 50 percent.
- The amount of light delivered to the space is uniformly reduced.

Step 2: System has been returned to initial operating conditions.

## NA7.6.4 Automatic Time Switch Control Acceptance

### **NA7.6.4.1 Construction Inspection**

Prior to Functional testing, verify and document the following:

- Automatic time switch control is programmed with acceptable weekday, weekend, and holiday (if applicable) schedules.
- Document for the owner automatic time switch programming including weekday, weekend, holiday schedules as well as all set-up and preference program settings.
- Verify the correct time and date is properly set in the time switch.
- Verify the battery back-up (if applicable) is installed and energized.
- Override time limit is set to no more than 2 hours.
- Automatic time switch controls have been certified to the Energy Commission in accordance with the applicable provision in the 2013 Building Energy Efficiency Standards section 119, and model numbers for all controls are listed on the Commission database as Certified Appliance and Control Devices.

### **NA7.6.4.2 Functional testing**

Step 1: Simulate occupied condition (use lighting control panel to adjust time-clock as necessary). Verify and document the following:

- All lights can be turned on and off by their respective area control switch.
- Verify the switch only operates lighting in the enclosed space (ceiling-height partitioned area) in which the switch is located.

Step 2: Simulate unoccupied condition (use lighting control panel to adjust time-clock as necessary). Verify and document the following:

- All non-exempt lighting turn off per the 2013 Building Energy Efficiency Standards section 131(d)1. Exempt lighting is defined as lighting serving areas that must be continuously lit 24 hours per day/365 days per year, lighting in corridors, guestrooms, dwelling units of high-rise residential buildings and hotels/motels and parking garages, and emergency egress areas.
- Manual override switch allows only the lights in the enclosed space (ceiling height partitioned) where the override switch is located to turn on or remain on until the next scheduled shut off occurs.

Step 3: System has been returned to initial operating conditions.

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## **NA7.7 Outdoor Lighting Acceptance Tests**

### NA7.7.1 Outdoor Motion Sensor Acceptance

#### **NA7.7.1.1 Construction Inspection**

Prior to Functional testing, verify and document the following:

- Motion sensor has been located to minimize false signals.
- Sensor is not triggered by motion outside of adjacent area.
- Desired motion sensor coverage is not blocked by obstructions that could adversely affect performance.

**NA7.7.1.2 Functional testing**

Step 1: Simulate motion in area under lights controlled by the motion sensor. Verify and document the following:

- Status indicator operates correctly.
- Lights controlled by motion sensors turn on immediately upon entry into the area lit by the controlled lights near the motion sensor.
- Signal sensitivity is adequate to achieve desired control.

Step 2: Simulate no motion in area with lighting controlled by the sensor but with motion adjacent to this area. Verify and document the following:

- Lights controlled by motion sensors turn off within a maximum of 30 minutes from the start of an unoccupied condition per §119(d).
- The occupant sensor does not trigger a false “on” from movement outside of the controlled area
- Signal sensitivity is adequate to achieve desired control.

**NA7.7.2 Outdoor Lighting Shut-off Controls****NA7.7.2.1 Construction Inspection**

Prior to Functional testing, verify and document the following:

- Controls to turn off lights during daytime hours are installed.
- Astronomical and standard time switch control is programmed with acceptable weekday, weekend, and holiday (if applicable) schedules.
- Demonstrate and document for the owner time switch programming including weekday, weekend, holiday schedules as well as all set-up and preference program settings.
- Lighting systems that meet the criteria of §132(c)2 shall have a scheduling control (time switch) installed which is able to schedule separately:
  - a reduction in outdoor lighting power by 50 to 80 percent
  - turning off all outdoor lighting covered by §132(c)2
- Verify that the correct time and date is properly set in the standard and astronomical time switch.
- Verify that the correct latitude, longitude and time zone are set in the astronomical time switch.
- Verify the battery back-up (if applicable) is installed and energized in the standard and astronomical time switch.

**NA7.7.2.2 Outdoor Photocontrol Functional testing**

Note photocontrol must be used in conjunction with time switch or motion sensor to meet the requirements of §132(c)2.

Step 1: Nighttime test. Simulate or provide conditions without daylight. Verify and document:

- Controlled lights turn on.

Step 2: Sunrise test: Provide between 10 and 30 horizontal footcandles (fc) to photosensor. Verify and document the following:

- Controlled lights turn off.

**NA7.7.2.3 Astronomical Time Switch Functional testing**

Step 1: Power off test. Program control with location information, local date, time and schedules. Disconnect control from power source for at least 1 hour. Verify and document:

- Control retains all programmed settings and local date and time

Step 2: Night schedule ON test. Simulate or provide times when the sun has set and lights are scheduled to be ON. Verify and document:

- Controlled lights turn on

Step 3: Night schedule OFF test. Simulate or provide times when the sun has set and lights are scheduled to be OFF. Verify and document:

- Controlled lights turn off

Step 4: Sunrise test: Simulate or provide the programmed offset time after the time of local sunrise.

- Controlled lights turn off

**NA7.7.2.4 Standard (non-astronomical) Time Switch Functional Testing**

Note: this control must be used in conjunction with a photocontrol to meet requirements of §132(c).

Step 1: Power off test. Program control with local date, time and schedules. Disconnect control from power source for at least 1 hour. Verify and document:

- Control retains all programmed schedules and local date and time

Step 2: On schedule test. Simulate or provide times when lights are scheduled to be ON. Verify and document:

- Controlled lights turn on

Step 3: Schedule test. Simulate or provide times when the sun has set and lights are scheduled to be OFF. Verify and document:

- Controlled lights turn off

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**NA7.8 Sign Lighting Acceptance Tests**

Reserved For Future Use

## **7.3 Appendix C: Non-Residential Construction Forecast Details**

### **7.3.1 Summary**

The Non-Residential construction forecast dataset is data that is published by the California Energy Commission's (CEC) demand forecast office. This demand forecast office is charged with calculating the required electricity and natural gas supply centers that need to be built in order to meet the new construction utility loads. Data is sourced from Dodge construction database, the demand forecast office future generation facility planning data, and building permit office data.

All CASE reports used the statewide construction forecast for 2014. The TDV savings analysis is calculated on a 15 or 30 year net present value, so it is correct to use the 2014 construction forecast as the basis for CASE savings.

### **7.3.2 Additional Details**

The demand generation office publishes this dataset and categorizes the data by demand forecast climate zones (FCZ) as well as building type (based on NAICS codes). The 16 climate zones are organized by the generation facility locations throughout California, and differ from the Title 24 building climate zones (BCZ). The Heschong Mahone Group (HMG) has reorganized the demand forecast office data using 2000 Census data (population weighted by zip code) and mapped FCZ and BCZ to a given zip code. The construction forecast data is provided to CASE authors in BCZ in order to calculate Title 24 statewide energy savings impacts. Though the individual climate zone categories differ between the demand forecast published by the CEC and the construction forecast, the total construction estimates are consistent; in other words, HMG has not added to or subtracted from total construction area.

The demand forecast office provides two (2) independent data sets: total construction and additional construction. Total construction is the sum of all existing floor space in a given category (Small office, large office, restaurant, etc.). Additional construction is floor space area constructed in a given year (new construction); this data is derived from the sources mentioned above (Dodge, Demand forecast office, building permits).

Additional construction is an independent dataset from total construction. The difference between two consecutive years of total construction is not necessarily the additional construction for the year because this difference does not take into consideration floor space that was renovated, or repurposed.

In order to further specify the construction forecast for the purpose of statewide energy savings calculation for Title 24 compliance, HMG has provided CASE authors with the ability to aggregate across multiple building types. This tool is useful for measures that apply to a portion of various building types' floor space (e.g. skylight requirements might apply to 20% of offices, 50% of warehouses and 25% of college floor space).

The main purpose of the CEC demand forecast is to estimate electricity and natural gas needs in 2022 (or 10-12 years in the future), and this dataset is much less concerned about the inaccuracy at 12 or 24 month timeframe.

It is appropriate to use the CEC demand forecast construction data as an estimate of future years construction (over the life of the measure). The CEC non-residential construction forecast is the best publicly available data to estimate statewide energy savings.

### **7.3.3 Citation**

“NonRes Construction Forecast by BCZ v7”; Developed by Heschong Mahone Group with data sourced August, 2010 from Abrishami, Moshen at the California Energy Commission (CEC)