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13. Acceptance Test Requirements

13.1 New Acceptance Test Requirements for 2016

A. Building Envelope, §110.6:

- No changes.

B. Mechanical Acceptance Tests, §120.5:

- Thermal Energy Storage (TES) Systems (NRCA-MCH-15-A)
  - Incorporates new acceptance criteria.
- Minor clarifications:
  - Outdoor Air (NRCA-MCH-02-A)
  - Supply Water Temperature Reset Controls (NRCA-MCH-09-A)
  - Hydronic System Variable Flow Controls (NRCA-MCH-10-A)
  - Fault Detection & Diagnostics for DX Units (NRAC-MCH-12-A)
  - Automatic Fault Detection & Diagnostic for Air Handling & Zone Terminal Units (NRCA-MCH-13-A)

C. Lighting Controls Acceptance Tests, §130.4:

- New Acceptance Test
  - Institutional Tuning of Lighting Controls (NRCA-LTI-05-A)
- Significant Alterations to Acceptance Tests
  - New sampling allowance for acceptance tests.
  - Changes to the lighting control occupancy sensor maximum time-out period.
  - Changes to the weighted area calculation procedure requirements.
- Minor clarifications:
  - Outdoor Lighting Acceptance Tests (NRCA-LTO-02-A)

D. Covered Process Spaces and Equipment, §120.6:

- New Acceptance Tests
  - Elevator Lighting and Ventilation Controls (NRCA-PRC-12-F)
  - Escalator and Moving Walkway Speed Control (NRCA-PRC-13-F)
- Changes to Acceptance Procedures
  - Commercial Kitchen Exhaust (NRCA-PRC-02-A)
  - Parking Garage Exhaust (NRCA-PRC-03-F)

13.2 Overview

From simple thermostats and manual light switches to complex building automation systems, controls are integral to building health, safety, comfort, and energy efficiency. However, building owners disable many building control and equipment components after occupancy due to lack of functionality from improper installation.

Acceptance test requirements specify targeted inspections and functional performance tests to demonstrate that the building components, equipment, systems, and interfaces conform to the *2016 Building Energy Efficiency Standards* (Energy Standards), Reference Nonresidential Appendix NA7, and applicable construction documents (plans and specifications). Furthermore, acceptance testing helps to ensure that the building meets its energy efficiency goals based on the original design in compliance with the energy standards and that the specified equipment or controls are functioning properly. This testing helps to eliminate issues found in the field. This conclusion was noted in a Public Interest Energy Research Program (PIER) report titled *Integrated Design of Small Commercial HVAC Systems, Element 4* that found a number of problems with package rooftop equipment. These problems include the following:

A. Economizers

Economizers reduce cooling energy use dramatically but often are inoperable. Economizers show a high rate of failure in the study. Of the units equipped with economizers, 64 percent were not operating correctly. Failure modes included dampers that were stuck or inoperable (38 percent), sensor or control failure (46 percent), and poor operation (16 percent). The average energy impact of inoperable economizers is about 37 percent of the annual cooling energy.

B. Cycling Fans

In 38 percent of the units tested, system fans cycled on and off with a call for heating or cooling. The supply of continuous fresh air during occupied hours relies on continuous operation of the HVAC unit supply fan.

C. Unoccupied Fan Operation

In 30 percent of the systems, fans ran continuously during unoccupied periods. While this practice improves space ventilation, a greater opportunity presents itself to save energy through thermostat setback and fan cycling when the space is unoccupied.

D. Simultaneous Heating and Cooling

Adjacent rooftop units controlled by independent thermostats provided simultaneous heating and cooling to a space in 8 percent of the units monitored in the study, largely due to occupant errors in the setup, thermostat misuse, or poor thermostat placement during construction.

E. No Outdoor Air

An inspection revealed that about 8 percent of the inspected units were not capable of supplying any outdoor air. In some cases, outdoor air intakes were not present or were sealed off at the unit. In other instances, outdoor air dampers were stuck shut, effectively preventing outdoor air intake.

13.2.1 General Requirements

Acceptance testing does not take the place of commissioning, or of test and balance procedures that may be required elsewhere in the Energy Standards, or that a building owner may incorporate voluntarily to assess his or her building. Instead, it serves as an adjunct process focusing only on demonstrating compliance with the Energy Standards and proper functionality as described by the approved building plans.

Acceptance testing is not required to be performed by a third party that is independent from the designer or the contractor. However, compliance with the duct sealing requirements specified in §140.4(l) must be verified by a certified, third-party HERS Rater or third party quality control program pursuant to the requirements in Nonresidential Appendix NA2.

Acceptance tests may be performed by one or more field technicians under the responsible charge of a licensed contractor or design professional responsible person eligible under Division 3 of the Business and Professions Code, in the applicable classification, to accept responsibility for the scope of work specified by the certificate of acceptance document. The responsible person must review the information on the certificate of acceptance document and sign it to certify compliance with the acceptance requirements.

Typically, individuals who participate in the acceptance testing/verification are contractors, engineers, or commissioning agents. The individuals who perform the field testing/verification and provide the information required for completion of the acceptance document (field technicians) are not required to be licensed contractors or licensed design professionals. Only the responsible person who signs the certificate of acceptance document must be licensed.

A certified acceptance test technician (ATT) is required to complete the lighting controls (NRCA-LTI-02-A), automatic daylighting (NRCA-LTI-03-A), demand responsive lighting controls (NRCA-LTI-03-A) and outdoor motion sensor and lighting shut-off controls (NRCA-LTO-02-A) acceptance tests and to sign the certificate of acceptance.

The acceptance tests related to mechanical systems are not required to be performed by a certified acceptance test technician. Although a certified acceptance test training provider has been approved by the Energy Commission, the industry certification threshold has not been surpassed. Once surpassed, then a certified acceptance test technician will be required to complete the associated mechanical acceptance tests and sign the certificate of acceptance.

The acceptance test procedures generally require the following:

- Review the bid documents to make sure that the building component (that is, equipment, sensors, devices and control sequences) are properly documented.
- Review the construction installation.
- Complete the required functional testing.
- Certify the acceptance test results on the certificate of acceptance.
- Submit the certificate to the enforcement agency prior to receiving a final occupancy permit.

13.2.2 Roles and Responsibilities

If more than one person is responsible for the acceptance testing, each person shall sign and submit the certificate of acceptance documentation applicable to the portion of the construction or installation for which he or she is responsible. Alternatively, the person with

chief responsibility for the system design, construction, or installation shall sign and submit the certificate of acceptance documentation for the entire construction or installation.

The owner is responsible for designating the responsible parties for acceptance test work. Applicable roles and responsibilities related to acceptance testing should be clearly called out by the owner early in the process to ensure accurate pricing and bids.

A. Field Technician

The *field technician* is responsible for performing and documenting the results of the acceptance procedures on the certificate of acceptance documents. The field technician must sign the certificate of acceptance to certify that the information provided on the certificate of acceptance is true and correct. The field technician does not require a contractor's, architect's or engineer's license but may require certification as an acceptance test technician.

- Given that the industry certification threshold for certified lighting ATTs has been satisfied, a certified ATT is required to perform the acceptance test referenced by §130.4 and to sign the certificate(s) of acceptance.
- When the industry certification threshold has been satisfied for mechanical ATTs, a certified ATT will then be required to perform the acceptance test referenced by §120.5 and sign the certificate(s) of acceptance.

The acceptance tests listed in §120.5 and §130.4 may require that the field technician be a certified ATT. Other acceptance tests, such as those found in §120.6, do not require that the field technician be a certified ATT.

B. Responsible Person

A certificate of acceptance must be signed by a responsible person who is licensed and eligible under Division 3 of the Business and Professions code to take responsibility for the scope of work specified by the certificate of acceptance. The responsible person can also perform the field testing and verification, and if this is the case, the responsible person must complete and sign both the field technician's signature block and the responsible person's signature block on the certificate of acceptance document. The *Responsible Person* assumes responsibility for the acceptance testing work performed by his Field Technician agent or employee. Aside from being licensed, the responsible person that conducts his or her own testing may also need to be a certified ATT if he or she is performing an acceptance test that requires a certified ATT.

C. Enforcement Agency

The certificate of acceptance must be submitted to the enforcement agency to receive the final certificate of occupancy. Enforcement agencies shall not release a *final* certificate of occupancy unless the submitted certificate of acceptance demonstrates that the specified systems and equipment have been shown to be performing in accordance with the applicable acceptance requirements.

The enforcement agency has the authority to require the field technician or responsible person to demonstrate competence to its satisfaction. When a certified ATT is required to complete an acceptance test, the enforcement agency must verify the technician certification status through the acceptance test technician certification provider (ATTCP) before issuing a final certificate of occupancy.

13.2.3 Acceptance Testing Process

The acceptance requirements require five major checkpoints to be conducted. They are:

1. Plan review.
2. Construction inspection.
3. Functional testing.
4. Signing of certification of acceptance.
5. Submission of certification of acceptance.

These are discussed in more detail below.

A. Plan Review

The responsible person must review the plans and specifications to ensure that they conform to the acceptance requirements, typically done prior to signing a certificate of compliance.

In reviewing the plans, the designer notes the appropriate certificate of compliance, all the respective acceptance tests that will be performed, as well as the parties responsible for performing the tests. An exhaustive list is required so that when the acceptance tests are bid, all parties are aware of the scope of acceptance testing on the project.

B. Construction Inspection

The construction inspection assures that installed equipment is capable of complying with the Energy Standards. Construction inspection also assures proper installation of equipment and current calibration.

The responsible person must perform a construction inspection prior to testing. Reviewing the acceptance requirements with the contractor before installation is very useful on several counts.

In some cases, performing tests immediately after installation is most economical, though this requires the complete installation of any associated systems and equipment necessary for proper system operation.

Awareness of the acceptance test requirements can allow the contractor to identify a design or construction practice that would not comply with the acceptance requirements prior to equipment installation.

Purchasing sensors and equipment with calibration certificates often reduces the amount of time required for site calibration, which can lower overall costs.

C. Functional Testing

A *field technician* assumes responsibility for performing the required acceptance requirements procedures. In some cases, the same field technician may not perform all the required acceptance tests for a project. However, for each acceptance test performed, the field technician who performs the test is responsible for identifying all performance deficiencies and, if necessary, repeating the test until the specified systems and equipment are performing in accordance with the acceptance requirements. The field technician who performs the testing signs the certificate of acceptance to certify the information recorded on the certificate is true and correct.

A responsible person ensures performance of the scope of work specified by the certificate of acceptance and reviews the test results provided by the field technician. The

responsible person signs the certificate of acceptance to indicate his or her overall responsibility for the project.

The responsible person may also perform the field technician's responsibilities, and, if so, must also sign the field technician declaration on the certificate of acceptance. If the acceptance test requires a certified ATT and the responsible person performs the acceptance test, then he or she must be a certified ATT.

D. Certification of Acceptance

Acceptance test forms include a certificate of acceptance and worksheets to assist in field verification. Table 13-1 shows the certificate of acceptance documents and related references.

Table 13-1: Acceptance Documents

Component	Document Name	Energy Standards Reference	Reference Nonresidential Appendix NA7
Envelope	NRCA-ENV-02-F – Fenestration Acceptance	§10-103(a)4 & §10-111 & §110.6	NA7.4.1
Mechanical	NRCA-MCH-02-A – Outdoor Air Acceptance	§10-103(b)4 & §120.1(b)2 & §120.5(a)1	NA7.5.1.1 NA7.5.1.2
	NRCA-MCH-03-A – Constant Volume, Single Zone, Unitary Air Conditioner and Heat Pump Systems	§120.1(c)2 & §120.2 & §120.5(a)2	NA7.5.2
	NRCA-MCH-04-A – Air Distribution Systems Acceptance	§120.5(a)3 § 140.4(l)	NA7.5.3
	NRCA-MCH-05-A – Air Economizer Controls Acceptance	§120.5(a)4 & §140.4(e)	NA7.5.4
	NRCA-MCH-06-A – Demand Control Ventilation Systems Acceptance	§120.1(c)4 & §120.5(a)5	NA7.5.5
	NRCA-MCH-07-A – Supply Fan VFD Acceptance	§120.5(a)6 & §140.4(c)2B & §140.4(c)2C	NA7.5.6
	NRCA-MCH-08-A – Valve Leakage Test	§120.5(a)8, §140.4(k)1 §140.4(k)5, §140.4(k)6	NA7.5.7
	NRCA-MCH-09-A – Supply Water Temperature Reset Controls Acceptance	§120.5(a)9 & 140.4(k)4	NA7.5.8
	NRCA-MCH-10-A – Hydronic System Variable Flow Control Acceptance	§120.5(a)7, §140.4(k)1, §140.4(k)5, §140.4(k)6	NA7.5.9
	NRCA-MCH-11-A – Automatic Demand Shed Control Acceptance	§120.2(h), 120.5(a)10	NA7.5.10
	NRCA-MCH-12-A – Fault Detection & Diagnostics (FDD) for Packaged Direct Expansion Units	§120.2(i), §120.5(a)11	NA7.5.11
	NRCA-MCH-13-A – Automatic Fault Detection & Diagnostics (FDD) for Air Handling Units & Zone Terminal Units Acceptance	§120.5(a)12	NA7.5.12

Mechanical	NRCA-MCH-14-A – Distributed Energy Storage DX AC Systems Acceptance	§120.5(a)13	NA7.5.13
	NRCA-MCH-15-A – Thermal Energy Storage (TES) System Acceptance	§120.5(a)14	NA7.5.14
	NRCA-MCH-16-A – Supply Air Temperature Reset Controls Acceptance	§140.4(f), 120.5(a)15	NA7.5.15
	NRCA-MCH-17-A – Condenser Water Supply Temperature Reset Controls Acceptance	Not required per Energy Standards. However, this test is required if this control strategy is implemented.	NA7.5.16
	NRCA-MCH-18-A – Energy Management Control System Acceptance	§110.2(e), §120.2(h), §120.5(a)17, §130.4(b), §130.5(f), §150.0(k)	--------
Indoor Lighting	NRCA-LTI-02-A Lighting Controls	§110.9(b), §130.1(c)	NA7.6.2
	NRCA-LTI-03-A Automatic Daylighting Controls	§130.1(d)	NA7.6.1
	NRCA-LTI-04-A Demand Responsive Lighting Controls	§130.1(e)	NA7.6.3
	NRCA-LTI-05-A Institutional Tuning Power Adjustment Factor	§140.6(a)2J	NA7.7.6.2
Outdoor Lighting	NRCA-LTO-02-A – Outdoor Lighting Acceptance Tests	§110.9(b), §130.2(a & c)	NA7.8
Process	NRCA-PRC-01-F – Compressed Air System Acceptance	§120.6(e)	NA7.13
	NRCA-PRC-02-F – Commercial Kitchen Exhaust	§140.9(b)	NA7.11
	NRCA-PRC-03-F – Parking Garage Exhaust	§120.6(c)	NA7.12
	NRCA-PRC-04-F – Refrigerated Warehouse – Evaporator Fan Motor Controls Acceptance	§120.6(a)3	NA7.10.2
	NRCA-PRC-05-F – Refrigerated Warehouse – Evaporative Condenser Controls Acceptance	§120.6(a)4	NA7.10.3.1
	NRCA-PRC-06-F – Refrigerated Warehouse – Air-Cooled Condenser Controls Acceptance	§120.6(a)4	NA7.10.3.2
	NRCA-PRC-07-F – Refrigerated Warehouse – Compressor Variable Speed Acceptance	§120.6(a)5	NA7.10.4
	NRCA-PRC-08-F – Refrigerated Warehouse – Electric Resistance Underslab Heating System Acceptance	§120.6(a)2	NA7.10.1
	NRCA-PRC-12-F – Elevator Lighting and Ventilation Controls	§120.6(f)5	NA7.14
	NRCA-PRC-13-F – Escalator and Moving Walkways Speed Control	§120.6(g)2	NA7.15

E. Submission of Certification of Acceptance

The completed and signed certificate of acceptance must be submitted to the local enforcement agency in accordance with the local laws, ordinances, regulations, or customs. There is no general requirement for a certificate of acceptance to be submitted to any other regulatory agency or to an ATTCP, though specific contractual agreements may require such submissions. For example, in many cases ATTCP will require that certified acceptance test technicians electronically submit all completed certificates of acceptance as a condition of maintaining their certification status.

13.2.4 Envelope and Mechanical Acceptance Testing Overview

The administrative requirements contained in the Energy Standards (§10-103(b)) require the envelope and mechanical plans and specifications to contain:

- Completed acceptance testing documents for mechanical systems and equipment shown in Table 13-1; submission of record drawings to the building owners within 90 days of receiving a final occupancy permit.
- Submission of operating and maintenance information to the building owner.
- Installation certificates for mechanical equipment (for example, factory-installed economizers).

13.2.4.1 Envelope and Mechanical Acceptance Test Issues

Acceptance testing must be tailored for each specific design, job site, and climatic condition. While the steps for conducting each test and the acceptance criteria remain consistent, the application of the tests to a particular site may vary. The following section discusses some of the known issues that occur when applying acceptance tests on-site.

A. General Issues − Envelope

Important aspects to the fenestration acceptance requirements are:

- Verification of thermal performance (U-factor, SHGC, and VT) for each specified fenestration product to ensure that it matches the fenestration certificate, building plans, energy compliance documentation, and the purchase order or receipt.
- When installed fenestration thermal performance is equal or better than the specified or listed on the energy documentation, then no further recompliance is required.
- When installed fenestration is less than the energy documentation, then recompliance is required. Installation of less efficient fenestration can increase the cooling load of the building and adversely affect the overall energy use of the building.
- When using the performance approach, the weighted average thermal performance per orientation is applicable if it is equal or better than the specified values as noted above; otherwise, recompliance is required.

B. General Issues – Mechanical Combining Tests to Reduce Testing Costs

Many of the acceptance tests overlap in terms of activities. For example, both Reference Nonresidential Appendix NA7.5.1.1 Ventilation Systems for Variable Air and Constant Volume Systems Acceptance and NA7.5.6 Supply Fan Variable Flow Controls (FVC) Acceptance require zone controls be overridden to force the system into full design flow and low flow conditions. Since the bulk of the time for either test is driving the zone

controls (for example, variable air volume [VAV] boxes) into a set position, one may combine these two tests: performing the superset of activities with the boxes at both design and part-load conditions. There are several places where combining tests will save time. These opportunities are summarized below and described again in the test descriptions.

Tests requiring override of zone controls:

- NA7.5.1.1 Ventilation Systems for Variable Air Volume Systems Acceptance
- NA7.5.6 Supply Fan Variable Flow Controls Acceptance

Tests requiring override of the OSA damper:

- NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance (or NA7.5.1.2 Constant Volume Systems Outdoor Air Acceptance)
- NA7.5.4 Air Economizer Controls Acceptance
- NA7.5.5 Demand Controlled Ventilation Systems Acceptance
- NA7.5.11 Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion Units

Tests requiring a change in the unit mode of operation:

- NA7.5.2 Constant Volume, Single-Zone, Unitary Air Conditioner and Heat Pumps Systems Acceptance
- NA7.5.4 Air Economizer Controls Acceptance

Tests requiring dead head of the circulation pump and overriding control valves:

- NA7.5.7 Valve Leakage Tests
- NA7.5.9 Hydronic System Variable Flow Controls Acceptance.

C. Internal Control Delays

Be aware of the potential for delays programmed into many control sequences. Delays prevent the system from instability. With delays between 5 to 30 minutes, the acceptance testing can be prolonged considerably.

Examples include the normal time that a damper uses to stroke (typically several minutes end to end) and antirecycle timers on refrigerant compressors (typically 5 to 15 minutes).

1. Initial Conditions

Each test instructs the contractor to return the systems to normal operating condition based on the initial schedules, set points, and control parameters. These initial settings shall be recorded prior to initiating testing.

2. Obtain Correct Control Sequences Before Testing

Before testing begins, be familiar with the control sequences. Otherwise, the contractor will not be able to customize the test to the particular systems or verify that the systems work as intended. In many cases, the testing will be performed in conjunction with the controls contractor. In addition, many of these tests can be performed as part of the equipment/system start-up process.

The equipment operations and maintenance (O&M) manual usually documents the internal electronic controls.

With pneumatic controls, the control drawings are the best resource to ascertain how the system controls function.

With DDC controls, review the existing control programming loaded in the controllers. An important note is that the actual control logic is often different from the sequences on the design plans and specifications due to a number of reasons including:

- Poorly written or incomplete sequences on the design drawings.
- Standard practices by the installing EMCS contractor.
- Issues that arose in the field during control system start-up and commissioning.

Functional testing based on incorrect sequences will not necessarily yield a valid result.

3. Estimated Time to Complete

To give the full picture to contractors, the test summaries below ("At-A-Glance") include estimates of the time to complete construction observation, as well as functional testing on each system. These estimates are made for a specific test on a specific system and need to be combined to estimate the total time for completion on all systems associated with the entire building. Use these estimates with caution; times will vary depending on several factors, including the complexity of the controls, the number of control zones, the number of similar tests, and other issues. Expect delays during the first test. Subsequent tests take less time as the tester becomes more experienced and familiar with the test.

4. Sensor Calibration

A variety of sensors control many facets of heating, ventilating, and air conditioning systems. Confirming each sensor measures the respective parameter accurately is crucial to proper system operation and energy performance. For example, if a supply fan variable frequency drive is controlled based on duct static pressure, then an accurate pressure sensor is understandably imperative.

The requirement found in a few test procedures for sensor calibration can be met by either having a calibration certificate provided with the sensor from the manufacturer or through field verification. A calibration certificate from the manufacturer verifies testing of a particular sensor per a traceable standard (typically National Institute of Standards and Technology [NIST]) and confirms the sensor measures accurately. Common practice assumes a factory-calibrated sensor accurate and needs no further testing. Field verification generally requires checking the measured value from the sensor installed in the system against a calibrated instrument. Typically most sensors can be checked at a single operating point if the expected measurement range does not vary significantly. Any adjustments needed to make the field-installed sensor correspond to the value measured by the calibrated instrument can be made at either the transmitter itself or within the control system database.

The following sensors require checking for calibration:

- Pressure sensors used in variable flow applications (that is, supply fan or pump variable frequency drive is controlled to maintain a specific pressure set point). The following test procedure(s) apply: NA7.5.6 Supply Fan Variable Flow Controls and NA7.5.9 Hydronic System Variable Flow Controls.
- Temperature sensors used to control field-installed economizers and supply water temperature reset. The following test procedure(s) apply: NA7.5.4 Air Economizer Controls Acceptance and NA7.5.8 Supply Water Temperature Reset Controls.

- Carbon dioxide sensors used to implement a demand-controlled ventilation control strategy. The following test procedure(s) apply: NA7.5.5 Demand-Controlled Ventilation Systems Acceptance.

D. VAV Control Systems

There are many ways to control minimum ventilation in a VAV system, including, but not limited to:

- Supply/return flow tracking.
- Direct outdoor air flow measurement.
- Constant differential pressure across dedicated ventilation air damper.
- Constant mixed air plenum pressure.

The term “system” refers to whatever type of control strategy employed to control minimum ventilation air flow. The following test procedure(s) apply: NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance. Overall, the system must be able to control flow to within 10 percent of the design outdoor air ventilation value.

E. Air and Water Measurements

Before granting an occupancy permit for a new building or space, or a new space conditioning system serving a building or space, balance the system in accordance with the procedures defined by the Testing Adjusting and Balancing Bureau (TABB) National Standards (2003); the National Environmental Balancing Bureau (NEBB) Procedural Standards (1983); or Associated Air Balance Council (AABC) National Standards (1989).

F. Factory Air Economizer Certification Procedure

§120.5(a)4 requires air economizer acceptance testing in accordance with NA7.5.4, Air Economizer Controls. This test assures economizers work per the intent of the Energy Standards §140.4(e) Economizers. NA7.5.4, Air Economizer Controls describes the requirements for the acceptance test, as well as provides a detailed test description.

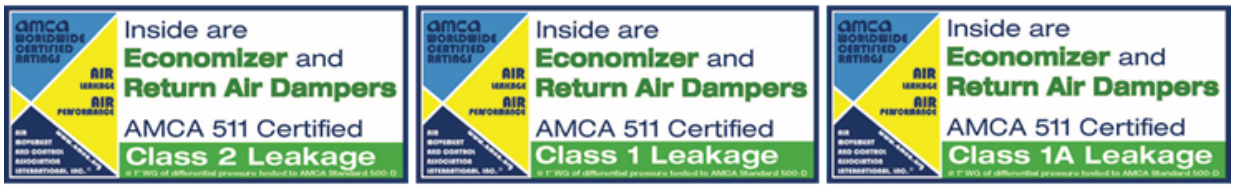
Air economizers installed by the HVAC system manufacturer and certified to the California Energy Commission as being factory installed, calibrated, and tested are exempted from the Air Economizer Controls acceptance test as described in the Nonresidential Reference Appendix NA7.5.4. The following sections describe the requirements of a “factory installed and calibrated economizer” certification and how to apply for Energy Commission approval of a certification program.

Inspection:

- Verify minimum outside air damper position can be adjusted. Verify outside and return air dampers modulate as necessary to achieve the desired position.
- Verify outside air dampers completely close when the unit is off.
- Verify outside air dampers move freely without binding.
- Provide a 5-year manufacturer warranty of economizer assembly.
- Provide an economizer specification sheet proving capability of at least 60,000 actuations
- Provide a product specification sheet proving compliance with Air Movement and Control Association (AMCA) Standard 500 damper leakage at 10 cfm/sf at 1.0 in.

w.g. Provide a product specification sheet showing the manufacturer's results after following the testing procedures of AMCA Standard 500 or AMCA certification by a third-party reviewer under AMCA Publication 511 may also be used to satisfy this requirement (Class 1A, 1, and 2 are acceptable). (See figure below)

Figure 13-1: AMCA 511 Certification Product Labels



Good, Class 2 = 10 cfm/sf max Better, Class 1 = 4 cfm/sf max Best, Class 1A = 3 cfm/sf max

Class 2, Class 1, & Class 1A Are All Acceptable

- Verify system has return fan speed control, relief dampers, or dedicated exhaust fans to prevent building over pressurization in full economizer model
- Verify calibration of outdoor air, return air, mixed air, and supply air sensors to known references within the following measurement tolerances:
  - Dry bulb and wet bulb temperatures accurate to ± 2°F over the range of 40°F to 80°F
  - Enthalpy accurate to ± 3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb
  - Relative humidity (RH) accurate to ± 5 percent over the range of 20 percent to 80 percent RH
- Verify the economizer instruction material provides the sensor performance curve. In addition, confirm the sensor output value measured during sensor calibration is plotted on the performance curve.
- Verify whether the high limit set point is fixed dry-bulb or fixed enthalpy + fixed dry-bulb; in either case, the control shall have an adjustable set point.
- Verify the location of sensors used for the high limit control to prevent false readings, for example, properly shielded from direct sunlight
- Verify that the high-limit shutoff set point is set to these default limit settings per Table 140.4-B, as referenced in §140.4(e)3:

No climate zones allow fixed enthalpy, differential enthalpy, and electronic enthalpy.

1. Functional Testing

Factory-installed and calibrated economizer certification shall document that the following conditions are met:

- During a call for heating, outside air dampers close to minimum ventilation position and return air dampers open.
- Demonstrate proper integration between economizer and compressor using the steps in Table 13-2.
- Demonstrate economizer high-limit control and dead band using the process in Table 13-3.

Table 13-2: Steps to Demonstrate Proper Integration

Step	Description	Purpose
1	Simulate OAT to 45°F and RAT to 75°F	-------
2	Generate call for cooling and increase OAT such that economizer damper modulates to position between minimum and 50 percent open with no mechanical cooling.	Test partial economizing at low OAT.
3	Verify economizer position is correct (between minimum and 50 percent) and stable with no hunting, compressor is not enabled, and heating is disabled. Record the OAT and economizer damper position.	------
4	Increase the OAT such that economizer damper modulates to any position within 50 percent to 100 percent open with no mechanical cooling.	Test partial economizing.
5	Verify economizer modulates open to a larger degree, is stable with no hunting, the return air damper modulates more closed, and the compressor is not enabled. Record the OAT and economizer damper position.	-------
6	Increase the OAT such that the compressor turns on and the economizer damper modulates more closed.	Test partial economizing and compressor integration.
7	Verify the compressor is enabled. Record the OAT at high limit and the economizer damper position.	
8	Verify the compressor turns off and the economizer damper modulates to 100 percent open.	Test full economizing.
9	Record the compressor run time (minutes)	------
10	Repeat Steps 7-8 when the compressor turns on again. Also verify the economizer damper modulates to close.	Test partial economizing and compressor integration.
11	Record the compressor off time between cycles (minutes)	-------
12	Slowly increase the OAT such that mechanical cooling is enabled and the economizer damper modulates to minimum position	Test minimum ventilation and compressor integration.
13	Verify economizer and return air damper positions are correct and stable with no hunting, compressor is enabled, and heating is disabled.	-------

Table 13-3: Steps to Demonstrate High-Limit Control and Dead band

Step	Description	Purpose
1	Simulate RAT to 80°F; OAT to 72°F	
2	Generate a call for cooling	
3	Verify that economizer is at minimum position	Test minimum ventilation above the high limit setpoint.
4	Incrementally lower the OAT	
5	Verify that economizer stays at minimum position until ambient air conditions are less than high limit setpoint then opens to 100 percent	Test the high limit setpoint from above.
6	Incrementally raise the OAT	Test the dead band.
7	Verify that economizer stays at maximum position until ambient air conditions are higher than high limit setpoint then closes to minimum position	Test the high limit setpoint from below.
8	Test passes if both conditions are met: i.) economizer controller will utilize a dead band between economizer enable/disable operation of no greater than 2°F and ii.) high limit control meets the requirements of Table 140.4-C as referenced in §140.4(e)3	

2. *Documents to Accompany Factory-Installed and Calibrated Economizer Certificate*

- Installation instructions. For systems with cooling capacities greater than 54,000 Btu/hr, instructions shall include methods to assure economizer control is integrated and is cooling, even when economizer cannot serve the entire cooling load.
- Sensor performance curve for high-limit shutoff sensors and instructions for measuring sensor output. Performance curve shall also contain test points during calibration plotted on the curve. Curve details shall show measurement resolution in increments of 1°F and 1 Btu/lb.
- Economizer specification sheet proving capability of at least 60,000 actuations.
- Provide a product specification sheet proving compliance with AMCA Standard 500 damper leakage at 10 cfm/sf at 1.0 in. w.g. A product specification sheet showing the manufacturer's results after following the testing procedures of AMCA Standard 500 or AMCA certification by a third party under AMCA Publication 511 can be used to satisfy this requirement (Class 1A, 1, and 2 are acceptable).

3. *Application for Factory-Installed and Calibrated Economizer Certification*

Manufacturers who wish to label their economizers as factory-installed and calibrated must provide the following information to the California Energy Commission:

- Brief description of test method, including:
  - Method of placing equipment in heating and cooling mode.
  - Method of calibrating high limit sensor.
  - Method of testing control and damper.
- Model numbers of products to be certified.
- Sample of factory-installed and calibrated economizer documentation that would accompany each qualifying economizer.

- Name and contact information of lead staff in charge of certification

  Send the application materials to:

  Building Standards Development Office

  California Energy Commission

  1516 Ninth St., MS 37

  Sacramento, CA 95814

4. Sample Certificate of Factory-Installed and Calibrated Economizers

"This document certifies that this economizer has been factory installed and calibrated according to the requirements of the California Energy Commission. As a result, this economizer is exempted from the functional testing requirements (but not the construction inspection requirements) as described in Appendix NA7.5.4 Air Economizer Controls' and on the MECH-5 acceptance testing document."

Date of economizer testing:	Model Number:
Supervisor:	Serial Number:
Technician:	Rated Cooling Capacity:
Economizer fully integrated? YES NO	

Table 13-4: Type of High-Limit Control and Setpoint (Check Appropriate Control Strategy)

Device Type	Control Type & Setpoint	Climate Zones	Required High Limit (Economizer Off When):	
			Equation	Description
Fixed Dry Bulb	□	1, 3, 5, 11-16	T_{OA} > 75°F	Outdoor air temperature exceeds 75°F
	□	2, 4, 10	T_{OA} > 73°F	Outdoor air temperature exceeds 73°F
	□	6, 8, 9	T_{OA} > 71°F	Outdoor air temperature exceeds 71°F
	□	7	T_{OA} > 69°F	Outdoor air temperature exceeds 69°F
Differential Dry Bulb	□	1, 3, 5, 11-16	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
	□	2, 4, 10	$T_{OA} > T_{RA}$ – 2°F	Outdoor air temperature exceeds return air temperature minus 2°F
	□	6, 8, 9	$T_{OA} > T_{RA}$ – 4°F	Outdoor air temperature exceeds return air temperature minus 4°F
	□	7	$T_{OA} > T_{RA}$ – 6°F	Outdoor air temperature exceeds return air temperature minus 6°F
Fixed Enthalpy + Fixed Drybulb	□	All	h_{OA} > 28 Btu/lb or T_{OA} > 75°F	Outdoor air enthalpy exceeds 28 Btu/lb of dry air or Outdoor air temperature exceeds 75°F

Note to installer: Economizer high-limit setpoint must be reset when needed based upon climate zone and/or device type.

Outside Air Calibration

a. Outside air conditions during calibration test from reference measurement: T_{OA} = _____ h_{OA} = _____
b. Outside air sensor output during calibration test: T_{OA} = _____ h_{OA} = _____ Units (V, mA etc) _____
c. Sensor measured value from sensor performance curve: T_{OA} = _____ h_{OA} = _____
d. Are sensor measurements within 2°F or 3 Btu/lb of reference measurement?

   (Yes, No, N/A) T_{OA} = _____ h_{OA} = _____

   - ☐ Sensor output plotted on sensor performance curve
   - ☐ Sensors used for the high limit control are properly shielded from direct sunlight

e. Return air calibration (for differential dry bulb controls only)
f. Return air temperature during calibration test from reference measurement: T_{return} = _____
g. Return air sensor output during calibration test: Units (V, mV, etc) _____
h. Sensor measured value from sensor performance curve T_{return} = _____
i. Are sensor measurements within 2°F of reference measurement?

   (Yes, No, N/A) T_{OA} = _____

☐ Sensor output plotted on sensor performance curve

Functional Tests Under Simulated Temperature Conditions

- During a call for heating, outside air dampers are closed to a minimum outside air setting and air dampers are opened.
- During a call for full cooling and ambient conditions below the high-limit shutoff set point, before mechanical cooling is enabled, the outside air dampers must be 100 percent open and the return dampers fully closed.
- For systems with cooling capacities greater than 54,000 Btu/h, during a call for full cooling, if the ambient conditions are below the high limit shutoff set point and economizer cannot provide full cooling, then mechanical cooling is modulated to maximize economizer cooling, N/A system cooling capacity ≤ 54,000 Btu/h
- During a call for cooling, if the measured ambient air condition is greater than the high-limit shutoff set point, the outside air dampers are closed to a minimum outside air damper position and the return air dampers are opened.
- Minimum outside air can be adjusted.
- The outside air dampers are closed when the unit is off.
- The outside air dampers move freely without binding.

Accompanying Documents

- Installation instructions.
- For systems with cooling capacities greater than 54,000 Btu/hr, instructions shall include methods to assure economizer control is integrated and is cooling even when

economizer cannot serve the entire cooling load. N/A system cooling capacity ≤ 54,000 Btu/h.

- Economizer specification sheet proving capability of at least 60,000 actuations.
- Provide a product specification sheet proving compliance with AMCA Standard 500 damper leakage at 10 cfm/sf at 1.0 in. w.g. A product specification sheet showing the manufacturer's results after following the testing procedures of AMCA Standard 500 or AMCA certification by a third party under AMCA Publication 511 can be used to satisfy this requirement (Class 1A, 1, and 2 are acceptable)
- Performance curve for high-limit shutoff sensors and instructions for measuring sensor output.

The (**Manufacturing Company Name**) certifies that all the information on this certificate for factory installed and calibrated economizers is true and that this economizer complies with all of the California Energy Commission requirements for factory-installed and calibrated economizers.

13.2.5 Lighting Acceptance Testing Overview

Acceptance requirements can effectively improve code compliance and help determine whether lighting equipment meets operational goals and if efficiency and effectiveness need to increase.

The administrative requirements contained in the Energy Standards (§10-103(b)) require:

- Completed certificate of compliance, installation, verification and acceptance documents for lighting controls, automatic daylighting controls, demand responsive lighting controls, and outdoor motion sensors and lighting shutoff controls.
- Record drawings are provided to the building owners within 90 days of receiving a final occupancy permit.
- Operating and maintenance information be provided to the building owner.
- Completed installation certificates for daylighting controls, occupant sensing devices, and automatic shut-off controls.

13.2.5.1 Lighting Acceptance Test Issues

Acceptance testing must be tailored for each specific design, job site, and/or climatic condition. While the steps for conducting each test remain consistent, the application of the tests to a particular site may vary. The following section discusses some of the known issues that occur when the acceptance tests are applied to a project.

A. Internal Control Delays

Be aware of the potential for delays programmed into many control sequences. Delays prevent the system from instability. With delays between 5 to 30 minutes, the acceptance testing can be prolonged considerably.

B. Initial Conditions

Each test instructs the contractor to return the systems to normal operating condition based on the initial schedules, set points, and control parameters. These should be recorded before initiating testing.

C. Obtain Correct Control Sequences Before Testing

Before testing begins, the contractor must be aware*:*

- How the control sequence are programmed.
- That written control sequences often do not include enough detail to test the system (or they are found to be incorrect).
- How to operate the control system.

D. Estimated Time to Complete

To give the full picture to contractors, the at-a-glance includes the time to complete construction observation as well as functional testing. In addition, the At-A-Glance indicates the time shown is per system (not per building).

13.2.6 Process Acceptance Testing Overview

§10-103(b)

The administrative requirements contained in the Energy Standards require the refrigerated warehouse plans to contain:

- Applicable refrigerated warehouse compliance documents: NRCC-PRC-06-E, which includes the required acceptance tests, and documents NRCC-PRC-07-E and NRCC-PRC-08-E, as applicable.
- A note that specifies that the record drawings ("as-built" drawings) are provided to the building owners within 90 days of receiving a final occupancy permit.

Furthermore, the administrative requirements contained in the Energy Standards require:

- Installation certificates for refrigeration warehouses: NRCI-PRC-01-E.
- Refrigerated warehouse acceptance testing documents, NRCA-PRC-04-A, NRCA-PRC-05-A, NRCA-PRC-06-A, NRCA-PRC-07-A and NRCA-PRC-08-A.
- Operating and maintenance information in the building after occupancy.

13.2.6.1 Process Acceptance Test Issues

Acceptance testing must be tailored for each specific design, job site, and/or climatic conditions. While the steps for conducting each test and the acceptance criteria remain consistent, the application of the tests to a particular site may vary. The following section discusses some of the known issues when performing the acceptance tests.

A. Cooling Loads

Some acceptance tests require an accurate determination of an adequate cooling load. For performing the acceptance test, the system cooling load may be artificially increased (such as by lowering the space temperature set point).

B. Initial Conditions

Each acceptance test includes a final instruction stating that any schedules, set points, and/or control parameters changed during the acceptance test shall be restored to pretest values. Record these initial settings before performing the acceptance test.

C. Internal Control Features

The field technician should be aware that many control functions include internal control features such as start-up and shutdown delays, fail-safes, control dead bands, and automatic overrides. These features protect system equipment and increase system stability. These features are necessary for the safe and efficient operation of the refrigeration system and disregarded when determining if a component passes or fails an acceptance test.

Before doing any acceptance testing, the field technician shall fully understand the control logic for each component under test. Close coordination and communication with the controls engineer, contractor, or component vendor may be necessary.

D. Estimated Time to Complete

The “at-a-glance” summaries include estimates of the time to complete construction inspection, as well as functional testing for each system component. These estimates are made for a test on a single component; actual time to complete the tests will vary depending on the complexity of the controls and the refrigeration system, the number of control systems, and other factors. Expect delays during the first test.

E. Sensor Calibration

In refrigerated warehouses, sensors used for refrigeration system control include numerous field-installed sensors, such as evaporator zone temperatures, suction and discharge pressure transducers, and outdoor temperature and humidity sensors. Sensors may also be factory-installed on equipment such as a screw compressor package. To ensure efficient system operation, as well as meet the construction inspection requirements for the acceptance tests, all sensors used for operational control of the system must have current calibration.

Sensors used for information or other purposes that do not relate to maintaining pressures, temperatures, or routine equipment sequencing and operational control are not subject to these calibration requirements.

For field-installed sensors, on-site calibration must be completed, even if the sensor was provided with a calibration certificate. For field-installed sensors, there are multiple potential sources of error in the readings between the sensor and the operator interface. Errors may include, but are not limited to, sensor error, transmitter error, conversion error, thermal drift, or electrical noise. To provide accurate values to the control system, calibrate from end-to-end (in other words, sensor to the operator interface).

The instruments used to calibrate the field-installed sensors must be highly accurate to prevent bias errors. This calibrating instrument, also called the calibration “standard,” must be calibrated at least every two years using a NIST traceable reference. The refrigerated warehouse refrigeration system acceptance tests **require calibrating instrument** measurement tolerances as follows:

- Temperature: ±0.7°F between -30°F to 200°F
- Pressure: ±2.5 psi between 0 and 500 psig
- Relative humidity (RH): ±1 percent between 5 percent and 90 percent RH

The calibration includes checking the sensor reading (as read from the operators interface) versus the calibration instrument reading. The control system values shall be adjusted according to the control system procedures, which may include zero and span values or single offset values for calibration, so that the reading from the operator readout

is within an acceptable deviation from the calibrating instrument reading. To ensure consistency with control system documentation and proper implementation of sensor function and signal conversion (for example, proper ranges and engineering units), perform calibration at more than one condition (such as temperature or pressure). Measurements taken for calibration values should be tested for repeatability in the event of a controller or computer power reset.

For factory-installed sensors on an equipment package that is used for system control, the package manufacturer may certify the sensor as calibrated using a NIST-traceable reference or using the preceding field calibration.

For refrigerated warehouses, the calibration requires documentation to be provided to the field technician completing the acceptance test and the building owner for documentation and use in ongoing system maintenance. Calibration documentation includes records showing the calibration date, instruments used in calibration, and any offsets or other calibration values adjusting sensor readings in the control system. This process requires both field-installed sensors and factory-installed sensors on equipment packages.

13.3 NA7.4.1 Fenestration Acceptance

At-A-Glance

NA7.4.1 Fenestration Acceptance
Use Document NRCA-ENV-02-F
Purpose of the Test
Envelope components require an NFRC or Energy Commission label certificate, including site-built fenestration. The label certificate matches the building plans and energy compliance documentation. This certificate of acceptance summarizes the results of the acceptance test, as specified in the Reference Nonresidential Appendix, NA7.4. Additional related references are in §10-103(a)4, §10-111, §116(a)5 of the Energy Standards.
Instrumentation
No instrumentation recommended.
Test Conditions
Not applicable.
Estimated Time to Complete
Not applicable.
Acceptance Criteria
Products will be either NFRC-rated or not rated. For NFRC-rated products, record and cross reference the rating. For unrated products, record and attach the NRCC-ENV-05-E document and cross reference against the building plans.
Potential Issues and Cautions
Important aspects to the fenestration acceptance requirements are the following: • Verify that thermal performance (U-factor, SHGC, and VT) of each specified fenestration product matches the fenestration certificate, building plans, and energy compliance documentation, and that each product matches purchase order or receipt.

- If the to-be-installed fenestration thermal performance is equal to or better than the specified or listed on the energy documentation, then no further recompliance is required.
- If the to-be-installed fenestration is less than the energy documentation, then recompliance is required. Installing less efficient fenestration can increase the cooling load of the building and change the overall energy use of the building.
- If using the performance approach, then the weighted average thermal performance per orientation can be used as long it's equal to or better than the specified values as noted above; otherwise, recompliance is required.

A. Construction Inspection

Review the building plans and any completed NRCC-ENV-05-E documents; confirm that all products are represented.

B. Functional Testing

For NFRC-rated products:

- Record the NFRC label certificate ID.
- If receipts or orders are available and they identify the NFRC ID number, then cross reference against the NFRC label certificate to match ID numbers.
- Cross reference the efficiencies listed on the NFRC label certificate of NRCC-ENV-05-E– to ensure they match the building plans window schedule of efficiencies.

For nonrated fenestration, attach a copy of the NRCC-ENV-05-E to the NRCA-ENV-02-F.

13.4 NA7.5.1 Outdoor Air: Variable Air and Constant Volume Systems

At-A-Glance

NA7.5.1 Variable Air Volume Systems Outdoor Air Acceptance
Use Document NRCA-MCH-02-A
Purpose of the Test
This test ensures the provision of adequate outdoor air ventilation through the variable air volume air handling unit at two representative operating conditions. The test consists of measuring outdoor air values at maximum flow and at or near minimum flow. The test verifies the introduction of a minimum volume of outdoor air, in accordance with §120.1(b)2, into the air handling unit and is within 10 percent of the required volume when the system is in occupied mode at these two conditions of supply airflow. Perform this test in conjunction with NA7.5.6 (NRCA-MCH-07-A) Supply Fan Variable Flow Controls Acceptance test procedures to reduce the overall system testing time as both tests use the same two conditions of airflow for their measurements. Related acceptance tests for these systems include: • NA7.5.4 Air Economizer Controls. • NA7.5.5 Demand Control Ventilation (DCV) Systems (if applicable). • NA7.5.6 Supply Fan Variable Flow Controls

Instrumentation

Performance of this test will require measuring outdoor air flow. When the system includes an airflow monitoring system (AFMS) on the outdoor air, then it may be used for the measurements if it has a calibration certificate or is field-calibrated. The instrumentation needed to perform the task may include, but is not limited to:

- An airflow measurement probe (for example, hot-wire anemometer or velocity pressure probe), or
- A watch or some equivalent device to measure time in minutes

Test Conditions

The test needs an override of the normal control operations. The control system of the air handling unit and zone controls must be complete, including:

- Supply fan capacity control (typically a variable speed drive).
- Air economizer control.
- Minimum outdoor air damper control.
- Zone airflow control (including zone thermostats and VAV boxes).

Installed systems shall be ready for system operation, including:

- Duct work
- VAV boxes.
- Control sensors (temperature, flow, pressure, and so forth).
- Electrical power to air handling unit and control system components.
- Completion of air handling unit start-up procedures, per manufacturer's recommendations.

Document the initial conditions before executing system overrides or manipulation of the set points and schedules. At the end of the test, return all systems to normal.

Reference NRCC-MCH-03-E or the mechanical equipment schedules to determine the total required outdoor airflow for the system.

Estimated Time to Complete

Construction inspection: 0.5 hours to 2 hours, depending on complexity and difficulty in calibrating the "system" controlling outdoor air flow.

Functional testing: 1 to 3 hours, depending on the type of zone control and the number of zones.

Acceptance Criteria

Field- or factory-calibrated sensor controlling outdoor air flow with documentation attached.

Measured outdoor airflow reading is within 10 percent of the total value found on the Energy Standards Mechanical Plan Check document NRCC-MCH-03-E, under the following conditions:

- Minimum system airflow or 30 percent of total design flow
- Design supply airflow

Potential Issues and Cautions
Use caution when performing test during winter months in cold climates. Since outdoor airflow must remain constant as supply fan flow is reduced, total supply flow can approach 100 percent outdoor air. Be sure that all freeze protection and heating coil controls are functioning before performing test. Coordinate test procedures with the controls contractor who may assist with manipulation of the BAS to achieve the desired operating conditions. Ensure disabling of economizer and demand controlled ventilation controls before performing the test.

A. Test Application

- Newly constructed and additions/alterations: Applies only to new variable air volume (VAV) systems
- Constant air volume systems outdoor air acceptance
- Newly constructed and additions/alterations: Applies only to new constant air volume (CAV) systems

B. Construction Inspection

1. Reference the supporting documentation as needed. Reference NRCC-MCH-03-E or the mechanical equipment schedules to determine the total required outdoor airflow for the system.
2. Indicate method and equipment used to measure airflow during the functional test (for example, hot-wire anemometer) on the acceptance document. Note calibration date; calibration date must be within one year.
3. Check the system type (VAV or CAV) on the acceptance document. (The following instructions apply only to VAV systems.)
4. Check that the sensors used to control outside air (OSA) flow is either factory- or field-calibrated. Attach the calibration certificate or field calibration results to the acceptance test document NRCA-MCH-02-A.
5. Check that a fixed minimum damper set point is not controlling OSA. The field technician shall review the operation sequences to ensure the system performs dynamic control of minimum outdoor air and reviews the installation to confirm all of the devices of that sequence are present.
6. Indicate the dynamic control method used to control OSA in the system. There are several means to dynamically control minimum OSA for VAV systems, and many ways for the designer to specify an active ventilation air control “system” intended to maintain a constant outdoor air flow rate as supply fan flow rate decreases.

   For example, an installed flow station measures outdoor air flow rate and modulates the outdoor air dampers accordingly. Or perhaps dampers are modulated to maintain a constant differential pressure across a dedicated outdoor air damper assembly. The sensors, equipment, and control strategy necessary to achieve the desired control shall be calibrated as a “system,” regardless of the control method of the outdoor airflow.

7. Indicate the method used to deliver outside air to the unit (for example, duct, return air plenum). For systems using return air plenums to distribute outside air to a zonal heating or cooling unit, confirm that outside air supply connects either:
    - Within 5 feet of the unit.
    - Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute.
8. Confirm the system program includes a preoccupancy purge for the 1-hour period immediately before normal occupancy of the building per §120.1(c)2. This confirmation is most easily accomplished by scheduling the unit to start one hour before actual occupancy. The purge amount must be the lesser of the minimum outdoor air rate or three complete building air changes (ACH).

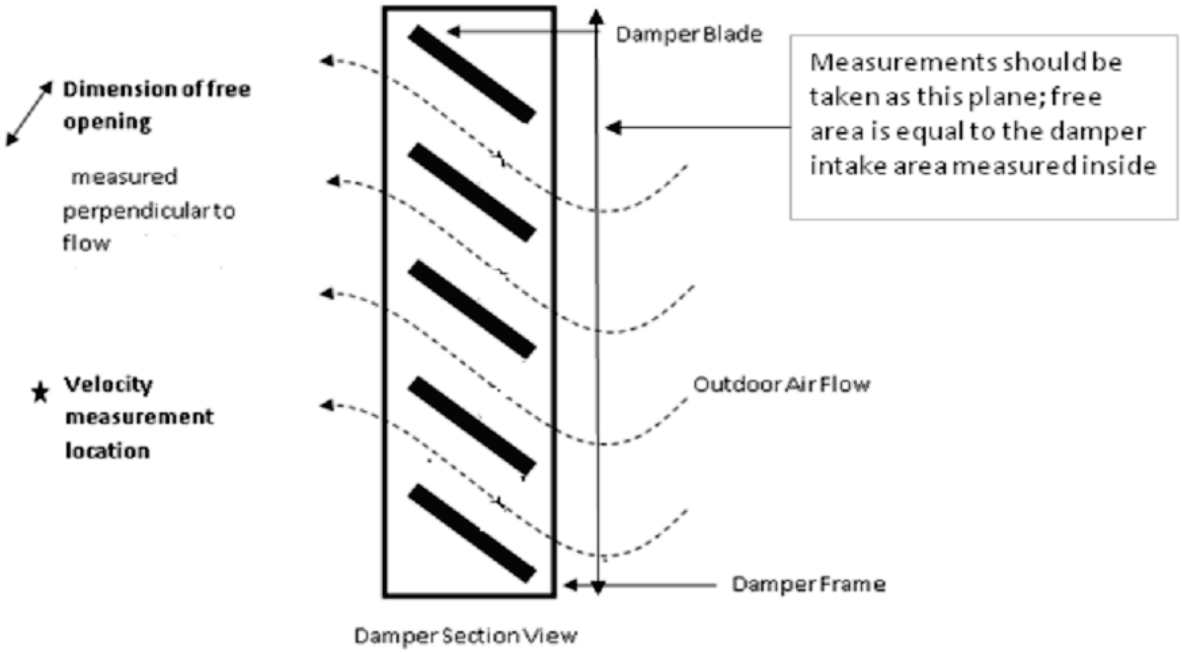
C. Functional Testing

Air handling systems with a dedicated fan providing ventilation air to the unit are exempt from measuring ventilation airflow at minimum and maximum supply airflow conditions. An independent ventilation air fan will deliver a constant minimum outdoor air volume to the air handling unit regardless of the speed of the supply fan. Therefore, the only verification needed for this system type would be to measure the actual CFM delivered by the dedicated ventilation air fan.

Follow the best practice guidelines below to increase accuracy of outdoor air flow measurements:

- Traverse measurements taken in supply, return or outdoor air ducts shall be located in an area of steady, laminar flow. If possible, take measurements at least six to eight duct diameters away from turbulence, air intakes, bends, or restrictions.
- When using face velocity measurements to calculate outdoor air flow, take particular care to accurately measure free area intake dimensions.
- When taking velocity measurements at the plane of the intake between damper blades where flow is restricted (that is, to achieve faster flows), free area shall be measured as the actual open space between dampers and should not include frames or damper blades. See Figure 13-2 below for illustration of free opening measurements.

Figure 13-2: Location for measurement of air flow through dampers



- Hot wire anemometers are more appropriate than velocity pressure probes for measuring low-speed flows (that is, less than 250 feet per minute). When measuring flow with a hot wire anemometer, make sure to position the measurement device perpendicular to the flow direction.
- Take multiple measurements and average results to minimize effects of fluctuations in system operation and environmental conditions (such as wind).

Your body can obstruct air flow and affect measurements. To increase measurement accuracy, position your body away from the intake and airflow.

Step 1: Disable demand control ventilation, if applicable.

Step 2: Verify unit is not in economizer mode. Disable the air economizer, if applicable.

For systems with an air economizer, disabling the economizer will prevent the outdoor air damper from modulating during the test due to atmospheric conditions rather than supply airflow variations. Disabling the economizer is necessary only if the system is in cooling mode and outdoor air temperature is below the economizer high-limit set point. The economizer can be disabled in several ways, depending on the control strategy used to modulate the outdoor air dampers:

- Use the high-limit switch by reducing the set point (return air value or outdoor air value if a comparative or changeover strategy, respectively, is used) below the current OSA dry-bulb or enthalpy measurement.
- Disable the economizer damper control loop through software if it is a DDC system.

Step 3: Modify VAV boxes to achieve full design airflow.

The intent is to measure outdoor air flow when the system is operating at or near the design airflow condition, or maximum airflow at full cooling. This point is provided along with the minimum operating point to test the minimum OSA control at either end of the control range. There are a number of ways to achieve design airflow including:

- Override all space temperature cooling set points to a low temperature (for example, 60°F cooling) that will force the VAV boxes into full cooling (may be accomplished by a global command or it may have to be done per box).
- Command all VAV boxes to design flow position (may be accomplished by a global command or it may have to be done per box).
- Set the VAV box minimum flow set point to be the same as maximum flow set point (may be accomplished by a global command or it may have to be done per box).

Verify and Document:

- Document the supply airflow at full cooling on the acceptance document.
- Document VFD speed; VFDs should be at or near 60Hz.
- Document the measured outdoor air reading. Document the required outdoor airflow as found on mechanical plan check document NRCC-MCH-03-E Column M, or mechanical equipment schedules. In the “Testing Calculation and Results” section of the acceptance document, confirm that measured outdoor air flow is within 10 percent of design outdoor air flow rate.
- Outdoor air flow can be measured directly, or indirectly, in a variety of ways. Acceptable methods for measuring outdoor air flow include, but are not limited to the following techniques:
    - Read the outdoor air flow value measured by an air flow monitoring station, if one is installed.
    - Traverse across the outdoor air duct to measure duct velocity, measure duct size, and calculate flow.
    - Measure face velocity at various points across outdoor air intake, measure intake damper size, and calculate flow.
    - Traverse across the supply and return ducts to calculate flow (outdoor airflow can be estimated as the difference between the supply and return airflow rates).
- Document time for OSA damper to stabilize after the VAV boxes open on the acceptance document. Confirm that dampers stabilize within 5 minutes. The intent is to ensure the proportional-integral-derivitative (PID)[1] control loops are tuned properly.

[1] A proportional-integral-derivative controller (PID controller) is a control mechanism commonly used in industrial control systems. A PID controller continuously calculates the difference between a measured process variable and a desired setpoint. In this case, the variable and setpoint are in relation to the VAV damper stability control.

Step 4: Drive all VAV boxes to either the minimum airflow, full heating airflow, or 30 percent of total design airflow.

The intent is to measure outdoor air flow when the system is operating at or near a minimum flow condition (for example, full heating). This point is provided along with the design point to test the minimum OSA control at either end of the control range. If the system has an airflow monitoring station (AFMS), it will test the accuracy of that AFMS at the lowest velocity, namely the least accurate point.

There are several ways to force the VAV boxes to a minimum position depending on the building automation system capabilities and control strategies used, for example:

- Override all space temperature set points to a wide range (e.g. 60°F heating and 90°F cooling) that will force the VAV boxes into the dead band (may be accomplished by a global command or it may have to be done per box).
- Command all VAV boxes to minimum flow position (may be accomplished by a global command or it may have to be done per box).
- Set maximum flow set point to be the same as minimum flow set point (may be accomplished by a global command or it may have to be done per box).

  An alternative method is to manually adjust the VFD until the system airflow is at the desired condition. If the VAV boxes are in control they will open up as you are doing this, so you need to provide some time (about 5 minutes) to allow the system to settle. Although this is acceptable for testing OSA, this would not meet the requirements of NA7.5.6 Supply Fan Variable Flow Controls for testing the stability of the pressure control loop. These two tests should be done concurrently to minimize cost.

Verify and Document:

- Document the supply airflow on the acceptance document.
- Document VFD speed.
- Document the measured outdoor air reading. In the “Testing Calculation and Results” section of the acceptance document, confirm that measured outdoor air flow is within 10 percent of design outdoor air flow rate found on mechanical plan check document NRCC-MCH-03-E Column M, or mechanical equipment schedules. The methods provided earlier for conducting field airflow measurements also apply here.
- Document time for OSA damper to stabilize after the VAV boxes open on the acceptance document. Confirm that dampers stabilize within 5 minutes. The intent is to ensure the PID control loops are tuned properly.

Step 5: Return system back to normal operating condition.

Ensure all schedules, set points, operating conditions, and control parameters are placed back at the initial conditions. Release any overrides on the economizer or demand ventilation controls.

13.5 NA7.5.1.2 Constant Volume Systems Outdoor Air Acceptance

At-A-Glance

NA7.5.1.2 Constant Volume Systems Outdoor Air Acceptance

Use Document NRCA-MCH-02-A

Purpose of the Test

This test ensures the constant volume air handling unit provides adequate outdoor air ventilation to the spaces served under all operating conditions.

Systems requiring demand ventilation controls per §120.1(c)3 must conform to §120.1(c)4E regarding the minimum ventilation rate when the system is in occupied mode.

Related acceptance tests for these systems include the following:

- NA7.5.2 Constant-Volume, Single-Zone, Unitary Air Conditioners and Heat Pump Systems
- NA7.5.4 Air Economizer Controls (if applicable)
- NA7.5.5 Demand-Controlled Ventilation Systems Acceptance (if applicable)

Instrumentation

Performance of this test will require measuring outdoor air flow. If the system was installed with an airflow monitoring station (AFMS) on the outdoor air, then it can be used for the measurements if it has a calibration certificate or is field-calibrated. The instrumentation needed to perform the task may include, but is not limited to:

- A means to measure airflow (typically either a velocity pressure probe or hot wire anemometer).
- A watch or some equivalent instrument to measure time in minutes

Test Conditions

To perform the test, override the control system of the air handling unit. The control system of the air handling unit must be complete.

All systems must be installed and ready for system operation, including:

- Air economizer controls.
- Duct work.
- Control sensors (temperature, flow, thermostats, and so forth).
- Electrical power to air handling unit and control system components.
- Completion of air handling unit start-up procedures, per manufacturer's recommendations.
- Documentation of the initial conditions before overrides or manipulation of the set points and schedules. All systems must be returned to normal at the end of the test.

Note: Systems requiring demand ventilation controls per §120.1(c)3 must conform to §120.1(c)4E regarding the minimum ventilation rate (refer to NA7.5.5 Demand Controlled Ventilation Systems Acceptance Test).

Estimated Time to Complete
Construction inspection: 0.5 hours **Functional testing**: 1 hour (depending on difficulty in measuring outdoor air flow)
Acceptance Criteria
System demonstrates a means of maintaining the minimum outdoor air damper position. Minimum damper position is marked on the outdoor air damper Measured outdoor air flow is within 10 percent of the total value found on the Energy Standards mechanical plan check document NRCC-MCH-03-E Column M.
Potential Issues and Cautions
Do not attempt to set the minimum damper position and perform the acceptance test at the same time. The acceptance test verifies the outdoor airflow of the system after calibration and system set-up is complete. Testing costs can be reduced by conducting the acceptance test immediately after set-up is concluded.

A. Test Application

- Newly constructed and additions/alterations: Applies only to new variable air volume (VAV) systems
- Constant air volume systems outdoor air acceptance
- Newly constructed and additions/alterations: Applies only to new constant air volume (CAV) systems

B. Construction Inspection

1. Reference the supporting documentation as needed. Reference NRCC-MCH-03-E or the mechanical equipment schedules to determine the total required outdoor airflow for the system.
2. Indicate method and equipment used to measure airflow during the functional test (for example, hot-wire anemometer) on the acceptance document. Note calibration date; calibration date must be within one year.
3. Check the system type (VAV or CAV) on the acceptance document (the following instructions apply only to CAV systems).
4. Check that the system is designed to provide a fixed minimum OSA when the unit is on and has a means of maintaining a minimum outdoor air damper position. Minimum position is marked on the outdoor air damper. The intent is that if the damper position is moved for any reason, it can be returned to the proper position to maintain design minimum outdoor air flow requirements.
    - Packaged HVAC systems without an economizer will most likely have a fixed outdoor air damper that can be adjusted manually.
    - Small packaged HVAC systems (< 20 tons) with an economizer will most likely have a controller/actuator that will control the outside and return air dampers (for example, a Honeywell W7459A economizer control package). The economizer control package is responsible for maintaining a minimum ventilation damper position as necessary and will most likely receive operation signals from either a thermostat or through a connection to a central DDC system.

- Large packaged HVAC systems (≥ 20 tons) will most likely have either a stand-alone economizer controller/actuator package (for example, a Honeywell W7459A) or a control package similar to a built-up system (that is, outside and return air dampers controlled by a DDC signal). The stand-alone economizer package may receive operation signals from a thermostat, an internal DDC controller, or a central DDC system. The "built-up" style economizer will most likely be controlled by an internal DDC controller or a central DDC system. Some large package systems may also have a dedicated outdoor air damper/actuator, independent of the economizer control strategy.
- Built-up HVAC system can control the outside and return dampers through a single actuator and damper linkages or through independent actuators and control signals. The control signals will most likely come from a central DDC system. Some built-up systems may also have a dedicated outdoor air damper/actuator, independent of the economizer control strategy.

5. Indicate the method being used to deliver outside air to the unit (for example, duct, return air plenum). For systems where return air plenum is used to distribute outside air to a zonal heating or cooling unit, confirm that outside air supply is connected either:
   - Within 5 feet of the unit.
   - Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute.
6. Confirm that preoccupancy purge has been programmed into the system for the 1-hour period immediately before the building is normally occupied per §120.1(c)2. Confirmation is most easily accomplished by scheduling the unit to start one hour prior to actual occupancy. The purge amount must be the lesser of the minimum outdoor air rate or three complete building air changes (ACH).

C. Functional Testing

- Follow the best practice guidelines below to increase accuracy of outdoor air flow measurements. Traverse measurements taken in supply, return, or outdoor air ducts should be located in an area of steady, laminar flow. Where possible, take measurements at least six duct diameters away from turbulence, air intakes, bends, or restrictions.
- When using face velocity measurements to calculate outdoor air flow, care should be taken to accurately measure free area dimensions of intake.
- When velocity measurements are taken at the plane of the intake between damper blades where flow is restricted (to achieve faster flows), free area should be measured as the actual open space between dampers and should not include frames or damper blades. See Figure 13-2 for illustration of free opening measurements.
- Hot wire anemometers are more appropriate than velocity pressure probes for measuring low-speed flows (that is, less than 250 feet per minute). When measuring flow with a hot wire anemometer, make sure to position the measurement device perpendicular to flow direction.
- Take multiple measurements and average results to minimize effects of fluctuations in system operation and environmental conditions (in other words, wind).

Your body can obstruct air flow and effect measurements. Position your body away from the intake and flow of air.

Step 1: Disable demand control ventilation, when applicable.

Step 2: Disable the air economizer when applicable and test at full supply airflow

When the system has an outdoor air economizer, force the economizer to the minimum position and stop outside air damper modulation.

For systems with an air economizer, disabling the economizer will prevent the outdoor air damper from modulating during the test due to atmospheric conditions rather than supply airflow variations. Disabling the economizer is necessary only if the system is in cooling mode and outdoor air temperature is below the economizer high limit setpoint. The economizer can be disabled in several ways, depending on the control strategy used to modulate the outdoor air dampers:

1. Use the high-limit switch by reducing the setpoint (return air value or outdoor air value if a comparative or changeover strategy, respectively, is used) below the current OSA dry-bulb or enthalpy measurement
2. Disable the economizer damper control loop through software if it is a DDC system.

Verify and Document

- Document the measured outdoor air reading. Document the required outdoor airflow rate found on mechanical plan check document NRCC-MCH-03-E Column M, or mechanical equipment schedules. In the “Testing Calculation and Results” section of the acceptance document, confirm that measured outdoor air flow is within 10 percent of design outdoor air flow

Outdoor air flow can be measured directly, or indirectly, in a variety of ways. Acceptable methods for measuring outdoor air flow include, but are not limited to, the following techniques:

1. Read the outdoor air flow value measured by an air flow monitoring station if one is installed.
2. Traverse across the outdoor air duct to measure duct velocity, measure duct size, and calculate flow.
3. Measure face velocity at various points across outdoor air intake, measure intake damper size, and calculate flow.
4. Traverse across the supply and return ducts to calculate flow. (Outdoor airflow can be estimated as the difference between the supply and return airflow rates.)

Step 3: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at the initial conditions. Release any overrides on the economizer or demand ventilation controls.

13.6 NA7.5.2 Constant Volume, Single-Zone, Unitary Air Conditioner and Heat Pumps Systems Acceptance

NA7.5.2 Constant Volume, Single-Zone, Unitary Air Conditioner and Heat Pumps Systems Acceptance
Use Document NRCA-MCH-03-A
Purpose of the Test
This test verifies the components of a constant volume, single-zone, unitary air conditioner and heat pump system function correctly, including: thermostat installation and programming, supply fan, heating, cooling, and damper operation.
Testing of the economizer, outdoor air ventilation, and demand-controlled ventilation are located in the following sections of the Reference Appendices: • NA7.5.1.2 Constant Volume System Outdoor Air Acceptance • NA7.5.4 Air Economizer Controls (if applicable) • NA7.5.5 Demand Control Ventilation (DCV) Systems (if applicable)
Instrumentation
Temperature meter, amp meter
Test Conditions
Unit and thermostat installation and programming must be complete. HVAC system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer's recommendations. Document the initial conditions before overrides or manipulation of the setpoints and schedules. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction inspection: 0.5 to 1 hour (depending on familiarity with thermostat programming) **Equipment test**: 1 to 2 hours

Acceptance Criteria

The following are verified through inspection:

- Thermostat is located within the space conditioning zone that is served by the respective HVAC system.
- Thermostat meets the temperature adjustment and dead band requirements of §120.2(b).
- Occupied, unoccupied, and holiday schedules have been programmed per the schedule of the facility.
- Preoccupancy purge has been programmed to meet the requirements of §120.1(c)2.

The following modes of operation function correctly:

- **Occupied heating mode operation**: The supply fan operates continuously, all heating stages operate, cooling is not enabled, and the outdoor air damper is at minimum position.
- **Occupied operation with no heating or cooling load**: The supply fan operates continuously, heating or cooling is not enabled, and the outdoor air damper is at minimum position.
- **Occupied cooling mode operation**: The supply fan operates continuously, all cooling stages operate, heating is not enabled, and outside damper is at minimum position.
- **Unoccupied operation with no heating or cooling load**: The supply fan shuts off, heating or cooling is not enabled, and the outdoor air damper is closed.
- **Unoccupied operation with heating load**: The supply cycles ON, heating is enabled, cooling is not enabled, and the outdoor air damper is either closed or at minimum position.
- **Unoccupied cooling mode operation**: The supply cycles ON, cooling is enabled, heating is not enabled, and the outdoor air damper is at minimum position.
- **Manual override mode**: System reverts to occupied mode, the supply fan turns ON for duration of override, heating or cooling is enabled as necessary, and the outdoor air damper opens to minimum position.

Potential Issues and Cautions
Ensure that the supply fan runs continuously in occupied mode and cycles appropriately in unoccupied mode. Cycling refers to the supply fan running only when heating or cooling is enabled. When testing the manual override, adjust the length of the override period to minimize test time. Be sure to reset the override period back to the correct length of time. Tip: Overall test time may be reduced (especially for rooftop HVAC units controlled by thermostats) if two people perform the test − one to manipulate the thermostat while someone else verifies operation at the packaged unit. The Energy Standards do not mandate the actual differential between occupied and unoccupied setpoints, only that the system must be adjustable down to 55°F for heating and up to 85°F for cooling and that the thermostat can be set for a 5°F dead band. Setback control is only required for climates where the winter median of extremes is less than or equal to 32°F. Setup control is only required for climates where the 0.5 percent summer design dry-bulb temperature is greater than or equal to 100°F.

A. Test Application

Newly Constructed and Additions/Alterations: Applies only to new constant-volume, single-zone, unitary units with direct expansion (DX) cooling. These units may be cooling only or heating and cooling.

The following acceptance test procedures are applicable to systems controlled by thermostats, internal DDC, or central DDC systems. Most of the tests can be performed through simple manipulation of the thermostat or the DDC system controlling each packaged HVAC unit. Specific details and examples of how to perform each test are provided below.

B. Construction Inspection

Prior to functional testing, verify and document the following:

1. Thermostat, or temperature sensor, is within the zone that the respective HVAC system serves.
2. Thermostat is wired to the HVAC unit correctly. This can be inferred from the acceptance tests.
3. In particular, ensure that multiple stage terminals (that is, first and second stage wires) on the thermostat, both cooling and heating stages, are wired to the corresponding circuits at the HVAC unit.
4. Verify that no factory-installed or field-installed jumpers exist across the first and second stage cooling terminals at the unit. (This will ensure that only the economizer can be enabled as the first stage of cooling.)
5. For heat pumps only, verify the “O” terminal on the thermostat is wired to the reversing valve at the unit.
6. For heat pumps only, verify thermostat dip switch or programmable software is set to heat pump.

7. Thermostat meets the temperature adjustment and dead band requirements of §120.2(b): The thermostat shall allow a heating setpoint of 55°F or lower and a cooling setpoint of 85°F or higher. The dead band shall be at least 5°F, where heating and cooling is shut off. On the acceptance document MECH-04A, note the minimum heating setpoint, maximum cooling setpoint, and dead band.
8. Occupied, unoccupied, and holiday schedules have been programmed per the schedule of the facility.

Preoccupancy purge has been programmed to meet the requirements of §120.1(c)2. This is typically accomplished by scheduling the unit to start one hour prior to actual occupancy. Check the method used to determine preoccupancy purge:

- The lesser of 15 cfm per person, or the conditioned floor area times the ventilation rate from the Energy Standards Table 120.1-A,

OR

- Three complete building air changes (ACH).

C. Functional Testing

The following procedures are applicable to systems controlled by a programmable thermostat, internal DDC (packaged systems only), or central DDC system.

As you complete each step, check the appropriate operating mode boxes on the acceptance document.

Step 1: Disable economizer control and demand-controlled ventilation systems (if applicable) to prevent unexpected interactions.

The economizer can be disabled by temporarily adjusting the high-limit setpoint. The demand-controlled ventilation system can be disabled by setting the CO_2 setpoint well below current zone CO_2 concentration.

Step 2: Simulate a heating demand during occupied condition.

- Either set the “occupied” time schedule to include actual time or adjust the time to be within the “occupied” time schedule.
- Set heating setpoint above actual space temperature.

Verify and Document

- Supply fan operates continually during occupied condition.
- Ensure all available heating stages operate; the heater stages on. This may require raising the heating setpoint even further so that multiple heating stages can become enabled. For example, many programmable thermostats and DDC control algorithms use time delays and deviations from setpoint to enable multiple heating stages. Setting the heating setpoint very high should prevent the first stage of heat from meeting setpoint and allow the system adequate time to enable the second or third stages.
- No cooling is provided by the unit.
- Outdoor air damper is open to minimum ventilation position (Note: Outdoor ventilation air requirements will be tested under section NA7.5.1.2 Constant Volume System Outdoor Air Acceptance).

Step 3: Simulate operation in the dead band (no-load condition) during occupied condition.

- Set “occupied” time schedule to include actual time or adjust time to be within the “occupied” time schedule (whichever is easier).
- Adjust heating and cooling setpoints so that actual space temperature is between the two values.

Verify and Document

- Supply fan operates continually during occupied condition.
- Confirm heating and cooling is not provided by the unit.
- Outdoor air damper is open to minimum ventilation position.

Step 4: Simulate a cooling demand during occupied condition.

- Set “occupied” time schedule to include actual time or adjust time to be within the “occupied” time schedule (whichever is easier).
- Set cooling setpoint below actual space temperature.

Verify and Document

- Supply fan operates continually during occupied condition.
- Ensure all available cooling stages operate; the compressor stages on. This may require lowering the cooling setpoint even further so that multiple cooling stages can become enabled. For example, many programmable thermostats and DDC control algorithms use time delays and deviation from setpoint to enable multiple cooling stages. Setting the cooling setpoint very low should prevent the first stage of cooling from meeting set point and allow the system adequate time to enable the second stage.
- No heating is provided by the unit.
- Outdoor air damper is open to minimum ventilation position.

Step 5: Simulate operation in the dead band (no-load condition) during unoccupied condition.

- Set “unoccupied” time schedule to include actual time or adjust time to be within the “unoccupied” time schedule (whichever is easier).
- Ensure actual space temperature is in between unoccupied heating and cooling setpoints. Adjust each setpoint as necessary to achieve desired control.

Verify and Document

- Supply fan shuts off during unoccupied condition.
- Unit does not provide heating or cooling.
- Outdoor air damper is fully closed.

Step 6: Simulate heating demand during unoccupied condition.

- Set “unoccupied” time schedule to include actual time or adjust time to be within the “unoccupied” time schedule (whichever is easier).

- Set heating setpoint above actual space temperature.

Verify and Document

- Supply fan cycles on with call for heating.
- Heating is provided by the unit; heater stages on.
- No cooling is provided by the unit.
- Outdoor air damper is either fully closed or at minimum position

Step 7: Simulate cooling demand during unoccupied condition.

- Set “unoccupied” time schedule to include actual time or adjust time to be within the “unoccupied” time schedule (whichever is easier).
- Set cooling setpoint above actual space temperature.

Verify and Document

- Supply fan cycles on with call for cooling.
- No heating is provided by the unit.
- Cooling is provided by the unit.
- Outdoor air damper is either fully closed or at minimum position.

Step 8: Simulate manual override during unoccupied condition.

- Set “unoccupied” time schedule to include actual time or adjust time to be within the “unoccupied” time schedule (whichever is easier).
- Engage the manual override, which may entail pushing an override button, triggering an occupant sensor, or enabling some other form of override control.

Verify and Document

- System reverts back to an “occupied” condition. For a DDC control system, verify the “active” heating and cooling setpoints correspond to those programmed for the occupied condition. For a programmable thermostat, the thermostat may display that it is in the “occupied” mode.
- System reverts back to an “unoccupied” condition when manual override period expires. It may be necessary to adjust the length of the override period to minimize test time.
- Check that the supply fan operates continually during occupied condition.
- Check that outside air damper is open to minimum ventilation position.

Step 9: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, overrides, and control parameters are placed back at the initial conditions. Confirm testing results on the certificate of acceptance document NRCA-MCH-03-A.

13.7 NA7.5.3 Air Distribution Systems Acceptance

At-A-Glance

NA7.5.3 Air Distribution Systems Acceptance
Use Document NRCA-MCH-04-A
Purpose of the Test
This test verifies all duct work associated with all nonexempt constant volume, single-zone, HVAC units (in other words, air conditioners, heat pumps, and furnaces) meet the material, installation, and insulation R-values per §120.4(a) and leakage requirements outlined either in §140.4(l) for new duct systems or §141.0(b)2D for existing duct systems. As detailed in the Energy Standards, this test is required only for single-zone units serving less than 5,000 ft² of floor area where 25 percent or more of the duct surface area is in one of the following spaces: • Outdoors. • In a space directly under a roof where the U-factor of the roof is greater than the U-factor of the ceiling. • In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces. • In an unconditioned crawlspace. • In other unconditioned spaces. Within these criteria, this test applies to both new duct systems and existing duct systems that are either being extended per §141.0(b)2D or the space conditioning system is altered by the installation or replacement of space conditioning equipment per §141.0(b)2E, including replacement of the air handler, outdoor condensing unit of a split-system air conditioner or heat pump, cooling or heating coil, or the furnace heat exchanger. Existing duct systems do not have to be tested if they are insulated or sealed with asbestos.
Instrumentation
Performance of this test will require measuring duct leakage. Equipment used: Fan flowmeter (a fan with a calibrated orifice used to pressurize the ducts) accuracy within 3 percent of measured flow. To view a list of the current certified equipment go to: http://www.energy.ca.gov/title24/equipment_cert/ama_fas/index.html Digital manometer (pressure meter) accuracy within 0.2 pascals. Duct leakage tests must be verified by a third-party HERS Rater who has been certified by a HERS Provider that has been approved by the California Energy Commission.

Test Conditions
For newly constructed buildings, all ductwork must be accessible for visual inspection before ceiling installation. All ductwork and grilles should be in place before performing the fan flow test to ensure the system depicts normal operating configuration. Hence, testing must occur after visual inspection and installation of the diffusers. HVAC system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer's recommendations.
Estimated Time to Complete
Construction Inspection: 0.5 to 2 hours, depending on duct access for visual inspections and availability of construction material documentation (that is, cut sheets and so forth) **Equipment Test**: 3 to 6 hours, depending on how long it takes to seal all supply diffusers and return grills.
Acceptance Criteria
Flexible ducts are not compressed or constricted in any way. Duct connections meet the requirements of §120.4 (new ducts only). Joints and seams are properly sealed according to requirements of §120.4 (new ducts only). Duct R-values meet the minimum requirements of §120.4(a) (new ducts only). Insulation is protected from damage and suitable for outdoor usage per §120.4(f) (new ducts only). The leakage fraction for new HVAC ducts does not exceed 6 percent per §140.4(l), where the leakage fraction is calculated by dividing total measured leakage flow rate by the total fan system flow rate. The leakage fraction for existing HVAC ducts does not exceed either 15 percent or overall system leakage is reduced by a 60 percent per §141.0(b)2D. The leakage fraction is calculated by either dividing total measured leakage flow rate by the total fan system flow rate *or* by comparing "pre-modification" and "post-modification" measured system leakage values. Obtain HERS Rater field verification as described in Reference Nonresidential Appendix NA1.
Potential Issues and Cautions
If this test is to be applied to existing duct systems that are having alterations made to the ducts or the HVAC equipment attached to the ducts, test the system leakage before making the alterations. Ensure all the supply and return diffusers/grills are sealed tightly, all access panels are in place, and duct ends are sealed tightly before leakage testing. After the test, remember to remove all blockages from the supply and return ducts (that is, where the supply and return ducts at the HVAC unit were blanked off).Seal any holes drilled in the supply and return ducts for the static pressure probes. Since a certified California HERS Rater must also verify duct leakage performance, it may be prudent to coordinate this test with the HERS Rater so that the HERS Rater can witness/verify the test simultaneously.

A. Test Application

This test applies to both new duct systems and to existing duct systems, which are either being extended per §141.0(b)2D, or the space conditioning system is altered by the installation or replacement of space conditioning equipment per §141.0(b)2E, including replacement of the air handler; outdoor condensing unit of a split-system air conditioner or heat pump, cooling or heating coil, or the furnace heat exchanger. Existing duct systems do not have to be tested if they are insulated or sealed with asbestos.

The duct work of these small single-zone systems with ducts in unconditioned spaces must meet the duct leakage requirements of §140.4(l) for new ducts or §141.0(b)2D for existing ducts. New duct systems or the extension of existing ducts must meet the requirements of §120.4, including construction materials, installation, and insulation R-values. Existing ducts are not required to be brought up to current standards in terms of insulation or requirements for joint seams and fasteners.

B. Construction Inspection

1. Review the drawings and construction to verify that the following items are specified in the construction set and installed in the field. (A comprehensive review of each duct is not required.)
    - Drawbands are either stainless steel worm-drive hose clamps or UV-resistant nylon duct ties. Verify compliance by reviewing material cut sheets and visual inspection.
    - Flexible ducts are not constricted in any way. For example, ensure the flex duct is not compressed against immovable objects, squeezed through openings, or contorted into extreme configurations (such as 180° angles). Do not bend flexible ducts so that the bend radius at the centerline is less than one duct diameter. A constricted flex duct can increase system static pressure as well as compromise insulation values. Verify compliance through visual inspection.
    - Joints and seams are not sealed with a cloth-backed rubber adhesive tape unless used in combination with mastic and drawbands. Verify compliance through visual inspection.
    - Duct insulation R-value shall comply with §120.4(a), §120.4(c), and §120.4(d) and can be verified by reviewing material cut sheets and through visual inspection.
    - Insulation is protected from damage or is suitable for outdoor usage, per §120.4(f). Verify compliance by reviewing material cut sheets and through visual inspection.

Duct inspection and leakage tests shall be performed before access to ductwork and associated connections are blocked by permanently installed construction material. The intent is to ensure construction modifications can be made, if necessary, before access to the ductwork is restricted.

C. Functional Testing

Refer to the *Scope of the Requirements* section above to determine when this test is required. When required, the test will often be conducted by the installer and verified by a HERS Rater using the procedures outlined in Reference Nonresidential Appendix NA2 and documented on compliance document, NRCA-MCH-04-A.

As described in Reference Nonresidential Appendix NA2.1.4.1, total fan flow, also known as *nominal air handler airflow*, shall be 400 cfm/ton for cooling or heating/cooling

equipment where a ton of cooling capacity is equal to 12 kBtu/h of cooling capacity. For heating-only equipment, total fan flow is 21.7 CFM per kBtuh rated output capacity. The cooling and heating capacity of equipment can be found on the product nameplate.

For new duct systems, the installer blocks all of the supply and return registers or diffusers. Then, the installer pressurizes the ducts with a fan flowmeter to a positive 25 Pa (0.1 inches of water) and record the leakage airflow measured by the fan flowmeter. This measured leakage is divided by the total fan flow to generate the leakage percentage value. When this leakage percentage is less than or equal to 6 percent, the system passes. Otherwise, the installer should locate and seal any leaks until the system conforms to the maximum 6 percent leakage requirement. Leaks are more detectable while positive pressure is in the ducts.

For existing duct systems needing additional ducts added, undergoing major repairs, or having equipment replaced that connects to the ducts, the leakage rate of the existing duct system shall be tested first before proceeding with any alterations. This leakage amount is the **pretest** leakage value. Next, proceed with the test method described above for new duct systems to measure the **final test** leakage rate, with the only exception that the maximum leakage allowed is increased to 15 percent.

If, after all accessible leaks are sealed, the leakage percentage is still above 15 percent, the installer has two options:

- If the final test leakage is 60 percent lower than the pretest leakage rate and a visual inspection finds no accessible leaks, crushed ducts, animal infestation, rusted ducts, and so forth, this will be sufficient to pass this requirement.
- If the system meets neither the 15 percent leakage percentage nor was it possible to reduce the pretested leakage value by 60 percent, then the system must pass a visual inspection by a HERS Rater. Unlike the other methods of compliance, this method cannot be sampled – every system must be inspected by the HERS Rater.

After completing the air distribution system acceptance test, the installer shall affix a sticker to the air handler access door describing whether the system met the prescriptive leakage requirements (6 percent leakage for new systems and 15 percent for existing systems) or if the system failed to meet this standard but all accessible leaks were sealed. The installer is responsible for supplying the stickers that may have their company logo on them. However, the preceding information must be on the sticker in 14 point font or larger.

D. Document Management

After conducting the air distribution system acceptance test, the installer or the permit applicant must arrange to have a HERS Rater perform the required third-party verification. Copies of the *Construction Inspection* and the *Air Distribution System Leakage Diagnostic* sections of the NRCA-MCH-04-A should be sent to the HERS Provider, HERS Rater; the builder (general contractor or construction manager), and the building owner at occupancy. A copy must also be posted at the construction site and made available for all applicable inspections by the enforcement agency.

The HERS Rater must perform field verification and diagnostic testing, document the results on a certificate of field verification and diagnostic testing, and send copies of the certificate of field verification and diagnostic testing to the builder (general contractor or construction manager) and the building owner at occupancy. A copy must also be posted at the construction site and made available for all applicable inspections by the enforcement agency. If the test complies by virtue of the tested leakage (6 percent for new ducts and 15 percent for existing duct) or by virtue of a 60 percent leakage reduction after

the system was repaired or altered, the building permit applicant may choose for the HERS field verification to be completed for the permitted space conditioning unit alone or as part of a designated sample group of up to seven space conditioning units for which the same installing company has completed work that requires field verification and diagnostic testing for compliance. If the sampling method is chosen, the HERS Rater must randomly select one system from the group for verification. For existing duct systems that fail both the 15 percent leakage rate and the 60 percent reduction in leakage, the HERS Rater must validate all of these systems (100 percent sampling) by visual inspection. Refer to Nonresidential Appendix NA1.5 for additional information about sampling.

E. Reference Material From Reference Nonresidential Appendix NA2

Below are excerpts of air distribution system acceptance testing requirements from Reference Nonresidential Appendix NA2.1 − Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems.

NA2.1.2 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

NA2.1.2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (that is, sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.

NA2.1.2.2 Duct Leakage Measurements

Duct leakage air flows during duct leakage testing shall be measured with digital gauges that have an accuracy of ± 3 percent or better.

All instrumentation used for duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the accuracy requirement specified NA2. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.

NA2.1.3.1 Apparatus for Duct Pressurization and Leakage Flow Measurement

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in NA2.1.2.

NA2.1.4.1 Nominal Air Handler Airflow

The nominal air handler airflow used to determine the target leakage rate for compliance for an air conditioner or heat pump shall be 400 cfm per rated ton of cooling capacity. Nominal air handler airflow for heating-only system furnaces shall be based on 21.7 cfm per kBtu/hr of rated heating output capacity.

NA2.1.4.2 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used by installers and raters to verify that total leakage meets the criteria for any sealed duct system specified in the compliance documents. Table 13-5 shows the leakage criteria and test procedures that may be used to demonstrate compliance.

Table 13-5: Duct Leakage Tests

Case	User and Application	Leakage Compliance Criteria (percent of Nominal Air Handler Airflow)	Procedure(s)
Sealed and tested new duct systems	Installer Testing HERS Rater Testing	6%	NA2.1.4.2.1
Sealed and tested altered existing duct systems	Installer Testing HERS Rater Testing	15%	NA2.1.4.2.1
Sealed and tested altered existing duct systems	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed Inspection and Smoke Test with 100 percent Verification	NA2.1.4.2.2 NA2.1.4.2.3 NA2.1.4.2.4

NA2.1.4.2.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The objective of this procedure is for an installer to determine or a rater to verify the total leakage of a new or altered duct system. The total duct leakage shall be determined by pressurizing the entire duct system to +25 Pa with respect to outside with all ceiling diffusers/grilles and HVAC equipment installed. When existing ducts are to be altered, this test shall be performed before and after duct sealing. The following procedure shall be used for the fan pressurization tests:

1. Verify that the air handler, supply and return plenums, and all the connectors, transition pieces, duct boots and registers are installed. The entire system shall be included in the test.
2. For newly installed or altered ducts, verify that cloth-backed rubber adhesive duct tape has not been used.
3. Seal all the supply and return registers, except for one return register or the system fan access. Verify that all outdoor air dampers and/or economizers are sealed prior to pressurizing the system.
4. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
5. Install a static pressure probe at a supply.
6. Adjust the fan flowmeter to produce a + 25 Pa (0.1 in water) pressure at the supply plenum with respect to the outside or with respect to the building space with the entry door open to the outside.
7. Record the flow through the flowmeter ($Q_{total,25}$).This is the total duct leakage flow at 25 Pa.
8. Divide the leakage flow by the total fan flow determined by the procedure in Section NA2.1.4.1 and convert to a percentage. If the leakage flow percentage is less than the criteria from Table 13-5, the system passes.

Duct systems that have passed this total leakage test will be sampled by a HERS Rater to show compliance.

NA2.1.4.2.2 Sealing of All Accessible Leaks

For altered existing duct systems that do not pass the leakage test NA2.1.4.2.1, this test will show if all accessible leaks are sealed. The following procedure shall be used:

1. At a minimum, complete the procedure in NA2.1.4.2.1 to measure the leakage before commencing duct sealing.
2. Seal all accessible ducts.
3. After sealing is complete, use the same procedure to measure the leakage after duct sealing.
4. Complete the smoke test[2] as specified in NA2.1.4.2.3
5. Complete the visual inspection as specified in NA2.1.4.2.4.

All duct systems that could not pass either the total leakage test or the leakage reduction test must be verified by a HERS Rater to demonstrate compliance. This is a sampling rate of 100 percent.

NA2.1.4.2.3 Smoke-Test of Accessible Duct Sealing

For altered existing ducts that fail the leakage tests, the smoke test will confirm that all accessible leaks have been sealed. The following procedure shall be used:

1. Inject either theatrical or other non-toxic smoke into a fan pressurization device that is maintaining a duct pressure difference of 25 PA (0.1 inches water) relative to duct surroundings, with all grilles and registers in the duct system sealed.
2. Visually inspect all accessible portions of the duct system during smoke injection.
3. The system shall pass the test if one of the following conditions is met.
   - No visible smoke exits the accessible portions of the duct system.
   - Smoke only emanates from the furnace cabinet that is gasketed and sealed by the manufacturer and no visible smoke exits from the accessible portions of the duct system.

NA2.1.4.2.4 Visual Inspection of Accessible Duct Sealing

For altered existing duct systems that fail to be sealed to 15 percent of total fan flow, this inspection will confirm that all accessible leaks have been sealed. The following procedure shall be used:

1. 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.

[2] For altered existing ducts that fail the leakage tests, the objective of the smoke test is to confirm that all accessible leaks have been sealed. See Nonresidential Appendices NA2.1.4.2 for duct leakage test procedures and requirements.

- Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes.

2. 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.

13.8 NA7.5.4 Air Economizer Controls Acceptance

At-A-Glance

NA7.5.4 Air Economizer Controls Acceptance
Use Document NRCA-MCH-05-A
Purpose of the Test
Functionally Testing an air economizer cycle verifies that an HVAC system uses outdoor air to satisfy space-cooling loads. There are two types of economizer controls: stand-alone packages and DDC controls. The stand-alone packages are commonly associated with small unitary rooftop HVAC equipment. DDC controls are typically associated with built-up or large packaged air handling systems. Cooling fan systems > 54,000 Btu/hr must have an economizer. Air economizers must be able to provide 100 percent of the design supply air with outside air; water economizers must be able to provide 100 percent of the design cooling load at 50°F dry-bulb and 45°F wet-bulb. The in-field economizer functional tests do not have to be conducted for units that are factory-installed and certified operational by the manufacturer to the Energy Commission's economizer quality control requirements. A copy of the manufacturer's certificate must be attached to the NRCA-MCH-05-A. Regardless of whether the economizer is field- or factory-installed, complete the construction inspection, including the compliance with high temperature lockout temperature setpoints.
Instrumentation
Instrumentation to perform the test includes: • Hand-held temperature probe (must be calibrated within the past year). • Device capable of calculating enthalpy (must be calibrated within the past year) • 1.2 kOhm resistor (when specified by the manufacturer). • 620 Ohm resistor (when specified by the manufacturer).

Test Conditions
Equipment installation is complete (including HVAC unit, duct work, sensors, control system, thermostats). Non-DDC DX systems are required to have a two-stage thermostat. The HVAC system must be ready for system operation, including completion of all start-up procedures per manufacturer's recommendations. For those units having DDC controls, it may be necessary to use the building automation system (BAS) to override or temporarily modify the variable(s) to achieve the desired control. BAS programming for the economizer, cooling valve control, and related safeties must be complete. For built-up systems all interlocks and safeties must be operable − for example, freeze protection, limit switches, static pressure cut-out, and so on. Document the initial conditions before overrides or manipulation of the settings. All systems must be returned to normal at the end of the test. Before conducting the test, demand control ventilation systems must be disabled, if applicable.
Estimated Time to Complete
Construction Inspection: 0.5 to 1 hours (depending on familiarity with the controls) **Functional Testing**: 0.5 to 2 hours (depending on familiarity with the controls and issues that arise during testing)
Acceptance Criteria
If the economizer is factory installed and certified, a valid factory certificate is required for acceptance. No additional equipment tests are necessary. Air economizer lockout setpoint complies with Energy Standards Table 140.4-B per §140.4(e)3. This table is reproduced in Table 13-6 located below. Outside sensor location accurately reads true outdoor air temperature and is not affected by exhaust air or other heat sources. All sensors are located appropriately to achieve the desired control. During economizer mode, the outdoor air damper modulates open to a maximum position, and the return air damper modulates 100 percent closed. The outdoor air damper is 100 percent open before mechanical cooling is enabled and remains at 100 percent open while mechanical cooling is enabled (economizer integration when used for compliance with §140.4(e)2B). The economizer is capable of providing partial cooling even when additional mechanical cooling is required to meet the load. For unit controls, the outdoor air damper may not begin to close until the leaving air temperature is below 45°F. When the economizer is disabled, the outdoor air damper closes to a minimum position, the return damper modulates 100 percent open, and mechanical cooling remains enabled. If the unit has heating capability, the outdoor air damper remains at minimum position when heating is enabled. When the unit is turned off or otherwise disabled, the outdoor air damper closes.

Potential Issues and Cautions
If conditions are below freezing when test is performed, coil(s) may freeze when operating at 100 percent outdoor air.
Outdoor air and relief dampers should be closed when the system is in unoccupied and warm-up modes, preventing problems with unconditioned air entering the building during unoccupied hours.
If the damper interlocks fail and the outdoor air damper does not open before the return damper closes, damage to the air handling unit or associated duct work may occur.
Air economizers with poor mixing can have excessively stratified air streams that can cause comfort problems or freeze stat trips[3]. Mixing problems are more likely to occur as the VAV system reduces flow, leading to reduced velocities in the mixing box and through the dampers.
Check for exterior doors standing open and other signs of building over pressurization when all units are on full economizer cooling (100 percent OSA).

A. Test Application

Newly Constructed and Additions/Alterations: All new equipment with air economizer controls must comply. Units with economizers that are installed at the factory and certified with the Energy Commission do not require functional testing but do require construction inspection.

There are basically two types of economizer controls:

1. Stand-alone packages (for example, Honeywell W7459A, Trane Precedent or Voyager, Carrier Durablade, which are most common). These are most commonly associated with rooftop packaged HVAC equipment.
2. DDC controls. These are typically associated with built-up or large packaged air handling systems

Test procedures for both economizer control types have been developed, and a brief description of each control strategy is provided below.

The typical economizer control will have the following components:

- A controller (stand-alone or DDC)
- An actuator that will drive both outside and return air dampers (sometimes separate actuators in built-up systems)
- An outdoor air sensor
- A return air sensor where differential high-limit controls are used
- A mixed/discharge air temperature sensor to which the economizer is controlled.

[3] A freezestat protects water coils in rooftop HVAC units from freezing. When a freezestat trips it opens the a hot water valve (either to full or partial) to remove the danger of damage from freezing water within the system. Typically freezestats must be rest by hand. Poorly functioning air economizers can cause freezestats to falsely trip or some cases may actually cause freezing conditions.

The sensor types used to measure outside and return air include dry-bulb temperature sensors, enthalpy sensors, and electronic enthalpy sensors (a combination of dry-bulb and enthalpy). §140.4(e)4E requires that outdoor air, return air, mixed air, and supply air sensors be calibrated to within specific accuracies, as follows:

- Dry-bulb and wet-bulb temperatures accurate to ±2°F over the range of 40°F to 80°F.
- Enthalpy accurate to ±3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb.
- Relative humidity (RH) accurate to ±5 percent over the range of 20 percent to 80 percent RH.

In general, a first-stage call for cooling from the zone thermostat will enable the economizer controller, which will either allow the outdoor air damper to open fully if outdoor air conditions are suitable or enable the compressor. When the zone thermostat calls for a second stage of cooling, the compressor is enabled to provide mechanical cooling.

The three strategies available for economizer control are:

1. Fixed dry-bulb.
2. Fixed enthalpy + fixed dry-bulb.
3. Differential dry-bulb.

The fixed dry-bulb and fixed enthalpy + fixed dry-bulb strategies both compare outdoor air conditions to a “fixed” setpoint to determine if the economizer can be enabled. On the other hand, the differential dry-bulb strategy compares outdoor air and return air conditions to enable the economizer when outdoor air conditions are more favorable.

The economizer is considered integrated if the economizer can operate simultaneously with the compressor or chilled water coil. If the controls disable the economizer when the compressor (or chilled water coil) is on, it is considered non-integrated. Where economizers are required by the Energy Standards, they must have integrated controls.

B. Construction Inspection

Air economizer high limit setpoint complies with Energy Standards Table 140.4-B (Table 13-6) per §140.4(e)3. For DDC control systems, the high limit setpoint should be a control parameter in the sequence of operations that can be verified for compliance. For stand-alone packages, the high limit setpoint is determined by settings on the controller (for example, A, B, C, D settings on the Honeywell W7459A controller or dip switches on a Trane control package). Consult with manufacturer’s literature to determine the appropriate A, B, C, D or dip switch settings.

Unit controls must have the mechanical capacity controls interlocked with the economizer controls, such that the economizer is at 100 percent open position when mechanical cooling is on and does not begin to close until the leaving air temperature is less than 45°F.

A *snap disk* is a temperature sensitive relay with a fixed temperature setpoint, and thus a type of fixed dry-bulb control. The snap disk closes the economizer circuit when the air temperature is below setpoint and opens the circuit when the air temperature exceeds setpoint. The Energy Standards specify if the high-limit control is a fixed dry-bulb, it must have an adjustable setpoint. Thus, a snap disk is not an acceptable high limit control device because it does not provide an adjustable setpoint.

1. Check that the air economizer outside (lockout) sensor location is adequate to achieve the desired control and prevent false readings. Outdoor air sensors should be located away from building exhausts and other heat sources like air-cooled condensers and cooling towers; should be open to the air but not exposed to direct sunlight (unless it is provided with a radiation shield); and could be located either directly in the air stream or remote from the unit (for example mounted on a north-facing wall).
2. Check that economizer reliability features are present per §140.4(e)4. This includes the following:
   - Verify the economizer has a 5-year warranty of the assembly.
   - Provide a product specification sheet proving economizer assembly capability of at least 60,000 actuations.
   - Provide a product specification sheet proving economizer damper sections are certified by AMCA 511 for a maximum damper leakage rate of 10 cfm/sf at 1.0 in. w.g. (Class 1A, 1, and 2 are acceptable.)
   - If the high limit setpoint is fixed dry-bulb or fixed enthalpy + fixed dry-bulb, then the control shall have an adjustable setpoint.
   - Outdoor air, return air, mixed air, and supply air sensors shall be calibrated as follows:
     - Dry-bulb and wet-bulb temperatures accurate to ±2°F over the range of 40°F to 80°F.
     - Enthalpy accurate to ±3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb.
     - Relative humidity (RH) accurate to ±5 percent over the range of 20 percent to 80 percent RH.
   - Check that the sensor performance curve(s) is provided by the factory with economizer instruction materials, and that sensor output values measured during sensor calibration are plotted on the performance curve(s).
   - Sensors used for high limit control shall be located to prevent false readings, including, but not limited to, being properly shielded from direct sunlight.
   - For unitary systems 65,000 Btu/hr or less, verify that a two-stage thermostat is used, and that the system is wired so that the economizer is the first stage of cooling and the compressor is the second stage.
   - Check that all systems have some method of relief to prevent over pressurization of the building when in full economizing mode (100 percent outdoor air). Most packaged HVAC units with stand-alone economizer controls will typically have barometric dampers to exhaust the return air when the return dampers are fully closed and the unit is in economizer mode. Built-up and larger packaged air handling units may control return fans, relief dampers, or dedicated relief fans to maintain building pressurization when the unit is in economizer mode.
   - For systems with DDC controls, check that lockout sensor(s) are either factory calibrated or field calibrated. For systems with non-DDC controls, check that manufacturer's startup and testing procedures have been applied.

Table 13-6: Air Economizer High Limit Shut off Control Requirements

Device Type [a]	Climate Zones	Required High Limit (Economizer Off When):	
		Equation [b]	Description
Fixed Dry Bulb	1, 3, 5, 11-16	T_{OA} > 75°F	Outdoor air temperature exceeds 75°F
	2, 4, 10	T_{OA} > 73°F	Outdoor air temperature exceeds 73°F
	6, 8, 9	T_{OA} > 71°F	Outdoor air temperature exceeds 71°F
	7	T_{OA} > 69°F	Outdoor air temperature exceeds 69°F
Differential Dry Bulb	1, 3, 5, 11-16	T_{OA} > T_{RA}°F	Outdoor air temperature exceeds return air temperature
	2, 4, 10	T_{OA} > T_{RA}-2°F	Outdoor air temperature exceeds return air temperature minus 2°F
	6, 8, 9	T_{OA} > T_{RA}-4°F	Outdoor air temperature exceeds return air temperature minus 4°F
	7	T_{OA} > T_{RA}-6°F	Outdoor air temperature exceeds return air temperature minus 6°F
Fixed Enthalpy[c] + Fixed Drybulb	All	h_{OA} > 28 Btu/lb [c] or T_{OA} > 75°F	Outdoor air enthalpy exceeds 28 Btu/lb of dry air [c] or Outdoor air temperature exceeds 75°F

a Only the high limit control devices listed are allowed to be used and at the setpoints listed. Others, such as dew point, fixed enthalpy, electronic enthalpy, and differential enthalpy controls, may not be used in any climate zone for compliance with §140.4(e)1 unless approval for use is provided by the Energy Commission Executive Director.

b Devices with selectable (rather than adjustable) setpoints shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

c At altitudes substantially different than sea level, the fixed enthalpy limit value shall be set to the enthalpy value at 75°F and 50 percent relative humidity. As an example, at approximately 6,000 foot elevation, the fixed enthalpy limit is about 30.7 Btu/lb.

Energy Standards Table 140.4-B

C. Functional Testing

Since the test procedures vary significantly between stand-alone packages and DDC controls, the procedures for each system type are provided. In addition, there can be significant differences in test procedures among various stand-alone packages. Contact your equipment supplier to see if they have equipment and test protocols that will allow you to easily field test their economizer to NA7.5.4 Air Economizer Controls for filling out document NRCA-MCH-05-A. While it would not be feasible to cover every variation, three of the most common stand-alone packages are discussed below. The common feature of these procedures is that they all exercise the economizer function either by enabling an

on-board diagnostic function or by “fooling” the control by inserting resistors that simulate mild weather conditions while the system is in cooling mode.

a. **Stand-Alone Package − Trane Voyager and Precedent Series**

Both of these control packages have internal test sequences that can be used to verify proper system operation. Each operating mode is enabled by providing a momentary (2-second) jump across the test terminals.

Step 1: Disable demand control ventilation (DCV) system modes, if applicable for the unit.

Step 2: Use internal test sequences to enable operating modes.

Refer to manufacturer’s literature for detailed description of procedures, including the basic steps are outlined below:

- 1st jumper – supply fan is enabled
- 2nd jumper – economizer mode is enabled
- 3rd jumper – compressor is enabled
- 4th jumper – heating stage is enabled

Verify and Document

- Verify the outdoor air damper opens completely and the return damper closes completely during economizer mode (Step 2 on the acceptance document NRCA-MCH-05-A).
- Verify that the outside air damper remains 100 percent open while using mechanical cooling when the demand cannot be met by outside air alone and the system is still below the lockout point.
- Outdoor air damper is at minimum position when the supply fan is enabled (Step 3 on the acceptance document NCRA-MCH-05-A).
- Outdoor air damper is at minimum position when the compressor is enabled and economizing is disabled (Step 3 on the acceptance document NRCA-MCH-05-A).
- Outdoor air damper is at minimum position when heating is enabled and economizing is enabled (Step 4 on the acceptance document NRCA-MCH-05-A).
- Verify the mixed/discharge cut-out sensor wire is landed on the SA terminal on the OEM board. If the sensor wire is not landed on the SA terminal, the economizer will not operate.

Step 3: **Turn off the unit.**

- Turn the unit *off* at the disconnect. This is Step 5 on the acceptance document NRCA-MCH-05-A.

Verify and Document

- Economizer dampers close completely.
- Return air damper opens.

Step 4: Return system to normal operation.

After restoring power, the unit returns to normal operation. This is Step 6 on the acceptance document NRCA-MCH-05-A.

Verify and Document

- Final economizer changeover dip-switch settings comply with Energy Standards Table 140.4-B per §140.4(e)3.

b. **Honeywell Controllers**

There are many Honeywell controllers available. The most common controller is the W7459A series with checkout, which may be used on other models. (Always refer to manufacturer's literature for additional information.) All Honeywell controllers have a 620 Ohm resistor across the SR and + terminals on the adjustment pot with "A, B, C, D" settings. For a fixed changeover strategy, the position of the adjustment pot with respect to the A, B, C, D settings will determine the economizer lockout setpoint. For a differential changeover strategy, the controller should be on the "D" setting. The controllers typically come from the factory with the adjustment pot at the "D" setting. This setting does not mean the use of a differential control strategy. The easiest way to verify a differential changeover strategy is to look at the SR and + terminals on the controller. When standard sensor wires are connected to the terminals, the controller uses a differential control strategy. When there is a 620 Ohm resistor jumpered across these terminals, then the controller uses a fixed control strategy.

Step 1: Disable demand controlled ventilation (DCV) system modes, if applicable for the unit.

Step 2: Simulate a cooling load and enable the economizer.

The simplest way to determine if the controller is functioning is to:

- Turn the unit *off* at the disconnect.
- Install a 1.2 kOhm resistor across the S_O and + terminals on the controller. (This is the outdoor air temperature sensor.)
- Install a 620 Ohm resistor across the S_R and + terminals on the controller. (This resistor is already installed for a fixed control strategy and must be installed only if there is a return air sensor.)
- Turn the economizer setpoint adjustment pot all the way to the "A" setting.
- Install a jumper across the R and Y1 terminals at the unit terminal strip.
- Turn the unit back *on* at the disconnect.

Verify and Document

- Outdoor air dampers open fully. Adjust linkages, if necessary, to ensure dampers are at the desired position.
- Return air dampers close completely. Adjust linkages, if necessary, to ensure dampers are at the desired position.
- Compressor runs when cooling load becomes too high for economizing to meet alone. The outdoor air dampers should remain 100 percent open at this point.

Step 3: Simulate a cooling load and disable the economizer.

- Turn the unit *off* at the disconnect.
- Leave the 1.2 kOhm resistor across the S_O and + terminals and 620 Ohm resistor across the S_R and + terminals in place.
- Turn the economizer setpoint adjustment pot all the way to the “D” setting.
- Leave jumper across the R and Y1 terminals at the unit terminal strip.
- Turn the unit back *on* at the disconnect.

Verify and Document

- Outdoor air dampers close to minimum position. Adjust linkages, if necessary, to ensure dampers are at the desired position.
- Return air dampers open completely. Adjust linkages, if necessary, to ensure dampers are at the desired position.
- Compressor operates.

Step 4: If the unit is equipped with heating, simulate a heating load with the economizer enabled.

- Turn the unit *off* at the disconnect.
- Leave the 1.2 kOhm resistor across the S_O and + terminals and 620 Ohm resistor across the S_R and + terminals in place.
- Turn the economizer setpoint adjustment pot all the way to the “A” setting.
- Remove the jumper across the R and Y1 terminals at the unit terminal strip, and place the jumper across the R and W1 terminals at the unit terminal strip.
- Turn the unit back *on* at the disconnect.

Verify and Document

- Outdoor air dampers remain at minimum position.
- Heating is enabled.
- Compressor does not operate.

Step 5: Turn off unit.

- Turn the unit *off* at the disconnect.

Verify and Document

- Economizer dampers close completely.
- Return air damper opens.

Step 6: Return system back to normal operating condition.

- Remove all jumpers and reconnect all wires.
- Turn the unit *on* at the disconnect.

Verify and Document

- Final economizer changeover setting (A, B, C, D) complies with Energy Standards Table 140.4-B per §140.4(e)3. Consult with manufacturer's literature to determine the appropriate A, B, C, D setting for **both** fixed dry-bulb **and** enthalpy control strategies. The controller must be set on "D" for all differential control strategies.

c. **Carrier Durablade**

Most Carrier HVAC units use the "Durablade" economizer control package, which uses a single damper "blade" that slides on a worm gear across both the outside and return air streams. Blade position is determined by end switches that will cut power to the drive motor when desired damper position is reached. Typically the economizer will be controlled by either a fixed dry-bulb or fixed enthalpy control strategy. Enthalpy control typically uses a customized Honeywell controller, and the checkout procedures outlined above can be used to determine economizer functionality. The following test procedures should be followed for a fixed dry-bulb strategy.

Step 1: Disable demand controlled ventilation (DCV) system modes, if applicable to the unit.

Step 2: Simulate a cooling load and enable the economizer.

The simplest way to determine if the economizer is functioning is to:

- Turn the unit *off* at the disconnect.
- Install a jumper across the outdoor air temperature thermostat.
- Install a jumper across the R and Y1 terminals at the unit terminal strip.
- Disconnect the wire from the Y2 terminal at the unit terminal strip. (This will prevent the second stage of cooling from being enabled during the test.)
- Turn the unit back *on* at the disconnect.

Verify and Document

- Damper blade slides completely across the return air duct, and mixed air plenum is open to the outdoor air intake. Adjust end switches as necessary to achieve the desired position.
- Compressor does not run.

Step 3: Simulate a cooling load and disable the economizer.

- Turn the unit *off* at the disconnect
- Remove the jumper and disconnect the outdoor air sensor completely from the circuit
- Leave Y2 disconnected
- Turn the unit back *on* at the disconnect

Verify and Document

- Damper blade returns to minimum outdoor air position. Adjust end switches as necessary to achieve the desired position
- Compressor operates

Step 4: If the unit is equipped with heating, simulate a heating load with the economizer disabled.

Continuing from above:

- Turn the unit *off* at the disconnect.
- Leave the 1.2 kOhm resistor across the S_O and + terminals and 620 Ohm resistor across the S_R and + terminals in place.
- Leave the economizer setpoint adjustment pot at the "D" setting.
- Remove the jumper across the R and Y1 terminals at the unit terminal strip, and place the jumper across the R and W1 terminals at the unit terminal strip.
- Turn the unit back *on* at the disconnect.

Verify and Document

- Economizer dampers close completely.
- Return air damper opens.

Step 5: Turn off unit

- Turn the unit *off* at the disconnect.

Verify and Document

- Economizer dampers close completely.
- Heating and cooling do not operate.

Step 6: Return system back to normal operating condition

- Remove all jumpers and reconnect all wires
- Turn the unit back *on* at the disconnect

Verify and Document

- Final economizer changeover setting complies with Energy Standards Table 140.4-B per §140.4(e)3

d. **DDC Controls**

Step 1: Disable demand controlled ventilation (DCV) system modes, if applicable.

For DDC systems, this may include overriding the readings from the CO_2 sensor(s) or temporarily disabling the sensor(s).

Step 2: Simulate a cooling load and enable the economizer.

Simulating a cooling load and enabling the economizer can be accomplished by:

- Commanding the discharge air temperature set point to be lower than current discharge conditions.
- For a fixed dry-bulb or enthalpy control strategy, raising the economizer lockout set point to be above current outdoor air conditions (if this is not the case already) to enable the economizer.

- For a differential dry-bulb control strategy, raise the return air conditions to be above current outdoor air conditions (if this is not the case already) to enable the economizer.

Verify and Document

- Verify outdoor air damper modulates open to a maximum position.
- Verify return air damper modulates closed and is 100 percent closed when the outdoor air dampers are 100 percent open. Return dampers should close tight to minimize leakage.
- Verify outdoor air damper is 100 percent open before mechanical cooling is enabled, which implies that cooling coil valves in chilled water systems should not modulate or compressors in DX systems should not start until the unit is in 100 percent economizer mode. Depending on the speed of the PID loop, mechanical cooling could be commanded on before the outdoor air dampers actually stroke fully open. When this situation occurs, the system has not failed the test. One remedy is to watch the output of the PID loop and verify that the command sent to the outdoor air damper reaches 100 percent before a command is sent to the mechanical cooling devices.
- Although space pressurization requirements are not part of the current Energy Standards, most systems employ some form of control strategy to maintain space pressure during economizer mode. Control strategies can include, but are not limited to, 1) return fan speed control, 2) dedicated relief fans, or 3) relief damper controls. Observe that the space served by the air handling unit being tested does not appear to experience any pressurization problems (in other words, perimeter doors pushed open or excessive airflow between zones served by different units).

Step 3: Simulate a cooling load and disable the economizer.

- Keep the discharge air temperature setpoint lower than current discharge conditions.
- For a fixed dry-bulb or enthalpy control strategy, lower the economizer lockout setpoint to be below current outdoor air conditions (if this is not the case already) to disable the economizer.
- For a differential dry-bulb or enthalpy control strategy; lower the return air conditions to be below current outdoor air conditions (if this is not the case already) to disable the economizer.

Verify and Document

- Outdoor air damper closes to a minimum position.
- Return air damper opens to normal operating position when the system is not in economizer mode.
- Mechanical cooling remains enabled to satisfy discharge air temperature setpoint.

Step 4: If the system has heating, simulate a heating demand and enable the economizer.

- Command the discharge air temperature setpoint to be higher than current discharge conditions.
- For a fixed dry-bulb or enthalpy control strategy, raise the economizer lockout setpoint to be above current outdoor air conditions (if this is not the case already) to keep the economizer enabled.

- For a differential dry-bulb control strategy, raise the return air conditions to be above current outdoor air conditions (if this is not the case already) to keep the economizer enabled.

Verify and Document

- Outdoor air dampers remain at a minimum position.
- Return air dampers remain open.
- Heating is enabled to satisfy discharge air temperature setpoint.
- Mechanical cooling is disabled.

Step 5: Turn off all systems.

Switch the system into unoccupied mode.

Verify and Document

- Outdoor air dampers close completely.
- Heating and cooling do not operate.

Step 6: Return system back to normal operating condition.

- Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions.

13.9 NA7.5.5 Demand Control Ventilation (DCV) Systems Acceptance

At-A-Glance

NA7.5.5 Demand Control Ventilation (DCV) Systems Acceptance
Use Document NRCA-MCH-06-A
Purpose of the Test
The purpose of the test is to verify that systems required to employ demand controlled ventilation (refer to §120.1(c)3) can vary outside ventilation flow rates based on maintaining interior carbon dioxide (CO_2) concentration setpoints. Demand Controlled ventilation refers to an HVAC system's ability to reduce outdoor air ventilation flow below design values when the space served is at less than design occupancy.CO_2 is a good indicator of occupancy load and is the basis used for modulating ventilation flow rates.
Instrumentation
To perform the test, it may be necessary to vary and possibly measure (if calibration is necessary) ambient CO_2 levels. The instrumentation needed to perform the task may include, but is not limited to: • Hand-held reference CO_2 probe calibrated to ±10 ppm • Manufacturer's calibration kit • Calibrated CO_2/air mixtures

Test Conditions
Equipment installation is complete (including HVAC unit, duct work, sensors, and control system). HVAC system must be ready for system operation, including completion of all start-up procedures per manufacturer's recommendations. Building automation system (BAS) programming (if applicable) for the air handler and demand Controlled ventilation strategy must be complete. To perform the test, it may be necessary to use BAS to override or temporarily modify the CO_2 sensor reading. Air Economizer is disabled so that it will not interfere with outdoor air damper operation during test. Document the initial conditions before overrides or manipulation of the settings. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction inspection: 0.5 to 1 hours (depending on CO_2 sensor calibration) **Functional testing**: 1 to 2 hours (depending on how ambient CO_2 concentration levels are manipulated, system response time to variations in CO_2)
Acceptance Criteria
Each CO_2 sensor is factory calibrated (with calibration certificate) or field calibrated. Each CO_2 sensor is wired correctly to the controls to ensure proper control of the outdoor air damper. Each CO_2 sensor is located correctly within the space 3 to 6 ft above the floor. Interior CO_2 concentration setpoint is ≤600 ppm plus outdoor air CO_2 value if dynamically measured or ≤1000 ppm if no OSA sensor is provided. A minimum OSA setting is provided whenever the system is in Occupied mode per §120.1(c)4E regardless of space CO_2 readings. A maximum OSA damper position for DCV control can be established per the *Exception* to §120.1(c)4C, regardless of space CO_2 readings. The outdoor air damper modulates open when the CO_2 concentration within the space exceeds setpoint, The outdoor air damper modulates closed (toward minimum position) when the CO_2 concentration within the space is below setpoint.
Potential Issues and Cautions
Lock out the economizer control during the test. Outdoor air damper may not modulate correctly if the economizer control strategy is controlling damper operation. Overall test time may be reduced (especially for rooftop HVAC units) if two people perform the test - one to vary the CO_2 concentration while someone else verifies operation of the outdoor air dampers. During the testing of the DCV controls, the outside damper will modulate open. Care should be taken to prevent freezing of coils when testing with cold temperatures outside.

A. Test Application

Newly Constructed and Additions/Alterations: All new DCV controls installed on new or existing HVAC systems must be tested.

Single-zone systems. The intent was to limit the demand Controlled ventilation requirement to systems that primarily serve spaces with variable occupancy. However, it is possible that a facility may have a majority of spaces with fixed occupancy and only a few variable occupancy zones that meet the requirement, but still must implement demand Controlled ventilation for those variable occupancy zones. Single-zone HVAC systems can include, but are not limited to: 1) constant volume packaged units with stand-alone economizer controllers (e.g., Honeywell W7340 Logic Module); or 2) constant volume systems with individual dampers/actuators and either stand-alone or centralized DDC control.

The Energy Standards require that only HVAC systems with the following characteristics must employ demand Controlled ventilation:

- The HVAC system must have an economizer. The reason for this requirement is that the system must have the ability to modulate outdoor air flow.
- Spaces served with specific use types or have the following occupancy densities, as described in the California Building Code (CBC) Chapter 10, must utilize DCV control:
    - Assembly areas, concentrated use (without fixed seating)
    - Auction rooms
    - Assembly areas, less concentrated use
    - Occupancy density of 40 ft^2 per person or less

  Occupancy density is calculated using CBC Section 1004.1.1 CBC for spaces without fixed seating and CBC Section 1004.7 for spaces with fixed seating. However, classrooms are exempt from the demand Controlled ventilation requirement.

The Energy Standards state that the system will maintain a minimum ventilation flow rate no less than the value calculated per §120.1(c)4E.

B. Construction Inspection

The CO_2 sensor is located within the control zone(s) between 3 feet and 6 feet above the floor or at the anticipated level of the occupant's heads. This is the critical range for measuring CO_2 since most occupants will be typically either sitting or standing within the space.

CO_2 sensor is either factory calibrated or field calibrated. A calibration certificate from the manufacturer will satisfy this requirement. In order to perform a field calibration check, follow the calibration procedures provided by the manufacturer. Some sensor manufacturers may require using equipment-specific calibration kits (kits may include trace gas samples and other hand-held devices) whereas others may be calibrated simply by using a pre-calibrated hand-held CO_2 measuring device and making proper adjustments through the sensor or ventilation controller.

Interior CO_2 concentration setpoint is ≤ 600 ppm plus outdoor air CO_2 value if outside concentration is measured dynamically. Otherwise, setpoint is ≤ 1000 ppm. Outdoor air CO_2 concentration can be determined by three methods:

1. Assume a value of 400 ppm without any direct measurement.
2. Measure outside concentration dynamically to continually adjust interior concentration setpoint.
3. Measure outside concentration one time during system checkout and use this value continually to determine inside concentration setpoint.

C. Functional Testing

Step 1: Disable the economizer.

Disabling the economizer will prevent the outdoor air damper from modulating during the test due to atmospheric conditions rather than CO_2 variations. The economizer can be disabled in a number of ways depending on the control strategy used to modulate the outdoor air dampers; however the simplest method would be to change the economizer changeover setpoint below current atmospheric conditions. The changeover setpoint is the value that will lock out the economizer, example control strategies include:

- Outdoor air dry-bulb temperature or enthalpy
- Comparison between outside and return air temperature or enthalpy

Step 2: Simulate a high space occupancy.

The intent of this test is to ensure the outdoor air damper modulates open when the CO_2 concentration within the space exceeds setpoint. Simulating a high space occupancy can be accomplished by, but not limited to: 1) commanding the setpoint value to be slightly below current concentration level; or 2) exposing the sensor to a known concentration of source gas (i.e. canister of CO_2 gas with a concentration greater than setpoint). In all cases you should endeavor to simulate a condition just slightly above the current CO_2 setpoint. Regardless of the method used to simulate an excessive CO2 load, ensure the condition persists long enough for the HVAC system to respond.

Verify and Document

Ensure the outdoor air damper modulates open.

If the CO_2 setpoint is lowered just below current concentration levels, the outdoor air damper will modulate open and the increased outdoor air should bring interior concentrations down to meet and maintain the new setpoint. If a known concentration of CO_2 gas was used to simulate an elevated concentration, then the outdoor air damper may modulate fully open since the “measured” concentration will not be influenced by the increase in outdoor air (Note that §121.0(c)4C states that outdoor ventilation rate is not required to exceed design minimum value calculated in §121(b)2, regardless of CO_2 concentration. Therefore, the outdoor air damper may only open to a position that provides the design minimum flow rate). If an unknown concentration was used to simulate a high load, then the outdoor air damper could modulate open and closed since the “measured” concentration may vary considerably throughout the test.

Step 3: Simulate a low occupant density.

The intent of this test is to ensure the outdoor air damper modulates towards minimum position when the CO2 concentration within the space is below setpoint. Eventually the outdoor air damper should close to a position that provides minimum ventilation flow rate per §121(c)4E, regardless of how far the measured interior concentration is below setpoint. Simulating a low occupant density can be accomplished by, but not limited to:

1. Commanding the setpoint value to be significantly higher than current concentration level;
2. Exposing the sensor to a known concentration of source gas (i.e. canister of CO2 gas with a concentration less than setpoint);
3. Open doors and windows to reduce CO2 concentration in the space. In each case you want the CO2 reading to be well below the setpoint.

Regardless of the method used to simulate a low occupant density, ensure the condition persists long enough for the HVAC system to respond.

Verify and Document

Ensure the outdoor air damper modulates towards minimum position. If setpoint is raised just above current concentration levels, the outdoor air damper will modulate closed and the reduced outdoor air should bring interior concentrations up to meet and maintain the new setpoint. If necessary, continue to adjust the setpoint upward until the outdoor air damper closes to a minimum position. If a known concentration of CO_2 gas was used to simulate a lowered concentration, then the outdoor air damper will most likely modulate to minimum position since the "measured" concentration will not be influenced by the decrease in outdoor air.

Step 4: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions.

13.10 NA7.5.6 Supply Fan Variable Flow Controls Acceptance

At-A-Glance

NA7.5.6 Supply Fan Variable Flow Controls
Use Document NRCA-MCH-07-A
Purpose of the Test
The purpose of the test is to ensure that the supply fan in a variable air volume application modulates to meet system airflow demand. In most applications, the individual variable air valve (VAV) boxes serving each space will modulate the amount of air delivered to the space based on heating and cooling requirements. As a result, the total supply airflow provided by the central air handling unit must also vary to maintain sufficient airflow through each VAV box. Airflow is typically controlled using a variable frequency drive (VFD) to modulate supply fan speed and vary system airflow. The most common strategy for controlling the VFD is to measure and maintain static pressure within the duct. Related acceptance tests for these systems include the following: • NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance
Instrumentation
The instrumentation needed to perform the task may include, but is not limited to: • Differential pressure gauge (must be calibrated within the past year) • Pitot tube • Drill

Test Conditions

If applicable, supply air temperature reset should be disabled during testing to prevent any unwanted interaction.

All systems and components must be installed and ready for system operation, including:

- Duct work
- VAV boxes
- Static pressure sensor(s) (note multiple sensors with separate control loops are often used on large systems with multiple branches)
- Electrical power to air handling unit
- Air handling unit start-up procedures are complete, per manufacturer's recommendations

BAS programming for the operation of the air handling unit and VAV boxes must be complete, including but not limited to:

- Supply fan motor control, either VFD or ECM motor control
- VAV box control (including zone temperature sensors and maximum/minimum flow rates)
- Before testing, ensure all schedules, setpoints, operating conditions, and control parameters are documented. All systems must be returned to normal at the end of the test.
- This test can and should be performed in conjunction with NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance test procedures.

Estimated Time to Complete

Construction inspection: 0.5 to 1.5 hours (depending on sensor calibration and minimum VFD speed verification)

Functional testing: 1 to 2 hours (depending on how total fan power at design airflow is determined and system control stability)

Acceptance Criteria

Static pressure sensor(s) is field calibrated to within 10 percent of reference sensor, with differential pressure gauge and pitot tube.

For systems without DDC controls to the zone level the pressure sensor setpoint is less than 1/3 of the supply fan design static pressure.

For systems with DDC controls with VAV boxes reporting to the central control panel, the pressure setpoint is reset by zone demand (box damper position or a trim and respond algorithm or other method that dynamically reduces duct static pressure setpoint as low as possible while maintaining adequate pressure at the VAV box zone(s) of greatest demand).

At full flow:

- Supply fan maintains discharge static pressure within ± 10 percent of the current operating control static pressure setpoint
- Supply fan control stabilizes within 5 minute period.

At minimum flow (at least 30 percent of total design flow): • 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.
Potential Issues and Cautions
Ensure that all disabled reset sequences are enabled upon completion of this test. Coordinate test procedures with the controls contractor since they may be needed to assist with manipulation of the BAS to achieve the desired operating conditions.

A. Test Application

Newly Constructed and Additions/Alterations: All new VAV fan controls installed on new or existing systems must be tested.

B. Construction Inspection

Instrumentation used to perform the test may include a calibrated differential pressure gauge, a pitot tube, and a drill. Note the date of calibration for the differential pressure gauge on the NRCA-MCH-07-A Document; calibration must be within the past year.

1. Check that the static pressure sensor location, setpoint, and reset control meet the requirements of §140.4(c)2, as follows:
   - Location: For a multi-zone system with a static pressure sensor located downstream of major duct splits, multiple sensors must be installed in each major branch while controlling fan capacity controlled to satisfy the sensor furthest below its setpoint.
   - Setpoint: Setpoint of must be no greater than one-third of the total design fan static pressure. Note the design total static pressure and the setpoint in I.W.C. on the NRCA-MCH-07-A document.
   - Setpoint Reset Control: For systems with direct digital control of individual zone boxes reporting to the central control panel, static pressure set points shall be reset based on the zone requiring the most pressure; i.e., the set point is reset lower until one zone damper is nearly wide open.
2. Verify that the supply fan includes a means to modulate airflow such as a variable speed drive.
3. Discharge static pressure sensor(s) shall be field calibrated. Performing a field calibration check requires measuring static pressure as close to the existing sensor as possible using a calibrated hand-held measuring device and comparing the field measured value to the value measured by the BAS. When the value measured by the BAS is within 10 percent of the field-measured value, the sensor is calibrated. Attach supporting documentation to the NRCA-MCH-07-A document.

C. Functional Testing

Supply air temperature reset should be disabled during testing to prevent any unwanted interaction.

Step 1: Drive all VAV boxes to achieve full design airflow.

- The intent is to verify proper supply fan operation at or near full flow condition. This typically occurs when all of the VAV boxes are operating at maximum cooling flow rate. There are a variety of ways to force the VAV boxes to a maximum cooling position depending on the building automation system capabilities and control strategies used, for example:
- Command all VAV boxes to maximum flow position (may be accomplished by a global command or it may have to be done per individual box or zone thermostat).
- Space temperature setpoint can be lowered below current space conditions to force the VAV box into maximum cooling (may be accomplished by a global command or it may have to be done per individual box or zone thermostat).

For this test, you cannot simply adjust the fan VFD to a maximum speed since the purpose of the test is to show the stability of the pressure control loop that automatically controls the fan speed. The fan speed must be set to AUTO.

Verify and Document

- Record system full design airflow in cfm (e.g. from design documents).
- Check that supply fan speed modulates to increase capacity. For VFD, record fan motor frequency (Hz).
- For multi-zone systems, check that supply fan maintains discharge static pressure setpoint within ±10 percent of the current operating set point. Verification can be accomplished by simply reading the value measured by calibrated pressure sensor and comparing it to setpoint.
- When tests depart from NA7.5.1 (document NRCA-MCH-02-A), check if another method was used for verifying VFD operation (besides commanding to maximum flow and cooling).
- Verify system operation and supply fan control stabilizes within 5 minutes. The intent is to ensure the PID control loops are tuned properly to prevent the system from hunting excessively.

Step 2: Drive all VAV boxes to a low airflow condition.

The intent is to verify proper supply fan operation when the system is at or near minimum flow conditions. There are a variety of ways to force the VAV boxes to a minimum position depending on the building automation system capabilities and control strategies used, for example:

- Command all VAV boxes to minimum flow position (using global command or per individual box).
- Set maximum flow setpoint to be the same as minimum flow setpoint (using a global command or per individual box).
- Space temperature setpoint can be raised above current space conditions to force the VAV box into minimum cooling or heating mode (using a global command, per individual box, or per zone thermostat).

Again, you cannot simply override the VFD as doing so negates the purpose of the test.

Verify and Document

- Supply fan speed decreases to meet flow conditions. For VFD, record fan VFD frequency (Hz).
- For systems with DDC to the zone level, check that current operating static pressure setpoint has decreased.
- For multi-zone systems, check that supply fan maintains discharge static pressure setpoint within ± 10 percent of the current operating set point. Verification can be accomplished by simply reading the value measured by calibrated pressure sensor and comparing it to setpoint.
- System operation and supply fan control stabilizes within 5 minutes. The intent is to ensure the PID control loops are tuned properly preventing the system from excessive hunting.

Step 3: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions.

13.11 NA7.5.7 Valve Leakage Acceptance

At-A-Glance

NA7.5.7 Valve Leakage Acceptance
Use Document NRCA-MCH-08-A
Purpose of the Test
This test ensures that control valves serving variable flow systems are designed to withstand the pump pressure over the full range of operation. Valves with insufficient actuators will lift under certain conditions causing water to leak and loss of flow control. This test applies to the variable flow systems covered by §140.4(k)1 Chilled and hot-water variable flow systems, §140.4(k)2 Chiller isolation valves, §140.4(k)3 Boiler isolation valves, and §140.4(k)5 Water-cooled air conditioner and hydronic heat pump systems. Related acceptance tests for these systems include the following: • NA7.5.9 Hydronic System Variable Flow Controls Acceptance Testing time will be greatly reduced if these acceptance tests are done simultaneously.
Instrumentation
Performance of this test will require measuring differential pressure across pumps. The instrumentation needed to perform the task may include, but is not limited to either a: • Differential pressure gauge or • Handheld hydronic manometer For accurate comparison with the pump curves, measure using the taps on the pump casing. Taps on the inlet and discharge piping to the pumps will not correlate to the pump curves.

Test Conditions
The whole hydronic system must be complete – all coils, control valves, and pumps installed; all piping is pressure tested, flushed, cleaned, filled with water; BAS controls, if applicable. All equipment start-up procedures are complete, per manufacturer's recommendations. Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction inspection: 0.5 to 2 hours (depending on availability of construction documentation and complexity of the system.) **Functional testing**: 30 minutes to 3 hours (depending on the complexity of the system and the number of valves)
Acceptance Criteria
Provisions have been made for variable flow: System has no flow when all coils are closed and the pump is turned on.
Potential Issues and Cautions
The Acceptance Agent will likely need access to the EMCS during testing Running a pump in a "dead head" condition (no flow) for more than 5 minutes can damage the pump seals or motor. Care must be taken to set up the test so that the pump only needs to run for 5 minutes or less. If balance valves are used for isolation of three-way valves or pumps, their initial position must be noted prior to using them for shut off of flow so that they can be returned to their initial position at the end of the test.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to chilled and hot water systems that are designed for variable flow. It also applies to new boilers and chillers where there is more than one boiler or chiller in the plant and the primary pumps are connected to a common header.

This test is required for the variable flow systems covered by §140.4(k)1 Chilled and hot-water variable flow systems, §140.4(k)2 Chiller isolation valves, §140.4(k)3 Boiler isolation valves, and §140.4(k)5 Water-cooled air conditioner and hydronic heat pump systems.

B. Construction Inspection

- Collect the pump curve data l and note the impeller size. The curve data establishes the conditions for which the pump operates. Beware pumps may ship with a different impeller than indicated on the plate of the pump.
- Ensure installation of all valve and piping arrangements per the design drawings in order to achieve the proper control. Doing so verifies each heat exchanger or coil has its own two-way control valve and flow measuring devices, where applicable.
- Confirm measuring devices are located adequately to achieve the most accurate results measurements (i.e. sufficient straight-line piping before and after the meter).

- Confirm piping arrangements are correct (for example: three-way valves may be located at one or more of the coils to achieve required system minimum flow rates).

C. Functional Testing

Step 1: Dead head One Pump.

The intent of this test is to establish a baseline pump pressure. Close off the system using either manual isolation or balance valves at the inlet or bypass of all three way valves. When using a balance valve, mark its initial position so that it may be reset after the test.

Verify and Document

Isolate one circulation pump and ensure all chillers (or boilers) are off. Close the isolation valve at the pumps discharge. Turn the pump on for no more than 5 minutes. Measure and note the pressure across the pump at this “dead head” condition. When the system is piped primary/secondary make sure there is a secondary pump. At the end of the measurement, turn off the pump and re-open the discharge valve.

Step 2: Close control valves.

The intent of this test is to ensure that all two-way valves and actuators can modulate fully closed. With the chillers (or boilers) off, start the same pump used in Step 1 and drive all HX or coil control valves closed. There are a variety of ways to close the control valves; examples of which include: resetting control setpoints so that valves respond accordingly; commanding the valves directly using the DDC control system (i.e., building automation system); or applying a fixed amount of air pressure to an actuator or valve in the case of a pneumatic control system. Again, ensure the pump operates for no more than 5 minutes in this dead head condition.

Verify and Document

Ensure each control valve closes completely under normal operating pressure. The intent is to confirm the actuator-valve torque requirements are adequate to shut the valve under normal operating system pressure. Verify complete closure by measuring the pressure across the operating pump. If the pressure is more than 5 percent less than the previous test, then one or more valves have not fully closed. Fix any leaks and retest.

Step 3: Return system back to normal operating condition.

Ensure all schedules, setpoints, isolation and balance valves, operating conditions, and control parameters are returned to their initial conditions.

13.12 NA7.5.8 Supply Water Temperature Reset Controls Acceptance

At-A-Glance

NA7.5.8 Supply Water Temperature Reset Controls Acceptance
Use Document NRCA-MCH-09-A
Purpose of the Test
This test ensures that both the chilled water and hot water supply temperatures are automatically reset based on either building loads or outdoor air temperature, as indicated in the control sequences. Many HVAC systems are served by central chilled and heating hot water plants. The supply water operating temperatures must meet peak loads when the system is operating at design conditions. As the loads vary, the supply water temperatures can be adjusted to satisfy the new operating conditions. Typically the chilled water supply temperature can be raised as the cooling load decreases, and heating hot water supply temperature can be lowered as the heating load decreases. This requirement only applies to chilled and hot water systems that are not designed for variable flow and that have a design capacity greater than or equal to 500 kBtuh (thousand BTU's per hour) , according to §140.4(k)4.
Instrumentation
Performance of this test will require measuring water temperatures as well as possibly air temperatures. The instrumentation needed to perform the task may include, but is not limited to: • Hand-held temperature probes for ice water or drywell bath. Devices must be calibrated within the last year.
Test Conditions
To perform the test, use the building automation system (BAS) to manipulate system operation to achieve the desired control. BAS programming for the operation of the chillers, boilers, air handling units, and pumps must include but may not be limited to: • Supply water temperature control, • Equipment start-stop control, • Installed and calibrated control sensors, and • Tuned control loops. All systems must be installed and ready for system operation, including: • Chillers, boilers, pumps, air handling units, valves, and piping; • Control sensors (temperature, humidity, flow, pressure, etc.) Verify all piping is pressure tested, flushed, cleaned, and filled with water. Confirm electric power supply to all equipment. Verify start-up procedures for all pieces of equipment are complete, per manufacturer's recommendations Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.

Estimated Time to Complete
Construction inspection: 0.5 to 1 hours (depending on availability of construction documentation (i.e. plumbing drawings, material cut sheets, specifications, etc.) as well as sensor calibration.) **Functional testing**: 1 to 2 hours (depending on familiarity with BAS, method employed to vary operating parameters, and time interval between control command and system response)
Acceptance Criteria
Supply water temperature sensors are field calibrated, to within one percent of calibrated reference sensor, with supporting documentation attached to MECH-09A document. Sensor performance complies with specifications. Supply water reset works according to control schedule, and actual water temperature is within 2 percent of control setpoint.
Potential Problems and Cautions
If the hot water temperature reset tests when there is minimal heating load, make sure to test the low end of the reset first (coldest hot water supply temperature).If the hottest supply water temperature is tested first, it may be difficult to dissipate the heat in the hot water loop without artificially creating a heating load. Waiting for a small heating load to dissipate the heat in the loop could add significant time to the test procedure. Where humidity control is required, chilled water supply water reset is not recommended.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to chilled or hot water systems that have a supply temperature reset control strategy programmed into the building automation system.

The most common control variables used to reset supply water temperature setpoint include are provided below:

- **Coil valve position.** A central energy management system is used to monitor cooling coil and/or heating coil valve positions to determine when the supply water temperature can be reset. The following example highlights a common heating hot water control strategy, in which all heating coil valve positions (central heating and re-heat coils) are monitored to determine current valve position. When all heating valves are less than 94 percent open, the hot water supply temperature lowers incrementally until one valve opens to 94 percent and maintains the setpoint. When any valve opens more than 98 percent, the hot water supply temperature incrementally raises and maintains until one valve drops back down to 94 percent open. A similar control strategy can be used to reset the chilled water supply temperature. The designer determines the chilled and hot water temperature setpoint values, which should be provided in the design narrative, specifications, or control drawings.
- **Outdoor air temperature.** Another very common control strategy is to reset supply water temperature based on outdoor air temperature. Depending on the building type, internal loads and design conditions, the designer may develop a relationship between the chilled and hot water supply temperatures necessary to satisfy building loads at various outdoor air temperatures. For example, hot water temperature may be reset linearly between 90°F and 140°F when the outdoor air temperature is below

35°F and above 50°F, respectively. The design values should be available from, the design narrative, specifications or control drawings.

- **Humidity control.** For special applications like hospitals, museums, semiconductor fabrication and laboratories, the cooling coil control may be based on maintaining a constant relative humidity within the space for not only comfort but also indoor air quality and moisture control (i.e. mold issues). Therefore, the temperature of the chilled water delivered to the coil should be sufficient to remove moisture from the supply air stream and the chilled water temperature can be reset upwards as the latent load decreases. The designer determines actual chilled water temperature setpoint reset schedules and provides them within the design narrative, specifications or control drawings.

B. Construction Inspection

Temperature sensors must be either factory calibrated or field calibrated by a Controls contractor, or other appropriate person. Depending on the control strategy used to reset supply water temperature, sensors can include, but are not limited to: supply water temperature sensors and outdoor air temperature sensors (when used for reset).

Field calibration requires using either a secondary temperature reference or placing the sensor in a known temperature environment (typically either an ice water or a calibrated dry-well bath). When field calibrating temperature sensors, perform a “through system” calibration, which compares the reference reading to the reading at either the EMCS front end or inside the controller (e.g. it includes any signal degradation due to wiring and transducer error). Hydronic system temperature sensors must calibrate to within one percent of the calibrated reference sensor, ice water or drywell bath.

Provide supporting calibration documentation and attach to the MECH-09A document.

C. Functional Testing

Step 1: Change reset control variable to its maximum value.

Manually change the control variable in order to reset supply water temperature. Check the method used to override the control variable on the NRCA-MCH-09-A document. These overrides include:

- For a valve position control strategy, command at least one coil valve to 100 percent open.
- Adjust discharge air temperature or zone temperature setpoints to drive a valve into a 100 percent open condition. For an outdoor air temperature control strategy, override actual outdoor air sensor to exceed maximum water temperature boundary value. For example, if the control strategy calls for 42°F chilled water when outdoor air temperature is above 70°F, command the sensor to read 72°F. For a humidity control sequence, command the humidity setpoint to be 5 percent below actual humidity conditions.

Verify and Document

- Chilled and/or heating hot water supply temperature setpoint is reset to the appropriate value determined by the designer per the control strategy.
- Actual supply water temperature changes to within 2 percent of the control setpoint.

Step 2: Change reset variable to its minimum value.

Manually change the control variable in order to reset supply water temperature. For a valve position control strategy, command all coil valves to only be partially open. Continuing with one of the examples above, if supply water temperature is reset when a valve is less than 94 percent open, command all valves to be 90 percent open. An alternate method would be to adjust discharge air temperature or zone temperature setpoints to drive a valve into a partially open condition. For an outdoor air temperature control strategy, override actual outdoor air sensor to exceed minimum water temperature boundary value. For example, if the control strategy calls for 90°F heating water when outdoor air temperature is above 50°F, command the sensor to read 52°F.

Verify and Document

- Verify chilled and/or heating hot water supply temperature setpoint is reset to the appropriate value determined by the designer per the control strategy.
- Verify actual supply water temperature changes to within 2 percent of the control setpoint.

Step 3: Test automatic control of reset control variable to automatic control.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back to automatic control.

Verify and Document

- Verify chilled and/or heating hot water supply set-point is reset to the appropriate value.
- Verify actual supply temperature changes to meet the setpoint. This process may take a few minutes for the water temperature to change depending on system conditions and equipment operation.
- Verify that the supply temperature is within 2 percent of the control setpoint.

13.13 NA7.5.9 Hydronic System Variable Flow Control Acceptance

At-A-Glance

NA7.5.9 Hydronic System Variable Flow Control Acceptance
Use Document NRCA-MCH-10-A
Purpose of the Test
All hydronic variable flow chilled water and water-loop heat pump systems with total circulating pump power larger than 5 hp shall vary system flow rate by modulating pump speed using either a variable frequency drive (VFD) or equivalent according to §140.4(k)6. Pump speed and flow must be controlled as a function of differential pressure, and pump motor demand must be no more than 30 percent design wattage at 50 percent design flow. As the loads within the building fluctuate, control valves should modulate the amount of water passing through each coil and add or remove the desired amount of energy from the air stream to satisfy the load. In the case of water-loop heat pumps, each two-way control valve associated with a heat pump closes when not operating The purpose of the test is to ensure that, as each control valve modulates, the pump variable frequency drive (VFD) responds accordingly to meet system water flow requirements. Note that this is not required on heating hot water systems with variable flow designs or for condensing water serving only water cooled chillers. The related acceptance tests for this systems is: • NA7.5.7 Valve Leakage Test (if applicable)
Instrumentation
The instrumentation needed to perform the task may include, but is not limited to: • Differential pressure gauge (hydronic manometer)
Test Conditions
To perform the test, use the control system to manipulate system operation to achieve the desired control. At a minimum, control system programming for the operation of the central equipment, control valves, and pumps must include, but not be limited to: • Equipment start-stop control, • Installed and calibrated control sensors, and • Tuned control loops. All systems must be installed and ready for system operation, including: • Heat pumps, cooling towers, boilers, pumps, control valves, piping, etc. • Control sensors (temperature, flow, pressure, etc.) Verify all piping is pressure tested, flushed, cleaned, and filled with water. Verify electrical power supply to all equipment. Confirm start-up procedures for all pieces of equipment are complete, per manufacturer's recommendations. Document the initial conditions before overrides or manipulation of the BAS. Return all systems to their initial condition after test.

Estimated Time to Complete
Construction inspection: 0.5 to 1 hour (depending on availability of construction documentation – i.e. plumbing drawings, material cut sheets, specifications, etc – as well as sensor calibration) **Functional testing**: 2 to 4 hours (depending on familiarity with BAS, method employed to vary operating parameters, verification method for system flow and VFD power)
Acceptance Criteria
Differential pressure sensor(s) are field calibrated. For systems without DDC to individual coils, pressure sensor(s) are located at or near the most remote HX or control valve, or the HX requiring the greatest differential pressure. For systems with DDC to individual coils, the pressure sensor(s) has no location restriction, but are reset according to the valve requiring the greatest pressure and shall be no less than 80 percent open. System controls to the setpoint stably.
Potential Problems and Cautions
Difficulties could be encountered with manipulating the control system if not familiar with the programming language. Therefore, a controls contractor should be on-site to assist with adjusting system operation and overriding controls.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to any water system that has been designed for variable flow, where the pumps are controlled by variable frequency drives (i.e. chilled and hot water systems, water-loop heat pump and air-conditioning systems).

§140.4(k)6 permits two general variable flow control strategies: (1) supply pressure reset by coil demand for systems with DDC controls to the coil level and (2) fixed pressure setpoint control.

Verify the minimum VFD speed setpoint. When the minimum speed is below 6Hz (10 percent) the pump motor may overheat. However, if the minimum speed is set too high, the system will not adjust down, preventing the full energy savings of the VFD. To achieve the highest energy savings, the minimum speed should be between 6Hz and 10Hz for variable flow systems. Note that this minimum speed may be provided either in the EMCS or at the VSD, but not both as a possible cumulative minimum is not desirable.

B. Construction Inspection

The static pressure location, setpoint, and reset control must meet the requirements of the §140.4(k)6B:

- For systems without DDC, pressure setpoint control is fixed and pressure sensor(s) are located at or near the most remote HX or control valve, or the HX requiring the greatest differential pressure.
- For systems with DDC to individual coils, the pressure sensor(s) locations are not restricted, but the sensors are reset according to the valve requiring the greatest pressure and shall be no less than 80 percent open.

- For heating hot water systems or condenser water systems, variable flow is not required, and an Acceptance Test is not required.

The differential pressure sensor (when applicable) is factory or field calibrated by a Controls contractor or other qualified person. Field calibration requires measuring system pressure (or differential pressure), as close to the existing sensor as possible using a calibrated hand-held measuring device. All pressure sensors must be within 10 percent of the calibrated reference sensor. Supporting documentation must be attached to the Acceptance Document NRCA-MCH-10-A.

C. Functional Testing

This method is acceptable to verify VFD operation even though the control does has a flow meter. If while at minimum flow, VFD speed decreases and system pressure is not greater than at full flow, the system is compliant.

Step 1: Modulate control valves to reduce water flow to 50 percent of the design flow or less, but not lower than the pump minimum flow.

Modulating control valves by simply commanding each valve to a specific position or by adjusting temperature setpoints within the existing temperature range.

Verify and Document

- Current pump operating speed decreased (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. Record the measured system pressure at the control sensor. Record the system pressure 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.

Open control valves so that they reach between 90 - 100 percent of design flow. Opening the control valves can be achieved in a variety of ways, such as resetting control setpoints so that the valves respond accordingly, or commanding the valves directly using the DDC control system.

Verify and Document

- Verify pump speed increases to 100 percent.
- Verify system pressure increases and is within 5 percent of current operating setpoint, Record the measured system pressure at the control sensor. Record the system pressure setpoint.
- Verify system pressure setpoint is greater than the setpoint recorded in Step 1.
- Verify system operation stabilizes within 5 minutes after test starts.

Step 3: Restore system to initial operating conditions.

13.14 NA7.5.10 Automatic Demand Shed Control Acceptance

At-A-Glance

NA7.5.10 Automatic Demand Shed Control Acceptance
Use Document NRCA-MCH-11-A
Purpose of the Test
All control systems with DDC to the zone level are required to enable centralized demand shed at non-critical control zones from either a single software or hardware point in the system §120.2(h). Field studies have shown that in typical commercial buildings resetting the zone temperatures up by 2°F to 4°F during on-peak times can reduce the peak electrical cooling demand by as much as 30 percent. This test ensures the central demand shed sequences have been properly programmed into the DDC system
Instrumentation
The instrumentation needed to perform the task may include, but is not limited to: • The front end computer to the DDC system
Test Conditions
To perform the test, use the control system to manipulate system. The entire HVAC installation and control system must be completed prior.
Estimated Time to Complete
Construction inspection: 0.5 hour to review the EMCS programming **Functional testing**: 0.5 to 1 hour (depending on familiarity with BAS)
Acceptance Criteria
The control system changes the setpoints of non-critical zones on activation of a single central hardware or software point. Then the system restores the initial setpoints when the point is released.
Potential Problems and Cautions
Difficulties could be encountered with manipulating the control system if not familiar with the programming language. Therefore, a controls contractor should be on-site to assist with the testing.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to construction inspection of the EMCS interface shed controls and testing.

B. Construction Inspection

- Inspect the EMCS interface enable activation of the central demand shed controls.

C. Functional Testing

Step 1: Engage the global demand shed system.

- This step can be done by either jumping the digital contact or simply overriding its condition in the EMCS front end. Wait 5-10 minutes to let the changes take effect.

Verify and Document

- The cooling setpoints in the non-critical spaces increase by the expected amount.
- The cooling setpoints in the critical spaces do not change.

Step 2: Disengage the global demand shed system.

- This step can be done by either removing the jumper from the digital contact or simply releasing the override of the point in the EMCS front end. Wait 5-10 minutes to let the changes take effect.

Verify and Document

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

13.15 NA7.5.11 Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion (DX) Units Acceptance

At-A-Glance

NA7.5.11 Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion (DX) Units Acceptance
Use Document NRCA-MCH-12-A
Purpose of the Test
The purpose of this test is to verify proper fault detection and reporting for automated fault detection and diagnostics systems for packaged DX units. Automated FDD systems ensure proper equipment operation by identifying and diagnosing common equipment problems such as temperature sensor faults, low airflow or faulty economizer operation. FDD systems help to maintain equipment efficiency closer to rated conditions over the life of the equipment.
Instrumentation
The system test for refrigerant charge requires a calibrated refrigerant gauge with an accuracy of plus or minus 3 percent.
Test Conditions
Packaged unit and thermostat installation along with programming must be complete. HVAC system must be installed and ready for operation, including completion of all start-up procedures, per manufacturer's recommendations. Prior to FDD verification, test the system operating modes. When the system includes a field-installed air economizer, test the economizer per NRCA-MCH-02-A.

Estimated Time to Complete
Construction inspection: 0.5 hour **Functional testing**: 1 to 2 hours FDD systems have the capability to report alarms to a remote server; accessible via a Web interface. It may be helpful to have two people conducting the test – one to perform testing on the unit and a second to verify reporting of the alarm to the remote interface.
Acceptance Criteria
The FDD system is able to detect a disconnected outside air temperature sensor and report the fault. The FDD system is able to detect excess outside air and report the fault. The FDD system is able to detect a stuck outdoor air economizer damper and report the fault. The saturated discharge and saturated suction temperatures must be measured within 5°F of a calibrated refrigerant gauge.
Potential Problems and Cautions
Compared to the pressure sensors, the temperature sensors can have a longer response time to reach a steady-state condition. Therefore, the FDD algorithms may have trouble working properly during transitional states – for example, when the fan or compressor first turns on. The tester should be aware of the potential for false alarms.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to any FDD system installed on a packaged direct expansion (DX) unit.

B. Construction Inspection

Prior to functional testing, verify and document the following:

- Verify that the installed FDD has been certified to the Energy Commission and is listed on the Energy Commission's website (http://www.energy.ca.gov/title24/equipment_cert/).

C. Functional Testing

For each HVAC unit to be tested do the following:

1. Test for Air Temperature Sensor Failure/Fault

Step 1: Verify the FDD system indicates normal operation.

Step 2: Disconnect outside air temperature sensor from unit controller. Verify and document the following:

- FDD system reports a fault.

Step 3: Connect outside air temperature sensor to unit controller. Verify and document the following:

- FDD system indicates normal operation.

2. Test for Excessive Outside Air

Step 1: Coordinate this test with NA7.5.1 Outdoor Air

- After passing the tests described in NA7.5.1 Outdoor Air, verify FDD system indicates normal operation.

3. Test for Economizer Operation

Step 1: Interfere with normal unit operation to generate an Air Economizer Control failure by immobilizing the outdoor air economizer damper according to manufacturer's instructions.

- After Air Economizer Controls fails, verify FDD system reports a fault.

Step 2: Successfully complete and pass tests described in NA7.5.4 Air Economizer Controls

- Verify FDD system reports normal operation.

13.16 NA7.5.12 FDD for Air Handling Units and Zone Terminal Units Acceptance

At-A-Glance

NA7.5.12 Automatic Fault Detection Diagnostics (FDD) for Air Handling Units and Zone Terminal Units Acceptance
Use Document NRCA-MCH-13-A
Purpose of the Test
Fault detection and diagnostics can also be used to detect common faults with air handling units and zone terminal units. Many FDD tools are standalone software products that process trend data offline. Maintenance problems with built-up air handlers and variable air volume boxes are often not detected by energy management systems because the required data and analytical tools are not available. Performing the FDD analysis within the distributed unit controllers is more practical because of the large volume of data. The acceptance tests are designed to verify that the system detects common faults in air handling units and terminal units. FDD systems for air handling units and zone terminal units require DDC controls to the zone level. Successful completion of this test provides a compliance credit when using the performance approach. An FDD system that does not pass this test may still be installed, but no compliance credit will be given.
Instrumentation
FDD tests for air handling units and zone terminal units require no additional instrumentation for testing, since control algorithms are embedded in unit controllers.
Test Conditions
The air handling unit should be installed and the heating, cooling and economizer modes of operation tested. To perform the test, use the building automation system (BAS) to manipulate system operation to achieve the desired control. BAS programming for the operation of the chillers, boilers, air handling units, and pumps must be complete. All equipment startup procedures must have been completed per manufacturer's instructions. All control sensors must be installed and control loops tuned. Document the initial conditions before any overrides to the building automation system.

Estimated Time to Complete
Acceptance tests will take 1-2 hours for each air handler. Time for acceptance testing for terminal units depends on the number of boxes to be tested.
Acceptance Criteria
The system is able to detect common faults with air handling units, such as sensor failures, damper failures, actuator failures, or improper operating modes. The system is able to detect and report common faults with zone terminal units, such as damper failure, actuator failure, or a control tuning issue.
Potential Problems and Cautions
Difficulties could be encountered with manipulating the control system if not familiar with the programming language. Therefore, a controls contractor should be on-site to assist with the testing.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to any FDD system installed on an air handling unit or a zone terminal unit. A minimum of 5 percent of the terminal boxes (VAV box) shall be tested.

B. Functional Testing

Testing of each Air Handling Units with FDD controls shall include the following tests:

1. **Sensor drift/failure**: The threshold for a sensor drift fault should be given in percentage of full range, or in units for each type of sensor (temperature, differential pressure / airflow rate, etc.).

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

   Step 2: Verify 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:** This fault reports a failed actuator, or a damper stuck in an open, closed, or fixed position.

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

   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 by maintaining the supply air temperature setpoint.

   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 minimum position (0 percent outdoor air) by raising the supply air temperature setpoint.

   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:** This test covers faults such as an actuator failure, a valve stuck in an open or closed position, and/or valve leaks.

   Step 1: From the control system workstation, command the heating coil valve to the full open position by temporarily setting the space heating setpoint higher than the current space temperature, if the system is not in heating mode.

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

   Step 3: Reconnect power to the actuator and command the heating coil valve to full open.

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

   Step 5: From the control system workstation, command the cooling coil valve to the full open position by temporarily setting the space cooling setpoint lower than the current space temperature, if the system is not in cooling mode.

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

   Step 7: Reconnect power to the actuator and command the cooling coil valve to full open.

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

The following tests are designed to capture faults when the system is running in an improper mode of operation such as simultaneous heating, mechanical cooling, and/or economizing. (For systems with integrated economizers, economizer and cooling operation can be simultaneously enabled.)

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

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

Step 3: From the control system workstation, override the mixing box dampers and verify the control workstation reports a fault.

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 units shall be tested.

1. **Sensor drift/failure**:

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

   Step 2: Verify the 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 – damper stuck open:**

   Step 1: Command the damper to be fully open. Override the space temperature setpoint below the current space temperature to force the system into maximum cooling. Another option is to command the VAV box to the maximum position through the control workstation.

   Step 2: Disconnect the actuator to the damper.

Step 3: Adjust the cooling setpoint such 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.

3. **Damper/actuator fault – 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 all setpoints to their original values to resume normal operation.

4. **Valve/actuator fault (For systems with hydronic reheat):** This fault could be caused by actuator failure or a valve stuck in an open or closed position. This test is only applicable to systems with hydronic reheat.

   Step 1: Command the reheat coil valve to (full) open by setting the heating setpoint temperature above the space temperature setpoint. Wait for the controls to respond to the command to open the reheat coil valve.

   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 all setpoints to their original values to resume normal operation.

5. **Feedback loop tuning fault:** This test is designed to capture a fault that might occur from excessive hunting or sluggish control.

   Step 1: Set the integral coefficient of the box controller (reset action) used for airflow control to a value 50 times the current value. Reduce the space temperature setpoint to be 3°F below the current space temperature to simulate a call for cooling.

   Step 2: Verify the damper cycles continuously over a period of several minutes. (The cycling period time depends on the type of controller used but is typically on the order of a few minutes.) Verify that the control system detects and reports the fault.

   Step 3: Reset the integral coefficient of the controller to its original value and reset the space setpoint to its original value to restore normal operation.

6. **Disconnected inlet duct**:

   Step 1: From the control system workstation, command the damper to a minimum position (full closed) by raising the space temperature setpoint.

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

   Step 3: Reset the space temperature setpoint back to its original value.

7. **Discharge air temperature sensor**:

   Step 1: Adjust zone setpoints to drive the box from dead band to full heating.

   Step 2: Verify the supply air temperature resets to the maximum setpoint while the airflow maintains at the dead band flow rate.

   Step 3: Verify that the airflow rate increases to the heating maximum flow rate to meet the heating load.

13.17 NA7.5.13 Distributed Energy Storage DX AC System Acceptance

At-A-Glance

NA7.5.13 Distributed Energy Storage DX AC Acceptance
Use Document NRCA-MCH-14-A
Purpose of the Test
This test verifies proper operation of distributed energy storage DX systems. Distributed energy systems reduce peak demand by operating during off peak hours and storing cooling, usually in the form of ice. During peak cooling hours the ice is melted to avoid compressor operation.
Instrumentation
Distributed energy storage acceptance tests require no additional instrumentation for testing.
Test Conditions
The DX equipment should be installed and operational. Perform pre-startup installation procedures as specified by the manufacturer. Verify that the building cooling is controlled by a standard indoor HVAC thermostat and not by factory installed controls. Verify that ice making is not controlled by the thermostat. The water tank should be filled to the proper level as specified by the manufacturer prior to the start of the test. Verify refrigerant piping connects and the system is charged with refrigerant.
Estimated Time to Complete
Construction Inspection: 0.5 hours **Acceptance Tests**: 2 hours
Acceptance Criteria
Verify nighttime ice making operation. Verify that tank discharges during on-peak cooling periods. Verify that the compressor does not run and the tank does not discharge when there is no cooling demand during on-peak periods. Verify that the system does not operate during a morning shoulder period when there is no cooling demand. Verify that the system operates in direct mode (with compressor running) during the morning shoulder time period.
Potential Problems and Cautions
These tests only apply to systems with storage capacity less than 100 ton-hours. Systems with storage above 100 ton-hours should be modeled using the thermal energy storage compliance option. Be sure the water tank is filled to the proper level indicated by the manufacturer prior to

the start of the tests. The tests require override of the system controller programming. Be sure to record the system settings prior to the start of the testing, and restore the system settings to their original values upon completion of the tests.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to constant and variable volume, direct expansion systems with distributed energy storage (DES/DXAC). This acceptance requirement is an addition to economizer and packaged equipment acceptance.

B. Construction Inspection

The distributed energy storage system third party submittal form should be verified, which contains the following information: testing laboratory, address, phone number, contact person, date tested, tracking number, model number, and manufacturer. The following performance information should be recorded and reported on the document NRCA-MCH-14-A:

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

C. Functional Testing

Step 1: Simulate cooling load during daytime period.

The intent of this test is to verify that during on-peak conditions the tank will discharge and the compressor will remain off.

- Set the time clock to on-peak hours (typically between 12 noon and 6 PM), or change the on-peak start time control parameter to be earlier than the current time. Set the space cooling setpoint to be below the current space temperature**.**

Verify and document

- Supply fan operates continually.
- If the system has ice storage, verify that the DES/DXAC runs in ice melt mode and that the compressor remains off. The supply fan operates continuously to provide cooling to the space. The refrigerant pump operates to circulate refrigerant to the evaporator coil(s).
- If the DES/DXAC system has no ice and there is a call for cooling, verify that the DES/DXAC system runs in direct cooling mode, with the compressor running. Verify that cooling is provided to the space.

Step 2: Simulate no cooling load during daytime conditions.

- This is done by setting the cooling setpoint above the current space temperature, and set the system time during the daytime period.

Verify and document

- 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 the morning shoulder time period (before noon).

- Set the space temperature setpoint to be above the current space temperature and set the system time clock to be between the hours of 6AM and noon.

Verify and document

- The DES/DXAC system remains idle.

Step 4: Simulate a cooling load during the morning shoulder time period (between 6 am and noon).

- Set the space setpoint below the current space temperature.

Verify and document

- Verify that the DES/DXAC system runs in direct cooling mode, with the compressor running.
- Verify that the tank does not discharge during this period.

Calibrating Controls

- Set the date and time back to the current date and time after completion of the acceptance tests, following manufacturer's instructions.

13.18 NA7.5.14 Thermal Energy Storage (TES) System Acceptance

At-A-Glance

NA7.5.14 Thermal Energy Storage (TES) System Acceptance
Use Document NRCA-MCH-15-A
Purpose of the Test
This test verifies proper operation of thermal energy storage (TES) systems. TES systems reduce energy consumption during peak demand periods by shifting energy consumption to nighttime. Operation of the thermal energy storage compressor during the night produces cooling energy, which is stored in the form of cooled fluid or ice in tanks. During peak cooling hours the thermal storage is used for cooling to prevent the need for chiller operation.
Benefits of the Test
The test will ensure that the TES system is able to charge the storage tank during off-peak hours and conversely discharge the storage tank during on peak hours. Since the chiller may operate more efficiently at night when ambient temperatures are lower, the system may save cooling energy in some climate zones.
Instrumentation
TES acceptance tests require no additional instrumentation for testing.

Test Conditions
The chiller, EMS, piping, and components should be installed and operational. The thermal storage tank should be without charge, or even partially charged (not fully charged), at the start of testing. The system should be configured with an on-peak cooling period (tank discharge) and an off-peak charging period. The cooling load can be met by storage if the tank has stored energy available or by compressor cooling if there is no stored energy available.
Estimated Time to Complete
Construction Inspection: 0.5 hours **Acceptance Tests**: 2 hours
Acceptance Criteria
The TES system and the chilled water plant is controlled and monitored by an EMS. Verify: • The TES system stores energy in storage/charge mode. • The storage charging stops when an end of charge signal is generated. • The TES system starts discharging with the compressor(s) in discharge mode. • The TES does not discharge and the cooling load is met by the compressor(s) in mechanical cooling only mode. • The TES discharges with the chiller sharing the load during discharge and mechanical cooling mode. • Storage does not discharge and all compressors are off during the off/storage-secure mode. • When applicable, tanks can be charged while serving in active cooling mode during charge-plus cooling mode.
Potential Problems and Cautions
Potential damage to the chiller, pumps, storage tanks, etc., by improper manipulation of the control system. Perform this test with the assistance of the controls vendor or facility operator.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to thermal energy storage systems used in conjunction with chilled water air conditioning systems.

B. Construction Inspection

Verify that the efficiency of the chiller meets or exceeds the requirements of §110.2.

Supporting documentation needed to perform the test includes:

- Construction documents (plans, drawings, equipment schedule, etc.)
- Approved submittals (for chillers, storage tanks, controls)
- Copy of manufacturers' product literature
- Copy of the Building Energy Efficiency Standards and Appendices

System Installation Information

The following information for both the chiller and the storage tank(s) shall be provided on the plans to document the key TES System parameters.

1. **Chiller(s)**
   - Manufacturer Brand and Model
   - Type (Centrifugal, Reciprocating, etc) and quantity
   - Heat rejection type (air, water, other)
   - Charge mode capacity (tons) at average fluid temperature
   - Discharge mode capacity (tons) at temperature
   - Discharge mode efficiency (kW/ton or EER) at design ambient temperature
   - Charge mode efficiency at nighttime design ambient temperature (kW/ton or EER)
   - Fluid type and percentage (nameplate)
2. **Storage**
   - Type (Ice-on-Coil Internal Melt, Ice-on-Coil External Melt, Encapsulated (e.g. ice balls), Ice Harvester, Ice Slurry, Other Phase Change Material (e.g. paraffin), Chilled Water, Brine (or chilled water with additives), Eutectic Salt, Clathrate Hydrate Slurry (CHS) Cryogenic, Other (specify)
   - Brand and Model
   - Number of Tanks
   - Height/width/depth, or height/diameter (if custom tanks)
   - Storage capacity per tank (ton-hours) at entering/leaving temperatures and hours discharged
   - Storage rate (tons) at flow rate (gpm) per tank
   - Minimum charging temperature based on chiller and tank selections
   - Discharge rate (tons) at entering/leaving temperatures and hours discharged

C. Functional Testing

Step 1: TES System Design Verification

The installing contractor(s) shall certify the following information, which verifies proper installation of the TES system components, consistent with system design expectations.

- Chiller(s) start-up procedure has been completed
- System fluid test and balance has been completed
- Air separation and purge has been completed
- Fluid (e.g. glycol) has been verified at the concentration and type indicated on the design documents
- The TES system has been fully charged at least once and charged duration noted
- The system has been partially discharged at least once and discharged duration noted
- The system is in partial charge state in preparation for Step 2
- Schedule of operation has been activated as designed

- Mode documentation describes the state of system components in each mode of operation

Step 2: TES System Controls and Operation Verification

The Acceptance Testing Technician shall verify the following information:

1. The TES system and the chilled water plant is controlled and monitored by an EMS.
2. The system has controls in place configured for the operator to manually select each mode of operation or use an EMS schedule to specify the mode of operation.
3. The scheduled operations listed below, not the times when the system will be in each mode of operation:
   - **Storage/charge mode.** Manually select storage mode. Verify that the TES system stores energy. If the TES operates on a schedule, note the times, what causes the TES to engage, and that the TES system enters energy storage mode.
   - **End of charge signal.** Simulated a full storage charge by changing the thermal storage manufacturer's recommended end of charge output sensor to the EMS. Verify that the storage charging stops.
   - **Discharge Mode.** Simulate a call for cooling. Manually select storage only discharge mode. Verify that the TES system starts discharging with the compressors off. Return to the off/secured mode. If the TES operates on a schedule, note times, what causes the TES to engage, and that the TES system starts discharging with the compressor(s) off.
   - **Mechanical cooling only mode.** Simulate a call for cooling. Manually select mechanical cooling only mode and verify that the storage does not discharge and the cooling load is met by the compressor(s) only. Return to the off/secured mode. If the TES operates on a schedule, not the times, what causes the TES to engage, and that the storage does not discharge and the cooling load is met by the compressor(s) only.
   - **Discharge and mechanical cooling mode.** Simulate a call for cooling. Manually select discharge and mechanical cooling mode. Verify that the TES system discharges with the chiller(s) sharing the load. Return to the off/secured mode. If the TES operates on a schedule, not the times, cause the TES to engage, and verify that the storage starts discharging with the compressor(s) sharing the load.
   - **Off/storage-secured mode**. Manually select the off/storage-secured mode. Verify that the storage does not discharge and all compressors are off. If the TES operates on a schedule, note the times, what causes the TES to engage, and that the storage does not discharge and all compressor(s) are off, regardless of the presence of calls for cooling.
   - **Charge plus cooling mode** If the provisions for this mode have been made by the system designer, verify that the tank(s) can be charged while serving an active cooling load, simulated by generating a call for cooling and entering the charge mode either manually or by time schedule. If the system disallows this mode of operation, verify that energy storage is disallowed or discontinued while an active cooling load is present.

13.19 NA7.5.15 Supply Air Temperature Reset Controls Acceptance

At-A-Glance

NA7.5.15 Supply Air Temperature Reset Controls Acceptance

Use Document NRCA-MCH-16-A

Purpose of the Test

The purpose of the test is to ensure that the supply air temperature in a constant or variable air volume application serving multiple zones, according to §140.4(f), modulates to meet system heating and cooling loads.

Space conditioning systems must have zone level controls to avoid reheat, re-cool, and simultaneous cooling and heating (§140.4(d)); or, must have controls to reset supply air temperature (SAT) by at least 25 percent of the difference between the design supply-air temperature and the design room air temperature (§140.4(f)2).

Air distribution systems serving zones with constant loads shall be designed for the air flows resulting from the fully reset (e.g. lowest/highest) supply air temperature.

The requirements for SAT reset apply to both CAV and VAV systems. Exceptions include:

- Systems with specific humidity needs for exempt process loads (computer rooms or spaces serving only IT equipment are not exempt),
- Zones served by space conditioning systems in which at least 75 percent of the energy for reheating, or providing warm air in mixing systems, is provided from a site-recovered or site-solar energy source,
- Systems in which supply air temperature reset would increase overall building energy use, and.
- Systems with controls to prevent reheat, re-cool, and/or simultaneous cooling and heating

  Supply air temperature may be reset in response to building loads, zone temperature, outside air temperature, or any other appropriate variable.

Instrumentation

The instrumentation needed to perform the task may include, but is not limited to:

- Hand-held temperature probe or temperature data logger, which was calibrated within the last year with date of calibration noted on the Acceptance Document MECH 16-A.

Test Conditions

Confirm all systems and components are installed and ready for system operation, including:

- Duct work
- Terminal boxes
- Heating and/or cooling coils
- Outside air dampers and controls
- Supply air temperature sensor(s)
- Electrical power to air handling unit

Air handling unit start-up procedures should be complete, per manufacturer's recommendations. If applicable, BAS programming for the operation of the air handling unit and terminal boxes should be complete, including but not limited to:

- Heating and cooling coil temperature control
- Terminal box control (including zone temperature sensors and reheat coils)
- Discharge air temperature sensor

Controls for economizer or outside air damper should be disabled during testing to prevent any unwanted interaction.

Before testing, ensure all schedules, set points, operating conditions, and control parameters are documented. All systems must be returned to normal at the end of the test.

Document current supply air temperature.

Estimated Time to Complete

Construction inspection: 0.5 to 1 hours (depending on sensor calibration)

Functional testing: 0.5 to 1 hours (depending on system control stability)

Acceptance Criteria

Construction Inspection Criteria: The temperature sensor(s) must be factory calibrated, field calibrated by a TAB technician, or field checked by test technician with a calibrated standard. Calibration certificate or other supporting documentation must be provided.

Functional Testing: For each system, the test criteria include:

- Supply air temperature controls modulate as intended.
- Actual supply air temperature decreases to meet the new set point within +/- 2°F.
- Supply air temperature stabilizes within 15 minutes. Supply air temperature and temperature setpoint must be documented in the acceptance form.

Potential Issues and Conditions

Coordinate test procedures with the controls contractor and building staff, if possible, since they may be needed to assist with manipulation of the BAS to achieve the desired operating conditions.

Check to make sure that chilled / hot water coils, if used, are not already fully open and calling for maximum cooling / heating. In this case, reverse Steps 1 and 2 and change the set point range as necessary to allow system to operate within acceptable bounds.

In general, take care to avoid demand peaks exceeding what would be encountered during the normal operation of the building.

Ensure that all disabled reset sequences are enabled upon completion of this test.

A. Test Application

Newly Constructed and Additions/Alterations: All new supply air temperature reset controls installed on new or existing systems must be tested.

Some of the most common control variables used to reset supply air temperature set point include, but are not limited to: outdoor air temperature; zone or return air temperature; zone box damper position; or number of zone boxes calling for heating or cooling. Examples of each control strategy are provided below:

- **Outdoor air temperature.** One control strategy is to reset supply air temperature based on outdoor air temperature. For example, cold deck or cooling mode temperature may reset linearly between 55°F and 65°F while the outdoor air temperature is between 50°F and 80°F, respectively.
- **Zone or return air temperature.** Another control strategy is to reset supply air temperature based on zone temperature or return air temperature. For example, supply air temperature may modulate to maintain a zone temperature dead band between 70°F and 76°F.
- **Zones calling for cooling or heating.** In a VAV system, the building automation system may reset the supply air temperature based either on the needs of the zone with the highest heating or cooling loads, or based on a certain percent response from the zone boxes for cooling or heating. For example, in a “trim and response” sequence, the air handler supply temperature may reset downwards by 0.5°F when the maximum system demand is above 100 percent, or reset upwards by 0.5°F when the maximum system demand is below 80 percent.

B. Construction Inspection

Reference the supporting documentation when needed.

1. Verify supply air temperature reset controls are installed per the requirements of the 2016 Energy Standards §140.4(f): Multi-zone systems shall include controls that automatically reset supply-air temperatures:
    - In response to representative building loads or to outdoor air temperature; and
    - By at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.
2. If an exception is taken to these requirements, note the exception, in which case the test is not needed.
3. Document all system air temperature sensor(s) are factory or field calibrated. Attach a copy of the calibration certificate, TAB verification results, or field verification results including results from system air sensors and calibrated reference standards.
4. Document the current supply air temperature.

C. Functional Testing

1. Disable economizer controls and/or outside air damper during testing to prevent any unwanted interaction or effect on air temperature.
2. Check to make sure that chilled and hot water coils, if used, are not already fully open and calling for maximum cooling or heating. If this is the case, reverse Steps 1 and 2 in the test and/or change the set point range as necessary to conduct this test.
3. Document the reset control parameter (e.g. zone air temperature).

Step 1: During occupied mode, adjust the reset control parameter to decrease the supply air temperature (to the lower supply temperature limit).

Override reset control variable to decrease supply air temperature.

For example, temporarily replace outside temperature signal with a high fixed temperature value for outside air temperature, or temporarily override zone damper signals to imitate all zones calling for maximum cooling. For example, if the supply air is currently 65°F, and the control strategy calls for 60°F cool supply air when outdoor air temperature is above 70°F, override the sensor reading to 75°F.

When the reset control variable input cannot be modified, change the limit of the variable around the currently occurring value. For example, if the control strategy calls for 55°F cool supply air when outdoor air temperature is above 80°F, and the current outdoor air temperature is 75°F, adjust the maximum limit from 80°F to 70°F.

Verify and Document

- Supply air temperature controls modulate as intended.
- Actual supply air temperature decreases to meet the new set point within +/- 2°F.
- Supply air temperature stabilizes within 15 minutes.
- Document both supply air temperature setpoint and actual supply air temperature.

Step 2: During occupied mode, adjust the reset control parameter to increase the supply air temperature (to the upper supply temperature limit).

Override reset control variable to increase supply temperature.

When the reset control variable input cannot be modified, change the limit of the variable around the currently occurring value. For example, modify the reset schedule to create an outside air set point low limit above the current outside air temperature, or shift the entire set point range.

Verify and Document

- Supply air temperature controls modulate as intended.
- Actual supply air temperature decreases to meet the new set point within +/- 2°F.
- Supply air temperature stabilizes within 15 minutes.
- Document both supply air temperature setpoint and actual supply air temperature.

Step 3: Restore reset control parameter to automatic control.

Ensure all set points, operating conditions, and control parameters are placed back at their initial conditions. Remove any system overrides initiated during the test.

Verify and Document

- Supply air temperature controls modulate as intended.
- Actual supply air temperature decreases to meet the new set point within +/- 2°F. Document both supply air temperature setpoint and actual supply air temperature.
- Supply air temperature stabilizes.

13.20 NA7.5.16 Condenser Water Temperature Reset Controls Acceptance

At-A-Glance

NA7.5.16 Condenser Water Supply Temperature Reset Controls Acceptance

Use Document NRCA-MCH-17-A

Purpose of the Test

The intent of the test is to verify that the condenser water supply (entering condenser water) temperature is automatically reset as indicated in the control sequences; based upon building loads, outdoor air wet-bulb temperature, or another appropriate control variable. All cooling tower system components (e.g. fans, spray pumps) should operate per the control sequences to maintain the proper condenser water temperature and pressure set points.

Chilled water plants serve many buildings, responding to the varying cooling loads throughout the year. As the loads vary, the chilled water supply temperatures adjust to satisfy the new operating conditions. Often, water-cooled chilled water plants can decrease the condenser water temperature in times of low cooling load. This occurrence can be demonstrated by running the cooling tower fans at a higher speed, staging on additional fans, or varying water distribution across the tower fill by closing and opening bypass valves. As a result, the cooling tower produces an energy penalty, however the chiller efficiency and the overall plant efficiency improves.

The requirement for condenser water reset acceptance only applies to those chilled water systems with a cooling tower implementing some kind of condenser water temperature reset control.

There is no code requirement that chilled water plants employ this type of control. However, if condenser water temperature reset is implemented, then it must be tested per the Energy Standards. The purpose of this test is not to evaluate whether a particular control sequence is the most appropriate for the facility, but whether the system follows the intended control sequence.

Instrumentation

Performance of this test will require measuring water temperatures, and possibly air temperature, relative humidity, system pressures, and system flow rates. The instrumentation needed to perform the task may include, but is not limited to:

- Hand-held temperature probe to calibrate or check existing sensors
- Humidity sensor or wet bulb temperature probe / psychrometer

Installed sensors should be checked for accuracy, and may be used for testing where appropriate. Any instruments used for testing or checking other sensors must be calibrated within the past year, with date of calibration noted on the Acceptance Document.

Test Conditions

To perform the test, it may be necessary to use the building automation system (BAS) to manipulate system operation to achieve the desired control. BAS programming for the operation of the chillers, cooling towers, air handling units, and pumps must be complete, including but not limited to:

- Chilled water and condenser water temperature control
- Equipment start-stop control
- All installed and calibrated control sensors
- Tuned Control loops

All systems must be installed and ready for system operation, including:

- Chillers, cooling towers, pumps, air handling units, valves, and piping.
- Control sensors (temperature, humidity, flow, pressure, valve position, etc.)
- Safeties, interlocks, and alarms (e.g. high/low water alarms, vibration, back-up system operation)

Verify all piping is pressure tested, balanced, flushed, cleaned, and filled with water. Verify electrical power is supplied to all equipment. Confirm start-up procedures for all equipment must be complete, per manufacturer's recommendations. At a minimum, all components and systems served by the chiller and cooling tower should have completed pre-functional checks and be capable of safe operation.

Document the initial conditions before overrides or manipulation of the BAS. Return all systems to their initial condition after test.

Estimated Time to Complete

Construction inspection: 1 to 3 hours (depending on availability of construction documentation – i.e. plumbing drawings, material cut sheets, specifications, etc. – as well as sensor calibration records.)

Functional testing: 2 to 5 hours (depending on familiarity with BAS, method employed to vary operating parameters, ambient conditions, building loads, and time interval between control command and system response)

Acceptance Criteria

Construction Inspection: All ambient temperature and relative humidity sensors used by the controller must be either calibrated (manufacturer calibrated with calibration certificates or field calibrated by TAB technician), or field checked against a calibrated sensor by the person performing the test.

Functional Test: System must meet the following criteria during the test:

- Condenser water temperature controls modulate as intended.
- Actual condenser water supply temperature decreases to meet new set point within ± 2°F.
- Cooling tower fan(s) stage properly and/or adjust speed accordingly to meet lower set point.
- Chiller load amps decrease.

Potential Problems and Cautions

Condenser water temperature reset is most effective on a moderately warm day. When testing during cold weather conditions, make sure that freeze protection controls are installed and functional to prevent equipment damage. Also ensure the conditioned spaces do not fall below safe temperatures, as this may cause discomfort or unsafe working conditions.

If conducting this test during hot weather conditions, make sure the chiller load amps don't increase as the condenser water temperature decreases. If so, you will need to conduct this test on a cooler day. Likewise, stop the test if the chiller begins to surge.

This test does not require operation of the plant equipment across all operating stages, so it is not necessary, nor desirable, that the system experience peak load conditions. However, the system cooling load must be sufficiently high to run the test. If necessary, artificially increase the load to perform the functional tests, or wait until a time of stable chiller operation. If necessary, reverse Steps 1 & 2 in the functional test based on atmospheric conditions and building loads.

If the system is designed to employ variable flow simultaneously with temperature reset, allow the system to operate as programmed but take care that the water flow rate stays within the minimum and maximum flow rate limits for the chiller(s) and cooling tower(s). Minimum flow through a cooling tower is important to provide even water distribution and full wetting of the fill to prevent scaling.

Exemption: There is an important exemption associated with this functional test to provide flexibility given the range of chilled water plant operations, as follows: If the control sequence differs significantly from that implied by the tests, and / or has already been tested during the building commissioning process, attach a description of the control sequence, a description of the tests that were done to verify the system operates according to the sequence, the test results, and a plot of any associated trend data.

A. Test Application

Newly Constructed and Additions/Alterations: All new condenser water temperature reset controls installed on new or existing systems must be tested.

Some control variables used to reset supply water temperature include, but are not limited to:

- **Outdoor air wet-bulb temperature.** A common control strategy is to reset supply water temperature based on outdoor wet bulb temperature. For example, the entering condenser water set point may be reset at a fixed amount (e.g. 7°F) above the outdoor air wet bulb temperature, with limits to meet the chiller and cooling tower operation. The cooling tower may then meet the set point by increasing or decreasing the amount of water circulating through the tower, staging on or off cooling tower fans, or adjusting tower fan motor speed for VFD-equipped fan motors. The designer determines nominal supply water and outdoor air temperatures, which are available in the design narrative, specifications or control drawings.
- **Condenser water and chilled water temperatures.** A cooling tower may operate to maintain a certain temperature difference between the condenser water supply and chilled water return. This process maintains chiller lift or pressure across the compressor. For example, the control may cycle tower fans on and off, or modulate fan speed, to maintain a 14°F difference between condenser water supply of 70°F – 78°F and chilled water return of 56°F – 62°F.

- **Load signal from chille**r. The condenser water temperature may follow a load signal from the chiller. For example, condenser water temperature may follow a "horseshoe" shape, increasing in times of highest and lowest load, and decreasing during low and moderate chiller loading. This strategy enables the chiller to maintain capacity at high load, benefiting from increased efficiency during times of moderate load, and maintaining adequate lift during times of lowest load.

B. Construction Inspection

Prior to functional testing, verify and document the following:

- Check if the condenser water supply system and control system are installed per the system design, as documented on the building plans or as-builts.
- Check if condenser water supply temperature control sequence, including condenser water supply high and low limits, are available and documented in the building documents.
- Check if all cooling tower fan motors are operational, cooling tower fan speed controls are installed, operational, and connected to cooling tower fan motors per OEM start-up manuals and sequence of operation.
- Check if cooling tower fan control sequence, including tower design wetbulb temperature and approach, are available and documented in the building documents.
- Check if the following temperature sensors are installed per plans: outdoor air drybulb and wetbulb, entering condenser water, and leaving chilled water. Note any discrepancies on the Acceptance Document.

All ambient dry bulb temperature, and relative humidity/wet bulb sensors used by controller must be factory calibrated (with certificate), field calibrated by TAB technician or other technician (with calibration results), or field checked against a calibrated reference standard by test technician (with results). Attach supporting documentation to the Acceptance Document.

When field calibrating temperature sensors, it is recommended that you perform a "through system" calibration that compares the reference reading to the reading at the EMCS front end or inside the controller (e.g. it includes any signal degradation due to wiring and transducer error).

Document the following from the control system or using test sensors:

- Current outdoor air dry bulb and wet bulb temperatures
- Current entering condenser water supply temperature
- Current leaving chilled water temperature

C. Functional Testing

If the control sequence differs significantly from that implied by the tests, and/or has already been tested during the building commissioning process, attach a description of the control sequence, a description of the tests that were done to verify the system operates according to the sequence, the test results, and a plot of any associated trend data.

Document reset control parameter (e.g. outside air wet-bulb temperature) on the Acceptance Document.

Step 1: Adjust the reset control parameter to decrease the condenser water temperature (toward the lower supply temperature limit).

Within the programmed reset strategy, change the reset control variable to its minimum value to decrease condenser water supply temperature downward towards the lower limit. For example, if the control strategy calls for the condenser water supply to reset downwards from 85°F to 70°F with a difference of 10°F above current ambient wet bulb temperature of 75°F, override the sensor reading to read a wet bulb temperature below 70°F.

If the reset control variable input cannot be modified, then change the limit of the variable around the currently occurring value. For example, in the example above, adjust the sequence to a difference of 6°F between the condenser water supply temperature and ambient wet bulb temperature.

Take care not to allow condenser water temperature to drop below the chiller low temperature limit. Allow time for the system to stabilize.

Verify and Document

- Condenser water temperature controls modulate as intended.
- Actual condenser water supply temperature decreases to meet new set point within ± 2°F.
- Cooling tower fan(s) stage properly and/or adjust speed accordingly to meet lower set point.
- Chiller load amps decrease.

Step 2: **Adjust the reset control parameter to increase the condenser water temperature (toward the upper supply temperature limit).**

Using the desired reset strategy, override reset control variable towards its maximum value to increase the condenser water supply temperature upward to its high limit. If the reset control variable input cannot be modified, then change the limit of the variable around the currently occurring value. Allow time for the system to stabilize.

Verify and Document

- Condenser water temperature controls modulate as intended.
- Actual condenser water supply temperature increases to meet new set point within ± 2°F.
- Cooling tower fan(s) stage properly and/or adjust speed accordingly to meet upper set point.
- Chiller load amps increase.

Step 3: Restore reset control parameter and system to automatic control.

Restore all controls and equipment to original settings, and/or restore the high and low limits of the reset control variable. Remove all system overrides initiated during test.

Verify and Document

- Condenser water temperature controls modulate as intended.
- Actual condenser water supply temperature changes to meet new set point within ± 2°F.
- Cooling tower fan(s) stage properly and/or adjust speed accordingly to meet set point.
- All equipment returns to normal operation.

13.21 Energy Management Control System Acceptance

At-A-Glance

Energy Management Control System Acceptance
Use Document NRCA-MCH-18-A
Purpose of the Test
This acceptance test ensures the central control system, when installed, is properly installed and configured and capable of meeting the applicable requirements of the Energy Standards. The EMCS is a complex, highly customized control system with many opportunities for installation and programming problems.
Test Conditions
All systems and components must be installed, powered and ready for system operation, including: • Controllers • Actuators • Sensors • EMCS programming All of the regular installation, start-up, testing, and commissioning tasks that a controls contractor normally performs during an EMCS installation should be complete before this test is conducted.
Estimated Time to Complete
1 to 2 hours, depending on familiarity with the EMCS, complexity of the EMCS, and the number of control points.
Acceptance Criteria
Test passes if all Construction Inspection boxes are checked and all Functional Testing results are “yes’.
Potential Problems and Cautions
This basic list of recommendations is intended to validate the readiness of the EMCS for any required acceptance criteria specified in the Energy Standards. This check should not take the place of a more comprehensive start-up testing or commissioning effort. This acceptance test should be completed prior to conducting the other acceptance tests that rely on the EMCS.

A. Test Application

Newly Constructed and Additions/Alterations: All new energy management control systems (EMCS) installed on new or existing systems must be tested.

B. Construction Inspection

Ensure the following actions have been completed:

- Factory start-up and check-out complete
- I/O point lists available
- Point-to-point verification completed
- Sequence of operations of each system are programmed
- Written sequences are available
- Input sensors are calibrated

Verification Checks

Conduct the following verification checks to validate the functionality of the EMCS:

- Verify the control graphics represent the system configuration.
- Verify control points are properly mapped to the graphics screen.
- Raise and lower a sampling of space temperature setpoints in the software and verify the system responds appropriately.
- Verify the time-of-day start-up and shut-down function initiates a proper system response.
- Verify trending capabilities by establishing trend logs for a sampling of control points.
- Verify alarm conditions are monitored.
- Verify the EMCS panel is installed on an emergency power circuit or has adequate battery back-up.

C. Functional Testing

This section includes test and verification procedures for lighting systems that require acceptance testing as listed below:

Document NRCA-LTI-03-A

- NA 7.6.1 Automatic Daylighting Controls Acceptance

Document NRCA-LTI-02-A

- NA 7.6.2.2 and 7.6.2.3 Occupant sensor Acceptance
- NA 7.6.2.4 and 7.6.2.5 Automatic Time Switch Control Acceptance

Document NRCA-LTI-04-A

- NA 7.6.3 Demand Responsive Controls

Document NRCA-LTO-02-A

- NA 7.8.1.2 Outdoor Motion Sensor Acceptance
- NA 7.8.2 Outdoor Lighting Shut-off Controls

13.22 NA7.6.2 Shut-off Controls Acceptance

NA7.6.2.2 and NA7.6.2.3 Occupancy Sensing Lighting Controls Acceptance

At-A-Glance

Occupant Sensor Acceptance
Use Document NRCA-LTI-02-A
Purpose of the Test
The purpose of the test is to ensure that occupant sensors are functioning properly to achieve the desired lighting control. There are two basic technologies in three configurations utilized in most occupant sensors: 1) infrared; 2) ultrasonic; and 3) a combination of infrared and ultrasonic.
Occupant sensors are used to automatically turn lights ON immediately when a space is occupied, and automatically turn them OFF when the space is vacated after a pre-set time delay. Some sensors are configured so the user must manually switch the lights ON but the sensor will automatically switch the lights OFF (manual-ON controls). These are commonly called ‘vacancy sensors’ and are included in this testing procedure. Automated lighting controls prevent energy waste from unnecessarily lighting an unoccupied space.
Instrumentation
This test verifies the functionality of installed occupant sensors visually and does not require special instrumentation.
Test Conditions
Occupant sensors are installed properly and located in places that avoid obstructions and minimize false signals. All luminaires are wired and powered. During the test, the space remains unoccupied. Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction Inspection: 0.25 to 0.5 hours (depending on visual and audible inspection requirements) **Equipment Test**: 0.5 to 1 hours (depending on necessity to adjust time delay or mask sensor to prevent false triggers)
Acceptance Criteria
Standard occupant sensor responds to “typical” occupant movement to turn the lights ON immediately. Manual ON occupant sensor requires occupant to switch lighting on. Multi-level occupant sensors meet uniformity requirements; the first stage activates between 50-70 percent of the lighting power; after that event the occupant has the ability to manually activate the alternate set of lights, activate 100 percent of the lighting, and deactivate all of the lights.

Conditions where partial ON/OFF controls are required in addition to or instead of the basic controls requirements are identified and the controls properly reduce lighting power by at least 50 percent.

Ultrasonic occupant sensors do not emit audible sound.

Lights controlled by the occupant sensor turn OFF at the preset time delay.

The programmed maximum time delay is not greater than 20 minutes.

Occupant sensor does not trigger a false ON or OFF.

Status indicator or annunciator operates correctly.

Potential Issues and Cautions

It is imperative that the test be performed during a time when the tester can have full control over the occupancy of the space.

The time delay can be adjusted to minimize test time, but the time delay setting must be reset upon completion of the test (not to exceed 20 minutes).

To avoid detection of significant air movement from an HVAC diffuser or other source, which can cause the sensor to turn the lights ON (this is most critical with ultrasonic sensors).

If motion in an adjacent area is causing an unwanted trigger, the technician may adjust the coverage pattern intensity or mask the sensor with an opaque material.

A. Test Application

The purpose of the test is to ensure that an occupant sensor functioning properly to achieve the desired lighting control. Occupant sensors are used to automatically turn lights on and keep them on when a space is occupied, and turn them off automatically when the space is unoccupied after a reasonable time delay. The time delay, typically adjustable, will prevent lights from rapid cycling through ON and OFF when spaces are occupied frequently but temporarily. It also helps avoid false OFF triggering when there is little apparent occupant movement.

B. Construction Inspection

Verify the following:

- Occupant sensors are located to minimize false signals.
- No closer than four feet from a HVAC diffuser.
- Passive infrared sensor pattern does not enter into adjacent zones.
- Occupancy sensors do not encounter any obstacles that could adversely affect desired performance.
- Ultrasonic occupant sensors do not emit audible sound 5 feet from source.
- Occupant sensors have been certified to the Energy Commission in accordance with the applicable provision in §110.9. Verify that model numbers of all occupant sensors are listed on the Energy Commission database as “Certified Appliances & Control Devices” (http://www.energy.ca.gov/appliances/database/).

Prepare for allowable sampling:

- For buildings with up to seven (7) occupancy sensors, all occupancy sensors must be tested and sampling may not be used.
- For buildings with more than seven (7) occupancy sensors, sampling may be done on spaces with similar sensors and space geometries.
  - Sampling shall include a minimum of 1 occupancy sensor for each group of up to 7 additional photocontrols.
  - 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 within the limits of the technician's authority to do so.

C. Functional Testing

a. **Part 1: Occupant sensor**

Step 1: Simulate an unoccupied condition.

Ensure the space being tested remains unoccupied during the test and wait for the lights to turn off (sensor delay time can be adjusted to shorten test time).

Verify and Document

1. Lights controlled by the occupant sensor turn off after the time delay. If the time delay was not adjusted prior to the test, ensure the maximum delay is not greater than 20 minutes. If the time delay was adjusted to minimize test time, return the time delay to initial conditions or 20 minutes, whichever is less.
2. Occupant sensor does not trigger a false ON. Ensure that any movement outside the desired control zone does not activate the lights. Examples include:
   - Walking past an open door of an enclosed office
   - Walking in an adjacent zone close to the control zone, (consider that designers sometimes employ overlapping sensor coverage areas as part of the design)
   - Movement other than occupants (i.e. air flow from HVAC system or furnishing movement due to external forces)

Step 2: For a representative sample of building spaces, simulate an occupied condition.

Verify and Document

- Status indicator or annunciator operates correctly.
- Most occupant sensors have an LED that will illuminate (typically flash) when motion is detected, where others may emit an audible sound.
- The lights in the control zone turn on immediately, except if the sensor has "manual-ON" capability. The occupant sensors that are required to have "manual-ON" capability are identified on the Lighting Control Worksheet.

b. **Part 2: Partial-OFF Occupant sensor**

Step 1: Simulate an unoccupied condition.

Verify and Document:

1. Lights controlled by the occupant sensor turn off after the time delay. If the time delay was not adjusted prior to the test, ensure the maximum delay is not greater than 20 minutes. If the time delay was adjusted to minimize test time, ensure that the time delay is returned to initial conditions or 20 minutes, whichever is less.
2. Occupant sensor does not trigger a false ON. Ensure that any movement outside the desired control zone does not activate the lights. Examples include:
   - Walking past the end of the aisle or book stack.
   - Walking in an adjacent zone close to the control zone, (consider that designers sometimes employ overlapping sensor coverage areas as part of the design, so ensure that the zone coverage test has a reasonable demarcation).
   - Movement other than occupants (i.e. air flow from HVAC system or furnishing movement due to external forces).
3. The following areas shall be controlled with occupancies sensors to meet the requirements indicated in the Table below.

NRCA-LTI-02-A
Full- or Partial-OFF in the Unoccupied Condition
Occupancy Sensing Control Setting Requirements & Exceptions

AREA	Exception	Minimum Lighting Power Reduction Requirement	Note	Energy Standards Section
Where Full or Partial-OFF occupant sensing controls are required. Comply with the following IN ADDITION to §130.1(c)1.				
Aisle Ways & Open Areas of Warehouses	No exception applied	50 percent	1	§130.1(c)6A
	Installed lighting power is 80 percent or less of the value allowed under the Area Category Method	40 percent		Exception 1 to §130.1(c)6A
	Installed metal halide lighting or high pressure sodium lighting	40 percent		Exception 2 to §130.1(c)6A
Library book stack aisles	No exception applied	50 percent	1, 2	§130.1(c)6B
Corridors & Stairwells	No exception applied	50 percent	3	§130.1(c)6C
Where only Partial-OFF occupant sensing controls are required. Comply with the following INSTEAD OF §130.1(c)1.				
Stairwells & Corridors for High-Rise Res &	No exception applied	50 percent	3, 4	§130.1(c)7A

Hotel/Motel	Installed lighting power is 80 percent or less of the value allowed under the Area Category Method	40 percent		Exception 1 to §130.1(c)7A
Parking Garage, Parking Area & Loading/Unloading Areas	No exception applied	At least one control step between 20 percent & 50 percent	3, 5, 6	§130.1(c)7B
	Installed Metal halide luminaires with a lamp plus ballast mean system efficacy of greater than 75 lumens per watt	At least one control step between 20 percent & 60 percent		Exception 1 to §130.1(c)7B

NOTES	
1	The occupant sensing controls shall independently control lighting in each aisle way, and shall not control lighting beyond the area being controlled by the sensor.
2	This requirement applies to library book stack aisles that are 10 feet or longer and accessible from only one end or 20 feet or longer and accessible from both ends.
3	The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated from all designed paths of egress.
4	This applies to stairwells and common area corridors that provide access to guestrooms and dwelling units of high-rise residential buildings and hotel/motels
5	No more than 500 watts of rated lighting power shall be controlled together as a single zone. A reasonably uniform level of luminance shall be achieved in accordance with the applicable requirements in Table 130.1-A.
6	Interior areas of parking garages are classified as indoor lighting for compliance with §130.1(c)7B. Parking areas on the roof of a parking structure are classified as outdoor hardscape and shall comply with the applicable provisions in §130.2.

Step 2: Simulate an occupied condition

Verify and document:

The occupant sensing controls turn lights fully ON in each separately controlled areas, Immediately upon an occupied condition

c. **Part 3: Partial-ON Occupant sensor**

Step 1: Simulate an occupied condition.

Simulate a situation where an occupant enters a space with a partial on sensor arrangement.

Verify and Document

- The occupant sensor will activate the first stage of lighting, between 50 to 70 percent of the total lighting connected load for the specific lighting equipment controlled.
- After the first stage occurs, manual switches are provided to activate the alternate set of lights, bringing the total power consumption up to the full connected load of the controlled lighting equipment.

Step 2: Simulate an unoccupied condition.

Verify and Document

- Both stages of lighting (automatic and manual stages) turn OFF with a maximum of 20 minute from the beginning of the unoccupied condition.
- Occupant sensor does not trigger a false ON. Ensure that any movement outside the desired control zone or HVAC operation does not activate the lights.

d. **Part 4: Occupant Sensor Serving Small Zones In Large Open Office Plan For Power Adjustment Factor (PAF)**

For each controlled zone that is being tested, first complete Functional Test 2 (Occupant Sensor) to confirm that the sensor is switching the lights on and off as required. Then enter the information described below:

- Area served by controlled lighting (square feet) - Size of the controlled zone, which is to say the zone underneath the lighting controlled by this occupant sensor. The boundaries of the controlled zone should lie halfway between one light fixture and the next, if the light fixtures are on a regular grid.
- Enter PAF corresponding to controlled area - From line (a) on the test form, enter the power adjustment factor that corresponds to the size of the controlled zone (≤125sf for PAF=0.4, 126-250sf for PAF=0.3, 251-500sf for PAF=0.2).
- Enter PAF claimed for occupant sensor control in this space from compliance documentation - enter the PAF for this controlled zone, from the Certificate of Compliance
- The PAF corresponding to the controlled area (line b), is less than or equal to the PAF claimed in the compliance documentation (line c) - This step is to ensure that the PAF calculated during the acceptance test is not less than the PAF that was claimed for the same zone on the compliance document.
- Sensors shall not trigger in response to movement in adjacent walkways or workspaces. The sensor switches on the lights only in response to movement within the group of workspace(s) that together constitute the controlled area. The lights must not trigger in response to movement in nearby areas.
- All steps are conducted in Functional Test 2 “Occupancy Sensor (On Off Control)” and all answers are Yes (Y) - This step verifies that Functional Test 2 has been conducted, to verify that the occupant sensor switches the lights between their high and low states as required.

13.23 NA7.6.2.4 and NA7.6.2.5 Automatic Time Switch Lighting Controls Acceptance

At-A-Glance

Automatic Time Switch Acceptance
Use Document NRCA-LTI-02-A
Purpose of the Test
This test ensures all non-exempt lights, per §130.1(c)1, are automatically turned off at a predetermined time and individual lighting circuits can be manually enabled, if necessary, during scheduled OFF periods. Lighting during typically unoccupied periods prevents energy waste.
Instrumentation
This test verifies the functionality of installed automatic time switch controls visually and does not require special instrumentation.
Test Conditions
All luminaires and override switches controlled by the time switch control system must be wired and powered. Lighting control system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer's recommendations. Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction Inspection: 0.5 to 2 hours (depending on familiarity with lighting control programming language) **Equipment Test**: 2 to 6 hours (depending on familiarity with lighting control programming language, number of lighting circuits and override switches to be tested, and programmed time delays between ON and OFF signals)
Acceptance Criteria
Automatic time switch controls are programmed with acceptable weekday, weekend, and holiday schedules, per building occupancy profile. The correct date and time are properly set in the lighting controller. Program backup capabilities are present to prevent the loss of the device's schedules for at least 7 days, and the device's time and date setting for at least 72 hours, if power is interrupted All lights may be either turned ON manually or turned ON automatically during the occupied time schedule. All lights turn OFF automatically at the scheduled times. The manual override switch is functional and turns associated lights ON when activated. Override time limit is no more than 2 hours, except for spaces exempt per §131(c)3.B.

If annunciator is installed, verify proper installation. Verify the annunciator warning to the occupants that the lights are about to turn OFF functions correctly.

Ensure that automatic time switches have been certified to the Energy Commission in accordance with the applicable provision in §110.9. Verify that model numbers of all automatic time switches are listed on the Energy Commission database as "Certified Appliances & Control Devices."

http://www.energy.ca.gov/appliances/database/

Potential Issues and Cautions

The manual override time limit can be adjusted to minimize test time, but the time limit setting must be reset upon completion of the test (not to exceed 2 hours).

When possible, perform the test when the spaces are unoccupied. Turning the lights OFF when other occupants are present can cause problems and unsafe working conditions.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to Occupant sensor, Manual Daylight Controls and Automatic Time Switch Control Acceptance. Functional testing and verification is required.

B. Construction Inspection

1. Verify automatic time switch controls are programmed with acceptable weekday, weekend, and holiday schedules. Non-exempt lights should be scheduled OFF a reasonable time after the space is typically unoccupied (i.e., 1 or 2 hours after most people vacate the space).
2. Verify schedule and other programming parameter documentation is available or posted to the owner. The documentation should include weekday, weekend, and holiday schedules as well as sweep frequency and/or override time period.
3. Verify correct date and time is properly set in the time switch. Lights will not be controlled correctly if the programmed date and time do not match actual values.
4. Verify the battery is installed and energized. The device shall have program backup capabilities that prevent the loss of schedules for at least 7 days, and the time and date settings for at least 72 hours if power is interrupted.
5. Override time limit is no more than 2 hours. When the lights are switched off, each lighting circuit can be turned back on manually. Most systems will either send out another OFF signal through the entire lighting network to command all lights back off, or an override timer will expire to turn off the lights which were manually turned on. Regardless of the control strategy, lights that were manually turned ON during an OFF period should only be operating for up to 2 hours before they are automatically turned off again.
6. Verify that override switch is readily accessible and located so that a person using the device can see the lights being controlled--for example, individual override switch per enclosed office or centrally located switch when serving an open office space.
7. Verify that model numbers of all automatic time switch controls are listed on the Energy Commission database as "Certified Appliances & Control Devices." http://www.energy.ca.gov/appliances/database/.

C. Functional Testing

Step 1: Simulate occupied condition.

Set ON time schedule to include actual time or adjust time to be within the ON time schedule (whichever is easier).

Verify and Document

Verify all lights can be enabled. Some systems may turn the lights on automatically at the scheduled time, but others may require that lights be turned on manually using their respective area control switch.

Step 2: Simulate unoccupied condition.

Set the OFF time schedule to include the actual time, or adjust the time to be within the OFF time schedule (whichever is easier).

Verify and Document

All non-exempt lights turn off. Most systems warn occupants that the lights are about to turn off by sending a pulse through the lighting circuits to “flicker” the lights or provide another form of visual or audible annunciation.

Manual override switch is functional. Enabling the manual override switch allows only the lights in the selected space where the switch is located to turn ON. This is particularly important in enclosed spaces to ensure only lights within the enclosed space are controlled, however, switches serving open spaces should also control only lights in the designated zone. The lights should remain ON throughout the override time period (refer to §130.1(c)3B for maximum override times) and the system indicates that the lights are about to be turned off again.

All non-exempt lights turn off when the next OFF signal is supplied to the lighting control circuits or the override time has expired. In order to reduce testing time associated with the complete OFF-Manual override-OFF sequence, the override time may be shortened so that the entire sequence can be witnessed within a reasonable amount of time.

Step 3: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions. Ensure the override time period is no more than 2 hours.

It is also good practice to leave a schedule in the timeclock itself for easy reference and to leave a blank schedule form so that the users can document any schedule changes.

13.24 NA7.6.1 Automatic Daylighting Control Acceptance

At-A-Glance

Automatic Daylighting Control Acceptance
Use Document NRCA-LTI-03-A
Purpose of the Test
The purpose of this test is to ensure that spaces mandated to have automatic daylighting control (refer to §130.1(d)) are installed and functioning as required by the Energy Standards. Automatic daylighting controls in Primary Sidelit and Skylit Daylit Zones are mandatory if the zone includes more than 120 Watts of lighting equipment. The lighting must have multiple stages of control that meet the requirements of Table 130.1-A and §130.1(d)2Dii. Automatic daylighting controls in Secondary Sidelit Zones are prescriptive and §140.6(d) outlines their functions.
Benefits of the Test
The controls save energy only if they are functioning correctly. Controls passing the test provide adequate illuminance under all daylight conditions while reducing lighting power in response to daylight in the space to save a significant fraction of lighting energy. If the control leaves the space too dark, visual quality is compromised and ultimately the control will be over-ridden resulting in no energy savings. If the control leaves lights on at too high a level, the full savings from the control are not realized.
Instrumentation
To perform the test, it will be necessary to measure ambient light levels and validate overall power reduction. In most cases, the only instrumentation required is: • Light meter (illuminance or foot-candle meter) For dimming ballasts, a default illuminance/power relationship can be used to estimate power consumption. Alternatively, the tester can choose to directly measure power or current or use the manufacturer's dimming performance data. Additional instrumentation or data that may be needed: • Hand-held amperage meter or power meter • Logging light meter or power meter • Manufacturer's light versus power curve for continuous dimming and step dimming ballasts
Test Conditions
All luminaires in the Daylit Zone must be wired and powered. Controls installed according to manufacturer's instructions Simulating a bright condition can be difficult; therefore, performing the test under natural sunny conditions is preferable. Document the initial conditions before testing. All systems must be returned to normal at the end of the test.

Estimated Time to Complete
Construction Inspection: 0.5 to 1 hour (depending on whether sensor calibration is necessary, familiarity with lighting control programming language, and availability of construction documentation – i.e. electrical drawings, material cut sheets, etc.) **Equipment Test**: 1 to 3 hours (depending on ability to manipulate ambient light levels, familiarity with lighting control programming language, and method employed for verifying required power reduction)
Acceptance Criteria
Lighting is correctly controlled so that general lighting fixtures in the Daylit Zone are controlled separately from lighting outside the Daylit zone. Photosensor has been located properly to minimize unauthorized tampering. [§130.1(d)2Di] The photosensor is physically separated from the location where calibration adjustments are made, or is capable of being calibrated in a manner that the person initiating calibration is remote from the sensor during calibration to avoid influencing calibration accuracy. [§110.9(b)2] Sensor located and oriented appropriate to the control type and location of Daylit Zone. Under conditions where no daylight is sensed by the control, the control system increases the light output of each fixture to the design light output. This may be full output, but in a space with multi-level lighting requirements, this could be commissioned to meet the design illuminance requirements. The controlled fixtures reduce lighting power to no greater than 35 percent of full-load power under fully dimmed and/or stepped conditions. [§130.1(d)2Div] For the continuous and stepped dimming control systems, the lamps do not “flicker” at reduced light output. [§110.9(b)3], which cites the Title 20 requirements for dimming. Title 20, Section 1605.3(l)2(F)2 states, “*Dimmer controls that can directly control lamps shall provide electrical outputs to lamps for reduced flicker operation through the dimming range…without causing premature lamp failure.”* Because there is no standard for evaluating flicker, this is intended to refer to visible flicker. Automatic daylighting systems shall provide multi-level control capability following the guidance in Table 130.1-A. [§130.1(d)2Dii] Stepped dimming and stepped switching control systems have a minimum time delay of 3 minutes or greater before a decrease in electric lighting. [§110.9(b)2] For the stepped dimming and stepped switching control systems, the dead band between steps is sufficiently large to prevent cycling between steps for the same daylight illuminance. [§110.9(b)2] A “Reference Location” is defined that is served by the controlled lights and receives the least amount of daylight. Usually this is a location that is furthest away from the windows or skylights but is still served by the controlled lighting equipment. A “Reference Illuminance” is defined at the Reference Location – this is the illuminance from electric lighting when no daylight is available. For continuous dimming systems; Under partial daylight conditions, the combined daylight and electric lighting illuminance from continuously dimmable fixtures at the Reference Location is no less than the Reference Illuminance and no greater than 150 percent of the Reference Illuminance.[§130.1(d)2Diii&iv]

When stepped lighting controls dim or turn off a step, the combined daylight and electric lighting illuminance from stepped dimming or stepped switching fixtures at the Reference Location is no less than the Reference Illuminance and no greater than 150 percent of the Reference Illuminance after the electric light is fully diminished. [§130.1(d)2Diii&iv]
Potential Issues and Cautions
Check fixture circuiting while access to wiring is relatively easy (i.e. while lift is available or before obstructions are installed). Simulating bright conditions and achieving proper luminance to perform the test can be difficult. Therefore, it is recommended that the test be performed under natural bright light conditions. For the stepped dimming and switching control systems, it is acceptable to shorten the time delay while performing the tests, but the time delay must be returned to normal operating conditions when the test is complete (at least 3 minutes).

A. Test Application

Newly Constructed and Additions/Alterations: Applies to properly located controls, field calibrated and set to appropriate lighting levels.

Preparing for Sampling:

- All photocontrols serving more than 5,000 ft² 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.
    - Sampling shall include a minimum of 1 photocontrol for each group of up to 5 additional photocontrols.
    - 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.

Definition of the Daylit Zones

The following information on the definitions of the Daylit Zones are only needed if the designer has not documented on the plans the Daylit Zones or if the as built location of windows and skylights do not correspond to the Daylit Zones on the plans. When the plans are incorrectly documenting the Daylit Zones, it is the tester's responsibility to identify the problem and inspect and test the system based upon the as-built configuration of the Daylit Zones. It is recommended that this is conducted in consultation with the designer.

- **Primary Sidlit Daylit Zone** is the combined Primary Sidelit Daylit Zone for each window without double counting overlapping areas. The floor area for each Primary Sidelit Daylit Zone is directly adjacent to vertical glazing below the ceiling with an

area equal to the product of the Primary Sidelit Daylit Zone width and the Primary Sidelit Daylit Zone depth.

- **Primary Sidelit Daylit Zone width** is the width of the window plus, on each side, the smallest of:
  - 0.5 times the window head height.
  - The distance to any 6 foot or higher permanent vertical obstruction.
  - The distance to any Skylit Daylit Zone.
- **Primary Sidelit Daylit Zone depth** is the horizontal distance perpendicular to the glazing that is the smaller of:
  - One window head height.
  - The distance to any 6 foot or higher permanent vertical obstruction.
  - The distance to any Skylit Daylit Zone.
- **Secondary Sidlit Daylit Zone** is the combined Secondary Sidelit Daylit Zone for each window without double counting overlapping areas. The floor area for each Secondary Sidelit Daylit Zone is directly adjacent to Primary Sidelit Daylit Zone with an area equal to the product of the Secondary Sidelit Daylit Zone width and the Secondary Sidelit Daylit Zone depth.
- **The Secondary Sidelit Daylit Zone width** is the width of the window plus, on each side, the smallest of:
  - 0.5 times the window head height.
  - The distance to any 6 foot or higher permanent vertical obstruction.
  - The distance to any Skylit Daylit Zone.
- **The Secondary Sidelit Daylit Zone depth** is the horizontal distance perpendicular to the glazing that begins from one window head height, and ends at the smaller of:
  - Two window head heights.
  - The distance to any 6 foot or higher permanent vertical obstruction.
  - The distance to any Skylit Daylit Zone.
- **Skylit Daylit Zone** is the combined Skylit Daylit Zone under each skylight without double counting overlapping areas. The daylight area under each skylight is bounded by the rough opening of the skylight, plus horizontally in each direction the smallest of:
  - 70 percent of the floor-to-skylight or skylight well height.
  - The distance to any permanent partition or permanent rack that is taller than 50 percent of the distance from the floor to the bottom of the skylight and oriented in a direction to cause a shadow.

  When the partitions fall within the floor plan rough opening of the skylight, they do not cause shadowing that reduces the overall coverage of the skylight. In these cases, the coverage area should not be limited by the partition.

Figure 13-3: Primary Sidelit Daylit Zone Plan view

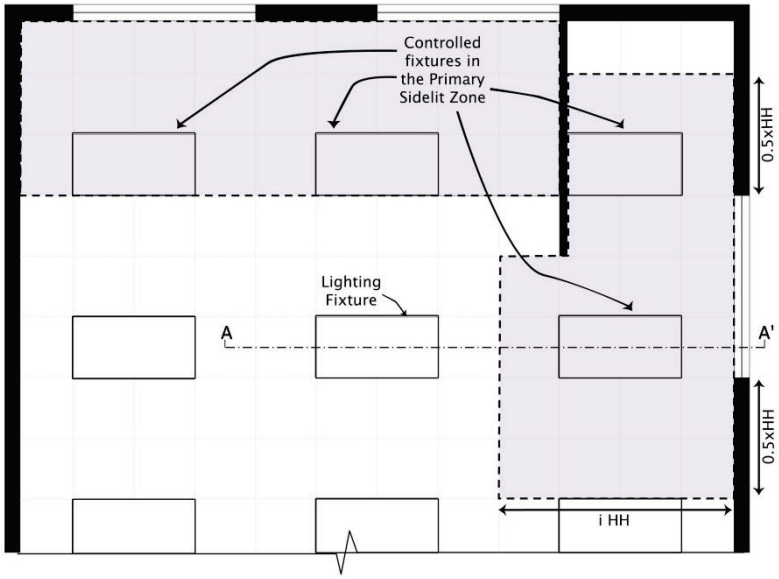
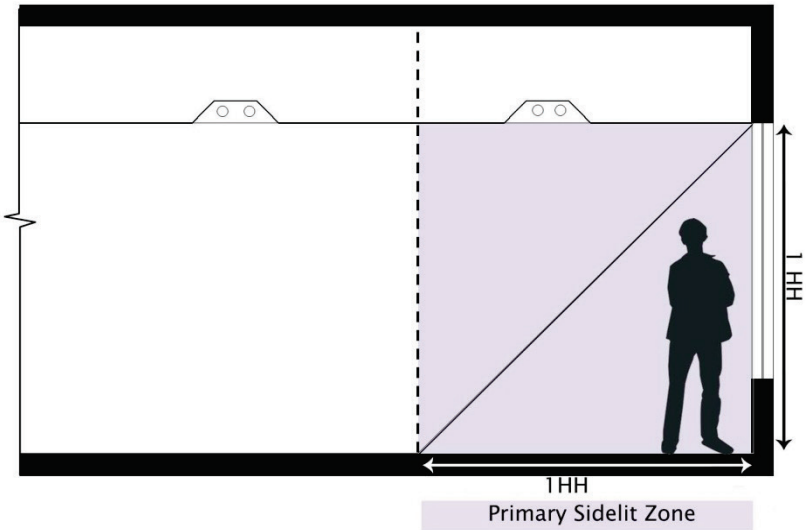


Figure 13-4: Side view of Primary and Secondary Sidelit Zones



- **Clearstory or monitor windows** have a different coverage pattern than the traditional skylight and are treated as windows, but the Daylit Zone is considered a Skylit Daylit Zone. The Skylit (Monitor) Zone depth under each monitor window is defined from the plane of the monitor window, extending towards the back by the smaller of:
  - 100 percent of the floor-to-head height of the monitor.
  - The distance to any permanent partition or permanent rack that is not directly below the monitor well, whichever is taller than fifty percent of the distance from

the floor to the bottom of the ceiling, and is oriented such that it will cast a substantial shadow to the back.

- **The Skylit (Monitor) Daylit Zone width** is the width of the monitor window plus the smaller of:
  - 50 percent of the floor-to-head height of the monitor window.
  - The distance to any permanent partition or permanent rack that is not directly below the monitor well, whichever is taller than fifty percent of the distance from the floor to the bottom of the ceiling, and is oriented such that it will cast a substantial shadow to the side.
  - In buildings with no partitions, the Skylit Daylit Zone under skylights is the footprint of the skylight plus in each direction 70 percent of the ceiling height or halfway to the next skylight, whichever is less. This is shown in Figure 13-5:

Figure 13-5: Elevation View of Skylit Daylit Zone under Skylight (no interior partitions)

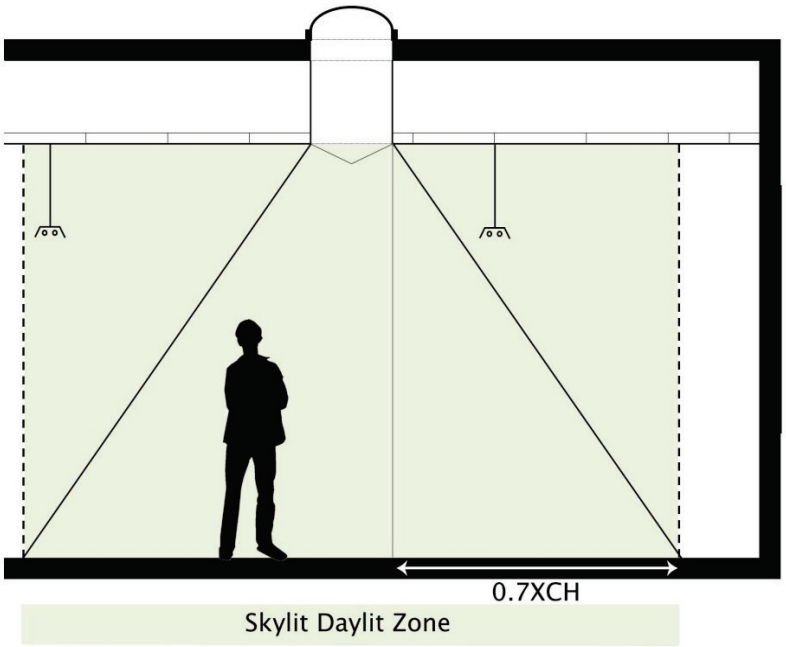
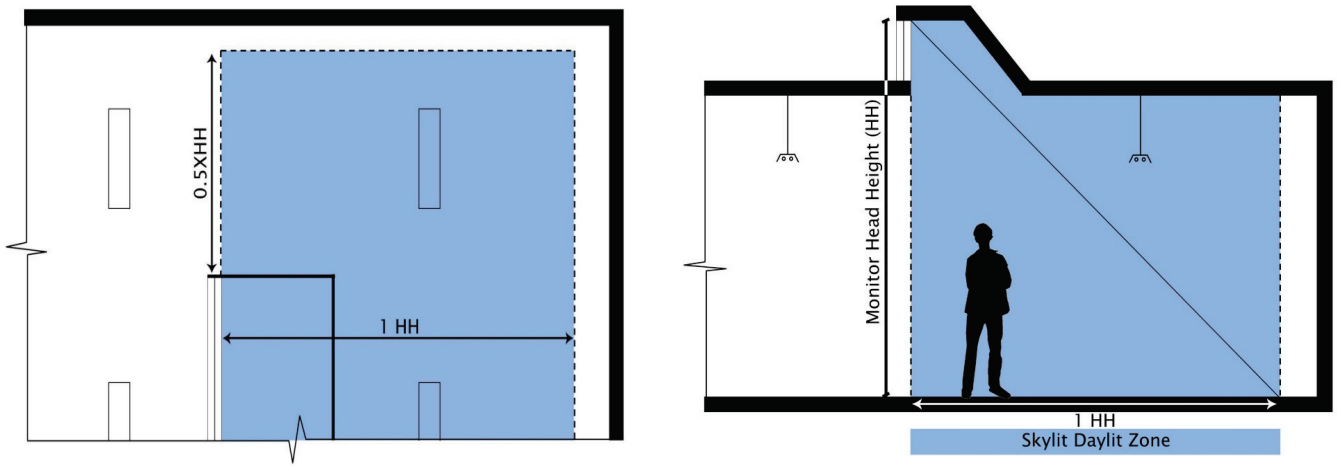


Figure 13-6: Plan and Elevation View of Skylit Daylit Zone under Monitor Window or Clearstory (no interior partitions)



If there are permanent partitions or racks below the skylight, the partitions may block portions of the full extent of the Skylit Daylit Zone. There are two conditions that must occur for a partition to reduce the Daylit Zone. A partition must be greater than 50 percent of the distance from the floor to the bottom of the skylight (or monitor window), and is not directly below the skylight or monitor well, and the partition must be oriented so that the object creates a shadow beyond it. This is illustrated in Figure 13-7 below.

Figure 13-7: Elevation View of Skylit Daylit Zone under Skylight (with interior partitions)

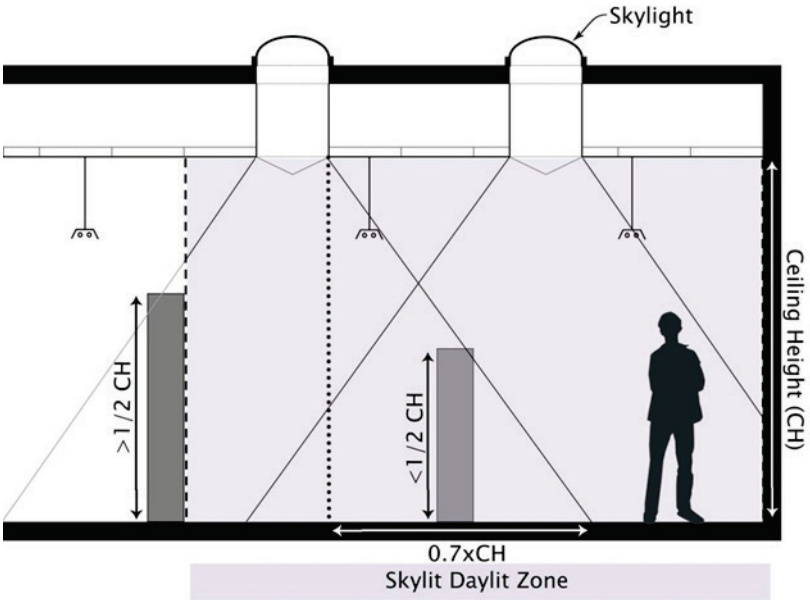


Figure 13-8: Plan View of Skylit Daylit Zone under Skylights (with interior partitions)

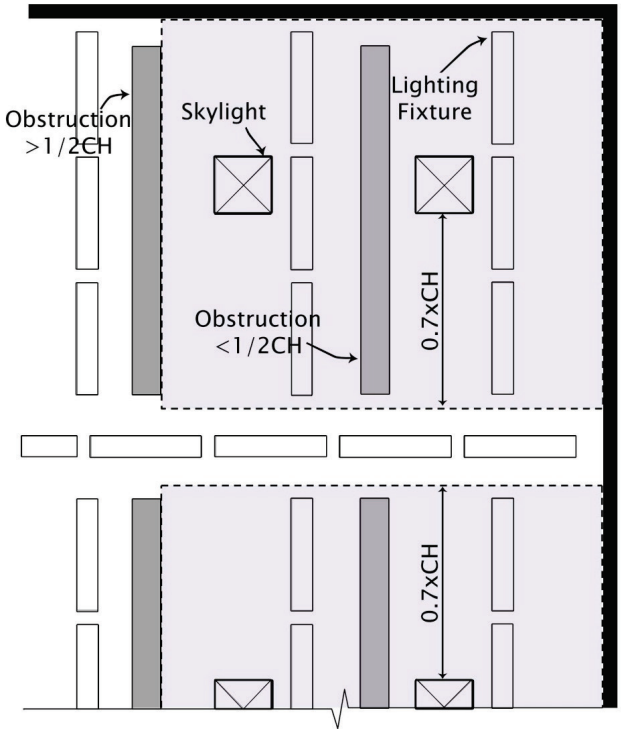
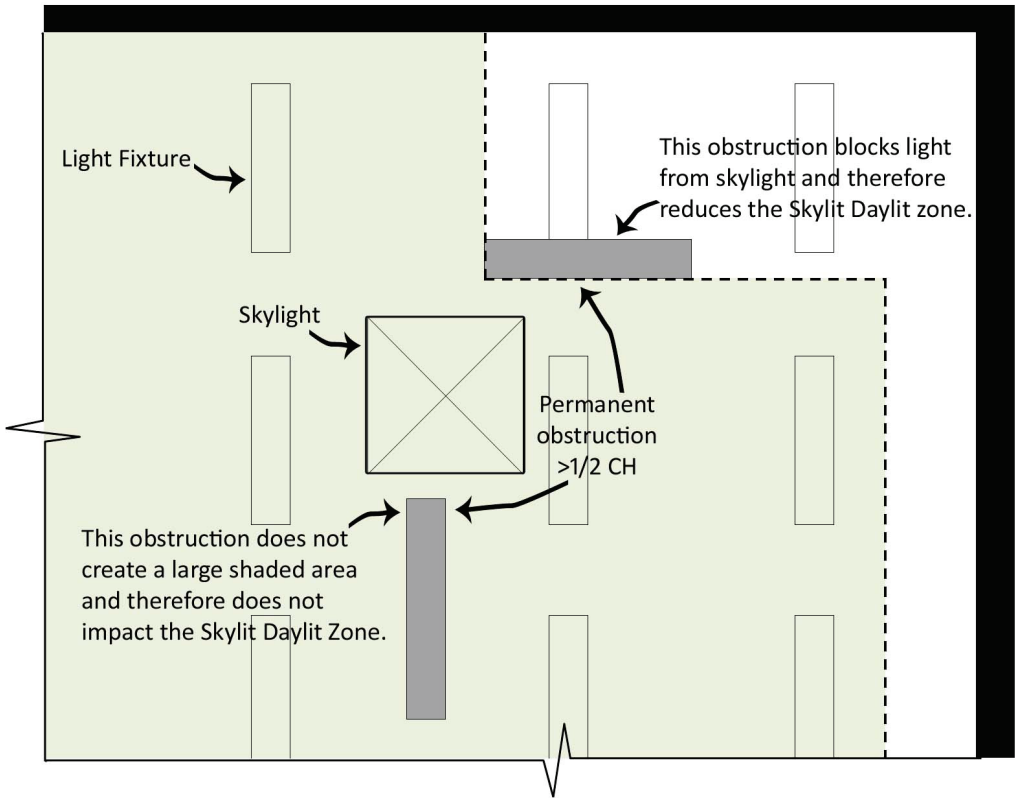


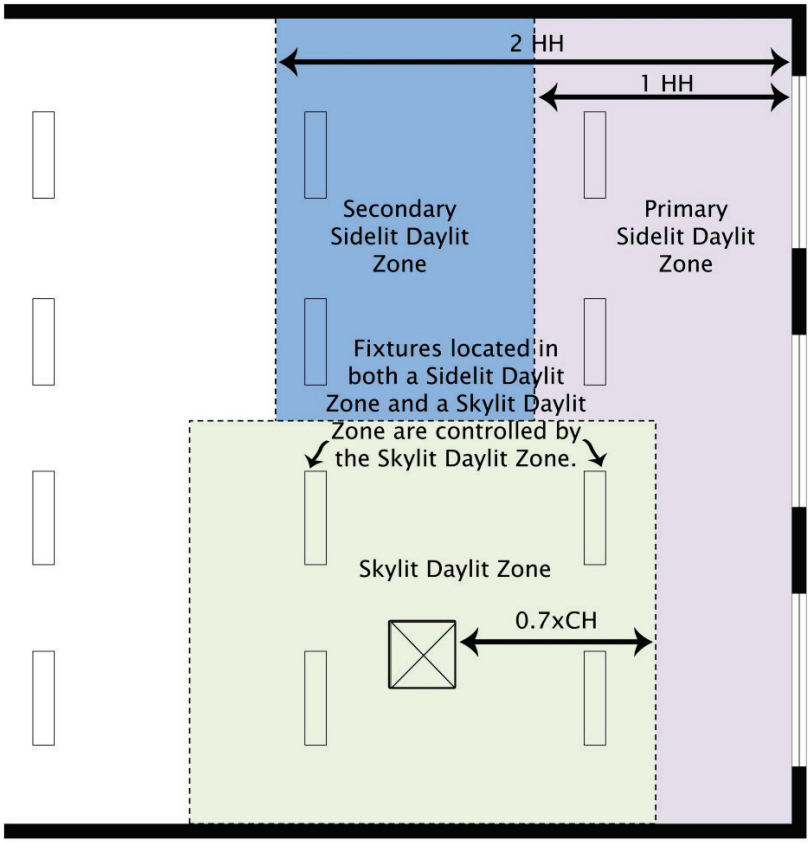
Figure 13-9: Example of Skylit Daylit Zone under Skylight (with interior partitions where one partition is not considered 'blocking')

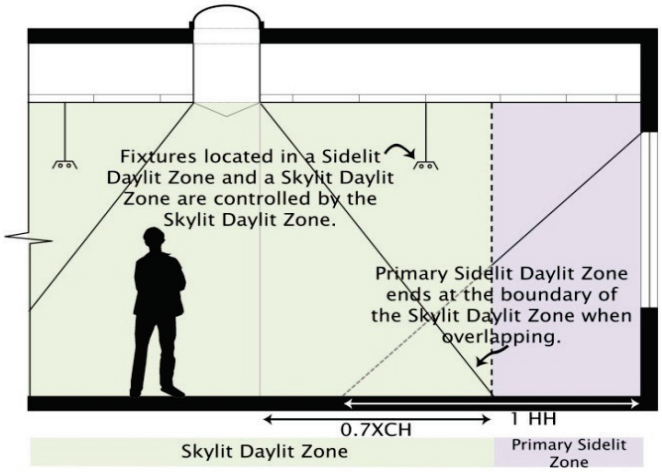


- **Hierarchy of Zones.** In situations where Zones overlap, there is a hierarchy of Zone assignment so that there is no condition where the lighting equipment is considered in more than a single Zone. The hierarchy is as follows:
  1. Skylit (including monitor windows or clearstories).
  2. Primary Sidelit.
  3. Secondary Sidelit.

  The lighting equipment is assigned based on which Zone it is within or touching, so a light fixture that is partially within two different Zones will be placed in the higher Zone, per the above hierarchy.

Figure 13-10: Plan and Elevation Views Showing Hierarchy of Assigned Daylit Zones





B. Construction Inspection

1. Purpose of the Test

The purpose of this construction inspection is to ensure that the daylighting controls that are installed in the space meet the location, specification and accessibility requirements per §110.9(b)2; and to ensure that control devices have been certified to the Energy Commission in accordance with the applicable provision in §110.9.

2. Criteria for Passing the Test

The system must pass all six key criteria identified in Document NRCA-LTI-03-A Part I:

- All Daylit Zones are clearly marked on plans or drawn on as-built drawings.
- All Daylit Zone type and control type is clearly identified on the Document.
- Sensors and controls are appropriate for the particular requirements of the daylighted area and intended functions, and are located in appropriate locations per §110.9(b)2 and §130.1(d).
- Sensor and control setpoints are documented by the installer.
- Daylighting controls only control those luminaires that are in the daylighted area for which they are intended and luminaires in Sidelit Daylit Zones are controlled separately from luminaires in Skylit Daylit Zones.
- Daylighting controls have been certified to the Energy Commission in accordance with §110.9(a)3.

3. How to Conduct the Test and Fill the Document

Step 1: Daylit Zones Shown on Plans

The building plans are required to have a drawing of the extents of the Daylit Zones when controls are required or controls are used to obtain lighting control credits.

If the plans do not have the Daylit Zones indicated for the spaces containing photocontrols, draw the Daylit Zones on the as-built plans and attach to the acceptance test documents. A copy should be sent to the designer and the building owner.

When there are more than one type of Daylit Zones present and thus daylighting control systems exist on site, these should be clearly marked on the plans, and also noted on the document. The user is able to specify up to three (3) systems per document.

For buildings with several daylighting controls, one may sample the controls for Acceptance Testing. When sampling, clearly note it on the documents. A separate sheet should be attached to the document with names of the other controls and systems that are being represented by the three systems on the document. At least one daylighting control shall be tested for each Daylit Zone category (Skylit, Primary Sidelit, and Secondary Sidelit).

Step 2: System Information

There are three types of Daylit Zones:

- The Skylit Daylit Zones under skylights,
- The Primary Sidelit Daylit Zones adjacent to within one window head height of the vertical glazing, and
- The Secondary Sidelit Daylit Zones, located between the corresponding Primary Sidelit Daylit Zone and two window head heights from the vertical glazing.

The window head height is the distance from the floor to top of the window. This is summarized in the Section titled "*Definition of Daylit Zones.*"

1. *Controlled Lighting Wattage:*

- Note the total wattage of luminaires that are controlled by the given control system. If there are multiple controls systems (A, B, C on the document), identify controlled wattage separately for each type of control system.
- When the Primary Sidelit Daylit Zone or Skylit Daylit Zone in a room (enclosed space) includes greater than 120 watts of lighting equipment, all general lighting in this daylighted area is required to be controlled by an automatic daylighting control.
- General lighting is defined as lighting that is "designed to provide a substantially uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect." Linear fluorescent troffers and pendants, high and low bay luminaires and other non-directional light sources are considered general lighting.
- When automatic daylighting controls are required in Primary Sidelit Daylit Zones, these lights must be separately controlled from the Secondary Sidelit Daylit Zone.
- The photocontrol must control only those fixtures in the daylighted area. A luminaire is considered to be in the Daylit Zone if any part of the luminaire touches the defined Daylit Zone. With long pendant fixtures that cross into Daylit Zone, the lamps that touch the Daylit Zone must be controlled separately from those not in the Daylit Zone.
- Luminaires and lamps that touch more than one Daylit Zone follow this hierarchy for assignment; 1. Skylit, 2. Primary Sidelit, 3. Secondary Sidelit.
- Controls for Sidelit Daylit Zones are required to be separate from controls for Skylit Daylit Zones.

Note: Identifying whether fixtures are controlled by a given sensor or control may be difficult without operating the system. For this reason, it may be better to conduct this portion of the construction inspection in conjunction with the functional performance test.

The controlled fixtures are readily identified by noting which fixtures are turned on and off or are dimming in response to the no daylight and full daylight functional performance tests.

2. *Control Type:*

- Identify the type of luminaire control used in each of the control systems identified in the document. There are three types of controls identified on the document:
- Continuous dimming controls are controls that alter the output of lamps in at least 10 steps.
- Step dimming controls alter the output of lamps in less than 10 steps (typically up to four steps between on and off).
- Step switching controls turns lamps or groups of lamps on and off without any steps between on and off.
- Stepped switching controls are able to provide multi-level lighting by having more than one group of lamps being controlled. Partial light output (and partial power consumption) of the stepped switching lighting system is provided by turning some of the lamps on.

3. Design Footcandles:

Note the design footcandles for general illumination in the Daylit Zone served by each of the control systems identified in the document. If the design light level is not known for a given control system, clearly identify that it is unknown.

Step 3: Sensors and Controls

- Loop Type and Sensor Location: Verify that all photosensors have been properly located. Per §130.1(d)2D, an individual photosensor must be located so that it is not readily accessible. This placement is intended to make it difficult to tamper with the photosensor. Photocontrols that are part of a wallbox occupant sensor do not comply and shall not be considered an acceptable photocontrol device.
- The photosensor must be located so that can readily sense daylight entering into the daylit area.
- Closed loop sensors – sensors that measure both daylight and the controlled electric light shall be located within the area served by the controlled lighting.
- Open loop sensors – sensors that mostly measure the daylight source shall be outdoors or near a skylight or window and typically oriented toward the window or skylight.

Control Adjustment Location: Adjustments to the controls must be "readily accessible" to authorized personnel or are in ceilings that are 11 ft. or less.

- Readily accessible means that one can walk up to the control adjustment interface and access it without climbing ladders, moving boxes etc. The control can be in a locked cabinet to prevent unauthorized access. Controls that can be adjusted via a wireless handheld device would also qualify as being readily accessible.
- Controls that are mounted in ceiling cavities must be within 2 ft. of the ceiling access and the ceiling access must be no more than 11 ft. above the floor.

Step 4: Control System Documentation

Verify that the setpoints, settings and programming on each of the control system device has been documented and provided by the installer.

Step 5: Daylit Zone Circuiting

Verify that the luminaires in the Daylit Zone are controlled separately from those outside the Daylit Zone. Further, verify that the luminaires in daylit areas near windows are circuited separately from the luminaires in daylit areas under skylights. Verify the correct Daylit Zone category for luminaires following the spacing requirements stated in the above sections. The Skylit Daylit Zone takes top priority in situations where Daylit Zones overlap, then Primary Sidelit, and finally, Secondary Sidelit. Finally, nte that separate circuiting is not a requirement and not necessary with digital systems.

Step 6: Daylighting Control Device Certification

Verify that installed daylighting controls have been certified to the Energy Commission in accordance with the applicable provisions of §110.9:

- Automatic Daylighting Control Devices
- Interior Photosensors

Verify that model numbers of all daylighting controls are listed on the Energy Commission database as "Certified Appliances & Control Devices" by visiting:

http://www.energy.ca.gov/appliances/database/

C. Functional Testing

There are two separate functional performance tests that are specific to the type of control being tested. The first test is suitable for continuous dimming systems and the second test is for step dimming or step switching controls (both described in detail below).

- Continuous dimming controls are controls that alter the output of lamps in at least 10 steps.
- Step dimming controls alter the output of lamps in less than 10 steps (typically up to four steps between on and off).
- Step switching controls turns lamps or groups of lamps on and off without any steps between on and off.
- Stepped switching controls are able to provide multi-level lighting by having more than one group of lamps being controlled. Partial light output (and partial power consumption) of the stepped switching lighting system is provided by turning some of the lamps on.

The tests for stepped switching and stepped dimming controls are combined as the discrete steps of light output render them sufficiently similar for functional testing.

Note: Many of the steps in these acceptance tests can be conducted while setting up the controls according to manufacturer's instructions. Read these tests prior to conducting equipment set-up and bring the documents along while conducting set-up. This way you can conduct the equipment set-up and perform the acceptance test at the same time.

1. Sampled functional performance testing of systems smaller than 5,000 ft²

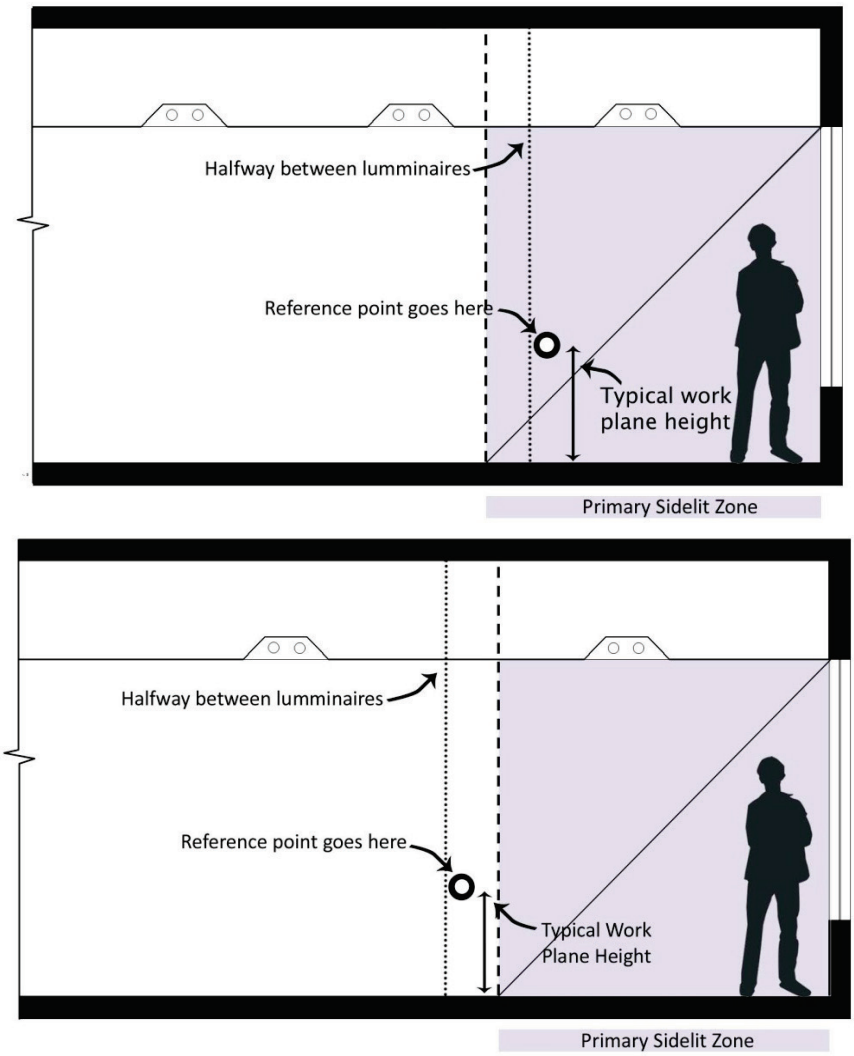
All photocontrols serving a Daylit Zone more than 5,000 ft² shall undergo functional testing. Photocontrols that are serving Daylit Zones less than 5,000 ft² are allowed to be tested on a sampled basis. The sampling rules are as follows:

- 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 within spaces with similar sensor types, cardinal orientations of glazing, and Daylit Zone categories (Skylit, Primary Sidelit, and Secondary Sidelit).
- If the first photocontrol in the sample group passes the functional test, the remaining building spaces in the sample group also pass, with the provision that the basic function of the rest are observed to appear to be functional.
- If any photocontrol in the sample group fails, it shall be repaired or replaced as required until it passes the test and all photocontrols in the sample group must be tested.
- This process shall repeat until all photocontrols have passed the test or the photocontrol tested passes on the first testing.

2. Zone Illuminated by Controlled Luminaires

The functional performance requirements for both continuous dimming and step (dimming or switching) controls call for "all areas being served by controlled lighting" being between 100 and 150 percent of the night time electric lighting illuminance. Without checking all points in the zone served by controlled lighting, verifying that the requirements are met at a worst case location somewhat removed from windows or skylights is sufficient. This location is called the "Reference Location" and is described in the functional performance tests in the next section.

Figure 13-11: Zone Illuminated by Controlled Luminaires and Reference Location for Measuring Reference Illuminance



Also note that the "zone illuminated by the controlled lighting" is not the same as the Primary Sidelit, Secondary Sidelit or Skylit Daylit Zones. The Sidelit and Skylit Daylit Zones define which luminaires must be controlled. Luminaires in the Sidelit or Skylit Daylit Zones must be controlled by automatic daylighting controls, and luminaires outside of these areas must not be controlled by the same automatic daylighting control.

The edge of the zone illuminated by the controlled lighting is halfway between the controlled lighting and the uncontrolled lighting. The only situation this is not so, is when the edge of the daylit zone is defined by a partition. The zone illuminated by the

controlled luminaires can be smaller than the daylit area when the uncontrolled luminaires are near the edge of the daylit area [see example (a) of Figure 13-11]. Alternatively the zone illuminated by the controlled luminaires can be larger than the daylit area when the controlled luminaires are near the edge of the daylit area [see example (b) of Figure 13-11].

Continuous Dimming Control Systems – Functional Performance Test

1. Purpose of the Test:

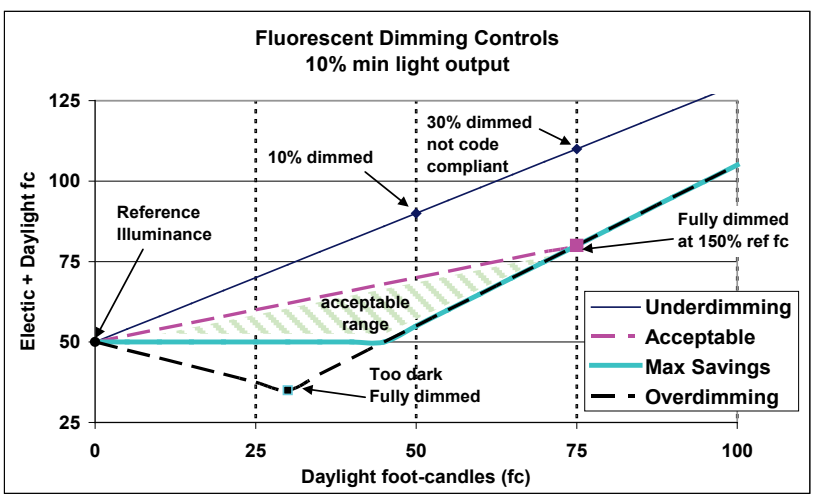
This test is for continuous dimming systems with more than 10 steps of light output from the controlled lighting. For instructions on acceptance testing of other systems with less than 10 steps of control, skip this section and proceed to the next section Stepped Switching or Stepped Dimming Control Systems Functional Performance Test.

2. Criteria for Passing the Test

Key criteria for passing the functional performance test are:

- When there is NO daylight in the space, all controlled luminaires are within a reasonable distance from design output or full rated output and power consumption.
- Where there is full daylight in the space (daylight alone provides adequate illumination in space), luminaires in the daylit zone use less than 35 percent of full rated power. Accommodation is made for a task tuned lighting system in this process.
- When there is partial daylight (between 60 and 95 percent of the design illuminance) in the space, the luminaires in the daylit zone are dimmed so that the illuminance at the reference location is between the design illuminance and 150 percent of the design illuminance.
- The shaded triangle labeled “acceptable range” in Figure 13-12, illustrates the range of total illumination levels that will comply with this requirement.

Figure 13-12: Performance of dimming controls - total light (daylight + electric light) versus daylight



3. How to Conduct the Test and Fill the Document

Step 1: Identify Reference Location

The Reference Location is the location in zone served by the controlled lighting that is receiving the least amount of daylight.

The Reference Location will be used for light level (illuminance in foot-candles) measurements in subsequent tests. The Reference Location is used in testing the daylighting controls so that it can be assured that all occupants in the zone served by the controlled lighting always have sufficient light.

The Reference Location can be identified using either the illuminance method or the distance method. The illuminance method is preferred.

Illuminance Method:

- Turn OFF controlled lighting and measure daylight illuminances within zone illuminated by controlled luminaires. Note that the zone illuminated by the controlled luminaires is not necessarily the same as the daylit area. See the Section above with the heading "*Zone Illuminated by Controlled Luminaires*."
- Identify the Reference Location; this is the location with lowest daylight illuminance in the zone illuminated by controlled luminaires. Note that zone illuminated by controlled luminaires is not necessarily the same as the Daylit Zone. See the note above with the heading "Zone Illuminated by Controlled Luminaires"
- Turn controlled lights back ON.

Distance Method:

- Identify the Reference Location; this is the location within the zone illuminated by controlled luminaires that is furthest way from daylight sources. Note that zone illuminated by controlled luminaires is not necessarily the same as the Daylit Zone. See the note above with the heading "Zone Illuminated by Controlled Luminaires". Note that this method is not likely to produce the most consistent result and should be avoided in preference to the illuminance method above.

Step 2: "No Daylight" Test

The purpose of the "no daylight" test is to provide a baseline light level, the Reference Illuminance, against which the test professional will be comparing the performance of the system during daylit conditions. This test is also verifying that the control is providing adequate light at night.

When conducting this test, the other lights in the space should be turned off. Simulate or provide conditions without daylight. This condition can be provided by any of the applicable methods:

- Conducting this part of the test at night, or
- Leave a logging light meter at the Reference Location(s) overnight. The logger should be collecting data on an interval no longer than 1 minute per reading, taking reading on even shorter intervals is recommended. You must disable any occupant sensor or time clock to use this approach.
- Closing blinds or covering fenestration so that very little daylight enters the **test** zone. Very little daylight is less than 1 fc for warehouses and less than 5 fc for all other occupancies. For open loop systems only, one may cover the photosensor to simulate no daylight conditions. Covering the sensor is not allowed for closed loop controls **to** assure that the control will work correctly at night as well during the day.

- When **daylight from the space** is not possible to exclude during this test, the Reference Illuminance can be calculated by subtracting the daylight illuminance from the combined illuminance (footcandles) of the electric lighting and daylight. The daylight illuminance is measured by turning off the controlled lights.

Reference Illuminance (Preferred Method):

Document the Reference Illuminance (fc) – the horizontal electric lighting illuminance (footcandles) at the Reference Location identified in Step 1.

- This measurement is taken by an illuminance sensor (light meter) 30 inches above floor level. The sensor should be facing upwards. Mounting the light meter on a tripod is recommended so that consistent measurements are taken. Try not to shade the meter with your body while taking measurements.

Power Measurement (Optional):

If a current or power measurement is going to be used in Step 3 to show power reduction under fully dimmed conditions, collect full load current or power. To best do this, ensure that the lighting system does not have any task tuning or lumen maintenance adjustments in the control system.

- This is not normally necessary for systems with dimming fluorescent ballasts. It is easier just to compare electric lighting illuminance. For more details see Step 3 "Full Daylight Test."

Full load rating or measurement:

The full load rating can be obtained a number of ways:

- One may also choose to manipulate the calibration adjustments (remember to write down the setting first before changing them) to obtain full light output from the controlled lighting. This might require turning the setpoint very low and turning the high limit very high. It may also require that the control system does not have active task tuning or lumen maintenance adjustments incorporated into the control system. Discuss your approach with the control manufacturer with their recommendations to get full light output. If the photosensor is accessible, covering the photosensor is a way to assure full light output.
- If you cannot eliminate all daylight from the area or other electric light from other luminaires: Turn the controlled lighting on and off. The difference in light level will be the contribution of the controlled lighting.
- If one is measuring power or amps, the rated amps can be directly measured under this condition. Verify that only the controlled lights in the daylit area are being measured. You may want to disconnect and re-energize this circuit to assure you are measuring what you intend.
- The rated amps or power from the manufacturer's cut-sheet is also sufficient.

Step 3: Full daylight test.

Simulate or provide bright conditions so that the illuminance (fc) from daylight only at the Reference Location identified in Step 1 is greater than 150 percent of the Reference Illuminance (fc) measured at this location during the 'no daylight' test documented in Step 2.

- Simulating a bright condition can be accomplished by opening all shading devices to allow natural daylight into the space.
- If natural conditions are not adequate at the time of the test, shine a bright flashlight or other light source onto the photosensor.
- Temporarily change the setpoint to a very low value for the duration of this test. Then return the setpoint to its normal setting.

Verify and document

- Lighting power reduction is at least 65 percent under fully dimmed conditions. Lighting power reduction can be determined as follows:
- Dimming fluorescent lighting is deemed to reduce power by 65 percent when the controlled electric light output is reduced by 75 percent or greater from rated output. With a task tuned lighting system, the dimming fluorescent lighting is deemed to reduce power by 65 percent when the controlled electric light output is reduced by 69 percent or greater.
- Dimming metal halide is deemed to have reduced power by 44 percent when light output is reduced by 75 percent.
- One method of attaining the 65 percent power reduction with dimming metal halide systems is to turn off half of the luminaires and dim the other half.
- The power reduction in higher performing dimming ballasts can be estimated from lighting output reductions if it is accompanied with a manufacturer's ballast cut sheets containing a ballast input power vs. percent light output curve or table.
- Power reduction can be directly measured using either a power meter or an ammeter. The percent reduction in current will be a sufficient representation of the percent reduction in power. Dimming fluorescent lighting is deemed to reduce power by 65 percent when the controlled electric load is reduced by 65 percent or greater from full connected load. With a task tuned lighting system, the dimming fluorescent lighting is deemed to reduce power by 65 percent when the controlled electric load is reduced by 56 percent or greater.

The system lighting power reduction is given by the following relations:

Reduction = Fraction of lights turned off + Fraction of lights dimmed x power reduction of the dimmed lamps

Where,

The power reduction of dimmed lamps =

(Rated power – dimmed power) / rated power

Example: When a metal halide dimming system dims half of the lamps and the other half of the lamps are automatically switched off. The System Power Reduction, SPR is:

SPR = 0.5 + (0.5 x 0.44) = 0.72 or 72 percent

This is above the 65 percent threshold.

- Verify that only luminaires in appropriate Daylit Zone are affected by daylight control.

- Primary Sidelit Daylit Zones have to be separately controlled from Secondary Sidelit Daylit Zones, and vice versa. They may use a single sensor for implementation, but the control response formulas must be distinct.
- Sidelit Daylit Zones have to be separately controlled from Skylit Daylit Zones.

The daylighting control assigned to a specific Daylit Zone shall not control fixtures beyond the Zone, with the exception of Primary and Secondary Sidelit Daylit Zones in which both share a boundary.

- Verify that light output is stable with no discernible flicker.

  The intent of this requirement is to ensure the lights do not flicker because occupants may override the system if light flicker is an annoyance. Flicker refers to a rapid fluctuation in light output that can be detected by the human eye.

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. These partial daylight illuminance conditions can be achieved by:

- Scheduling the test so that daylight conditions are within this fairly broad range of illuminances.

Verify and document

- Measured combined illuminance of daylight and controlled electric lighting (fc) at the Reference Location
- Verify this measured illuminance is no less than the Reference Illuminance documented in Step 2, and
- Verify this measured illuminance is no greater than 150 percent of the Reference Illuminance (fc) documented in Step 2

This test assures that the control does not over-dim and leave people with insufficient light in the Reference Location of the Zone served by the controlled lights. This also makes sure that the control does not under-dim thus misses energy savings opportunities. By setting the upper bound of illuminance to 150 percent of the Reference Illuminance, this leaves plenty of room for non-optimal configurations, adaptation compensation, and variations in the sensor field of view.

Note: Adaptation compensation is a control strategy that accounts for people needing less light at night. When someone walks into a store late at night from a parking lot with light levels at 1 fc they may not need or want light at 50 fc. Thus a store may decide to have higher light levels during the day than at night. This protocol would allow daytime light levels that are 50 percent higher than the night time light levels.

Stepped Switching or Stepped Dimming Control Systems Functional Performance Test

1. *Purpose of the Test:*

This functional performance test is for systems that have no more than 10 discrete steps of control of light output. For instructions on how to test systems with more than 10 steps of control including those systems where the dimming appears to be continuous proceed to the previous section: Continuous Dimming Control Systems - Functional Performance Test.

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

If these tests are to be conducted manually (spot measurements) it is recommended to test the system with the time delay minimized or otherwise overridden so the test can be conducted more quickly.

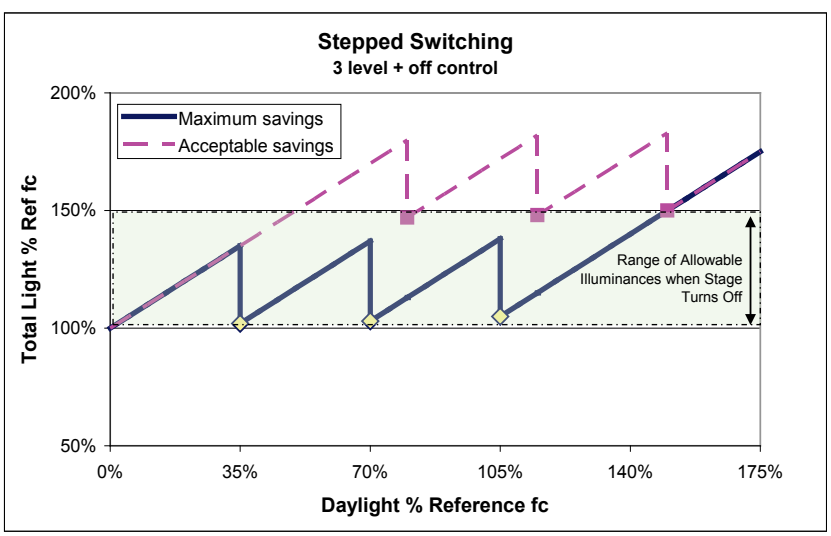
These tests can also be conducted with a logging (recording) light meter. In this case, the time delay should be left on so the recorded data also shows the results of the time delay. In the logging method, one would print out a plot of the day's illuminance at the Reference Location and annotate the plot showing where each stage of lighting had shut off and how the light level just after shutting off for each stage is between the Reference Illuminance and 150 percent of the Reference Illuminance.

2. Criteria for Passing the Test:

Key criteria for passing the functional performance test are:

- When there is NO daylight in the space, all controlled luminaires are at rated lighting output and power consumption.
- When there is full daylight in the space (daylight alone provides greater than 150 percent of the Reference Location illumination in space), luminaires in the daylit zone use less than 35 percent of rated power.
- When there is some daylight in the space, the luminaires in the daylit zone are switched or dimmed appropriately.
- If the control has three steps of control or less all steps of control are tested. If the control has more than three steps of control, testing three steps of control is sufficient for showing compliance.
- There is a time delay of at least 3 minutes between when daylight changes from little daylight to full daylight and the luminaire power consumption reduces through dimming.

Figure 13-13: Performance of compliant switching controls - total light (daylight + electric light) versus daylight



As shown in Figure 13-13, the acceptance tests will confirm that the total illuminance at the reference location is between 100 and 150 percent of the reference illuminance. The highlighted points on the plots (squares and diamonds) indicate the daylight and total light levels at the reference location just after the lights on each stage of control have turned off or dimmed.

The plot of the “Maximum savings” control illustrates how this control maximizes the possible lighting energy savings without under-lighting the space. Systems with lower control setpoints than the “Maximum savings” control would not be compliant as the control would under-light the space during certain times of the day and would likely lead to the control being disabled.

The plot of the “Acceptable savings” control shows how this control maintains light levels above the reference illuminance for all daylight hours but still saves enough energy to be minimally compliant. Systems with higher setpoints than those of the “Acceptable savings” control would not be compliant.

3. How to Conduct the Test and Fill the Document

Step 1: Identify Reference Location

The Reference Location is the location in Zone served by the controlled lighting that is receiving the least amount of daylight. The Reference Location will be used for light level (illuminance in foot-candles) measurements in subsequent tests. The Reference Location is used in testing the daylighting controls so that it can be assured that all occupants in the Zone served by the controlled lighting always have sufficient light.

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 lighting controls are NOT staged based on distance 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 zone illuminated by controlled luminaires
- Identify the Reference Location; this is the location with lowest daylight illuminance in the zone illuminated by controlled luminaires.
- Turn controlled lights back ON.

Distance Method:

- Identify the Reference Location; this is the location within the zone illuminated by controlled luminaires that is furthest way from daylight sources. Note that zone illuminated by controlled luminaires is not necessarily the same as the Daylit Zone. See the note above with the heading “Zone Illuminated by Controlled Luminaires”. Note that this method is not likely to produce the most consistent result and should be avoided in preference to the illuminance method above.

Step 2: 'No Daylight' Test

Simulate or provide conditions without daylight for a stepped switching or stepped dimming control system. This condition can be provided by any of the applicable methods:

- Conducting this part of the test at night.
- Leave a logging light meter at the Reference Location(s) overnight, (the logger should be collecting data on an interval no longer than 1 minute per reading, taking reading on even shorter intervals is recommended). The occupant sensor or time clock system must be overridden for this approach to work.
- Closing blinds or covering fenestration so that very little daylight enters the zone you are testing, (very little daylight is defined as less than 1 fc for warehouses and less than 5 fc for all other occupancies).
- Cover the photosensor.

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.

When conducting this test, the other lights in the space should be turned off.

Verify and document

- Automatic daylight control system turns ON all stages of controlled lights.
- Document the Reference Illuminance (fc) – the horizontal electric lighting illuminance (footcandles) at the Reference Location identified in Step 1.
- This measurement is taken by an illuminance sensor (light meter) 30 inches above floor level. The sensor should be facing upwards. Mounting the light meter on a tripod is recommended so that consistent measurements are taken. Try not to shade the meter with your body while taking measurements.
- When it is not possible to exclude daylight from the space during this test, the Reference Illuminance can be calculated by subtracting the daylight illuminance from the combined illuminance (footcandles) of the electric lighting and daylight. The daylight illuminance is measured by turning off all nearby lights including the controlled lights.
- For step dimming controls, calculate power consumption using manufacturer-provided cut-sheet information or measure the power consumption.
- (Optional) If a current or power measurement is going to be used in Step 3 to show power reduction under full daylight conditions, collect full load current or power. *Note:* no power measurements are needed for step switching systems.

Step 3: Full Daylight Test

Simulate or provide bright conditions so that the illuminance (fc) from daylight only at all of the Reference Location(s) identified in Step 1 is greater than 150 percent of the corresponding Reference Illuminance(s) documented in Step 2.

- Simulating a bright condition can be accomplished by opening all shading devices to allow natural daylight into the space.

- If natural conditions are not adequate at the time of the test, shine a bright flashlight or other light source onto the photosensor.
- Temporarily change the setpoint to a very low value for the duration of this test then return the setpoint to its normal settings.

Verify and document

- Lighting power reduction of controlled luminaires is at least 65 percent of rated power consumption. Methods of doing this include:
- For switching systems, at least 2/3s of the lamps are turned off.

  Note: for switching systems, power measurement is unnecessary. The fraction of power reduction is easily estimated without taking power measurements. The fraction of power reduction is calculated by counting the number of lamps that are switched off versus the total number of lamps providing general lighting in the Daylit Zone.
- For stepped dimming systems, either calculate the fraction of rated power at the dimming stage from the ballast manufacturer's cut sheet or calculate from power measurements taken during the No daylight and full daylight tests.
- If using the manufacturer's cut-sheet, wattage at full output and dimmed amounts are given. A copy of this cut-sheet must be attached to the acceptance testing form. Count the number of dimmed fixtures and those fully turned off to calculate reduced power operation. If calculated power is 35 percent or less of the power calculated in Step 2, this meets the criteria.
- If using measured power or current draw of the controlled fixtures. If measured power or current draw is 35 percent or less the value from Step 2, the criteria is met.
- Only luminaires in Daylit Zones (Skylit Daylit Zone, Primary Sidelit Daylit Zone and Secondary Sidelit Daylit Zone) are affected by daylight control.
- Automatic daylight control system reduces the amount of light delivered to the space relatively uniformly as per §130.1(d).
- All lights are dimmed.
- Alternating lamps, alternative fixtures or alternating rows of fixtures are turned off.

Step 4: Partial daylight test

For each stage of control 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. This step is repeated for up to three stages of control between full on and full dimmed or full off condition.

One of the stages selected for testing should reduce power draw between 30 and 50 percent of system rated power (for switching systems a stage that turns off between a third and a half of the lamps). That test will help confirm that the system can reduce power between 30 and 50 percent.

Simulate or provide moderately bright conditions so that each control stage turns on and off or dims. Methods to do this include:

- **Adjusting blinds or shades.** Note that the time delay needs to be disabled to use this method. Slowly increase the daylight illuminance until a stage of lighting turns off. Make note of the total combined and electric lighting illuminance at the Reference Location just after the stage of lights turned off. Continue increasing daylight illuminance by opening blinds or shades for at least two more stages of control
- **Light logging.** Leave a logging light meter at the Reference Location(s) for one day with a bright afternoon. Note that the occupant sensor system must be disabled to use this method. The logger should be collecting data on an interval no longer than 1 minute per reading, taking reading on even shorter intervals is recommended.
- **Open loop ratio method.** If the system is open loop (the light sensor senses mainly daylight) the amount of daylight in the space is presumed proportional to the amount measured at the open loop sensor. Adjust setpoint until control turns lights off or are dimmed. Make note of daylight illuminance at the reference location and control setpoint or sensor illuminance display.

If the sensor measures 300 fc while there is 30 fc of daylight at the Reference Location, the ratio of Sensed fc to fc at Reference Location is 10 to 1. If the needed daylight illuminance is 50 fc a setpoint of 500 sensed fc is deemed to provide control at 50 fc.

Verify and document the following for each tested control stage:

The tests do not need to be performed for more than three stages of control.

- The total daylight and electric lighting illuminance level measured at its Reference Location just after the stage of control dims or shuts off the stage of lighting.
- The total measured illumination shall be no less than the Reference Illuminance measured at this location during the No Daylight test documented in Step 2.
- The total measured illumination shall be no greater than 150 percent of the Reference Illuminance.
- The control stage shall not cycle on and off or cycle between different levels while daylight illuminance remains constant.

  Cycling is prevented by having a dead band that is sufficiently large. The dead band is the difference between the setpoint for turning the control stage ON and the setpoint for turning that control stage OFF. The dead band must be greater than the sensor measurement of the light level steps to prevent cycling of lamps on and off.

For manual testing, control time delay is overridden so it is quickly apparent if the dead band is set appropriately.

- If the dead band is too small, the system will cycle. This will be an annoyance and may lead to the system being disabled by irritated occupants.
- If the dead band is set too large, the system will not save as much energy as it could.
- To manually set a dead band, adjust the daylight level or the setpoint so that the setpoint matches the daylight illuminance. Reduce the dead band until the system cycles and then increase the dead band until the system stops cycling.

Step 5: Verify time delay

- Verify that time delay automatically resets to normal mode within 60 minutes of being over ridden.
- Set normal mode time delay to at least 3 minutes.
- 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.

Note: One can force a change of state and by dropping the setpoint substantially and timing how long it takes for the control stage to switch off or dim.

13.25 NA 7.6.3 Demand Responsive Controls Acceptance

At-A-Glance

Demand Responsive Controls Acceptance
Use Document NRCA-LTI-04-A
Purpose of the Test
The purpose of the test is to ensure that the demand responsive control is capable of reducing the power consumption of the lighting system to no more than 85 percent of full power (or, if the lighting system is “tuned” to a lower output, 85 percent of the tuned output). The test also confirms that the lighting system produced a reasonably uniform level of light during a demand response event.
With a fully functional demand responsive lighting system, the building owner or operator can save money by reducing their lighting power consumption during periods of high power cost and/or periods of grid instability. As well as saving money, this also improves the reliability of the power grid for all consumers.
Instrumentation
This test requires EITHER an illuminance meter or a power meter (with a current transformer and voltmeter). Alternatively, if the lighting system has an inbuilt method of measuring (not estimating) the lighting power being consumed, this inbuilt measurement may be used instead.
Test Conditions
All luminaires are wired and powered. Put the lighting system into a state that is representative of typical daytime use. Identify the input(s) to the lighting system that are intended to function as demand responsive controls. These will be listed in column H of the lighting control schedule on the Lighting Certificate of Compliance, NRCC-LTI-02-E. If possible, take measurements in non-daylit areas, to make the calculations loss prone to error.
Estimated Time to Complete
Construction Inspection: 0.25 to 0.5 hours **Equipment Test**: 0.5 to 1 hours (depending on the number of controlled luminaires)

Acceptance Criteria
The demand response system(s) are able to receive and respond to a suitable demand response signal from a utility or other provider, or from another building system. Note that the functional test does not actually require a demand response signal to be given; it only requires the tester to verify that the system is capable of receiving and responding. The demand response system is capable of reducing the power consumed by the lighting system to no more than 85 percent of full output, while preserving adequate uniformity in task areas.
Potential Issues and Cautions
If using Method 1 (Illuminance Measurement), find a way to mark the exact locations in which the illuminance measurements were made, because even slightly differences in the location of the illuminance meter, or the angle at which it is held, can significantly affect the readings. If possible, take readings away from shadowed areas. If illuminance measurements or power measurements are taken in daylit areas with photocontrols, the values can change very significantly in just a few minutes, due to changes in daylight availability. Try to take measurements as far from sources of daylight as possible.

A. Test Application

Newly Constructed Buildings: Applies to demand responsive lighting controls.

Preparing for Sampling:

- For buildings with up to seven (7) enclosed spaces requiring demand responsive lighting controls, all spaces shall be tested.
- For buildings with more than seven (7) enclosed spaces requiring demand responsive lighting controls, sampling may be done on additional spaces with similar lighting systems.
    - Sampling shall include a minimum of 1 enclosed space for each group of up to 7 additional enclosed spaces.
    - If the first enclosed space with a demand responsive lighting control in the sample group passes the acceptance test, the remaining building spaces in the sample group also pass.
    - If the first enclosed space with a demand responsive lighting control in the sample group fails the acceptance test the rest of the enclosed spaces in that group must be tested.
- If any tested demand responsive lighting control system fails it shall be repaired, replaced or adjusted until it passes the test.

B. Construction Inspection

Verify the following:

- The demand responsive control is capable of receiving a demand response signal directly or indirectly through another device and that it complies with the requirements in §130.5(e).

  §130.5(e): *Demand responsive controls and equipment shall be capable of receiving and automatically responding to at least one standards based messaging*

protocol, which enables demand response after receiving a demand response signal.

Definition from §101: *DEMAND RESPONSE SIGNAL is a signal sent by the local utility, Independent System Operator (ISO), or designated curtailment service provider or aggregator, to a customer, indicating a price or a request to modify electricity consumption, for a limited time period.*

This requirement has three main elements:

1. "Capable of receiving". The demand response control must have an electronic input that can carry a messaging protocol, as described below. This does not need to be a dedicated input; it can carry other signals in addition to the demand response signal. In practice, this could be an EMCS connection.
2. "Automatically responding to". The control must be capable of responding to the demand response signal automatically, without human assistance or intervention.
3. "Standards based messaging protocol". The term 'protocol' refers to a format for conveying messages, so the input to the demand responsive control must be able to convey different messages. It must be more than just a contact closure or similar binary input.

- If the demand response signal is received from another device (such as an EMCS), that system must itself be capable of receiving a demand response signal from a utility meter or other external source.

  This means that the EMCS or other system must meet the same requirements given above for a demand responsive control. It must be capable of receiving a standards-based protocol, and the lighting system must respond automatically.

C. Functional Testing

The functional test ensures that the demand responsive control can set the lighting to a lower-power condition, in line with the requirements set out in Energy Standards, Reference Appendix NA7.

1. Criteria for Passing the Test

The demand responsive system must:

- Reduce the lighting power to no more than 85 percent of "full output". Full output is defined in the field test as being the output of the lighting system when all manual switches are on, but some luminaires may be dimmed or switched below their maximum output because they are "tuned" or because they are controlled by automatic systems such as photocontrols and vacancy sensors.
- Ensure that the visual conditions for occupants under the demand response condition are still comfortable, and allow them to work uninterrupted during the event. When the demand responsive control is activated, the output of the lighting system must still be at least half of its output in the "full output" condition.
- Ensure that light levels do not go below any preset minimums that have been determined, for instance, by facilities managers. This is the purpose of the "minimum output test".

Simulating a Demand Response Event

If the demand responsive control has a “test mode” that allows the demand response condition to be simulated, this is adequate for the Acceptance Test; the tester does *not* have to confirm that the demand responsive control responds to a real signal.

However, if the control does not have a test mode, then the input signal must be simulated. In some cases this may be simple, for instance if the control responds to a contact closure. However, if the control can only be tested by providing it with a specific demand response signal, then that signal must be generated during the Acceptance Test.

Taking Illuminance Measurements

Using the illuminance measurement method (Method 1) requires the tester to take two illuminance measurements at the same location several minutes apart. This process can incur a high degree of error, which can be minimized by observing these precautions:

- Find easily-repeatable locations. Leave a marker such as a sticky note to record the exact location of the illuminance meter, or put the meter in a clearly defined location such as a join between cubicle partitions.
- Avoid shadows. Shadows can move in between measurements if they’re caused by daylight, and if the edge of the shadow falls across the illuminance meter’s sensor, the reading will be very unreliable.
- Avoid daylit areas. Daylight can vary in brightness significantly in the course of just a few seconds, so place the illuminance meter as far as possible from windows, ideally not in direct line of sight.
- Hold the meter at arm’s length, or squat below the level of the sensor. Many illuminance meters require a button to be held in while taking measurements, and your body and head will shade the sensor. Minimize the error caused by this effect by holding the meter at arm’s length or by squatting down to remove your head and body from the path of the incoming light.

Area-Weighting Calculations

The area-weighting calculations required by the functional test are simple, though the equation on the documents is complicated. An example is given below in Table 13-7.

The following measurements were taken in a building, for the full output test. For convenience, all the daylight measurements are zero.

Table 13-7: Example of an Area-Weighting Calculation

Lines a and c have been omitted for clarity		Space number		
		1	2	3
b.	Take one illuminance measurement at a representative location in each space, using an illuminance meter.	30 fc	35 fc	40 fc
d.	Take one illuminance measurement at the same locations as above, with the electric lighting system in the demand response condition.	15 fc	20 fc	40 fc
e.	Turn off the electric lighting and measure the daylighting at the same location (if present)	0 fc	0 fc	0 fc
f.	Calculate the reduction in illuminance in the demand response condition, compared with the design full output condition. [((line b - line e)- (line d – line e)) /(line b - line e)]	50 percent	43 percent	0 percent
g.	Note the area of each controlled space	2000 sf	800 sf	1300 sf
h.	The area-weighted reduction must be at least 0.15 (15 percent) but must not reduce the combined illuminance from electric light and daylight to less than 50 percent of the design illuminance in any individual space.	{(50 percentx2000) + (43 percentx800) + (0 percentx1300)} = 2000 + 800 + 1300 = 32.8 percent……so the space complies.		

13.26 NA 7.7.6.2 Lighting Controls Installed to Earn a Power Adjustment Factor (PAF) for Institutional Tuning

At-A-Glance

Lighting Controls Installed to Earn a Power Adjustment Factor (PAF) for Institutional Tuning
Use Document NRCA-LTI-05-A
Purpose of the Test
Institutional Tuning is the process of adjusting the maximum light output of lighting systems to support visual needs or save energy. Institutional tuning differs from personal tuning in that the control strategy is implemented at the institutional rather than the individual user level, and maximum light level adjustments are available only to authorized personnel. Completion of this acceptance test certifies that lighting systems receiving the Institutional Tuning Power Adjustment Factor, comply with §140.6(a)2J and Reference Nonresidential Appendix NA7.7.6.2.

Instrumentation
Recommended Instrumentation: • Light meter (luminance or foot-candle meter) • Hand-held amperage meter or power meter • Logging light meter or power meter
Test Conditions
All luminaires are wired and powered. Put the lighting system into a fully operational state.
Estimated Time to Complete
Construction Inspection: 0.25 to 0.5 hours **Equipment Test**: 0.5 to 1 hours (depending on the number of controlled luminaires)
Acceptance Criteria
To qualify for the PAF an Institutional Tuning in Table 140.6-A of the Energy Standards, the tuned lighting system shall comply with all of the following requirements: • The lighting controls shall limit the maximum output or maximum power draw of the controlled lighting to 85 percent or less of full light output or full power draw; and • The means of setting the limit is accessible only to authorized personnel; and • The setting of the limit is verified by the acceptance test required by §130.4(a)7; and • The construction documents specify which lighting systems shall have their maximum light output or maximum power draw set to no greater than 85 percent of full light output or full power draw.
Potential Issues and Cautions
Luminaries that qualify for other PAFs may also qualify for the Institutional Tuning PAF. However, PAFs may only be added together if permitted in Table 140.6-A of the Energy Standards.

A. Test Application

Newly Constructed Buildings only. Luminaries that qualify for other PAFs may also qualify for the Institutional Tuning PAF. However, PAFs may only be added together if permitted in Table 140.6-A.

Prepare for Sampling:

- For buildings with up to seven (7) enclosed areas, to claim the Institutional Tuning PAF, all areas must be tested.
- For buildings with more than seven (7) areas, to claim the Institutional Tuning PAF, random sampling may be done on (7) seven of the larger enclosed areas with tuned dimming systems.

- If any of the areas in the sample group of (7) seven areas fails the acceptance test, another group of (7) seven areas must be tested.
- If any tested system fails, it shall be tuned until it passes the test.

B. Construction Inspection

Prior to Functional Testing, verify and document the following:

- The controls or the methods of controlling the maximum output of luminaires is such that the maximum light output of the controlled lighting system can be limited and that normal operation of the controlled lighting does not override the maximum light output.
- The controls are not readily accessible to unauthorized personnel.

C. Functional Testing

For each area to be tested, do the following:

- The acceptance test technician shall either observe the first seven (7) systems being successfully tuned or shall verify systems that have already been tuned using the sampling protocol described in NA7.7.6.2.
- If the acceptance test technician is observing the tuning of the system, the party responsible for the tuning shall certify that the remainder of the system is tuned in a similar manner.

Observation of the systems during Institutional Tuning

Step 1: Determination of maximum power or output prior to Institutional Tuning

- Set all lighting controls to provide maximum output of the tested system without applying the limits specified for institutional tuning.
- Measure the full light output at a location where the luminance is due to the controlled lighting, or measure the power draw of the controlled lighting.

Step 2: Institutional Tuning and Post-tuning Measurement

- Apply the limits specified for institutional tuning to the lighting system. Do not alter any other control settings.
- Verify the light or power reduction after institutional tuning by measuring the light output at the same location as in Step 1 or measure the power draw of the same circuit as in Step 1.
- If the light output or power draw measured in Step 2(b) is 85 percent or less of the light output or power draw measured in Step 1(b), the system passes this test; otherwise the system fails this test.

Verification of systems already tuned

Step 1: Measurement of tuned lighting system

- Set all lighting controls except Institutional Tuning controls to provide maximum output of tested system. Controls set to maximum light output include but not limited to: manual dimmers, multilevel occupancy sensing, and automatic daylighting controls.

- Measure full light output at location where most of the luminance is due to the controlled lighting or measure power draw of the controlled lighting.

Step 2: Measurement of lighting system with Institutional Tuning overridden

- Reset Institutional Tuning controls to allow full light output. Set all lighting controls to provide maximum output of tested system including but not limited to: Institution Tuning control, manual dimmers, multilevel occupancy sensing, and automatic daylighting controls.
- Measure full light output at the same location as in Step 1 or measure the power draw of the same circuit as in Step 1.
- If the light output or power draw measured in Step 1(b) is 85 percent or less of the light output or power draw measured in Step 2(b), the system passes this test; otherwise the system fails this test.

Step 3: Restore Institutional Tuning settings

- If tested system passed the test in Step 2, restore Institutional Tuning to initial settings.

13.27 NA7.8 Outdoor Lighting Shut-off Controls

At-A-Glance

NA7.8 Outdoor Lighting Shut-off Controls
Use Document NRCA-LTO-02-A
Purpose of the Test
The purpose of these tests is to ensure that all outdoor lighting regulated by §130.2(c) are automatically turned off during daytime and are controlled by a motion sensor, photocontrol, astronomical time-switch control, part-night outdoor lighting control or automatic scheduling control, as required. Automated controls to turn off outdoor lighting during daytime hours, and when not needed during nighttime hours, prevent energy waste.
Instrumentation
This test verifies the functionality of installed automatic controls visually and does not require special instrumentation.
Test Conditions
All outdoor luminaires must be wired and powered. Lighting control system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer's recommendations.
Estimated Time to Complete
Construction Inspection: 0.5 to 2 hours (depending on familiarity with lighting control programming language) **Equipment Test**: 0.5 to 2 hours (depending on familiarity with lighting control programming language, number of lighting circuits to be tested)

Acceptance Criteria
Lights turn off when daylight is available. Automatic time switch controls turn off the lighting when not needed at night Motion sensors reduce lighting power by at least 40 percent but not exceeding 90 percent. The correct date and time are properly set in the lighting controllers. Astronomical time switch controls and automatic time switch controls have been certified to the Energy Commission in accordance with the applicable provision in §110.9. Verify that model numbers of all such controls are listed on the Energy Commission database as "Certified Appliances & Control Devices." http://www.energy.ca.gov/appliances/database/

A. Test Application

Newly Constructed and Additions/Alterations: Applies to functional testing and verification of motion sensor location and ensures the sensor coverage is not blocked by obstruction.

- Verifies the sensor signal sensitivity is adequate.
- Verifies the outdoor lighting shut-off control during daytime hours.
- Verifies the astronomical and standard shutoff controls are programmed for weekdays, weekends and holiday schedules.

NA7.8.1 – and NA 7.8.2 Motion Sensor

The motion sensor must be installed in conjunction with a photocontrol or astronomical time switch that automatically turns off the outdoor lighting when daylight is available.

Prepare for allowable sampling:

- For buildings with up to seven (7) outdoor motion sensors, all outdoor motion sensors shall be tested.
- For buildings with more than seven (7) outdoor motion sensors for outdoor lighting system, sampling may be done on outdoor areas with similar sensors that cover similar unobstructed areas.
    - Sampling shall include a minimum of 1 outdoor motion sensor for each group of up to 7 additional outdoor motion sensors.
    - If the first sensor in the sample group passes the acceptance test, the remaining outdoor areas in the sample group also pass.
    - If the first sensor in the sample group fails the acceptance test, the rest of the sensors in that group shall be tested.
- Any failed sensor in the sample group shall be repaired or replaced and retested until the sensor passes the test.

B. Construction Inspection

Prior to Functional testing, verify and document:

- 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 obstruction that could adversely affect performance.

- Desired sensor coverage is not blocked by obstructions that could adversely affect performance.

C. Functional Testing

Test conditions: Simulate or provide conditions so that outdoor photocontrol or astronomical time switch is in night time mode and is otherwise turning lights ON.

Simulate motion in area under lights controlled by the sensor.

Verify and document

- 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.

Simulate no motion in area with lighting controlled by the sensor.

Verify and document

- Lights controlled by motion sensors turn off within a maximum of 20 minutes from the start of an unoccupied condition per §110.9(b).
- The occupant sensor does not trigger a false “on” from movement outside of the controlled area.
- Signal sensitivity is adequate to achieve desired control.

NA 7.8.3 and NA 7.8.4 Photocontrol

B. Construction Inspection

Verify and document:

- The photocontrol is installed.

C. Functional Testing

Verify and document:

- During daytime simulation, all controlled outdoor lights are turned off.
- During nighttime simulation, all controlled outdoor lights are turned on.

NA7.8.5 and NA 7.8.6 Astronomical Time-Switch Control

B. Construction Inspection

Prior to Functional Testing, confirm and document:

- Verify the astronomical time-switch control is installed.
- Verify the astronomical time switch control is programmed with acceptable ON schedule and OFF schedule
- Demonstrate and document for the time switch programming including ON schedule and OFF schedule, for weekday, weekend, and holidays (if applicable).
- Verify the correct time and date is properly set in the control.

C. Functional Testing

Verify and document:

- During daytime simulation, all controlled outdoor lights are turned off.
- During nighttime simulation, all controlled outdoor lights are turned on in accordance with the astronomical schedule.
- During nighttime simulation, all controlled outdoor lights are turned off in accordance with the programmed schedule.

NA7.8.7 and NA 7.8.8 Part-night Outdoor Lighting Control

Note: The part-night outdoor lighting control must be installed in conjunction with a photocontrol or astronomical time switch that automatically turns off the outdoor lighting when daylight is available.

B. Construction Inspection

Prior to Functional Testing for time based control type, confirm and document:

- Verify the part-night outdoor lighting control is installed.
- Verify the control is programmed with acceptable schedules.
- Demonstrate and document for the lighting control programming including both ON schedule and OFF schedule, for weekday, weekend, and holidays (if applicable).
- Verify the correct time and date is properly set in the control.

Prior to Functional Testing for occupancy-based control type, verify and document:

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

C. Functional Testing

For time-based control type, verify and document:

- During daytime simulation, all controlled outdoor lights are turned off.
- During nighttime simulation, all controlled outdoor lights are turned on in accordance with the ON schedule.
- During nighttime simulation, all controlled outdoor lights are turned off or reduced in light level in accordance with the OFF schedule.

For occupancy-based control type, verify and document:

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

- Status indicator operates correctly.
- Lights controlled by 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 occupancy in area with lighting controlled by the sensor. Verify and document:

- Lights controlled by the sensor are off or reduces light output within a maximum of 20 minutes from the start of an unoccupied condition.
- The sensor does not trigger a false “on” from movement outside of the controlled area.
- Signal sensitivity is adequate to achieve desired control.

NA7.8.9 and NA 7.8.10 Automatic Scheduling Control

B. Construction Inspection

Prior to functional testing, confirm and document:

- Verify the automatic scheduling control is installed.
- Verify the control is programmed with acceptable schedules.
- Demonstrate and document for the lighting control programming including both ON schedule and OFF schedule, for weekday, weekend, and holidays (if applicable).
- Verify the correct time and date is properly set in the control.

C. Functional Testing

Verify and document:

- During daytime simulation, all controlled outdoor lights are turned off.
- During nighttime simulation, all controlled outdoor lights are turned on in accordance with the ON schedule.
- During nighttime simulation, all controlled outdoor lights are turned off in accordance with the OFF schedule.

13.28 NA7.13.1 Compressed Air Systems

At-A-Glance

NA7.13 Compressed Air System Acceptance
Use Document NRCA-PRC-01-A
Purpose of the Test
The purpose of functionally testing the controls of a compressed air system is to confirm that the controls are set up in a compliant manner. A compliant system will choose the most efficient combination of compressors, given the current air demand as measured by a sensor, according to §120.6(e)2 of the Energy Standards. This test is designed for flexibility, as this covers both newer compressed air systems designed for use with controls and older compressed air systems under direction of controls for the first time.

Instrumentation

Instrumentation to perform the test includes:
• Power meter(s) for each compressor
• Pressure transducer(s) for each compressor
• Sensor or set of sensors to measure or infer current air demand, including but not limited to:
  o Flow meter
  o Set of pressure transducers
  o Pressure transducers and power meters

Test Conditions
Equipment installation is complete (including compressors, storage, controls, and piping). Compressed air system must be ready for system operation, including completion of all start-up procedures per manufacturer's recommendations. For a new compressed air system, the trim compressor(s) must be identified prior to conducting the test. Document the initial conditions before overrides or manipulation of the settings, if any. All systems must be returned to normal at the end of the test. If using a valve to achieve a steady demand, ensure that this will not affect any equipment downstream.
Estimated Time to Complete
Construction Inspection: 1 to 1.5 hours (depending on complexity of the system) **Functional Testing**: 1 to 3 hours (depending on familiarity with the controls and issues that arise during testing)
Acceptance Criteria
The states of each compressor will be observed throughout the duration of the test. By the end of the 10-minute duration, each compressor must not exhibit short-cycling or blow-off. For new compressed air systems, the trim compressors are the only compressors that can be partially loaded. All base compressors must be either fully loaded or off by the end of the test.
Potential Issues and Cautions
For older systems, it may not be feasible to run at a steady demand for 10 minutes. In these cases, still observe the compressors to ensure that the controls are operating efficiently.

A. Test Application

Newly Constructed and Additions/Alterations: All new compressed air systems, and all additions or alterations of compressed air systems, where the total combined online horsepower of the compressor(s) is 25 horsepower or more, must be tested.

The purpose of the installed controls is to choose the best combination of compressors for a given current demand. This test verifies that the installed controls have been set up to make these choices.

Ideally, the best combination of compressors keeps all base compressors either fully loaded or off with any given demand. The only compressors that should be partially-loaded are compressors that operate well partially-loaded, deemed as trim compressors.

This test is designed for flexibility, as this covers both older and newer compressed air systems. Older compressed air systems may be under direction of controls for the first time and may require compressors to be partially loaded.

Controls need to be able to determine real-time demand with a sensor (or calculate demand by a set of sensors). A flow sensor may do the task directly.

B. Construction Inspection

Prior to the functional test, the system and compressor specifications must be documented. In addition, the method for determining the current air demand and the state of each of the compressors must also be documented. Having this documented will assist in determining if the controls are working properly. The following sections provide instructions on the data that must be verified during the Construction Inspection and included on the Acceptance Document.

a. Compressor Specifications

Note the following data on the Acceptance Document. Most of this information can be identified from compressor specification sheets or the nameplate. This includes:

- Size (in rated horsepower)
- Rated Capacity (in actual cubic feet per minute)
- Control Type
  - Fixed Speed
  - Variable Speed
  - Variable Displacement
  - Inlet Modulation
  - Centrifugal
  - Other
- Designation as a Trim Compressor

If in doubt, contact the plant manager or controls designer, who should have this information readily available.

b. System Specifications

Note the online system capacity on the Acceptance Document. The online system capacity refers to the sum total capacity of all the compressors that will be in operation and connected to the control system. Once the compressor specifications are identified, taking the sum of every compressor's rated capacity should yield the online system capacity.

Note the operating system pressure on the Acceptance Document. The operating system pressure should match up with the rated operating pressure of each of the compressors, also found in the specification sheets.

c. Method for Determining Current Air Demand

Note the method for determining the current air demand on the Acceptance Document. There are a variety of ways to determine current air demand, which is the load required to safely run all downstream operating equipment. Since equipment operation is variable, the current air demand will also be variable. Tracking the real-time air demand is important to a well-functioning control system.

The controls designer should be aware of this method, as it is crucial to the operation of the controls.

It's important to document the following in this explanation of the method:

- Sensors and tools being used to determine the current air demand.
- What each sensor is measuring.
- Calculations (if necessary) used to determine the current air demand (in acfm).

d. **Method for Determining the State of the Compressors**

A compressor, at any given time, is operating in one of the following states:

- Off (0 percent of Rated Power)
- Unloaded (15-35 percent of Rated Power)
- Partially Loaded
- Fully Loaded (100 percent of Rated Power)

As with current air demand, there are a few ways you can determine the state of the compressor. All states, aside from the Partially Loaded state, can be easily determined with a power meter and the rated power of the compressor. For example, if a compressor is fully loaded, the power meter for this compressor should read near 100 percent of the rated power. If the compressor is unloaded, it will be approximately 15-35 percent of rated power. If the compressor is off, it should be at or near 0 kW of power.

Determining if a compressor is partially loaded would vary based on the compressor's control scheme. A fixed speed compressor would cycle between loaded and unloaded (or off and on) if it were partially loaded.

Both variable speed drive and variable displacement compressors match power and air output somewhat linearly. As air output decreases, then power also decreases in direct proportion. Thus, operating between 35-99 percent rated power may qualify as partially loaded.

The best way to determine if a compressor is Partially Loaded is to install a flowmeter at the discharge of the compressor. If the acfm output is less than the rated acfm of the compressor, it is running Partially Loaded. When there is no flow, but the motor is still running, the compressor is Unloaded. When there is no flow and the motor is not running (the power reading is near 0 kW), the motor is considered OFF.

Note the method for determining the compressors' states on the Acceptance Document.

In addition to these states, it is important that none of the compressors exhibit the following behavior:

- Short-cycling (loading and unloading more often than once per minute)

  Short-cycling is easily measured with a stopwatch and a power meter or flowmeter. Simply observe if any compressors are cycling between the loaded and unloaded state. If so, measure the frequency by counting how many cycles are achieved over the 10 minute duration of the test. If it is more than 10 on-off cycles, then the compressor is short-cycling.

- Blowoff (venting compressed air at the compressor itself)

Blowoff is a state that will need to be observed rather than measured. This is sometimes used to limit flow delivered to a compressed air system, where the air is vented to the atmosphere. This is usually noisy and obvious, though compressors can be outfitted with silencers. For Centrifugal compressors, this is sometimes necessary to prevent surge (and compressor damage) when running at partial load. The reason for exhibiting blowoff at a particular compressor should be noted during the Functional Testing.

C. Functional Testing

Step 1: Verify that the methods from the Construction Inspection have been employed by confirming the following:

- Compressor states can be observed and recorded for every compressor.

  As documented in the Construction Inspection, ensure that the proper tools are installed and operational. Confirm that if external sensors are needed to determine the state of each compressor, they are calibrated. The power meter and flow meter should read levels that are at or below the rated power input and air capacity, respectively (as recorded in Document NRCA-PRC-01-A).

- The current air demand (in acfm) can be measured or inferred.

  The easiest way to accomplish this is to install a flowmeter at the common header. This can be achieved by other methods, but this will need to be documented in the Notes section of Document NRCA-PRC-01-A.

Step 2: Run the compressed air supply system steadily at as close to the expected operational load range as can be practically implemented for at least 10 minutes.

Verify the following:

- System is running steadily for at least 10 minutes.

  It is the intent to observe a system running normally and at steady state.

- System is running near to the expected operational load range.

  Confirm that the controls are operating as expected. Running the system in the typical operational range is one way to accomplish this intent, though will require some communication with the plant manager to get an idea of this range. For example, does the system typically operate closer to 40-50 percent or 80-90 percent of the total online system capacity?

- Downstream equipment is not affected by a test valve being open, if applicable.

  Running a system steadily may be difficult without a valve installed near a common header (in the distribution system upstream of the demand side of the system) that will release air to the atmosphere. If a test valve is not used, it's recommended that the plant manager be contacted to determine a good time during the day when the system will be running steadily for a period longer than 10 minutes. For the case with a test valve, the pressure may drop below what is safe for some equipment. If there is equipment that must be running during the time of the test, take this into account when deciding how to perform the test.

If it is not possible to achieve a steady air demand for a 10 minute period of time, document the reason why and observe the state of the compressors during the 10 minute test. Observe any anomalies and document this in the Notes section.

Step 3: Observe and record the states of each compressor and the current air demand during the test.

Fill out the table for Step 3 in Document NRCA-PRC-01-A. If any state is difficult to determine, then document your specific observations and measurements in the Notes section.

Step 4: Confirm that the system exhibits the following behavior following the test:

- No compressor exhibits short-cycling.

  If any compressor was cycling between loaded and unloaded during the test, and if the number of on-off cycles exceeds 10, this portion of the test fails. Circle N in Document NRCA-PRC-01-A.

- No compressor exhibits blowoff.

  If any compressor is venting pressurized air to the atmosphere, this portion of the test fails. Circle N in Document NRCA-PRC-01-A

- The trim compressors are the only compressors partially loaded, while the base compressors will either be fully loaded or off by the end of the test. (only applicable for new systems)

  This is a requirement for new systems because these systems are required to have properly sized trim compressors. If the new systems are designed properly, the controls should operate in a manner that has the trim compressors responsible for the trim load on top of fully loaded base compressors.

  If any compressor is in the Partially Loaded state that is not a trim compressor, this portion of the test fails. Circle N in Document NRCA-PRC-01-A.

  For an existing system, circle NA in NRCA-PRC-01-A.

Step 5: Return system to initial operating conditions.

13.29 NRCA-PRC-02-A: Commercial Kitchen Exhaust

At-A-Glance

NA7.11.1 Commercial Kitchen Exhaust
Use Document NRCA-PRC-02-A
Purpose of the Test
The following acceptance tests apply to commercial kitchen exhaust systems with Type I exhaust hoods. All Type I exhaust hoods used in commercial kitchens shall be tested.
Instrumentation
Smoke candles or smoke puffers (smoke bombs are not permitted), actual cooking at the normal production rate is also a reliable method of generating smoke. Space differential pressure sensor. Recording Analog Manometer with Pitot Tube and VelGrid.
Test Conditions
Exhaust and make-up air systems are installed and fully functional. Demand Ventilation Control systems (if installed) are fully functional and have been set up and calibrated by the installing contactor.

For Kitchens with greater than 5,000 cfm of Type I and Type II kitchen hood exhaust, All Type I hoods meet the requirements of Table 140.9-A.
Estimated Time to Complete
Construction inspection: 0.5 hour **Functional testing:** 1 hour (for each system)
Acceptance Criteria
• Smoke was fully captured. • All Type I hoods are drawing exhaust at less than or equal to the values in Table 140.9-A. • DCV and MUA system respond. • Timed override works • DCV and MUA systems respond to full load conditions (all Yes)
Potential Issues and Cautions
Coordinate test procedures with the facility supervisor since they may be needed to assist with the manipulation of the control system.

A. Test Application

Newly Constructed and Additions/Alterations: All newly installed Type 1 exhaust hoods used in commercial kitchens must be tested.

B. Construction Inspection

Verify exhaust and replacement air systems are installed, power is supplied and the control systems such as demand control ventilation are calibrated.

For kitchen/dining facilities having total Type 1 and Type II kitchen hood exhaust airflow rates greater than 5,000 cfm, calculate the maximum allowable exhaust rate for each Type 1 hood per Table 140.9-A.

C. Functional Testing

The following acceptance test applies to systems with and without demand control ventilation exhaust systems. These tests shall be conducted at full load conditions.

Step 1: Operate all sources of outdoor air providing replacement air for the hoods.

Step 2: Operate all sources of recirculated air providing conditioning for the space in which the hoods are located.

Step 3: Operate all appliances under the hoods at operating temperatures.

Step 4: Verify that the thermal plume and smoke is completely captured and contained within each hood at full load conditions by observing smoke or steam produced by actual cooking operation and/or by visually seeding the thermal plume using devices such as smoke candles or smoke puffers. Smoke bombs shall not be used (note: smoke bombs typically create a large volume of effluent from a point source and do not necessarily confirm whether the cooking effluent is being captured). For some appliances (e.g., broilers, griddles, fryers), actual cooking at the normal production rate is a reliable method of generating smoke). Other appliances that typically generate hot moist air

without smoke (e.g., ovens, steamers) need seeding of the thermal plume with artificial smoke to verify capture and containment.

Step 5: Verify that space pressurization is appropriate (e.g. kitchen is slightly negative relative to adjacent spaces and all doors open/close properly).

Step 6: Verify that each Type 1 hood has an exhaust rate that is below the maximum allowed.

Step 7: Make adjustments as necessary until full capture and containment and adequate space pressurization are achieved and maximum allowable exhaust rates are not exceeded. Adjustments may include:

- Adjust exhaust hood airflow rates.
- Add hood side panels.
- Add rear seal (back plate).
- Increase hood overhang by pushing equipment back.
- Relocate supply outlets to improve the capture and containment performance.

Step 8: Measure and record final exhaust airflow rate per Type 1 hood.

The following additional acceptance test shall be performed on all exhaust hoods with demand control ventilation exhaust systems.

Step 1: Turn off all kitchen hoods, makeup air and transfer systems.

Step 2: Turn on one of the appliances on the line and bring to operating temperature. Confirm that:

1. DCV system automatically switches from off to the minimum flow setpoint.
2. The minimum flow setpoint does not exceed the larger of:
    - 50 percent of the design flow.
    - The ventilation rate required per §120.1.
3. The makeup air and transfer air system flow rates modulate as appropriate to match the exhaust rate.
4. Appropriate space pressurization is maintained.

Step 3: Press the timed override button. Confirm that system ramps to full speed and back to minimum speed after override times out.

Step 4: Operate all appliances at typical conditions. Apply sample cooking products and/or utilize smoke puffers as appropriate to simulate full load conditions. Confirm that:

1. DCV system automatically ramps to full speed.
2. Hood maintains full capture and containment during ramping to and at full-speed.
3. Appropriate space pressurization is maintained.

13.30 NRCA-PRC-03-F: Parking Garage Exhaust

At-A-Glance

NA7.12.1 Parking Garage Exhaust
Use Document NRCA-PRC-03-F
Purpose of the Test
Verify that airside economizers function properly
Instrumentation
Space differential pressure sensor CO span gas with a concentration of 30 ppm (+/- 2 percent)
Test Conditions
Each CO sensor has a valid factory calibration certificate (+/-5 percent) CO sensors are located in areas of high CO concentration per 120.6(c) CO control setpoint is at or below 25ppm for all sensors per 120.6(c)
Estimated Time to Complete
Construction inspection: 1 hour **Functional testing:** 2 hour
Acceptance Criteria
During a time of low activity • All sensors active and reading a setpoint of <25ppm • Exhaust fans are running at minimum speed. • Exhaust fans are drawing <30 rated power. Applied required CO span gas testing • All sensors active and reading a setpoint of between 25 and 35ppm • Exhaust fans are running at maximum speed. • Exhaust fans go back to minimum speed when span gas is removed. • Temporary override of the programmed sensor calibration/replacement; observation that fans ramp to full speed and an EMCS alarm is set. • System in unoccupied mode: observation that fans ramp to full speed and an alarm is received by the facility operators. • Programmed occupied sensor proximity zone alarm differential; observation that fans ramp to full speed and an alarm is received by the facility operators.
Potential Issues and Cautions
Coordinate test procedures with the facility supervisor since they may be needed to assist with the manipulation of the control system.

A. Test Application

Newly Constructed and Additions/Alterations: All newly installed parking garage ventilation systems with carbon monoxide control must be tested.

B. Construction Inspection

Verify and document the following tests prior to the functional testing:

- Carbon monoxide control sensor is factory-calibrated per §120.6(c).
- The sensor is located in the highest expected concentration location in its zone per §120.6(c).
- Control setpoint is at or below the CO concentration permitted by §120.6(c).

C. Functional Testing

Conduct the following tests with garage ventilation system operating in occupied mode and with actual garage CO concentration well below setpoint.

Step 1: With all sensors active and all sensors reading below 25 ppm, observe that fans are at minimum speed and fan motor demand is no more than 30 percent of design wattage.

Step 2: Apply CO span gas with a concentration of 30 ppm, and a concentration accuracy of +/- 2 percent, one by one to 50 percent of the sensors but no more than 10 sensors per garage and to at least one sensor per proximity zone. For each sensor tested observe:

- CO reading is between 25 and 35 ppm.
- Ventilation system ramps to full speed when span gas is applied.
- Ventilation system ramps to minimum speed when span gas is removed.

Step 3: Temporarily override the programmed sensor calibration/replacement period to 5 minutes. Wait 5 minutes and observe that fans ramp to full speed and an alarm is received by the facility operators. Restore calibration/replacement period.

Step 4: Temporarily place the system in unoccupied mode and override the programmed unoccupied sensor alarm differential from 30 percent for 4 hours to 1 percent for 5 minutes. Wait 5 minutes and observe that fans ramp to full speed and an alarm is received by the facility operators. Restore programming.

Step 5: Temporarily override the programmed occupied sensor proximity zone alarm differential from 30 percent for 4 hours to 1 percent for 5 minutes. Wait 5 minutes and observe that fans ramp to full speed and an alarm is received by the facility operators. Restore programming.

13.31 NA7.10.2 Evaporator Fan Motor Controls

At-A-Glance

NA7.10.2 Evaporator Fan Motor Controls
Use Document NRCA-PRC-04-A
Purpose of the Test
This test ensures that the evaporator fans modulate their speed in response to either the space temperature or humidity, as required per §120.6(a)3B. Note that control strategies using humidity are very uncommon and accordingly only methods based on temperature will be described below. If humidity is included in the control logic, the design engineer should be involved in designing the test method.
Instrumentation
Performance of this test will require measuring the temperature of the space served by the evaporators under test. The instrumentation needed to perform the task may include, but is not limited to a temperature calibrated to +/- 0.7°F between -30°F and 200°F.
Test Conditions
The test will be performed by varying the control parameters used by the evaporator fan motor control system. Therefore, the evaporator fan control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test. The test should not be performed if the evaporator is in defrost, if a scheduled defrost is eminent, or if the evaporator was recently in defrost. Document the value of the initial control parameters before starting the test.
Estimated Time to Complete
Construction inspection: 0.5 hours (for each evaporator) **Functional testing:** 1 hour (for each evaporator)
Acceptance Criteria
• Evaporator fan controls modulate to increase fan speed, and evaporator fan speed increases in response to controls, when the test temperature setpoint is lowered in 1 degree increments below any control dead band range. • Evaporator fan controls modulate to decrease fan speed, and evaporator fan speed decreases in response to controls, when the test temperature setpoint is raised in 1 degree increments below any control dead band range until fans go to minimum speed.
Potential Issues and Cautions
Coordinate test procedures with the refrigeration or controls contractor, or the facility supervisor since they may be needed to assist with the manipulation of the control system. Fan speeds change slowly in normal operation, so the test requires adequate time to allow response.

A. Test Application

Newly Constructed Buildings: Applies to functional testing and verification of evaporator motor fan motor variable speed controls.

B. Construction Inspection

The field technician should check the following:

- All temperature and sensors have been calibrated and read accurately.
- All sensors are mounted in a location away from direct evaporator discharge air draft.
- All evaporator motors are operational and rotate in the correct direction.
- Fan speed control is operational and connected to evaporator fan motors.
- All speed controls are in “auto” mode.
- Records showing calibration was performed, what offsets or control system calibration values were used, and documentation of the instrumentation used for calibration.

C. Functional Testing

Step 1: Measure the current space temperature and program this temperature as the test temperature into the control system**. Allow 5 minutes for system** to **normalize.**

Verify whether the evaporator fans are controlled based on the space temperature. This step brings the temperature setpoint for the evaporator within range to the current conditions of the space.

Step 2: Using the control system, lower the test temperature setpoint in 1 degree increments below any control dead band range.

Verify:

- Evaporator fan controls modulate to increase fan motor speed, by observing control system readout or variable speed drive readout values.
- Evaporator fan motor speed increases in response to controls, by observation of fan speed or sound level.

Step 3: Using the control system, raise the test temperature setpoint in 1 degree increments above any control dead band range until fans go to minimum speed**.**

Verify:

- Evaporator fan controls modulate to decrease fan motor speed, by observing control system readout or variable frequency drive readout values.
- Evaporator fan motor speed decreases in response to controls, by observation of fan speed or sound level.

Document:

- Record the minimum fan motor control speed and how it was determined.

Note: Control system parameters may utilize percent of full speed, frequency (Hz), or sometimes RPM. Variable Frequency Drive (VFD) readouts may also provide these values, and may not read the same as the control system. The control system programmer may be needed to explain readout values.

Step 4: Restore the control system to correct control setpoints.

Confirm that the control system is restored back to initial space temperature setpoint.

13.32 NA7.10.3.1 Evaporative Condenser Fan Motor Variable Speed Controls

At-A-Glance

NA7.10.3.1 Evaporative Condensers and Condenser Fan Motor Variable Speed Controls
Use Document NRCA-PRC-05-A
Purpose of the Test
This test ensures that the condensing temperature of the condenser is reset in response to ambient wet-bulb temperature, per §120.6(a)4E. This test ensures that the condenser fan speed is continuously variable, and the condenser fans are controlled in unison per §120.6(a)4C. This test ensures that the minimum condensing temperature control setpoint is 70°F or lower, per §120.6(a)4C.
Instrumentation
Performance of this test will require measuring the ambient wet-bulb temperature, relative humidity, and condenser operating pressure. The instrumentation needed to perform the task may include, but is not limited to: • A temperature sensor calibrated to +/- 0.7°F between -30°F and 200°F • A relative humidity (RH) sensor calibrated to +/- 1 percent between 5 percent and 90 percent RH • A pressure sensor shall be calibrated to +/- 2.5 psi between 0 and 500 psig
Test Conditions
The test will be performed by varying the control parameters used by the condenser control system. Therefore, the condenser control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test. Document the value of the initial control parameters before starting the test.
Estimated Time to Complete
Construction inspection: 1 hour (for one evaporative condenser) **Functional testing:** 3 hour (for one evaporative condenser)
Acceptance Criteria
• The evaporative condenser minimum condensing temperature control setpoint is 70°F or lower. • The target condensing temperature is reset in response to ambient wet-bulb temperature, by using a temperature difference (TD) between the condensing temperature and the ambient wet-bulb temperature.

- The condenser fan speed is continuously variable and the condenser fans are controlled in unison – varying the speed of all fans serving a common high-side at the same time.

Potential Issues and Cautions

Coordinate test procedures with the refrigeration or controls contractor, or the facility supervisor since they may be needed to assist with the manipulation of the control system.

To ensure proper overall system operation, make sure that the system pressure is not held at excessively low or high values for an extended period of time when varying the saturated condensing temperature (SCT) control setpoint. Avoid abrupt changes in pressure. Coordinate with facility operator or refrigeration contractor.

A. Test Application

Newly Constructed Buildings: Applies to functional testing and verification of fan motor variable speed control for evaporative condensers.

B. Construction Inspection

The field technician should check the following:

- The minimum saturated condensing temperature (SCT) control setpoint is at or below 70°F.
- The SCT value used by the control system is the temperature equivalent reading of the condenser pressure sensor.
- All drain leg pressure regulator valves (if used) are set below the minimum condensing temperature/pressure setpoint and all receiver pressurization valves, such as the outlet pressure regulator (OPR), are set lower than the drain leg pressure regulator valve setting. This ensures that the pressure regulator valve and receiver pressurization valve settings do not force the actual condensing temperature to be higher than the minimum condensing temperature setpoint. (Note: These regulators are only used on small systems and rarely with evaporative condensers.)
- All pressure, temperatures and humidity sensors have been calibrated and read accurately.
- Temperature and humidity sensors are mounted in a location away from direct sunlight.
- All sensor readings used by the condenser controller convert or calculate to the correct conversion units at the controller (e.g., saturated pressure reading is correctly converted to appropriate saturated temperature; dry-bulb and relative humidity sensor readings are correctly converted to wetbulb temperature, etc.).
- All condenser motors are operational and rotate in the correct direction.
- All condenser fan speed controls are operational and connected to condenser fan motors, and not in bypass.
- All speed controls are in “auto” mode.
- Records showing calibration was performed, what offsets or control system calibration values were used, and documentation of the instrumentation used for calibration.

C. Functional Testing

The system cooling load must be sufficiently high to run the test, i.e. with a condensing temperature above the minimum SCT setpoint. The loads can often be increased somewhat as required to perform the Functional Testing. For example, the cooling loads can be temporarily increased by lowering the zone temperature setpoint or allowing more infiltration into the space by opening doors.

If there is insufficient load or the weather is too cold to operate the condensers above the minimum SCT setpoints, there are several options: The test could be scheduled for a warmer day, additional load could be arranged, or a portion of the condenser capacity could be reduced. Methods for reducing condenser capacity include turning off part of the spray pumps, or covering part of the condenser surface (e.g. with cardboard) or fans (taking care not to overload motors).

Step 1: Override any possible conflicting controls. This may include, but is not limited to heat reclaim, hot gas defrost, or defrost head pressure override before performing functional tests.

Work with refrigeration contractor or facility staff to disable controls that may interfere with the Functional Testing.

Step 2: Document current conditions

- Ambient dry-bulb temperature (DBT), wet-bulb temperature (WBT), and relative humidity (RH).
- Current condenser control temperature difference (Control TD) parameter in the control system. Some control systems may use a pressure equivalent.
- Refrigeration system condensing temperature (SCT) or condensing pressure in psig.
- Calculate the actual condenser temperature difference (Actual TD) which is the temperature difference between the current SCT and the current WBT. This value may be the same as the Control TD.
- Current head pressure control setpoint in °F SCT or psig.

Step 3: Program into the control system a condensing temperature/pressure setpoint equal to the reading or calculation obtained in Step 2. This is typically accomplished by setting the condenser Control TD parameter to the Actual TD from Step 2. The resulting SCT or psig setpoint will be referred to as the “Test Setpoint.” Allow 5 minutes for condenser fan speed to normalize.

Step 4: Using the control system, raise the Test Setpoint in 1 degree (or 3 psi) increments until the condenser fan control modulates to minimum fan motor speed. Raising the test setpoint can be accomplished by increasing the Control TD parameter. The fans may cycle off completely if the control range limit is met so it is important to increase the Test Setpoint in small increments to produce a slow control response.

Verify:

- Condenser fan motor speed decreases.
- All condenser fan motors serving common condenser loop decrease speed in unison in response to controller output; observed at the control system and at the condensers(s).

Document:

- Minimum fan motor control speed (rpm, percent of full speed, or Hz) as observed in the control system and VFD readouts, as available.

Step 5: Using the control system, lower the Test Setpoint in 1 degree (or 3 psi) increments until the condenser fan control modulates to increase fan motor speed**.** Lowering the Test Setpoint can be accomplished by decreasing the Control TD parameter.

Verify:

- Condenser fan motor speed increases.
- All condenser fan motors serving common condenser loop increase speed in unison in response to controller output observed at the control system and at the condensers(s).

Step 6: Document the current minimum saturated condensing temperature (Min. SCT) setpoint, which should be set to 70°F SCT or lower.

Document:

- Current minimum SCT setpoint in the control system

Using the control system, change the Min. SCT setpoint to a value greater than the current system SCT**.**

Depending on system load or weather condition:

1. Reduce the Control TD and/or reduce system load to reduce the operating SCT until actual operation is observed at the Min. SCT value. Verify that fan speed modulates to maintain the Min SCT Value.
2. If weather conditions are too warm, and on load is too high to accomplish the previous test from part A, the Min. SCT setpoint can be increased (above the 70°F value) to observe control at the higher value. Verify that fan speed modulates to maintain this temporary Min. SCT value.

Step 7: Using the control system, restore the system head pressure controls to original settings documented in Steps #2 and 6 (Control TD, Min SCT)**.**

Verify that the control system is restored back to correct control setpoints.

Step 8: Restore any controls that were disabled in Step 1.

Verify that the control system is restored back to original conditions.

13.33 NA7.10.3.2 Air Cooled Condenser Fan Motor Variable Speed Controls

At-A-Glance

NA7.10.3.2 Air Cooled Condenser Fan Motor Variable Speed Controls
Use Document NRCA-PRC-06-A
Purpose of the Test
This test ensures that the condenser fan speed is continuously variable, and the condenser fans are controlled in unison per §120.6(a)4D. This test ensures that the air cooled condenser minimum condensing temperature control setpoint is 70°F or lower, per §120.6(a)4D. This test ensures that the condensing temperature of the condenser is reset in response to ambient dry-bulb temperature, per §120.6(a)4E.
Instrumentation
Performance of this test will require measuring the ambient drybulb temperature and condenser operating pressure. The instrumentation needed to perform the task may include, but is not limited to: • A temperature sensor calibrated to +/- 0.7°F between -30°F and 200°F. • A pressure sensor shall be calibrated to +/- 2.5 psi between 0 and 500 psig.
Test Conditions
The test will be performed by varying the control parameters used by the condenser control system. Therefore, the condenser control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test. Document the value of the initial control parameters before starting the test.
Estimated Time to Complete
Construction inspection: 1 hour (for one air cooled condenser) **Functional testing:** 3 hour (for one air cooled condenser)
Acceptance Criteria
• The condenser minimum condensing temperature control setpoint is 70°F or lower. • The target condensing temperature of the condenser is reset in response to ambient drybulb temperature, by using a constant temperature difference (TD) between the condensing temperature and the ambient drybulb temperature. • The condenser fan speed is continuously variable, and the condenser fans are controlled in unison – varying the speed of all fans serving a common high-side at the same time.

Potential Issues and Cautions
Coordinate test procedures with the refrigeration or controls contractor, or the facility supervisor since they may be needed to assist with the manipulation of the control system. To ensure proper overall system operation, make sure that the system pressure is not held at excessively low or high values for an extended period of time when varying the saturated condensing temperature (SCT) control setpoint. Avoid abrupt changes in pressure. Coordinate with facility operator or refrigeration contractor.

A. Test Application

Newly Constructed Buildings: Applies to functional testing and verification of fan motor variable speed controls for air-cooled condensers.

B. Construction Inspection

The field technician should check the following:

- The minimum saturated condensing temperature (SCT) control setpoint is at or below 70°F.
- The SCT value used by the control system is the temperature equivalent reading of the condenser pressure sensor.
- All drain leg pressure regulator valves (if used) are set below the minimum condensing temperature/pressure setpoint and all receiver pressurization valves, such as the outlet pressure regulator (OPR), are set lower than the drain leg pressure regulator valve setting. This ensures that the pressure regulator valve and receiver pressurization valve settings do not force the actual condensing temperature to be higher than the minimum condensing temperature setpoint. (Note: These pressure regulators are only used on small systems.)
- All pressure and temperature sensors have been calibrated and read accurately.
- Temperature and humidity sensors are mounted in a location away from direct sunlight.
- All sensor readings used by the condenser controller convert or calculate to the correct conversion units at the controller (e.g., saturated pressure reading is correctly converted to appropriate saturated temperature).
- All condenser motors are operational and rotate in the correct direction.
- All condenser fan speed controls are operational and connected to condenser fan motors, and not in bypass.
- All speed controls are in “auto” mode.
- Records showing calibration was performed, what offsets or control system calibration values were used, and documentation of the instrumentation used for calibration.

C. Functional Testing

The system cooling load must be sufficiently high to run the test, i.e. with a condensing temperature above the minimum SCT setpoint. The loads can often be increased somewhat as required to perform the Functional Testing. For example, the cooling loads can be temporarily increased by lowering the zone temperature setpoint or allowing more infiltration into the space by opening doors.

If there is insufficient load or the weather is too cold to operate the condensers above the minimum SCT setpoints, there are several options:

The test could be scheduled for a warmer day, additional load could be arranged, or a portion of the condenser capacity could be reduced. Methods for reducing condenser capacity include covering part of the condenser surface (e.g. with cardboard) or fans (taking care not to overload motors).

Step 1: Override any possible conflicting controls. This may include, but is not limited to heat reclaim, hot gas defrost, or defrost head pressure override before performing functional tests.

Work with the refrigeration contractor or facility staff to disable controls that may interfere with the Functional Testing.

Step 2: Document current conditions

- Ambient drybulb temperature (DBT).
- Current the condenser control temperature difference (Control TD) parameter in the control system (some control systems may use a pressure equivalent).
- Refrigeration system condensing temperature (SCT) or condensing pressure in psig.
- Calculate actual condenser temperature difference (Actual TD), which is the temperature difference between the current SCT and the current DBT. This value may be the same as the Control TD.
- Current head pressure control setpoint in °F SCT or psig.

Step 3: Program into the control system a condensing temperature/pressure setpoint equal to the reading or calculation obtained in Step 2. This is typically accomplished by setting the condenser Control TD parameter to the Actual TD from Step 2. The resulting SCT or psig setpoint will be referred to as the “Test Setpoint.” Allow 5 minutes for condenser fan speed to normalize.

Step 4: Using the control system, raise the Test Setpoint in 1 degree (or 3 psi) increments until the condenser fan control modulates to minimum fan motor speed. Raising the test setpoint can be accomplished by increasing the Control TD parameter. The fans may cycle off completely if the control range limit is met so it is important to increase the Test Setpoint in small increments to produce a slow control response**.**

Verify:

- Condenser fan motor speed decreases.
- All condenser fan motors serving common condenser loop decrease speed in unison in response to controller output; observed at the control system and at the condenser(s).

Document:

- Minimum fan motor control speed (rpm, percent of full speed, or Hz) as observed in the control system and at the condenser(s).

Step 5: Using the control system, lower the Test Setpoint in 1 degree (or 3 psi) increments until the condenser fan control modulates to increase fan motor speed**.** Lowering the Test Setpoint can be accomplished by decreasing the Control TD parameter.

Verify:

- Condenser fan motor speed increases.
- All condenser fan motors serving common condenser loop increase speed in unison in response to controller output; observed at the control system and at the condenser(s).

Step 6: Document the current minimum saturated condensing temperature (Min. SCT) setpoint that should be set to 70°F SCT or lower.

Document:

- Current minimum SCT setpoint in the control system.

Step 7: Using the control system, change the Min. SCT setpoint to a value greater than the current system SCT**.**

Depending on system load or weather condition:

1. Reduce the Control TD and/or reduce system load to reduce the operating SCT until actual operation is observed at the Min. SCT value. Verify that fan speed modulates to maintain the Min SCT Value.
2. When weather conditions are too warm, and on load is too high to accomplish the previous test from Part A, the Min. SCT setpoint can be increased (above the 70°F value) to observe control at the higher value. Verify that fan speed modulates to maintain this temporary Min SCT value.

Verify:

- Condenser fan controls modulate to decrease capacity (speed).
- All condenser fans serving common condenser loop modulate in unison.
- Condenser fan controls stabilize within a 5 minute period.

Step 8: Using the control system, restore the system head pressure controls to original settings documented in Steps #2 and 6 (Control TD, Min SCT)**.**

Verify that the control system is restored back to correct control setpoints.

Step 9: Restore any controls that were disabled in Step 1.

Verify that the control system is restored back to original conditions.

13.34 NA7.10.4 Compressor Variable Speed Controls

At-A-Glance

NA7.10.4 Compressor Variable Speed Controls
Use Document NRCA-PRC-07-A
Purpose of the Test
The test ensures that the applicable compressors control compressor speed in response to the refrigeration load, per §120.6(a)5B.
Instrumentation
None
Test Conditions
To perform the test, it will be necessary to override the normal operation of the controls. The control system for the compressor must be complete, including: • Variable speed drive on all applicable screw compressors. • Controls to control the compressor motor speed. Document the initial control settings before executing system overrides or manipulation of the setpoints. The compressor control system must be returned to normal operation at the end of the test.
Estimated Time to Complete
Construction inspection: 1 hour (for one compressor) **Functional testing:** 2 hour (for one compressor)
Acceptance Criteria
• Compressor speed decreases with decrease in load, and the slide valve (or other unloading means) are held at 100 percent capacity until the compressor speed reaches the minimum allowable setpoint. • With an increase in load, the compressor slide valve (or other unloading means) should load to 100 percent capacity, and then the compressor speed should start in increase.
Potential Issues and Cautions
Coordinate test procedures with the refrigeration or controls contractor, or the facility supervisor since they may be needed to assist with the manipulation of the control system.

A. Test Application

Newly Constructed Buildings: Applies to functional testing and verification of compressor variable speed controls.

B. Construction Inspection

The field technician should check the following:

- All applicable single open-drive screw compressors dedicated to a suction group have variable speed control.
- All pressure and temperature sensors have been calibrated and read accurately.
- All sensor readings used by the compressor controller convert or calculate to the correct conversion units at the controller (e.g., saturated suction pressure reading is correctly converted to appropriate saturated suction temperature (SST)).
- All compressor motor speed controls are operational and connected to compressor motors.
- All speed controls are in “auto” mode.
- Compressor panel control readings for “RPMs”, “percent speed”, “kW”, and “amps” match the readings from the PLC or other control systems.
- Compressor data is correctly entered into the PLC or other control system, to the extent required for proper control (e.g. minimum speed)
- Records showing calibration was performed, what offsets or control system calibration values were used, and documentation of the instrumentation used for calibration.

C. Functional Testing

The system cooling load must be sufficiently high for the test, but the compressor should be not operating at fully capacity. Artificially increase the load by decreasing the zone setpoint, or decrease the load by increasing the zone setpoint or turning off evaporators as needed to perform the Functional Testing.

Step 1: Override any floating suction pressure functionality before performing functional tests.

Work with the refrigeration contractor or facility staff to disable controls that may interfere with the Functional Testing.

Step 2: Document current operating conditions. Note these may be the same as the current setpoint.

- Current suction pressure
- Current saturated suction temperature

Step 3: Document current setpoint: *S*uction pressure setpoint or saturated suction temperature setpoint.

Program into the control system a target setpoint equal to the current operating condition measured in Step #2. Allow 5 minutes for system to normalize. This will be referred to as the “test suction pressure/saturated suction temperature setpoint”.

Step 4: Using the control system, increase the test suction setpoint in small increments until the compressor controller modulates to decrease compressor speed. An increase of 1psi or 1°F SST will be appropriate. The increase will need to consider any control dead band or time delay that is in place.

Verify:

- Compressor speed decreases
- Compressor speed continues to decrease to minimum speed
- Any slide valve or other unloading means does not unload until after the compressor has reached its minimum speed.

Step 5: Using the control system, decrease the test suction setpoint in small increments until the compressor controller modulates to increase compressor speed**.** A decrease of 1psi or 1°F SST will be appropriate. The decrease will need to consider any control dead band or time delay that is in place. You must wait a sufficient amount of time so that any timer or delay can expire.

Verify:

- Any slide valve or other unloading means first goes to 100 percent before compressor speed increases from minimum
- Compressor begins to increase speed
- Compressor speed continues to increase to 100 percent

Step 6: Using the control system, program the suction pressure or saturated suction temperature setpoint back to original settings as documented in Step #3**.**

Confirm that the control system is restored back to correct control setpoints.

Step 7: Restore any controls that were disabled in Step 1.

Verify that the control system is restored back to original conditions.

13.35 NA7.10.1 Electric Resistance Underfloor Heating Systems

At-A-Glance

NA7.10.1 Electric Resistance Underfloor Heating Systems
Use Document NRCA-PRC-08-A
Purpose of the Test
This test ensures that the electric resistance underfloor heating system is thermostatically controlled and disabled during the summer on-peak period defined by the electric utility provider. The test verifies that the electric resistance heater is controlled according to the underfloor temperature, and is forced off during the summer on-peak period, as required per §120.6(a)2.
Instrumentation
Performance of this test will require measuring the amperage of the electrical circuit(s) powering the underfloor heating system. The instrumentation needed to perform the task may include, but is not limited to: • A clamp on amp meter

Test Conditions
The test will be performed by varying the control parameters used by the underfloor heater control system. Therefore, the underfloor heater control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test. Document the value of the initial control parameters before starting the test.
Estimated Time to Complete
Construction inspection: 2 hours (for one system) **Functional testing:** 4 hours (for one system)
Acceptance Criteria
The underfloor electric resistance heater must do the following: • Turn off when the temperature setpoint is lower than the underfloor temperature (including any dead band or offset). • Turn on when the temperature setpoint is higher than the underfloor temperature (including any dead band or offset). • Automatically turn off (and remain off) if the date and time of the control system falls within the summer on-peak period of the electric utility provider, regardless of the underfloor temperature.
Potential Issues and Cautions
Coordinate test procedures with the refrigeration or controls contractor or the facility supervisor since they may be needed to assist with manipulation of the control system.

A. Test Application

Newly Constructed Buildings with Electric Underfloor Heating Systems: Applies to functional testing and verification of the electric resistance underfloor heating system controls.

B. Construction Inspection

The Field Technician should review that the summer on-peak period is programmed into the electric resistance underfloor heating systems.

C. Functional Testing

Step 1: Using the control system, lower the underfloor temperature setpoint to cycle off the electric resistance heater.

Verify and Document:

- Measure the current of the electric heater circuits(s) to confirm the electric resistance heater circuit is off.

Step 2: Using the control system, raise the underfloor temperature setpoint to cycle on the electric resistance heater.

Verify and Document:

- Measure the current of the electric heater circuits(s) to confirm the electric resistance heater circuit is on.

Step 3: Using the control system, change the control system's date and time to correspond to the local utility company summer on-peak period.

Verify and Document:

- Measure the current of the electric heater circuits(s) to confirm the electric resistance heater circuit is off.

Step 4: Restore the control system to correct date and time, and underfloor temperature control setpoints.

Confirm that the control system is restored back to correct date and time, and that the control system is restored to the initial conditions for the underfloor temperature setpoint and schedules.

13.36 NA7.14.1 Elevator Lighting and Ventilation Controls

At-A-Glance

NA7.14.1 Elevator Lighting and Ventilation Controls
Use Document NRCA-PRC-12-F
Purpose of the Test
This test is to ensure that the shut off control turns off the lighting and ventilation fan when the elevator is not occupied for more than 15 minutes. The control system must be able to detect occupancy, and keep the ventilation fan on, in the event that someone is occupying the elevator cabin and the elevator conveyance or doors malfunction §120.6(f).
Instrumentation
This test verifies the functionality of installed automatic controls visually after a prolonged period of time. A clock or stopwatch will be needed.
Test Conditions
The test will be performed by varying the control parameters used by the elevator lighting and ventilation fan control system. Therefore, the elevator lighting and ventilation fan control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test.
Estimated Time to Complete
Construction inspection: 15 min (for one system) **Functional testing:** 1 hour (for one system)
Acceptance Criteria
The elevator lighting and ventilation fan control systems must do the following: Turn off when the cabin doors have been closed for more than 15 • Turn on when the elevator is activated • Remain on after more than 15 minutes with the doors closed
Potential Issues and Cautions
Verifying the lighting and ventilation fans remain on with the doors closed for more than 15 minutes.

A. Test Application

Newly Constructed Buildings and Additions/Alterations: Applies to functional testing and verification of the lighting and ventilation fan system controls.

B. Construction Inspection

The Field Technician must verify that the occupancy sensors have been installed in a location that will minimize false signals, such as pedestrian traffic in the elevator lobby. Also, if an ultrasonic sensor is being used the Field Technician must verify that the sensor does not emit an audible sound.

***C.* Functional Testing**

Step 1: Open the elevator doors.

Verify and Document:

- The lighting and ventilation system turn on.

Step 2: Exit the elevator and allow the doors to close. After 15 minutes, open the elevator doors.

Verify and Document:

- The lighting and ventilation system were off and activated as the elevator doors open. If this method proves too hard to visually verify the lighting and ventilation system were off, then measure the power output of the elevator controls and verify that the lighting and fan power turns off after 15 minutes of being unoccupied.

Step 3: Enter the elevator cabin. Once the doors close, wait 15 minutes.

Verify and Document:

The lighting and ventilation system remained on after 15 minutes.

13.37 NA7.15.1 Escalator and Moving Walkway Speed Control

At-A-Glance

NA7.15.1 Escalator and Moving Walkway Speed Control
Use Document NRCA-PRC-13-F
Purpose of the Test
This test is to ensure that the speed of the escalator or moving walkway slows when not occupied. The control system must be able to detect occupancy, and approaching pedestrians in either direction. §120.6(g).
Instrumentation
This test verifies the functionality of installed automatic controls visually after a prolonged period of time. A clock or stopwatch and calculator will be needed.
Test Conditions
The test will be performed by varying the control parameters used by the escalator or moving walkway control system. Therefore, the control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test.

Estimated Time to Complete
Construction inspection: 30 min (for one system) **Functional testing:** 1 hour (for one system)
Acceptance Criteria
The control systems must do the following: • Reduces speed to a minimum when passengers are not detected • Ramp up to maximum speed when the controls detect an approaching passenger • Sound an alarm if a pedestrian is approaching the conveyance in the wrong direction.
Potential Issues and Cautions
Verifying the sensors are located in the corrected, unobstructed location.

A. Test Application

Newly Constructed Buildings and Additions/Alterations: Applies to functional testing and verification of the speed control system.

B. Construction Inspection

Verify and Document:

- The variable speed drive is installed
- The occupancy sensors have been located to minimize false signals, such as from pedestrians using an adjacent conveyance
- The occupancy sensors do not encounter any obstructions
- Ultrasonic occupancy sensors do not emit an audible sound

C. Functional Testing

Step 1: Determine the Speed of the conveyance using the controller interface (If this method is not applicable skip this step and proceed to Step 2)

Verify and Document:

- The full speed is less than 100 ft/min
- The slow speed is 10 ft/min
- The acceleration and deceleration does not exceed 1 ft/sec

If the speed of the conveyance is determined using this method, then skip steps 2, 4, 6 and 9.

Step 2: Measure the diagonal length of the conveyance

Document:

- The diagonal length in feet.

Step 3: Measure the speed of the conveyance

Document:

- Using a stopwatch, board the conveyance and measure the travel time from one landing to the other. Document the time in seconds.

Step 4: Calculate the speed of the conveyance.

Document:

- Using the data from Steps 2 and 3, divide the length (in feet) by the travel time (in seconds).
- Convert the ft/sec to ft/min by multiplying the ft/sec by 60.

Step 5: Conveyance reduces speed

Verify and Document:

- Using a stopwatch, stand away from the escalator and wait approximately 3 times the escalator travel time. (Step 3 multiplied by 3).
- Verify that the conveyance has slowed to a minimum speed.

Step 6: Verify the minimum speed of the conveyance.

Verify and Document:

- Using a stopwatch, record the time it takes for one step of the conveyance to travel from one landing to the other.
- Using the length from Step 2, Divide the length by the time measured above. This will determine the minimum speed.

Step 7: Verify the occupancy controls

Verify and Document:

- While the conveyance is still at minimum speed, approach at a normal walking pace and verify the conveyance ramps up to full speed before boarding.
- After waiting for the conveyance to reduce speed to a minimum. Approach the conveyance from multiple angles and verify the conveyance ramps up to full speed.

Step 8: Verify the alarm

Verify and Document:

- After waiting for the conveyance to reduce speed to a minimum approach the conveyance from the wrong direction (the exit).
- Verify that the conveyance ramps up to full speed
- Verify that an audible alarm is triggered to alert passengers that they are entering from the wrong direction.

Step 9: Calculate the acceleration of the conveyance

Verify and Document:

- When the conveyance is at minimum speed, approach the conveyance and record the amount of time it takes to reach maximum speed.
- Take the difference of the high and low speeds in ft/sec and divide it by the recorded time above. Verify that the acceleration does not exceed 1 ft/sec.

13.38 Acceptance Test Technician Certification Provider (ATTCP)

13.38.1 Provider Qualifications

The requirements to become either a Lighting Controls or Mechanical Nonresidential Acceptance Test Technician Certification Provider (ATTCP) are very similar. Therefore, in this section we will address both the Lighting Controls and Mechanical ATTCP application requirements together, calling out specific differences when warranted. The perspective ATTCP must submit a written application to the Energy Commission that contains the following three major elements:

A. **Organizational Structure**

a. ***Requirement:*** ATTCPs shall provide written explanations of the organization type, by-laws, and ownership structure. ATTCPs shall explain in writing how their certification program meets the qualification requirements of §10-103.1(c) (or §10-103.2(c)). ATTCPs shall explain in their application to the Energy Commission their organizational structure and their procedures for independent oversight, quality assurance, supervision and support of the acceptance test training and certification processes (§10-103.1(c)1 and §10-103.2(c)1).

b. ***Intent:*** This requirement is necessary to ensure, at a minimum, that the organizations providing certification services to the building industry have a business structure that is conducive to train, certify and oversee Acceptance Test Technicians (ATTs).

c. ***Compliance:*** The Energy Commission has approved several ATTCP applicants and all applications included Articles of Incorporation, Bylaws, Trust Agreements and in one case, the Section 501(c) status (with the corresponding employer identification number) of the organization. Also, a copy of the ethics policy for the ATTCP, while optional, is recommended. This section of the application should also include a description of how the organization is conducive to providing training, certification, oversight and support to the technicians that they will be certifying.

   The ATTCP may also describe what qualifications and experience the ATTCP may have to operate and oversee an accreditation program.

B. **Certification of Employers**

a. ***Requirement:*** The ATTCPs shall provide written explanations of their certification and oversight of Acceptance Test Employers (ATEs). This explanation shall document how the ATTCP ensures that the employers are providing quality control and appropriate supervision and support for their Acceptance Test Technicians (§ 10-103.1(c)2 and § 10-103.2(c)2).

b. ***Intent:*** ATEs must have an understanding of what tasks the ATT is responsible to complete. Additionally, the ATE must manage and provide support to the ATT in performing their tasks. The ATTCP is required to describe the training and requirements that they will place on the ATE for these endeavors and issue certificates to qualified ATE applicants.

c. ***Compliance:*** The Energy Commission recognizes that there are many roads to compliance in regards to ATE training, certification and oversight. Technical training typically consists of 4 to 24 hours of instruction. Quality control, supervision and support requirements implemented by the ATTCP on the ATE can vary considerably. Some elements that the ATTCP might consider implementing, but that are not specifically required by the Energy Commission regulations include the following:

- The ATTCP may develop a policy to address where a change in employment results in no ATE manager or supervisor having completed the ATE training.
- The ATTCP may adopt an ethics policy for ATEs.
- Union contracting requirements: The ATTCP may be restricted to serving unionized technicians only and as a result the ATTCP may require that the ATE be a party in good standing with a union contract. This may entail several significant requirements for the ATE.
- Third-party certificate holders: The ATTCP may require that the ATE hold a valid certificate from a third party such as specific types of Testing and Air Balancing (TAB) training.
- Multiple office management requirements: The ATTCP may consider how they will implement ATE training and certification requirements where an ATE has multiple offices. The ATTCP may consider requiring that an ATE with multiple offices shall ensure a middle or senior management level employee at each office has completed the ATE certification training.
- Restrictive employment practices: the ATTCP may restrict the ATE from employing an ATT that is certified by a different ATTCP. Additionally, the ATTCP may restrict the ATE from holding certificates from multiple ATTCPs.
- Licensing, insurance and safe practices requirements: The ATTCP may require the ATE to provide initial and ongoing proof of workers compensation and general liability insurance (typically a minimum dollar amount is specified), local business licenses, Injury and Illness Prevention Program and Code of Safe Practices (typically required to be consistent with the California Code of Regulations, Sections 1509 and 3203).
- Equipment Policy: The ATTCP may require the ATE to agree to requirements for ensuring that the ATE and ATT possess and properly maintain diagnostic equipment.

C. Certification of Technicians

a. ***Requirement:*** ATTCPs shall include with their application a complete copy of all training and testing procedures, manuals, handbooks and materials. ATTCPs shall explain in writing how their training and certification procedures include, but are not limited to, the following (§10-103.1(c)3 et sec and §10-103.2(c)3 et sec):

i. Training Scope. The scope of the training shall include both hands-on experience and theoretical training to certify competency in the technologies and skills necessary to perform the acceptance tests.

ii. ATT Training.

- **Curricula**. ATTCP training curricula for ATTs shall include, but not be limited to, the analysis, theory, and practical application as required in regulation. The curricula requirements for the Lighting Controls and Mechanical ATT training are significantly different from each other and can be found in §10-103.1(c)3Bi and §10-103.2(c)3Bi.
- **Hands-on training**. The ATTCP shall describe in their application the design and technical specifications of the laboratory boards, equipment and other elements that will be used to meet the hands-on requirements of the training and certification.
- **Prequalification**. Participation in the technician certification program shall be limited to persons who have at least three years of professional experience and expertise (in either lighting controls and electrical systems or mechanical systems) as determined by the ATTCP.
- **Instructor to Trainee Ratio**. The ATTCP shall document in its application to the Energy Commission why its instructor to trainee ratio is sufficient to ensure the integrity and efficacy of the curriculum and program based on industry standards and other relevant information.
- **Tests**. The ATTCP shall describe the written and practical tests used to demonstrate each certification applicant's competence in all specified subjects. The ATTCPs shall retain all results of these tests for five years from the date of the test.
- **Recertification**. The ATTCP shall recertify all ATTs and ATEs prior to the implementation of each adopted update to the Energy Standards as these updates affect the acceptance test requirements.

iii. ATE Training. Training for ATEs shall consist of at least a single class or webinar consisting of at least four hours of instruction that covers the scope and process of the acceptance tests in the Energy Standards.

iv. Complaint Procedures. The ATTCPs shall describe in their applications to the Energy Commission procedures for accepting and addressing complaints regarding the performance of any ATT or ATE certified by the ATTCP, and explain how building departments and the public will be notified of these proceedings.

v. Certification Revocation Procedures. The ATTCPs shall describe in their applications to the Energy Commission procedures for revoking their certification of ATTs and ATEs based upon poor quality or ineffective work, failure to perform acceptance tests, falsification of documents, failure to comply with the documentation requirements of these regulations or other specified actions that justify decertification.

vi. Quality Assurance and Accountability. The ATTCP shall describe in their application to the Energy Commission how their certification business practices include quality assurance and accountability measures, including but not limited to independent oversight of the certification processes and procedures, visits to building sites where certified technicians are completing acceptance tests,

certification process evaluations, building department surveys to determine acceptance testing effectiveness, and expert review of the training curricula developed for Building Energy Efficiency Standards, §130.4. The ATTCP shall review a random sample of no less than 1 percent of each ATT's completed compliance documents, and shall perform randomly selected on-site audits of no less than 1 percent of each ATT's completed acceptance tests. Independent oversight may be demonstrated by accreditation under the ISO/IEC 17024 standard.

vii. Certification Identification Number and Verification of ATT Certification Status. Upon certification of an ATT, the ATTCP shall issue a unique certification identification number to the ATT. The ATTCP shall maintain an accurate record of the certification status for all ATTs that the ATTCP has certified. The ATTCP shall provide verification of current ATT certification status upon request to authorized document Registration Provider personnel or enforcement agency personnel to determine the ATT's eligibility to sign Certificate of Acceptance documentation.

b. ***Intent:*** These requirements are the most significant of the ATTCP regulations. They encapsulate all the required training, testing, certification and oversight for the ATTs that the ATTCP must provide. These requirements describe the level of experience, education, professionalism and accountability of the ATT that the Energy Commission is seeking and that the ATTCP must enforce.

c. ***Compliance:***

- The training must include both classroom and laboratory training. In essence, the technician must be instructed on all acceptance tests and then practice those instructions in a laboratory setting. Furthermore, the ATT must be educated on the general science regarding acceptance testing, as well as the procedure to complete and submit the correct acceptance test documents.
- The classroom training must include all of the curricula listed in the regulation, in addition to training on the acceptance tests themselves. Several ATTCPs require extensive classroom training to accomplish this educational requirement. However, one ATTCP requires that each applicant hold a third party certificate of training that the Energy Commission found to be equivalent to the curricula required.
- Each ATT applicant must be prequalified with three years of professional experience (in either lighting controls and electrical systems or mechanical systems). Professional experience is defined by the ATTCP, but generally means experience in a professional occupation that provides training and work experience related to the systems subject to lighting control or mechanical acceptance testing. The ATTCP must clarify the process that they will used to determine what experience is considered professional and relevant to either lighting controls or mechanical acceptance testing as well as to what extent the ATTCP will verify that experience. The following are some relevant questions that the ATTCP should consider when establishing an ATT applicant's prequalified experience but are not required by regulation:
    - How is the experience documented (for example letters from employers or other written evidence) and how is it related to lighting control or mechanical acceptance testing requirements?

- Should professional experience be demonstrated by requiring applicants to be certified in specifically identified professions, such as:
  - California licensed electrical contractors
  - California licensed mechanical or HVAC contractors
  - California certified general electricians
  - California licensed air conditioning repair contractors
  - California licensed professional engineers
  - Lighting control manufacturer representative
  - Certified commissioning professionals
  - Other professional occupations that are demonstrated to provide industry accepted training and work experience relevant to the systems subject to lighting control or mechanical acceptance testing.

- ATTCPs must have a sufficient number of instructors to effectively train the amount of participants in both classroom and laboratory work. Typically, the instructor to student ratio for classroom training is much higher than for laboratory training. In the applications that the Energy Commission has approved, classroom instructor to student ratios were between 1:25 and 1:35; for laboratory training, the ratios were between 1:6 and 1:12. Most importantly, each ATTCP application included a discussion of the basis for each ratio.
- All ATT applicants will have to take both a written and practical test to demonstrate the applicant's competence in all specified subjects to become a certified ATT. The ATTCP is required to retain all results of these tests for five years from the date the test was taken. When developing and implementing both written and practical tests, the ATTCP may consider the following issues:
  - Consider validating exams by subject matter experts for content.
  - Pilot testing and statistical analysis by qualified psychometricians can identify poor quality questions and bias as well as validating a passing score.
  - Checking exam question response option frequency and other measurements of consistency may help validate the exam rigor and justify passing scores and performance standards.
  - Annually evaluate exam questions to confirm reliability, rigor and lack of bias.
  - Validation for lack of bias consistent with the Uniform Guidelines on Employee Selection Procedures (1978) Federal Register, 43(166), 38290-38315.
  - Adopt measures to ensure exam security such as having multiple versions of exams with random question generation and at least twice the number of questions in a validated question bank than are scored on any given test.
- ATTCPs are required to recertify ATTs each time the Energy Standards are updated with new or modified acceptance test requirements. Recertification is required for all ATTs following an update to the Energy Standards and the Energy Commission approval of the ATTCP training and testing materials. The ATTCP will submit their training and testing materials and recertification process to the Energy Commission for approval. Once approved, the ATTCP will implement the recertification process.

- ATTCPs are required to have procedures for accepting and addressing complaints regarding the performance of any certified ATT or ATE and must have a clear explanation on how building departments and the public can complete these procedures.
- ATTCPs have the authority to decertify ATTs and ATEs based upon poor quality or ineffective work, failure to perform acceptance tests, falsification of documents, failure to comply with the documentation requirements of these regulations or other specified actions that justify decertification.
    - ATTCPs must include quality assurance, independent oversight and accountability measures, such as, independent oversight of the certification processes and procedures, visits to building sites where certified ATTs are completing acceptance tests, certification process evaluations, enforcement agency surveys to determine acceptance testing effectiveness, and expert review of the training curricula developed for the Standards. Independent oversight may be demonstrated by accreditation under the ISO/IEC 17024 standard. The regulations require that the ATTCP review a random sample of no less than 1 percent of each technician's completed compliance documents, and perform randomly selected on-site audits of no less than 1 percent of each ATT's completed acceptance tests. The consequences of failed audits should be fully described by the ATTCP. ATTCPS might consider whether to require a higher percentage of document and on-site audits the first few years of operation in order to ensure that any initial issues with training or compliance are identified and addressed. For example, one ATTCP proposed the following: For the first three years of operation, review a random sample of 6 percent of each technician's completed documents and perform on-site audits of 6 percent of acceptance tests.
    - For years 4 and 5 of the ATTCP operation, review a random sample of 4 percent of each technician's completed documents and perform on-site audits of 4 percent of acceptance tests.
    - After 5 years of operation, reduce a random sample of 2 percent of each ATT's completed compliance documents and perform on-site audits of 2 percent of acceptance tests.
- Once approved, the ATTCP will issue a unique certification identification number to the ATT and maintain an accurate record of the certification status of the ATT. The regulations require that ATTCPs provide verification of current ATTs' certification status upon request to authorized document Registration Provider personnel or enforcement agency personnel to determine the ATTs' eligibility to sign Certificate of Acceptance documentation according to all applicable regulations. Energy Standards compliance will also be facilitated by requiring the ATT to include their assigned certification number on the compliance documentation, thereby allowing the enforcement agency and the Energy Commission to track the effectiveness of this certification program.
- The ATTCP is not required to implement an on-line presence of any kind for the purposes of compliance with these regulations. However, the applications that the Energy Commission has approved all include the implementation of an on-line presence to contend with the ATT/ATE application processing, complaints process, certification status and ATT/ATE contact information.

13.38.2 Requirements for ATTCPs to Provide Regular Reports

A. Requirements: The ATTCP shall provide the following regular reports to the Energy Commission (§10-103.1(d) and §10-013.2(d)):

a. ***Annual Report:*** The ATTCP shall provide an annual report to the Energy Commission summarizing the certification services provided over the reporting period, including the total number of Acceptance Test Technicians and Employers certified by the ATTCP:

i. During the reporting period.

ii. To date.

The annual report shall include a summary of all actions taken against any Acceptance Test Technician or Employer as a result of the complaint or quality assurance procedures described by the ATTCP as required under §10-103.1(c)3D and §10-103.1(c)3F and §10-103.2(c)3D and §10-103.2(c)3F.

b. ***Update Report:*** The ATTCP shall have not less than six months following the adoption of an update to the Energy Standards to prepare an Update Report. The ATTCP shall submit an Update Report to the Energy Commission not less than six months prior to the effective date of any newly adopted update to the Energy Standards, The ATTCP shall report to the Energy Commission what adjustments have been made to the training curricula, if any, to address changes to the Energy Standards Acceptance Testing requirements, adopted updates to the Energy Standards or to ensure training is reflective of the variety of lighting controls (or mechanical systems) that are currently encountered in the field. All required update reports shall contain a signed certification that the ATTCP has met all requirements under §10-103.1(c) or §10-103.2(c)). Update reports shall be approved through the Amendment Process provided under §10-103.1(f).

All required reports shall contain a signed certification that the ATTCP has met all requirements for this program.

B. Intent: There are two basic reporting requirements for the ATTCP. These reporting requirements are intended to ensure that the Energy Commission has a reasonable level of control on the ATTCP without being unnecessarily involved in the day to day operations of the ATTCP.

C. Compliance:

- The regulations require the ATTCP to submit two periodic reports to the Energy Commission. The first is an annual report documenting the training and certification activities during that year. This report can include adjustments that are proposed, however, these proposals must be approved by the Energy Commission staff or possibly at a formal Energy Commission business meeting. The second report is an update report, where the ATTCP identifies what changes they will need to make to their training and certification requirements in response to changes the Energy Commission has made to the Energy Standards.

13.38.3 Amendment of ATTCP Approved Applications

A. Requirement: The ATTCP may amend a submitted or approved application as described in this Section (§10-103.1(f) and §10-103.2(f)).

*a. **Amendment Scope.***

i. **Nonsubstantive Changes.** A nonsubstantive change is a change that does not substantively alter the requirements of the application materials for the ATTCP, ATT, or ATT Employer. For amendments making only nonsubstantive changes, the ATTCP shall submit a letter describing the change to the Energy Commission as an addendum to the application.

ii. **Substantive Changes.** A substantive change is a change that substantively alters the requirements of the application materials for the ATTCP, ATT, or ATT Employer. For amendments making any substantive changes, the ATTCP shall submit the following:

- A document describing the scope of the change to the application, the reason for the change and the potential impact to the ATTCP, ATT, and ATT Employer as an addendum to the application;
- A replacement copy of the affected sections of the ATTCP application with the changes incorporated; and
- A copy of the affected sections of the ATTCP application showing the changes in underline and strikeout format.

b. ***Amendment Review.*** Amendments submitted prior to approval of an ATTCP application shall be included in the application's Application Review and Determination process specified in §10-103.1(e) or §10-103.2(e).

Amendments submitted after approval of an ATTCP's application that contain only nonsubstantive changes shall be reviewed by the Executive Director for consistency with §10-103.1 or §10-103.2. Amendments determined to be consistent with this Section shall be incorporated into the approval as errata.

Amendments submitted after approval of an ATTCP's application that contain any substantive changes shall be subject to the Application Review and Determination process specified in §10-103.1(e) or §10-103.2(e). If the Energy Commission finds that the amended application does not meet the requirements of §10-103.1or §10-103.2, then the ATTCP shall either abide by the terms of their previously approved application or have their approval suspended.

B. Intent: The amendment process is intended to give the ATTCP an opportunity both during their initial application approval process and post-approval to modify their application or operations. The intent is for ATTCPs to operate as openly as possible with the Energy Commission and address issues as they arise.

C. Compliance: the amendment process is divided in to two groups, substantive and nonsubstantive changes, both during an application review and after the approval of an application. The substantive issues will generally result in an approval from the Energy Commission at a regular Business Meeting. While nonsubstantive issues can be resolved by Staff.

13.38.4 Nonresidential Mechanical Acceptance Test Training and Certification

The Mechanical ATTCP has one additional consideration that is no longer a requirement for the Lighting Controls ATTCP. The Lighting Controls ATTCP has satisfied the Industry Certification Thresholds, which requires that only Certified ATTs can be the signatory for the lighting controls acceptance testing. The Mechanical ATTCP, as of this writing, has not surpassed this threshold.

A. Requirement: Industry Certification Thresholds

Field Technicians can complete acceptance tests for mechanical found in §120.5 without being a certified Mechanical Acceptance Test Technician until the following ATTCP requirements are met (§10-103.2(b)):

1. A minimum of 300 Mechanical Acceptance Test Technicians have been trained and certified to complete the acceptance tests of §120.5 by ATTCP(s) approved by the Energy Commission.
2. ATTCPs provide reasonable access, determined by the Energy Commission, for the training and certification for the majority of professions qualified to complete the work of mechanical field technicians. These professions include: Professional engineers, HVAC installers, mechanical contractors, TABB certified technicians, controls installation and startup contractors and certified commissioning professionals who have verifiable training, experience and expertise in HVAC systems. The Energy Commission will consider, in its determination of “reasonable access,” factors such as certification costs commensurate with the complexity of the training being provided, prequalification criteria, curriculum and, class availability throughout the state.

B. Intent

The Threshold requirements have several goals:

1. To make sure that there are enough certified technicians to cover the entire acceptance testing workload that exists in all counties of California.
2. To make sure that any qualified person has access to become certified if they so choose.
3. To ensure that the market is not impacted significantly by a scarcity of certified ATTs.

C. Compliance

When appropriate, the Energy Commission will take up the question of the Threshold requirements for the Nonresidential Mechanical ATTCP program.