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## 8. Acceptance Requirements

Acceptance requirements ensure that equipment, controls and systems operate as required by the Standards. The activities specified in these requirements have three aspects:

- Visual inspection of the equipment and installation
- Review of the certification requirements, and
- Functional tests of the systems and controls

Mechanical acceptance requirements are outlined in §121, §122 & §125 of the Standards. Lighting acceptance requirements are outlined in §131. Both mechanical and lighting acceptance requirements are detailed in Appendix NJ of the Non-Residential ACM Manual.

The acceptance process is a way of assuring that the installation was done in a way that meets the requirements of the Standards. This process assures not only that the appropriate equipment was purchased and installed, but that that equipment is operating properly.

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### 8.1 Overview

Acceptance requirements are defined as the application of targeted inspection checks and testing to determine whether specific building systems conform to the criteria set forth in the Standards and to plans or specifications.

Third party review is not required in the Standards. The Standards permit the Acceptance Agent to be the installing contractor, design professional or an agent selected by the owner. This Acceptance Agent's role should focus on the following areas:

- Review the bid documents to make sure that sensor locations, devices and control sequences are properly documented,
- Review the installation, perform acceptance tests and document results, and
- Document the operating and maintenance information, complete installation certificate and indicate test results on the Certificate of Acceptance, and submit the certificate to the building department prior to receiving a final occupancy permit.

Acceptance testing is not intended to take the place of commissioning or test and balance procedures that a building owner might incorporate into a building project. It is an adjunct process focusing only on demonstrating compliance with the Standards.

This chapter summarizes the requirements for acceptance testing including:

- Section 8.1 Overview provides an overview of roles, responsibilities and reasons for the acceptance requirements.

- Section 8.2 Acceptance Testing Process discusses how acceptance testing fits into plan review, construction inspection, system and equipment testing and certification (Certificate of Occupancy).
- Section 8.3 Forms includes a list of forms necessary for completing the acceptance requirements.
- Section 8.4 Mechanical Acceptance Testing addresses requirements for inspecting and testing mechanical systems and equipment.
- Section 8.5 Lighting Acceptance Testing addresses requirements for inspecting and testing lighting systems and equipment.
- Section 8.6 Test Procedures for Mechanical Systems
- Section 8.7 Test Procedures for Lighting Equipment
- Section 8.8 Mechanical Forms for Acceptance Requirements details the compliance forms used to document the mechanical acceptance testing.
- Section 8.9 Lighting Forms for Acceptance Requirements details the compliance forms used to document the lighting acceptance testing.

### **8.1.1 Roles and Responsibilities**

The installing contractor, engineer of record or owners agent can act as the Acceptance Agent who shall be responsible for documenting the inspection and testing results of the acceptance requirement procedures on the Acceptance Test forms (see Section 8.3 Forms). To make sure that the tests are performed, it is critical that the engineer of record document in the construction documents who is to perform these tests and the details of the tests to be performed. This could be integrated into the specifications for testing and air balance, energy management and control system, equipment startup procedures or commissioning. It is quite possible that the work will be performed by a combination of the Test and Balance (TAB) contractor, mechanical/electrical contractor and the Energy Management Control System (EMCS) contractor so roles and responsibilities should clearly be called out to get accurate pricing.

A Certificate of Acceptance signed by the Acceptance Agent is required to be submitted to the building department in order to receive the final Certificate of Occupancy. Building departments 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 Standards. In addition to the Certificate of Acceptance, each test form requires a signature and license number, as appropriate, for the party who has performed the test. Design professionals and contractors should review the contract provided by the owner to make sure it covers the scope of the acceptance testing procedures.

Building officials have authority to require the Acceptance Agent to demonstrate competence, to the satisfaction of the building official. Building officials should place extra scrutiny on situations where there may be either real or perceived compromising of the independence of the Acceptance Agent, and exercise their authority to disallow a particular Acceptance Agent from being used in their

jurisdiction or disallow Acceptance Agent practices that the building official believes will result in compromising of Acceptance Agents independence.

### 8.1.2 When Are Acceptance Tests Required?

In general the Acceptance Tests apply to new equipment and systems installed in either new construction or retrofit applications. The scope of each test and the specific exceptions to this rule are noted in the following paragraphs. If an acceptance test is required, the MECH -1-A along with the each specific test must be submitted to the building department before a final occupancy permit can be granted.

#### ***Mechanical Test Procedures***

##### *MECH-2-A: Ventilation System Acceptance Document*

- Variable Air Volume Systems Outdoor Air Acceptance

New Construction and Retrofit:

- Applies only to new Variable Air Volume (VAV) systems
- Constant Volume Systems Outdoor Air Acceptance

New Construction and Retrofit:

- Applies only to new Constant Air Volume (CAV) systems

##### *MECH-3-A: Packaged HVAC System Acceptance Document*

- Constant Volume Packaged HVAC Systems Acceptance

New Construction and Retrofit:

- Applies only to new single-zone units with direct expansion (DX) cooling. These units may be cooling only or heating and cooling.

##### *MECH-4-A: Air-Side Economizer Acceptance*

- *New Construction and Retrofit:* All new equipment with air-side economizers must comply. Units with economizers that are installed at the factory and certified with the Commission do not require equipment testing but do require construction inspection.

##### *MECH-5-A: Air Distribution Acceptance*

- New Construction (§144K): Only required for single zone units (heating only, cooling only or heating and cooling) serving 5,000 ft<sup>2</sup> of space or less where 25% or more of the duct surface area is in one of the following spaces:
- Outdoors, or

- In a space directly under a roof where the U-factor of the roof is greater than the U-factor of the ceiling, or
- In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces, or
- In an unconditioned crawlspace; or
- In other unconditioned spaces.

Downshot units with ducts in spaces with insulation on the walls and roof need not be sealed. Units with extensive ductwork on the roof or in an uninsulated attic may need to be sealed (it depends on the surface area ratio).

*Retrofit:* The same scope limitations for zone size, unit type and ductwork location apply as in new construction. With these constraints, requirements for sealing and testing apply to:

- New ductwork serving either new or existing single-zone units (§149D)
- New ductwork as an extension of existing ductwork with either new or existing single-zone units, and
- Existing ductwork where the single-zone unit is being replaced or having a major component replaced (§149E) including:
  - Cooling coil
  - Furnace
  - Condenser coil (split system) or
  - Condensing unit (split system)

Different levels of leakage requirements apply to new and existing ductwork (see §149D).

*MECH-6-A: Demand Control Ventilation Acceptance Document*

- *New Construction and Retrofit:* All new DCV controls installed on new or existing packaged systems must be tested.

*MECH-7-A: Supply Fan Variable Flow Controls*

- New Construction and Retrofit:
  - All new VAV fan volume controls installed on new or existing systems must be tested.

*MECH-8-A: Hydronic System Control Acceptance Document*

- Variable Flow Controls
- New Construction and Retrofit:
  - Applies to chilled and hot water systems.
  - Hydronic System Automatic Isolation Controls
- New Construction and Retrofit:

- 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.
- Hydronic System Supply Water Temperature Reset Controls
  - New Construction and Retrofit:
    - Applies to new constant flow chilled and hot water systems that have a design capacity greater than or equal to 500,000 Btu/hr. Note this is not required for systems that are designed for variable flow.
    - Water-loop Heat Pump Controls
  - New Construction and Retrofit:
    - Applies to all new water-loop heat pump systems where the combined loop pumps are greater than 5 hp.
  - Pump Variable Frequency Drive Control
    - New Construction and Retrofit:
      - Applies to all new distribution pumps on new variable flow chilled, hydronic heat pump or condenser water systems where the pumps motors are greater than 5 hp.

### ***Lighting Test Procedures***

All of the lighting acceptance tests apply to new equipment and controls installed on new or existing lighting systems. These tests include:

#### *LTG-2-A: Lighting Control Acceptance Document*

- Occupancy Sensor Acceptance
- Manual Daylight Controls Acceptance
- Automatic Time Switch Control Acceptance

#### *LTG-3-A: Automatic Daylight Control Acceptance Document*

### **8.1.3 Why Test for Acceptance?**

Building control systems are an integral component of a new building. From simple thermostatic controls and manual light switches to complex building automation systems, controls are an integral part of building health, safety and comfort. They also are a key component of a building's energy efficiency. A PIER report titled, Integrated Design of Small Commercial HVAC Systems, Element 4, [http://www.energy.ca.gov/reports/2003-11-17\\_500-03-082.PDF](http://www.energy.ca.gov/reports/2003-11-17_500-03-082.PDF) found the following problems with package rooftop equipment:

- ***Economizers.*** Economizers show a high rate of failure in the study. Of the units equipped with economizers, 64% were not operating

correctly. Failure modes included dampers that were stuck or inoperable (38%), sensor or control failure (46%), or poor operation (16%). The average energy impact of inoperable economizers is about 37% of the annual cooling energy.

- **Refrigerant charge.** A total of 46% of the units tested were improperly charged, resulting in reductions in cooling capacity and/or unit efficiency. The average energy impact of refrigerant charge problems was about 5% of the annual cooling energy.
- **Low airflow.** Low airflow was also a common problem. Overall, 39% of the units tested had very low airflow rates (< 300 cfm/ton). The average flowrate of all units tested was 325 cfm/ton, which is about 20% less than the flowrates generally used to rate unit efficiency. Reduced airflow results in reduced unit efficiency and cooling capacity. The annual energy impact of low airflow is about 7% of the annual cooling energy.
- **Cycling fans.** System fans were found to be cycling on and off with a call for heating or cooling in 38% of the units tested. The supply of continuous fresh air during occupied hours relies on continuous operation of the HVAC unit supply fan.
- **Unoccupied fan operation.** Fans were also observed to run continuously during unoccupied periods in 30% of the systems observed. While this practice improves the ventilation of the space, it represents an opportunity to save energy through thermostat setback and fan cycling during unoccupied periods.
- **Simultaneous heating and cooling.** Adjacent units controlled by independent thermostats were observed to provide simultaneous heating and cooling to a space in 8% of the units monitored in the study. This was largely due to occupant errors in the set up and use of the thermostats, and poor thermostat placement during construction.
- **No outdoor air.** A physical inspection revealed that about 8% of the units were not capable of supplying any outdoor air to the spaces served. In some cases, outdoor air intakes were not provided or were sealed off at the unit. In other instances, outdoor air dampers were stuck shut, preventing outdoor air intake.

Acceptance testing is a way of assuring that targeted building systems were designed, constructed and started up to the intent of the Standards.

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## 8.2 Acceptance Testing Process

The acceptance requirements require four major check-points to be conducted. They are:

- Plan review
- Construction inspection
- Testing

- Certificate of Occupancy

These will be discussed in more detail below.

### **8.2.1 Plan Review**

The installing contractor, engineer of record or owners agent shall be responsible for reviewing the plans and specifications to assure they conform to the acceptance requirements. This is typically done prior to signing a Certificate of Compliance.

In reviewing the plans, the designer will be noting on the MECH-1-C and LTG-1-C code compliance forms, all of the respective mechanical and lighting systems that will require acceptance 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.

### **8.2.2 Construction Inspection**

The installing contractor, engineer of record or owners agent shall be responsible for performing a construction inspection prior to testing. Reviewing the acceptance requirements with the contractor prior to installation is very useful on several counts.

In some cases, it is most economical to perform testing immediately after installation.

Awareness of the acceptance test may result in the contractor identifying a design or construction practice that would not comply with the acceptance testing requirements prior to installation.

Purchasing equipment with calibration certificates reduces the amount of required site calibration and may keep overall costs down.

The purpose of the construction inspection is to assure that the equipment that is installed is capable of complying with the requirements of the Standards. Construction inspection also assures that the equipment is installed correctly and is calibrated.

### **8.2.3 Testing**

The installing contractor, engineer of record or owners agent shall be responsible for undertaking all required acceptance requirement procedures. They shall be responsible for identifying all performance deficiencies, ensuring that they are corrected and again implementing the acceptance requirement procedures until all specified systems and equipment are performing in accordance with the Standards.

The installing contractor, engineer of record or owners agent shall be responsible for documenting the results of the acceptance requirement procedures on the acceptance test forms and indicate satisfactory completion by signing the Certificate of Acceptance.

**8.2.4 Certificate of Occupancy**

Building departments shall not release a final Certificate of Occupancy until a Certificate of Acceptance is submitted that demonstrates that the specified systems and equipment have been shown to be performing in accordance with the Standards. The installing contractor, engineer of record or owners agent upon completion of undertaking all required acceptance requirement procedures shall record their State of California Contractor’s License number or their State of California Professional Registration License Number on each Certificate of Acceptance that they issue.

**8.3 Forms**

Acceptance tests are documented using a series of forms. These include a Certificate of Acceptance and individual worksheets to assist in field verification. Table 8-1 shows the acceptance forms and reference Standards sections:

*Table 8-1 – Acceptance Forms*

Section	Form Name	Standards Reference	ACM Manual Appendix Reference
Lighting	LTG-1-A Certificate of Acceptance	§10-103	N/A
	LTG-2-A Lighting Controls	§119(d) and §131(d)	NJ 6.2, 6.3 and 6.4
	LTG-3-A Automatic Daylighting	§119(e)	NJ 6.1
Mechanical	MECH-1-A Certificate of Acceptance	§10-103	N/A
	MECH-2-A Ventilation Systems – Variable and Constant Volume	§121(b)2	NJ 3.1 and 3.2
	MECH-3-A Packaged HVAC Systems	§121(b)2, §122	NJ 4.1
	MECH-4-A Air-Side Economizer	§144(e)	NJ 7.1
	MECH-5-A Air Distribution Systems	§144(k)	NJ 5.1
	MECH-6-A Demand Control Ventilation	§121(c)4	NJ 8.1
	MECH-7-A Supply Fan VFD	§144(c)	NJ 9.1
	MECH-8-A Hydronic Systems Control	§144(j)	NJ 10.1 – 10.5

The forms listed above can be found in Appendix A.

**8.4 Mechanical Acceptance Testing Overview**

**8.4.1 Administration**

§10-103 (b)

The administrative requirements contained in the Standards require the mechanical plans and specifications to contain:

- Completed acceptance testing forms for mechanical systems and equipment shown in Table 8-2, record drawings are provided to the building owners within 90 days of receiving a final occupancy permit,
- operating and maintenance information are provided to the building owner, and
- installation certificates for mechanical equipment.
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*Table 8-2 – Mechanical Acceptance Tests*

Outdoor Air for Variable Air Volume Systems
Outdoor Air for Constant Volume Systems
Package Single-Zone System Controls
Air Distribution Systems
Air-Side Economizers
Demand Control Ventilation Systems
Variable Frequency Drive Fan Systems
Hydronic System Variable Flow Controls
Hydronic Pump Isolation Controls and Devices
Supply Water Reset Controls
Water-Loop Heat Pump Control
Variable Frequency Drive Pump Systems

#### **8.4.2 Field Process**

The construction inspection is the first step in performing the acceptance tests. In general, this inspection should identify:

- Mechanical equipment and devices are properly located, identified, calibrated and set points and schedules established.
- Documentation is available to identify settings and programs for each device, and
- For some air distribution systems (as identified in §144(k)), this may include select tests to verify acceptable leakage rates while access is available.

Testing is to be performed on the following devices:

- Minimum ventilation controls for constant and variable air volume systems
- Zone temperature and scheduling controls for package single-zone systems
- Duct leakage on a subset of small single-zone systems depending on the ductwork location
- Air-side economizer controls for economizers that are not factory installed and tested

- Demand control ventilation systems
- Fan volume controls for variable air volume systems
- Variable flow controls for chilled water and hot water systems serving more than 3 coil control valves.
- Isolation valves on chillers and boilers in plants with more than one chiller or boiler being served by the same primary pumps through a common header
- Supply water reset controls for constant flow chilled and hot water systems with a design capacity greater than 500,000 Btu/hr
- Water-loop heat pump isolation valve controls for systems with a combined circulation loop pump horsepower greater than 5 hp
- Variable frequency drive pump systems

### **8.4.3 Mechanical Acceptance Test Issues**

Acceptance testing must be tailored for each specific design, job site, and climactic conditions. 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.

#### ***General Issues***

##### *Combining tests to reduce testing costs*

Many of the acceptance tests overlap in terms of activities. For example, both NJ.3.1 Variable Air Volume Systems Outdoor Air Acceptance and NJ.9.1 Supply Fan Variable Flow Controls Acceptance require that the 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 the process of driving the VAV boxes into a set position it makes sense to combine these two tests: performing the superset of activities with the boxes at both design and part-load conditions. There are a number of places where combining tests will save time. These are summarized here and described again in the individual test descriptions below.

- Tests that require override of zone controls: NJ.3.1 Variable Air Volume Systems Outdoor Air Acceptance and NJ.9.1 Supply Fan Variable Flow Controls Acceptance.
- Tests that require override of the OSA damper: NJ.3.1 Variable Air Volume Systems Outdoor Air Acceptance (or NJ.3.2 Constant Volume Systems Outdoor Air Acceptance), NJ.7.1 (Air-Side) Economizer Acceptance, and NJ.8.1 Demand Control Ventilation Acceptance.
- Tests that require changing the unit mode of operation: NJ.4.1 Constant Volume Packaged HVAC Systems Acceptance and NJ.7.1 Air-Side Economizer Acceptance.

- Tests that require deadheading the circulation pump and overriding control valves: NJ.10.1 Variable Hydronic Flow Controls Acceptance (alternate 2), NJ.10.2 Automatic Isolation Controls Acceptance and NJ.10.4 Water-loop Heat Pump Controls Acceptance (alternate 2),. Note that systems with flow measurement capabilities can use alternate 1 for both NJ.10.1 Variable Hydronic Flow Controls Acceptance and NJ.10.4 Water-loop Heat Pump Controls Acceptance which do not require deadheading of the pump but do require closing control valves.

#### *Internal control delays*

Be aware of the potential for delays programmed into many control sequences. The purpose of delays is to prevent the system from controlling too rapidly and becoming unstable. With delays between five to 30 minutes, the acceptance testing can be prolonged considerably.

Examples include the normal time that it takes to stroke a damper (typically several minutes end to end) and anti-recycle timers on refrigerant compressors (typically on the order of 5 to 15 minutes).

#### *Initial conditions*

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

#### *Obtain correct control sequences before testing*

It is essential to know exactly what the control sequences are before testing begins. 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. Also many of these tests can be performed as part of the start-up process.

- Electronic controls are usually documented in the equipment O&M manual.
- With pneumatic controls, you need to review the control drawings to ascertain how the system is being controlled.
- With DDC controls, it is best to review the control programming that is currently loaded in the controllers. It is important to note that the actual control logic is often different from the sequences on the design plans and specifications for 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 startup and commissioning.

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

#### *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 equipment testing. These estimates are made for a specific test on a specific system; they need to be aggregated to estimate the time for completion on the entire building. These estimates need to be used with caution; times will vary depending on a number of factors including the complexity of the controls, the number of control zones, the number of similar tests and other issues. Expect that the first time a test is performed it will take longer. Subsequent tests will take less time as tester becomes more experienced and familiar with the test.

#### **8.4.4 Sensor Calibration**

A variety of sensors are used to control many facets of heating, ventilating, and air conditioning systems. Confirming that a sensor is measuring 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 it is imperative that the pressure sensor is measuring accurately. A precise definition of calibration is to perform a set of test procedures under specific conditions in order to establish a relationship between the value indicated by a measuring device and the corresponding values that would be realized by the standard being applied. The most common testing standards have been developed by the National Institute of Standards and Technology (NIST). However, the term “calibration” used in the acceptance tests simply refers to verification that the measured value from a sensor will correspond reasonably well (within 10% for pressure or light and within 2°F for temperature) to the actual state of the medium being measured.

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 that the particular sensor was tested per a traceable standard (typically NIST) and confirmed to be measuring accurately. A factory-calibrated sensor is assumed to be accurate and requires no further testing. Field verification generally requires checking the measured value from the sensor against a calibrated instrument while the sensor is installed in the system. Typically most sensors can be checked at a single operating point if the expected measurement range does not vary significantly. Any adjustments that are necessary 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 are required to be checked for calibration.

- Pressure sensors used in variable flow applications (i.e. supply fan or pump variable frequency drive is controlled to maintain a specific pressure setpoint). This is applicable to test procedure(s): NJ9.1 Supply Fan Variable Flow Controls; NJ10.4 Water-loop Heat Pump Controls; and NJ10.5 (Pump) Variable Frequency Drive Controls. Accuracy to 10%.

- Temperature sensors used to control field-installed economizers and supply temperature reset. This is applicable to test procedure(s): NJ7.1 Economizer Acceptance; and NJ10.3 Supply Water Temperature Reset Controls. Accuracy to 2°F.
- Carbon dioxide sensors used to control outside air dampers. This is applicable to test procedure(s): NJ8.1 Demand Control Ventilation Acceptance. Accuracy to 75 PPM (parts per million) of CO<sub>2</sub> concentration.
- Flow sensors only if used to control outside air dampers. This is applicable to test procedure(s): NJ3.1 Variable Air Volume Systems Outdoor Air Acceptance. Overall the system need to be able to control flows to within the 10% of the design outside air value.

Zone temperature sensors or thermostats do not need to be checked for calibration. Typically if these sensors are out of calibration, zone temperature setpoint will most likely be adjusted to accommodate for any variation between measured and actual values. In order to satisfy the “calibration” requirement outlined in NJ4.1 Constant Volume Package HVAC Systems Acceptance, simply review manufacturer’s cut sheet.

#### **8.4.5 Air and Water Measurements**

**Balancing.** It is recommended that before an occupancy permit is granted for a new building or space, or a new space-conditioning system serving a building or space is operated for normal use, the system should be balanced 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).

#### **8.4.6 Factory Air-Side Economizer Certification Procedure**

When a manufacturer supplies an HVAC unit with a factory-installed economizer section certified to meet California Energy Commission economizer quality control requirements, the manufacturer shall be responsible for verifying that the unit meets the following acceptance requirements.

Equipment components shall be certified as passing inspections or tests shown in Table 8-3.

Table 8-3 – Certification of Air-Side Economizer Components

Component	Factory Inspect and/or Test
Outdoor Temperature Sensor or Enthalpy	Enclosure mounted outdoor temperature or enthalpy sensor is calibrated and properly shielded from direct sunlight.
High-Limit Switch	Test and verify high-limit switch showing compliance with Standards Table 144-C per §144 (e)3.
Air-Side Economizer Controller	Test and verify that economizer sequences in an integrated fashion per §144(e)2B and can modulate up to 100% outside air per §144(e)1A..

In addition to component certification, the equipment shall pass the following operational tests:

Step 1: Test the equipment under a simulated cooling load and verify the following:

- Economizer damper modulates open per §144(e)1.A. to maximum position to satisfy cooling space temperature setpoint.
- Return air damper modulates closed and is completely closed when economizer damper is 100% open.
- Economizer damper is 100% open before mechanical cooling is enabled.
- Relief fan, or return fan (if integral to the unit) is operating or barometric relief dampers (if integral to the unit) freely swing open.
- Mechanical cooling is only enabled if cooling space temperature setpoint is not met with economizer at 100% open.

Step 2: Continue from Step 1 and disable the economizer using the high-limit switch. Verify and document the following:

- Economizer damper closes to minimum position.
- Return air damper opens to normal operating position.
- Relief fan, if applicable, shuts off or barometric relief dampers close. Return fan (if applicable) may still operate even when the economizer is disabled.
- Mechanical cooling remains enabled.

For units with economizers that are factory installed and certified operational by the manufacturer to California Energy Commission economizer quality control requirements, the in field economizer acceptance test does not have to be conducted. A copy of the certification certificate must be attached to the MECH-4-A. All pre-test inspection procedures must be completed.

**8.4.7 Alternate Test Procedures for Hydronic System Controls Acceptance**

It is important to make sure that control valves are selected to be able to shut off fully against the circulating pump pressure. Failure to do so wastes pump energy and may also cause systems to perform reheat (or recool) to make up for valve leakage. When the acceptance tests were first written, they included a provision that all valve actuators must be reviewed to ensure that they are sufficient to close off against the pump pressure. In a system with hundreds of

control valves this is both impractical and costly. Alternate 2 of NJ.10.1 Variable Hydronic Flow Controls tests all of the valves in a hydronic system at the same time to demonstrate the control valve ability to shut off flow.

Alternate 1 of the NJ.10.5 (Pump) Variable Frequency Drive Controls Acceptance required measurement of the hydronic flow and drive power both at full load and 50% flow conditions. This was intended to demonstrate the provision of §144(j)6 that requires a variable speed drive or equivalent control that draws no more than 30% full load power at 50% flow. The purpose of this test in the Standards is to determine if a control other than a variable speed drive can meet or exceed the performance of a variable speed drive. If the pumps are controlled by variable speed drives their power and flow do not need to be measured as they generally meet the 30% power at 50% flow provision if the hydronic loop control pressure is kept constant or is reduced with reduced flow.. Measuring the control loop pressure at full and low flow in Alternate 2 of the NJ.10.5 (Pump) Variable Frequency Drive Controls Acceptance test validates that the VFD control is responding correctly.

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## 8.5 Lighting Acceptance Testing Overview

Acceptance requirements can effectively improve code compliance and help determine whether lighting equipment meets operational goals and whether it should be adjusted to increase efficiency and effectiveness.

### 8.5.1 Administration

§10-103 (b)

The administrative requirements contained in the Standards require the lighting plans and specifications to contain:

- Completed acceptance testing forms for automatic daylighting controls, manual daylight switching, occupant sensing devices and automatic shut-off 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, and
- Requirement for the issuance of installation certificates for daylighting controls, occupant sensing devices and automatic shut-off controls.

For example, the plans and specifications would require automatic shut-off lighting controls. A construction inspection would verify the device location and wiring is complete. Acceptance tests would verify proper zoning, on-off functions and overrides to assure the shut-off system is properly functioning. Owners' manuals and maintenance information would be prepared for delivery to the building owner. Finally, record drawing information, including programming information for the automatic shut-off lighting controls must be submitted to the building owner within 90 days of the issuance of a final occupancy permit.

### **8.5.2 Constructability Plan Review**

Although acceptance testing does not require a plan review to be performed by the construction team, the construction team should review the construction drawings and specifications to understand the scope of the acceptance tests and raise critical issues that might affect the success of the acceptance tests prior to starting construction. Any constructability issues associated with the lighting system should be forwarded to the design team so that necessary modifications can be made prior to equipment procurement and installation. As an example, understanding the construction inspection requirements for manual or automatic daylighting controls (NJ6.3 and NJ6.1) could prevent expensive rewiring if the circuiting requirements are understood prior to installing the wiring.

### **8.5.3 Field Process**

#### *Construction Inspection*

“Do it right the first time.” It is better to check that the wiring plan complies with the acceptance test requirements before installation. The alternative may result in the wiring not passing the construction acceptance test and rewiring.

Construction inspection should occur while wiring is installed. If changes have to be made to circuiting, it is better to do this while a lift is still on site or before obstructions are installed.

Key circuiting issues are:

- Wiring for multi-level control. Lamps, luminaires or rows of luminaires are regularly assigned to different circuits so that light levels can be increased uniformly by switching
- Lighting in the daylit zone has to be on separate circuits from other lighting and, in most cases, must also be wiring for multi-level control.

Construction inspection should also identify:

- Lighting control devices are properly located, calibrated and setpoints or schedules established,
- Documentation is available to identify settings and programs for each device, and

Testing is to be performed on the following devices:

- Automatic daylighting controls
- Manual daylighting controls
- Occupancy sensing devices, and
- Automatic shut-off controls

#### 8.5.4 Lighting Acceptance Test Issues

Acceptance testing must be tailored for each specific design, job site, and climactic conditions. 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.

##### *General Issues*

###### *Internal control delays*

Be aware of the potential for delays programmed into many control sequences. The purpose of delays is to prevent the system from controlling too rapidly and becoming unstable. With delays between five to 30 minutes, the acceptance testing can be prolonged considerably.

###### *Initial conditions*

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

###### *Obtain correct control sequences before testing*

It is essential to know exactly how the control sequences are programmed before testing begins. Otherwise, the contractor will not be able to customize the test to the particular systems or verify that the systems work as intended. Written control sequences often do not include enough detail to test the system against, or they are found to be incorrect. Testing based on incorrect sequences will not necessarily yield a valid result. In addition, to be successful, the contractor will need to know how to manipulate the control system.

###### *Time to complete*

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

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#### 8.6 Test Procedures for Mechanical Systems

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

Use the MECH-2-A for

- NJ.3.1 Variable Air Volume Systems Outdoor Air Acceptance
- NJ.3.2 Constant Volume Systems Outdoor Air Acceptance

Use the MECH-3-A for

- NJ.4.1 Constant Volume Packaged HVAC Systems Acceptance

Use the MECH-4-A for

- NJ.7.1 Air-Side Economizer Acceptance

Use the MECH-5-A for

- NJ.5.1 Air Distribution Acceptance

Use the MECH-6-A for

- NJ.8.1 Packaged Systems DCV Acceptance

Use the MECH-7-A for

- NJ.9.1 Supply Fan Variable Flow Controls

Use the MECH-8-A for

- NJ.10.1 Variable Flow Controls
- NJ.10.2 Automatic Isolation Controls
- NJ.10.3 Supply Water Temperature Reset Controls
- NJ.10.4 Water-loop Heat Pump Controls
- NJ.10.5 Variable Frequency Drive Control

The numbers preceding each test are keyed to the section of the Nonresidential ACM Manual, Appendix NJ where the required test is documented.

## 8.6.1 NJ.3.1 Variable Air Volume Systems Outdoor Air Acceptance At-a-Glance

### NJ.3.1 Variable Air Volume Systems Outdoor Air Acceptance Use Form MECH-2-A

#### Purpose of the Test

This test ensures that adequate outside air ventilation is provided through the variable air volume air handling unit under all operating conditions. The test consists of measuring outside air valves at maximum flow and at or near minimum flow. The test verifies that the minimum volume of outside air, as required per §121(b)2, is introduced to the air handling unit when the system is in occupied mode at any supply airflow. Note that this test should be performed in conjunction with NJ.9.1 Supply Fan Variable Flow Controls Acceptance test procedures to reduce the overall system testing time. Related acceptance tests for these systems include the following:

- NJ.7.1 (Air-Side) Economizer Acceptance (if applicable)
- NJ.8.1 Demand Control Ventilation Acceptance (if applicable)
- NJ.9.1 Supply Fan Variable Flow Controls Acceptance

#### Benefits of the Test

Bringing adequate outside air into all spaces promotes good indoor air quality. The Standards require that minimum ventilation be provided during all normally occupied times to prevent indoor air quality problems.

Variable air volume systems will modulate the total supply airflow to meet varying loads. In systems with a fixed minimum position on the outside air (OSA) damper this will lead to variations in OSA as the supply volume varies. The minimum OSA needs to be dynamically controlled to provide minimum ventilation throughout the entire range of supply fan operation. A number of methods are presented in Chapter 4 of this manual.

#### Instrumentation

Performance of this test will require measuring outside airflow. 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).
- If the system was installed with an airflow monitoring station (AFMS) on the outside air, it can be used for the measurements if it has a calibration certificate or is field calibrated.

#### Test Conditions

To perform the test, it will be necessary to override the normal operation of the controls. The control system of the air handling unit and variable air volume (VAV) boxes must be complete, including:

- Supply fan capacity control (typically a variable speed drive )
- Air-Side Economizer control
- Minimum outside air damper control
- VAV box control (including zone thermostats and box minimums)

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

- Duct work
- VAV boxes
- Control sensors (temperature, flow, pressure, etc.)
- Electrical power to air handling unit
- Completion of air handling unit 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.

**Time to Complete**

**Construction inspection:** 0.5 hours (review of flow station with calibration certificate) to 2 hours (to test calibration of a damper with a calibrated flow curve)

**Equipment testing:** 1 to 3 hours (depending on the type of zone control and the number of zones)

**Acceptance Criteria**

Outside airflow station is calibrated (if applicable)

Calibration curve of outside air vs. outside air damper position, inlet vane signal, or VFD signal was completed during system TAB procedures.

Measured outside airflow is no less than 90% of the Standards requirement found on Mechanical Plan Check document MECH-3-CC-05 at:

- Minimum system airflow or 30% of total design flow, whichever is greater
- Design supply airflow
- If a dedicated minimum ventilation fan exists, the measured CFM delivered regardless of the speed of the supply fan is within 10% of design minimum outside air found on Mechanical Plan Check document MECH-3-C column I. Note that this design minimum outside air ventilation rate can be significantly greater than the calculated minimum outside air to account for building pressurization issues, special requirements of the space or the preferences of the owner.

**Potential Issues and Cautions**

Use caution when performing test during winter months in cold climates. Since outside airflow must remain constant as supply fan flow is reduced, total supply flow can approach 100% outside air. Be sure that all freeze protection and heating coil controls are functioning before performing 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.

Ensure economizer control is disabled before performing test.

## **8.6.2 Test Procedure: NJ.3.1 Variable Air Volume Systems Outdoor Air Acceptance, Use MECH-2-A**

### ***Construction Inspection***

The system was designed to dynamically maintain the minimum OSA throughout the full range of supply airflow.

If an outside airflow station is part of the system, it is calibrated

If the system relies on a calibrated damper, there is a calibration curve of outside air vs. outside air damper position, inlet vane signal, or VFD signal that is documented in the TAB report.

Attach the calibration certificate to the acceptance test form and check the calibration certificate box under the "Construction Inspection" section of MECH-2-A.

### ***Checkout Procedure if the System Has a Flow Station Installed***

If the manufacturer provides a calibration certificate specifically for the flow station, this is acceptable. Note this includes traditional airflow monitoring stations with an array of pitot-tubes or hot-wire anemometers and other calibrated systems to measure flow. There are several manufactured products that correlate flow to a damper's position using a corresponding pressure measurement. If the calibration certificate indicates that the damper has been calibrated across its intended range of operation, this is sufficient. Attach the calibration certificate to the acceptance test form and check the "Calibration certificate" box in the "Construction Inspection" section of MECH-2-A.

If the manufacturer does not provide a calibration certificate specifically for the flow station, then the flow station must be calibrated in the field with the calibration documented to the satisfaction of the acceptance testing agent. Methods for field calibration of airflow monitoring stations include:

1. Traverse across the outside air duct to measure duct velocity, measure duct size, and calculate flow.
2. Measure face velocity at various points across outside air intake, measure intake damper size, and calculate flow.
3. Traverse across the supply and return ducts to calculate flow (outside airflow can be estimated as the difference between the supply and return flow rates).
4. Measure differential pressure across flow station at test ports and use manufacturer's *pressure vs. flow* curve to determine airflow (least desirable since not actually measuring flow).

After calibrating the flow station to within 10% of measured flow, check the "Field calibration" box in the "Construction Inspection" section of MECH-2-A.

### ***Checkout Procedure if the System Does Not Have a Flow Station Installed***

If the system does not use an airflow monitoring station to directly measure airflow, the Acceptance Agent should review the sequences of operation to ensure that the system has been designed for dynamic control of minimum

outdoor air and review the installation to make sure that all of the devices that are part of that sequence are indeed installed.

There are a number of means to dynamically control minimum OSA. A survey of common methods are presented in Chapter 4 of the Non-Residential User's Manual. After validating that the sequence of control will dynamically control outside air check the "System is designed to dynamically control minimum OSA" box in the "Construction Inspection" section of MECH-2-A.

### **Equipment Testing**

**Step 1: Disable the air-side economizer, if applicable.** For systems with an air-side economizer, disabling the economizer will prevent the outside 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 outside air temperature is below the economizer high limit setpoint. The economizer can be disabled in a number of ways depending on the control strategy used to modulate the outside air dampers:

- Use the high limit switch by reducing the setpoint (return air value or outside 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 2: Disable the demand control ventilation, if applicable.** For systems with demand control ventilation, this control must be disabled during the test of the minimum OSA control as it may interfere with the setpoint for the minimum OSA control. On a multiple zone system, the demand control ventilation will almost assuredly be provided using a DDC control package. Using the DDC software, the reset signal to the minimum OSA control loop can be set to a fixed point equal to the design minimum OSA at full occupancy.

**Step 3: Drive all VAV boxes to the greater of the minimum airflow or 30% of total design airflow.** The intent is to measure outside airflow when the system is operating at or near a minimum flow condition. This point is provided along with the design point to test the minimum OSA control at either end of its control range. If the system has an airflow monitoring station (AFMS) it will test the accuracy of that AFMS at the lowest velocity, its least accurate point. 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:

- Override all space temperature setpoints to a wide range (e.g. 60F heating and 90F cooling) that will force the VAV boxes into the deadband (may be accomplished by a global command or it may have to be done per individual box).
- Command all VAV boxes to minimum flow position (may be accomplished by a global command or it may have to be done per individual box).

- Set maximum flow setpoint to be the same as minimum flow setpoint (may be accomplished by a global command or it may have to be done per individual box).

In all three cases, you must release or restore the zone or box controls to their pretest settings after the test is complete.

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. Be warned that although this is acceptable for testing OSA, this would not meet the requirements of test NJ.9.1 Supply Fan Variable Flow Controls Acceptance for testing the stability of the pressure control loop. These two tests should be done concurrently to minimize cost.

### **Verify and Document**

Measured outside airflow is within 10% of design outside air flowrate found on Mechanical Plan Check document MECH-3-C column I. Acceptable methods for measuring outside airflow include, but are not limited to the following techniques. The recommendations provided earlier for field airflow measurement methods apply here.

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

System operation stabilizes within 15 minutes. The intent is to ensure the PID control loops are tuned properly so that the system does not hunt.

**Step 4: Drive all VAV boxes to achieve design airflow.** The intent is to measure outside airflow when the system is operating at or near full design 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:

- Override all space temperature setpoints to be 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).
- 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).

In either case, you must release or restore the zone or box controls to their pretest settings after the test is complete.

Again, we do not recommend simply forcing the supply fan VFD to a maximum speed since building pressure/return fan/exhaust damper control strategies may adversely impact overall system and outside airflow rates. It is much better to allow the system to react as intended under “normal” operating conditions.

### ***Verify and Document***

Measured outside airflow is within 10% of design outside air flowrate found on Mechanical Plan Check document MECH-3-C column I. Acceptable methods for measuring outside airflow include, but are not limited to the following techniques. The recommendations provided earlier for field airflow measurement methods apply here.

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

System operation stabilizes within 15 minutes. The intent is to ensure the PID control loops are tuned properly so that the system does not hunt.

**Step 5: Return system back to normal operating condition.** Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions. Release any overrides on the economizer or demand ventilation controls.

### ***Exception to Equipment Testing Procedures***

Air handling systems that have a dedicated fan providing ventilation air to the unit would be exempt from measuring ventilation airflow at minimum and maximum supply airflow conditions. An independent ventilation air fan will deliver a constant minimum outside 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.

### ***Verify and Document***

Measured outside airflow is within 10% of design outside air flowrate found on Mechanical Plan Check document MECH-3-C column I. Acceptable methods for measuring outside airflow include, but are not limited to:

- Read the airflow value measured by the flow station.
- Traverse across the outside air duct to measure duct velocity, measure duct size, and calculate flow.
- Measure face velocity at various points across outside air intake, measure intake damper size, and calculate flow.
- Traverse across the supply and return ducts to calculate flow (outside airflow can be estimated as the difference between the

supply and return flow rates)

### 8.6.3 NJ.3.2 Constant Volume Systems Outdoor Air Acceptance At-a-Glance

## NJ.3.2 Constant Volume Systems Outdoor Air Acceptance Use Form MECH-2-A

### Purpose of the Test

The purpose of the test is to ensure that adequate outside air ventilation is provided through the constant volume air handling unit to the spaces served under all operating conditions. The intent of the test is to verify that the minimum volume of outside air, as required per §121(b)2, is introduced to the air handling unit during typical space occupancy. Note that systems requiring demand ventilation controls per §121(c)3 must conform to §121(c)4.E regarding the minimum ventilation rate when the system is in occupied mode.

Related acceptance tests for these systems include the following:

- NJ.4.1 Constant Volume Packaged HVAC Systems Acceptance
- NJ.7.1 (Air-Side) Economizer Acceptance (if applicable)
- NJ.8.1 Demand Control Ventilation Acceptance (if applicable)

### Benefits of the Test

Bringing adequate outside air into all spaces promotes good indoor air quality. Accurately setting outdoor air ventilation rates will avoid over-ventilation and under-ventilation, which leads to heating and cooling energy waste and indoor air quality problems, respectively.

### Instrumentation

Performance of this test will require measuring outside airflow. 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)
- If the system was installed with an airflow monitoring station (AFMS) on the outside air it can be used for the measurements if it has a calibration certificate or is field calibrated.

<b>Test Conditions</b>
<p>To perform the test, it may be necessary to override the control system of the air handling unit. The control system of the air handling unit must be complete.</p> <p><b>All systems must be installed and ready for system operation, including:</b></p> <ul style="list-style-type: none"> <li>• Duct work</li> <li>• Control sensors (temperature, flow, thermostats, etc.)</li> <li>• Electrical power to air handling unit</li> <li>• Completion of air handling unit start-up procedures, per manufacturer's recommendations</li> <li>• 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.</li> </ul> <p>Note: Systems requiring demand ventilation controls per §121(c)3 must conform to §121(c)4.E regarding the minimum ventilation rate (refer to NJ.8.1 Demand Control Ventilation Acceptance Test).</p>
<b>Time to Complete</b>
<p><b>Construction inspection:</b> 0.5 hours</p> <p><b>Equipment testing:</b> 1 hour</p>
<b>Acceptance Criteria</b>
<p>System has a fixed or motorized minimum outdoor air damper, or economizer, capable of maintaining a minimum outdoor air damper position.</p> <p>Measured outside airflow is within 10% of design outside air flowrate found on Mechanical Plan Check document MECH-3-C column I. Note that this design minimum outside air ventilation rate can be significantly greater than the calculated minimum outside air to account for building pressurization issues, special requirements of the space or the preferences of the owner.</p>
<b>Potential Issues and Cautions</b>
<p>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.</p>

**8.6.4 Test Procedure: NJ.3.2 Constant Volume Systems Outdoor Air Acceptance, Use Form MECH-2-A**

***Construction Inspection***

System has a fixed or motorized minimum outdoor air damper, or economizer, capable of maintaining a minimum outdoor air damper position.

- Packaged HVAC systems without an economizer will most likely have a fixed outside 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 (i.e. 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 outside 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 outside air damper/actuator, independent of the economizer control strategy.

### ***Equipment Testing***

**Step 1: Disable the air-side economizer, if applicable.** For systems with an air-side economizer, disabling the economizer will prevent the outside 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 outside air temperature is below the economizer high limit setpoint. The economizer can be disabled in a number of ways depending on the control strategy used to modulate the outside air dampers:

- Use the high-limit switch by reducing the setpoint (return air value or outside 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 2: Disable the demand control ventilation, if applicable.** For systems with demand control ventilation, this control must be disabled during the test of the minimum OSA control as it may interfere with the setpoint for the minimum OSA control. On a multiple zone system, the demand control ventilation will almost assuredly be provided using a DDC control package. Using the DDC software, the reset signal to the minimum OSA control loop can be set to a fixed point equal to the design minimum OSA at full occupancy.

### ***Verify and Document***

Measured outside airflow is within 10% of design outside air flowrate found on Mechanical Plan Check document MECH-3-C column I. Acceptable methods for measuring outside airflow include, but are not limited to, the following

techniques. The recommendations provided earlier for field airflow measurement methods apply here.

- Traverse across the outside air duct to measure duct velocity, measure duct size, and calculate flow.
- Measure face velocity at various points across outside air intake, measure intake damper size, and calculate flow.
- Traverse across the supply and return ducts to calculate flow (outside airflow can be estimated as the difference between the supply and return flow rates).

**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. Release any overrides on the economizer or demand ventilation controls.

**8.6.5 NJ.4.1 Constant Volume Packaged HVAC Systems Acceptance**

At-a-Glance

NJ.4.1 Constant Volume Packaged HVAC Systems Acceptance Use Form MECH-3-A	
<b>Purpose of the Test</b>	The purpose of the test is to verify the individual components of a constant volume packaged HVAC system function correctly, including: thermostat installation and programming and supply fan, heating, cooling, and damper operation. Testing of the economizer, outdoor air ventilation, and demand control ventilation are located in the following sections: <ul style="list-style-type: none"> <li>• NJ.3.2 Constant Volume System Outdoor Air Acceptance</li> <li>• NJ.7.1 (Air-Side) Economizer Acceptance (if applicable)</li> <li>• NJ.8.1 Demand Control Ventilation Acceptance. (if applicable)</li> </ul>
<b>Benefits of the Test</b>	Packaged HVAC systems, one of the most common systems in use in commercial buildings, routinely have operational problems that lead to comfort complaints and energy waste. The test procedures for these units will improve efficiency of new installations, promote quality installations, and verify appropriate control settings.
<b>Instrumentation</b>	None required

Test Conditions
<p>Packaged unit and thermostat installation and programming must be complete.</p> <p>HVAC system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer's recommendations.</p> <p>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.</p>
Time to Complete
<p><b>Construction inspection:</b> 0.5 to 1 hour (depending on familiarity with thermostat programming)</p> <p><b>Equipment test:</b> 1 to 2 hours</p>
Acceptance Criteria
<p>The thermostat is wired to the unit correctly (note this can be inferred from the acceptance tests).</p> <p>The heating and cooling setpoints and schedules have been programmed into a thermostat or central DDC system. The heating and cooling setpoints can be adjusted to least 5°F apart.</p>
Acceptance Criteria
<p>The following modes of operation function correctly:</p> <ul style="list-style-type: none"> <li>• <b>Occupied heating mode operation:</b> The supply fan operates continuously, all heating stages operate, cooling is not enabled, and the outdoor air damper is at minimum position.</li> <li>• <b>Occupied operation with no heating or cooling load:</b> The supply fan operates continuously, heating or cooling are not enabled, and the outdoor air damper is at minimum position.</li> <li>• <b>Occupied cooling mode operation without economizer:</b> The supply fan operates continuously, all cooling stages operate, heating is not enabled, and outside damper is at minimum position.</li> <li>• <b>Unoccupied operation with no heating or cooling load:</b> The supply fan shuts off, heating or cooling are not enabled, and the outdoor air damper is closed.</li> <li>• <b>Unoccupied operation with heating load:</b> The supply cycles ON, heating is enabled, cooling is not enabled, and the outdoor air damper is at minimum position.</li> <li>• <b>Unoccupied cooling mode operation without economizer:</b> The supply cycles ON, cooling is enabled, heating is not enabled, and the outdoor air damper is at minimum position.</li> <li>• <b>Override mode:</b> System reverts to occupied mode, the supply fan turns ON for duration of override, heating or cooling is enabled as necessary, outdoor air damper opens to minimum position.</li> </ul>

**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, it may be necessary to 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.
- 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 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 deadband.
- 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% summer design dry-bulb temperature is greater than or equal to 100°F.

**8.6.6 Test Procedure: NJ.4.1 Constant Volume Packaged HVAC Systems Acceptance, Use Form MECH-3-A**

**Test Comments**

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

**Construction Inspection**

***Thermostat, or temperature sensor, is located within the zone that the HVAC system serves.***

Thermostat is wired to the unit correctly. Note that this can be inferred from the acceptance tests.

1. In particular, ensure that multiple stage terminals (i.e., 1st and 2nd stage wires) on the thermostat, both cooling and heating stages, are wired to the corresponding circuits at the unit.
2. Verify that no factory-installed or field-installed jumpers exist across the 1st and 2nd stage cooling terminals at the unit (this will ensure that only the economizer can be enabled as the 1st stage of cooling).
3. For heat pump only, verify the “O” terminal on the thermostat is wired to the reversing valve at the unit.

4. For heat pump only, verify thermostat dip switch or programmable software is set to heat pump.

Thermostat is capable of achieving a 5°F deadband between heating and cooling setpoints.

Setup and setback (unoccupied) setpoints have been enabled (if required).

Occupied, unoccupied, and holiday schedules have been programmed. Schedules are programmed into an individual thermostat or central DDC system. Note that some thermostat brands require that the thermostat be in the “program” mode of operation in order for time schedules to be enabled.

Pre-occupancy purge has been programmed per §121(c)2. This is most easily accomplished by scheduling the unit to start one hour prior to actual occupancy.

### ***Equipment Testing***

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

#### ***Step 1: Simulate heating load during occupied condition. (Mode A on MECH-3-A form).***

- Set “occupied” time schedule to include actual time or adjust time to be within the “occupied” time schedule (which ever is easier).
- Set heating setpoint above actual space temperature.

#### ***Verify and Document***

- Supply fan operates continually during occupied condition.
- Ensure all available heating stages operate. 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 deviation from setpoint to enable multiple heating stages. Setting the heating setpoint very high should prevent the 1st stage of heat from meeting setpoint and allow the system adequate time to enable the 2nd or 3rd stages.
- Cooling is not enabled.
- Outside air damper is open to minimum ventilation position (Note: Outdoor ventilation air requirements will be tested under section **NJ.3.2 Constant Volume System Outdoor Air Acceptance**).

#### ***Step 2: Simulate dead band operation during occupied condition. (Mode B)***

- Set “occupied” time schedule to include actual time or adjust time to be within the “occupied” time schedule (which ever 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.
- Heating or cooling should not be enabled.
- Outside air damper is open to minimum ventilation position.

**Step 3: For systems without an economizer, simulate cooling load during occupied condition. Mode F**

- Set “occupied” time schedule to include actual time or adjust time to be within the “occupied” time schedule (which ever 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. 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 1st stage of cooling from meeting setpoint and allow the system adequate time to enable the 2nd stage.
- Heating is not enabled.
- Outside air damper is open to minimum ventilation position.

**Step 4: Simulate dead band operation during unoccupied condition. Mode D**

- Set “unoccupied” time schedule to include actual time or adjust time to be within the “unoccupied” time schedule (which ever 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.
- Neither heating or cooling is enabled.
- Outside air damper is completely shut.

**Step 5: Simulate heating load during unoccupied condition.**

**Mode C Note:** This test is only applicable for all systems in a climate where the design winter median of extremes is less than or equal to 32°F (that are not exempt by §122(e)2.A).

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

- Set heating setpoint above actual space temperature.

*Verify and Document*

- Supply fan cycles on with call for heating.
- Heating is enabled.
- Cooling is not enabled.

**Step 6: For systems without an economizer, simulate cooling load during unoccupied condition.**

Mode G Note: systems with an economizer will be tested for proper system operation under a cooling load in section NJ.7.1 Economizer Acceptance. This test is only applicable for those systems in a climate where the 0.5% summer design dry-bulb temperature is greater than or equal to 100°F (other systems are exempted by §122(e)2.B).

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

*Verify and Document*

- Supply fan cycles on with call for cooling.
- Heating is not enabled.
- Cooling is enabled.
- Outside air damper.

**Step 7: Simulate manual override during unoccupied condition. Mode E**

- Set “unoccupied” time schedule to include actual time or adjust time to be within the “unoccupied” time schedule (which ever is easier).
- Engage the manual override. This could entail pushing an override button, triggering an occupancy 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.
- Supply fan turns on and stays on for the duration of the timed override period.
- Heating or cooling is enabled as necessary to maintain space temperature setpoint. Actual operation of the equipment depends on whether heating or cooling is needed at the time of the test.

- Outside air damper opens to minimum ventilation position and remains open for the duration of the timed override period. If the system has an economizer and there is call for cooling during the manual override, then the economizer should be enabled as necessary.
- System reverts back to an “unoccupied” condition at the end of the timed override period. It may be necessary to adjust the length of the override period to minimize test time.

***Step 8: For systems with an economizer, simulate cooling load during occupied condition (Mode H).***

- Set “occupied” time schedule to include actual time or adjust time to be within the “occupied” time schedule (which ever 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. 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 1st stage of cooling from meeting setpoint and allow the system adequate time to enable the 2nd stage.
- Heating is not enabled
- System passes tests for economizer in **NJ.7.1 Air-Side Economizer Acceptance** and documented on form **MECH-4-A**.

***Step 9: For systems with an economizer, simulate cooling load during unoccupied condition (Mode I).***

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

*Verify and Document*

- Supply fan cycles on with call for cooling.
- Heating is not enabled.
- Cooling is enabled.
- Outside air damper is closed.
- System passes tests for economizer in **NJ.7.1 Air-Side Economizer Acceptance** and documented on form **MECH-4-A**.

**Step 10: Return system back to normal operating condition.**

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

**8.6.7 NJ.7.1 Air-Side Economizer Acceptance****At-a-Glance****NJ.7.1 (Air-Side) Economizer Acceptance****Use Form MECH-4-A****Purpose of the Test**

The purpose of functionally testing an air-side economizer cycle is to verify that an HVAC system uses outside air to satisfy space cooling loads when outside air conditions are acceptable. There are two types of economizer controls:

- stand-alone packages and DDC controls. The stand-alone packages are commonly associated with rooftop packaged HVAC equipment and DDC controls are typically associated with built-up or large packaged air handling systems. Test procedures for both economizer control types are provided.

For units with economizers that are factory installed and certified operational by the manufacturer to California Energy Commission economizer quality control requirements, the in field economizer acceptance test does not have to be conducted. A copy of the certification certificate must be attached to the MECH-4-A. All pre-test inspections must be completed regardless of whether the economizer is factory or field installed.

**Benefits of the Test**

Ensuring that the economizer fully utilizes outside air for “free cooling” can save significant cooling energy compared to operating mechanical refrigeration.

Provision and control of building relief prevents building over pressurization which is a common reason for economizers being disabled by building operators.

Since an economizer cycle will bring in outdoor air beyond what is required for ventilation purposes, it will improve building indoor air quality.

**Instrumentation**

None required

<b>Test Conditions</b>
<p>Equipment installation is complete (including HVAC unit, duct work, sensors, control system, thermostats).</p> <p>Simple systems are required to have a two-stage thermostat.</p> <p>HVAC system must be ready for system operation, including completion of all start-up procedures per manufacturer's recommendations.</p> <p>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.</p> <p>For built-up systems all interlocks and safeties must be operable--for example, freeze protection, limit switches, static pressure cut-out, etc.</p> <p>Document the initial conditions before overrides or manipulation of the settings. All systems must be returned to normal at the end of the test.</p>
<b>Time to Complete</b>
<p>Construction Inspection: 0.5 to 1 hours (depending on familiarity with the controls)</p> <p>Equipment Testing: 0.5 to 2 hours (depending on familiarity with the controls and issues that arise during testing)</p>
<b>Acceptance Criteria</b>
<p>If the economizer is factory installed and certified, a valid factory certificate is required for acceptance. No additional equipment tests are necessary.</p> <p>Air-Side Economizer lockout setpoint complies with Table 144-C per Standards Section 144(e)3. Outside sensor location accurately reads true outdoor air temperature and is not affected by exhaust air or other heat sources.</p> <p>All sensors are located appropriately to achieve the desired control.</p> <p>During economizer mode, the outside air damper modulates open to a maximum position and return air damper modulates 100% closed.</p> <p>The outside air damper is 100% open before mechanical cooling is enabled and for units 75,000 Btuh and larger remains at 100% open while mechanical cooling is enabled (economizer integration when used for compliance).</p> <p>When the economizer is disabled, the outside air damper closes to a minimum position, the return damper modulates 100% open, and mechanical cooling remains enabled.</p>

**Potential Issues and Cautions**

If conditions are below freezing when test is performed, coil(s) may freeze when operating at 100% outside 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-Side Economizers with poor mixing can have excessively stratified air streams that can cause comfort problems or freezestat trips. 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% OSA).

### **8.6.8 Test Procedure: NJ.7.1 Air-Side Economizer Acceptance, Use Form MECH-4-A**

#### ***Purpose (Intent) of Test***

There are basically two types of economizer controls: 1) stand-alone packages (i.e. Honeywell W7459A, Trane Precedent or Voyager, Carrier Durablade, which are most common); and 2) DDC controls. The stand-alone packages are most commonly associated with rooftop packaged HVAC equipment and DDC controls 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.

If the economizer is factory installed and certified **by the manufacturer to the California Energy Commission**, no field testing is required.

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 outside air sensor; a return air sensor where differential high-limit controls are used; and a mixed/discharge air temperature sensor to which the economizer is controlled. 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).

In general, a first-stage call for cooling from the zone thermostat will enable the economizer controller, which will either allow the outside air damper to open fully if outside air conditions are suitable or enable the compressor. The four strategies available for economizer control are: 1) fixed dry-bulb; 2) fixed enthalpy; 3) differential dry-bulb; and 4) differential enthalpy. The fixed dry-bulb and enthalpy strategies both compare outside air conditions to a "fixed" setpoint to determine if the economizer can be enabled, whereas differential dry-bulb and enthalpy strategies compares outside air and return air conditions to enable

the economizer when outside air conditions are more favorable. When the zone thermostat calls for a second-stage of cooling, the compressor is enabled to provide mechanical cooling. 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 Standards, they must have integrated controls.

### ***Construction Inspection***

Air-Side Economizer high temperature lockout setpoint complies with Standards Table 144-C per §144(e)3. For DDC control systems, the lockout setpoint should be a control parameter in the sequence of operations that can be verified for compliance. For stand-alone packages, the lockout 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. Note that snap disks may not comply with lockout requirements in some climate zones. A snap disk is a thermostat-type control device with a fixed setpoint. The snap disk will close the economizer circuit when air temperature is below setpoint and open the circuit when the air temperature exceeds setpoint. Snap disks are not adjustable and can disable the economizer anywhere between 65°F and 70°F. Hence, snap disks will fail unless the manufacturer can provide documentation verifying the snap disk operating temperature complies with Standards Table 144-C. The control complies if the high limit lockout setpoint is less than the values specified in the table.

Table 8-4 – Standards Table 144-C Air Economizer High Limit Shut Off Control Requirements

Device Type	Climate Zones	Required High Limit (Economizer Off When):	
		Equation	Description
Fixed Dry Bulb	1, 2, 3, 5, 11, 13, 14, 15 & 16	$T_{OA} > 75^{\circ}\text{F}$	Outside air temperature exceeds 75°F
	4, 6, 7, 8, 9, 10 & 12	$T_{OA} > 70^{\circ}\text{F}$	Outside air temperature exceeds 70°F
Differential Dry Bulb	All	$T_{OA} > T_{RA}$	Outside air temperature exceeds return air temperature
Fixed Enthalpy <sup>a</sup>	4, 6, 7, 8, 9, 10 & 12	$h_{OA} > 28 \text{ Btu/lb}^b$	Outside air enthalpy exceeds 28 Btu/lb of dry air <sup>b</sup>
Electronic Enthalpy	All	$(T_{OA}, RH_{OA}) > A$	Outside air temperature/RH exceeds the "A" set-point curve <sup>c</sup>
Differential Enthalpy	All	$h_{OA} > h_{RA}$	Outside air enthalpy exceeds return air enthalpy
<i>a Fixed Enthalpy Controls are prohibited in climate zones 1, 2, 3, 5, 11, 13, 14, 15 &amp; 16.</i>			
<i>b At altitudes substantially different than sea level, the Fixed Enthalpy limit value shall be set to the enthalpy value at 75°F and 50% relative humidity. As an example, at approximately 6000 foot elevation the fixed enthalpy limit is approximately 30.7 Btu/lb.</i>			
<i>c Set point "A" corresponds to a curve on the psychrometric chart that goes through a point at approximately 75°F and 40% relative humidity and is nearly parallel to dry bulb lines at low humidity levels and nearly parallel to enthalpy lines at high humidity levels.</i>			

- For stand-alone packages only, 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. The two-stage space thermostat must have wires connected to Y1 and Y2 on the thermostat landed on the respective Y1 and Y2 terminals at the unit. There should not be any jumpers installed across Y1 and Y2 at the thermostat or the unit. For York units in particular, verify that the "J1" jumper located on the OEM board has been removed. The units come from the factory with the "J1" jumper installed and must be removed in the field (the "J1" jumper is the same as having a jumper across the Y1 and Y2 terminals – the compressor and economizer come on simultaneously on a call for cooling, which effectively makes the economizer inoperable). Note that if a single-stage thermostat is installed, there should not be any jumper between Y1 and Y2.
- Air-Side Economizer outside (lockout) sensor location is adequate to achieve the desired control. Outside 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).
- Ensure all systems have some method of relief to prevent over pressurization of the building. 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 actively maintain building pressurization when the unit is in economizer mode.

### ***Equipment 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 between various stand-alone packages themselves. Contact your equipment supplier to see if they have equipment and test protocols that will allow you to easily field test their economizer to ACM NJ.7.1 Air-Side Economizer Acceptance for filling out form MECH-4-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.

### ***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. Use internal test sequences to enable operating modes.***

Refer to manufacturer’s literature for detailed description of the procedures, however 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***

- Outside air damper is at minimum position when the supply fan is enabled.
- The outside air damper opens completely and the return damper closes completely during economizer mode.
- Outside air damper is at minimum position when the compressor is enabled.
- Outside air damper is at minimum position when heating is enabled.
- 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 2. Return system to normal operation.**

Taking the system out of test mode can be accomplished by shutting power off to the unit. The unit will return to normal operation when power is restored.

*Verify and Document*

- Final economizer changeover dip-switch settings comply with Standards Table 144-C per §144(e)3.

**Honeywell controllers.** There are many Honeywell controllers available, but the most common is the W7459A series and most of the procedures used to check out this controller can be used on the others as well (always refer to manufacturer's literature for additional information). All Honeywell controllers have an 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. Note that the controllers typically come from the factory with the adjustment pot at the "D" setting, but this does not mean a differential control strategy is being used. The easiest way to verify a differential changeover strategy is to look at the S<sub>R</sub> and + terminals on the controller. If standard sensor wires are connected to the terminals, then it is a differential control strategy. If there is a 620 Ohm resistor jumpered across these terminals, then a fixed control strategy is being used.

**Step 1. 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 1.2K Ohm resistor across the S<sub>O</sub> and + terminals on the controller (this is the outside air temperature sensor).
- Install a 620 Ohm resistor across the S<sub>R</sub> and + terminals on the controller (this resistor is already installed for a fixed control strategy and must only be installed 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.
- Disconnect the wire from the Y2 terminal at the unit terminal strip (this will prevent the 2nd stage of cooling from being enabled during the test).
- Turn the unit back ON at the disconnect.

*Verify and Document*

- Outside 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 does not run.

**Step 2. Simulate a cooling load and disable the economizer.**

Continuing from above:

- Turn the unit OFF at the disconnect.
- Leave the 1.2K Ohm resistor across the S<sub>O</sub> and + terminals and 620 Ohm resistor across the S<sub>R</sub> 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.
- Leave Y2 disconnected.
- Turn the unit back ON at the disconnect.

*Verify and Document*

- Outside 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 3: Return system back to normal operating condition.**

Remove all jumpers and reconnect all wires.

*Verify and Document*

- Final economizer changeover setting (A,B,C,D) complies with Standards Table 144-C per §144(e)3. Consult with manufacturer’s literature to determine the appropriate A, B, C, D setting for both fixed dry-bulb or enthalpy control strategies. The controller must be set on “D” for all differential control strategies.

**Carrier Durablade.** Most Carrier HVAC units utilize 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 utilizes 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. 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 outside 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 2nd 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 outside air intake. Adjust end-switches as necessary to achieve the desired position.
- Compressor does not run.

**Step 2. Simulate a cooling load and disable the economizer.**

Continuing from above:

- Turn the unit OFF at the disconnect.
- Remove the jumper and disconnect the outside 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 outside air position. Adjust end switches as necessary to achieve the desired position.
- Compressor operates.

**Step 3: Return system back to normal operating condition.**

Remove all jumpers and reconnect all wires.

*Verify and Document*

- Final economizer changeover setting complies with Standards Table 144-C per §144(e)3.

**DDC Controls**

**Step 1. 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 setpoint to be lower than current discharge conditions.
- For a fixed dry-bulb or enthalpy control strategy, raising the economizer lockout setpoint to be above current outside air conditions (if this is not the case already) to enable the economizer.

- For a differential dry-bulb or enthalpy control strategy; raising the return air conditions to be above current outside air conditions (if this is not the case already) to enable the economizer.

*Verify and Document*

- Outside air damper modulates open to a maximum position.
- Return air damper modulates closed and is 100% closed when the outside air dampers are 100% open. Return dampers should close tight to minimize leakage.
- Outside air damper is 100% open before mechanical cooling is enabled. This 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% economizer mode. Depending on the speed of the PID loop, it is possible that mechanical cooling could be commanded on before the outside air dampers actually stroke fully open. If this occurs, it does not mean the system has failed the test. One option is to watch the output of the PID loop and verify that the *COMMAND* sent to the outside air damper reaches 100% before a command is sent to the mechanical cooling devices.
- Although space pressurization requirements are not part of the current 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 (i.e., perimeter doors pushed open or excessive airflow between zones served by different units).

**Step 2. Simulate a cooling load and disable the economizer.**

Continuing from the procedures outlined in Step 1:

- 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 outside 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 outside air conditions (if this is not the case already) to disable the economizer.

*Verify and Document*

- Outside 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 3: Return system back to normal operating condition.***

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

## 8.6.9 NJ.5.1 Air Distribution Acceptance At-a-Glance

### NJ.5.1 Air Distribution Acceptance Use Form MECH-5-A

#### Purpose of the Test

The purpose of this test is to verify all duct work associated with all non-exempt constant volume, single-zone, HVAC units (i.e. air conditioners, heat pumps, and furnaces) meet the material, installation, and insulation R-values per §124(a) requirements of §144(k), including construction materials, installation, insulation R-values, and that duct leakage does not exceed the maximum allowable leakage fraction per §144(k) for new duct systems or §149(b)1D for existing duct systems.

As detailed in the Standard this test is only required for single-zone units serving 5,000 ft<sup>2</sup> of space or less where 25% or more of the duct surface area is in one of the following spaces:

- Outdoors, or
- In a space directly under a roof where the U-factor of the roof is greater than the U-factor of the ceiling, or
- In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces, or
- In an unconditioned crawlspace; or
- In other unconditioned spaces.

Within this criteria, this test applies to both new duct systems and to existing duct systems which are either being extended or the space conditioning system is altered by the installation or replacement of space conditioning equipment 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.

#### Benefits of the Test

Duct construction and insulation can have adverse impacts on energy usage and duct-system durability. These are most acute where the ducts are located in unconditioned spaces or out of doors.

#### Instrumentation

Performance of this test will require measuring airflow. Equipment used:

- Fan flowmeter (a fan with a calibrated orifice used to assure the ducts) accuracy within 3% of measured flow. Contact CalCerts, CBPCA, or CHEERS for proper equipment.
- Digital manometer (pressure meter) accuracy within 0.2 Pascals.

Duct leakage tests must be verified by a certified HERS rating agency certified by the California Energy Commission. There are currently three companies that certify HERS raters. They can be found at <http://www.CalCerts.com>, <http://www.CBPCA.org/> or <http://www.CHEERS.org>.

<b>Test Conditions</b>
<p>For new construction all ductwork must be accessible for visual inspection. Hence, visual inspection must be performed before ceiling is installed.</p> <p>All ductwork and grilles should be in place before performing the fan flow test to ensure system depicts normal operating configuration. Hence, testing must occur after visual inspection and installation of the diffusers.</p> <p>HVAC system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer's recommendations.</p>
<b>Time to Complete</b>
<p><b>Construction Inspection:</b> 0.5 to 2 hours (depending on duct access for visual inspections and availability of construction material documentation – i.e. cut sheets, etc.)</p> <p><b>Equipment Test:</b> 3 to 6 hours (depending on how long it takes to seal all supply diffusers and return grilles and whether total system airflow is measured rather than calculated)</p>
<b>Acceptance Criteria</b>
<p>Flexible ducts are not constricted in any way.</p> <p>Drawbands are either stainless steel worm-drive hose clamps or UV-resistant nylon duct ties. Joints and seams are not sealed with a cloth-back rubber adhesive tape unless used in combination with mastic and drawbands.</p> <p>Duct R-values comply with Standards and insulation is protected from damage per Standards.</p> <p>For new duct systems, the leakage fraction for the HVAC duct system does not exceed 6%, where the leakage fraction is calculated by dividing total measured leakage flow rate by the total fan system flow rate.</p> <p>For existing duct systems (covered by Standard Sections 149b1(D or E), the leakage fraction for the HVAC duct system does not exceed either 15% or leakage is reduced by a 60% The leakage fraction is calculated by dividing total measured leakage flow rate by the total fan system flow rate.</p> <p>Duct installation, insulation and leakage verified by a Home Energy Rating System (HERS) rater.</p>
<b>Potential Issues and Cautions</b>
<p>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.</p> <p>Ensure all of the supply and return diffusers/grilles are sealed tightly, all access panels are in place, and duct ends are sealed tightly prior to leakage testing.</p> <p>After the test, remember to remove all blockages from the supply and return ducts (i.e., 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.</p> <p>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.</p>

### **8.6.10 Test Procedure: NJ.5.1 Air Distribution Acceptance, Use Form MECH-5-A**

#### ***Scope of the Requirements***

This test only applies to single-zone units serving 5,000 ft<sup>2</sup> of space or less where 25% or more of the duct surface area is in one of the following spaces:

- Outdoors, or
- In a space directly under a roof where the U-factor of the roof is greater than the U-factor of the ceiling, or
- In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces, or
- In an unconditioned crawlspace; or
- In other unconditioned spaces

Within this criteria, this test applies to both new duct systems and to existing duct systems which are either being extended or the space conditioning system is altered by the installation or replacement of space conditioning equipment 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.

#### ***Purpose (Intent) of Test***

The duct work of these small single-zone systems with ducts in unconditioned spaces must meet the requirements of §144(k) for duct leakage and new duct systems must meet the requirements of §124 including construction materials, installation, and insulation R-values.

#### ***Construction Inspection***

The first component of the construction inspection is to assure that the duct system falls under the scope this test (see above *Scope of the Requirements*). Most of the rest of the construction inspection applies to new duct systems. For existing duct system the purpose of this test is to assure the ducts do not leak excessively and do not require that existing ducts have to be brought up to current standards in terms of insulation, or requirements for fasteners. Perform a brief review of 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 (i.e., 180° angles). Flex duct that is constricted can increase system static pressure as well as compromise insulation values. Verify compliance through visual inspection.

- Duct leakage tests shall be performed before access to ductwork and associated connections are blocked by permanently installed construction material. The intent here is to ensure construction modifications can be made, if necessary, before access to the ductwork is restricted.
- Joints and seams are not sealed with a cloth-back rubber adhesive tape unless used in combination with mastic and drawbands. Verify compliance through visual inspection.
- Duct R-values are verified. Duct insulation R-value shall comply with §124(a), 124(c), and 124(d), and can be verified by reviewing material cut sheets and through visual inspection.
- Insulation is protected from damage per §124(f). Verify compliance by reviewing material cut sheets and through visual inspection.

### **Equipment Testing**

Refer to the Scope section above for where this test is required. Where it is required the test will often be conducted by the installer and verified by a HERS rater using the procedures outlined in the Nonresidential ACM Manual, Appendix NG, Section 4.3.8.2 and documented on compliance form, MECH-5-A.

The primary metric calculated is the leakage fraction of **total fan flow**. Total fan flow is based on the cooling capacity of heating and cooling equipment and based on the heating capacity of heating only equipment. Total fan flow is determined to be 400 cfm/ton for cooling or heating and 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 21.77 cfm per kBtu. The cooling and heating capacity of equipment can be found on the product nameplate.

For new duct systems, the installer blocks off all of the supply and return registers or diffusers and pressurizes the ducts with a fan flowmeter to 25 Pascals (Pa) and records the leakage airflow measured by the fan flowmeter. This leakage amount at 25 Pa is divided by the total fan flow for the leakage percentage. If this leakage percentage is less than or equal to 6%, the system passes. If the system does not pass, then the installer should look of all accessible leaks and seal any gaps. It is easier to find leaks with the ducts pressurized as one can often feel the air escaping from larger gaps.

For existing duct systems that are having additional ducts added or are having major repairs or replacement of equipment connected to the ducts, the leakage rate of the existing duct system should be tested first before any alterations proceed. This leakage amount is the **Pre-test** leakage value. After the additional ducts or equipment repairs or replacements conducted, then the ducts are sealed along any fittings or joints. After blocking off all supply and return registers or diffusers, the ducts are then pressurized using a fan flowmeter to 25 Pascals (Pa) and the fan flowmeter measures the **final test** leakage rate at 25 Pa. This final test leakage amount at 25 Pa is divided by the total fan flow for the leakage percentage. If this leakage percentage is less than or equal to 15%, the system passes. If the system does not pass, then the installer should look of all accessible leaks and seal any gaps. It is easier to find leaks with the ducts pressurized as one can often feel the air escaping from larger gaps.

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

If the final test leakage is 60% lower than the pre-test leakage rate and a visual inspection finds no accessible leaks, crushed ducts, animal infestation, rusted ducts etc., this will be sufficient to pass this requirement.

If the system meets neither the 15% leakage percentage nor was it possible to reduce the pre-tested leakage value by 60%, 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 acceptance test, the installer shall affix a sticker to the air handler access door describing if the system met the prescriptive leakage requirements (6% leakage for new systems and 15% for existing systems or if the system) or if the system failed to meet this standard but that all accessible leaks were sealed. The installer supplies three stickers and can have their company logo on them. However, the following information must be on the sticker in 14 pt font or larger.

### ***Document management***

After conducting the air distribution acceptance test, the installer will contact the HERS rater so that the results can be validated. The *Construction Inspection* and the *Installer Certification* portion of MECH-5-A will be sent to the HERS Provider, the Builder (General Contractor or Construction Manager), the Building Owner at Occupancy and the Building Department.

The HERS rater will validate the results by filling out the HERS Rater Compliance Statement portion of MECH-5-A and send copies to the Builder (General Contractor or Construction Manager), the Building Owner at Occupancy and the Building Department. If the test complies by virtue of the tested leakage (6% for new ducts and 15% for existing ducts) or by virtue of a 60% leakage reduction before the system was repaired or altered, the HERS rater will sample ducts system by installer, having only to sample every one out of seven systems. For existing duct systems that fail both the 15% leakage rate and the 60% reduction in leakage, the HERS rater will validate all of these systems (100% sampling) by visual inspection.

### ***Reference material from ACM Manual Appendix NJ***

Below are excerpts of air distribution acceptance testing requirements from ACM Manual Appendix NG Standard Procedure for Determining the Energy Efficiencies of Single-Zone Nonresidential Air Distribution Systems in Buffer Spaces or Outdoors

#### ***NG.4.1 Instrumentation Specifications***

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

*NG.4.1.1 Pressure Measurements*

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of  $\pm 0.2$  Pa. All pressure measurements within the duct system shall be made with static pressure probes.

*NG.4.1.2 Duct Leakage Measurements*

The measurement of air flows during duct leakage testing shall have an accuracy of  $\pm 3\%$  of measured flow using digital gauges.

All instrumentation used for duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the above accuracy requirement. 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.

*NG.4.2 Apparatus**NG.4.2.1 Duct Pressurization***California Air Distribution Acceptance (Duct Leakage) Certification**

"The leakage of the air distribution ducts was found to be \_\_\_CFM @ 25 Pascals or \_\_\_% of total fan flow.

This system (check one):

Has a leakage rate that is **equal to or lower** than the prescriptive requirement of 6% leakage for new duct systems or 15% leakage for alterations to existing systems. It meets the prescriptive requirements of California Title 24 Energy Efficiency Standards.

Has a leakage rate **higher than** 6% leakage for new duct systems or 15% leakage for altered existing systems. It does NOT meet the meet or exceed the prescriptive requirements of the Title 24 standards. However, all accessible ducts were sealed.

Signed: \_\_\_\_\_

Print name: \_\_\_\_\_

Print Company Name: \_\_\_\_\_

Print Contractor License No: \_\_\_\_\_

Print Contractor Phone No: \_\_\_\_\_

Do not remove sticker

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section NG.4.1.2.

*NG.4.3.7 Total Fan Flow*

The total fan flow for an air conditioner or a heat pump for **all climate zones** shall be equal to 400 cfm/rated ton with rated tons defined by unit scheduled capacity at the conditions the unit's ARI rating standard from Section 112 of the Standard. Airflow through heating only furnaces shall be based on 21.7 cfm/kBtuh rated output capacity.

*NG.4.3.8.2 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 NG-3 shows the leakage criteria and test procedures that may be used to demonstrate compliance. In addition to the minimum tests shown, existing duct systems may be tested to show they comply with the criteria for new duct systems.

*Table 8-5 – NG-3 Duct Leakage Tests*

Case	User and Application	Leakage criteria, % of total fan flow	Procedure
Sealed and tested new duct systems	Installer Testing HERS Rater Testing	6%	NG 4.3.8.2.1
Sealed and tested altered existing duct systems	Installer Testing HERS Rater Testing	15% Total Duct Leakage	NG 4.3.8.2.1
	Installer Testing and Inspection HERS Rater Testing and Verification	60% Reduction in Leakage and Visual Inspection	NG 4.3.8.2.2 RC4.3.6 and RC4.3.7
	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed And Visual Inspection	NG 4.3.8.2.3 RC4.3.6 and RC4.3.7

*NG.4.3.8.2.1 Total Duct Leakage Test 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 both the supply and return ducts to 25 Pascals with all ceiling diffusers/grilles and HVAC equipment installed. When existing ducts are to be altered, this test shall be performed prior to and after duct sealing. The following procedure shall be used for the fan pressurization tests:

- 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.

- For newly installed or altered ducts, verify that cloth backed rubber adhesive duct tape has not been used.
- Seal all the supply and return registers, except for one return register or the system fan access. Verify that all outside air dampers and /or economizers are sealed prior to pressurizing the system.
- Attach the fan flowmeter device to the duct system at the unsealed register or access door.
- Install a static pressure probe at a supply.
- Adjust the fan flowmeter to produce a 25 Pascal (0.1 in water) pressure difference between the supply duct and the outside or the building space with the entry door open to the outside.
- Record the flow through the flowmeter ( $Q_{\text{total},25}$ ) - this is the total duct leakage flow at 25 Pascals.
- Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than 6% for new duct systems or less than 15% for altered duct systems, the system passes.
- Duct systems that have passed this total leakage test will be sampled by a HERS rater to show compliance.

#### *NG 4.3.8.2.2 Leakage Improvement from Fan Pressurization of Ducts*

For altered existing duct systems which have a higher leakage percentage than the Total Duct leakage criteria in Section NG 4.3.8.2.1, the objective of this test is to show that the original leakage is reduced through duct sealing as specified in Table NG-3. The following procedure shall be used:

- Use the procedure in NG 4.3.8.2.1 to measure the leakage before commencing duct sealing.
- After sealing is complete use the same procedure to measure the leakage after duct sealing.
- Subtract the sealed leakage from the original leakage and divide the remainder by the original leakage. If the leakage reduction is 60% or greater of the original leakage, the system passes.
- Complete the Visual Inspection specified in NG 4.3.8.2.4.

Duct systems that have passed this leakage reduction test and the visual inspection test will be sampled by a HERS rater to show compliance.

#### *NG 4.3.8.2.3 Sealing of All Accessible Leaks*

For altered existing duct systems that do not pass the Total Leakage test (NG 4.3.8.2.1), the objective of this test is to show that all accessible leaks are sealed and that excessively damaged ducts have been replaced. The following procedure shall be used:

- Complete each of the leakage tests
- Complete the Visual Inspection as specified in NG 4.3.8.2.4.

All duct systems that could not pass either the total leakage test or the leakage improvement test will be tested by a HERS rater to show compliance. This is a sampling rate of 100%.

*NG 4.3.8.2.4 Visual Inspection of Accessible Duct Sealing*

For altered existing duct systems that fail to be sealed to 15% of total fan flow, the objective of this inspection is to confirm that all accessible leaks have been sealed and that excessively damaged ducts have been replaced. The following procedure shall be used:

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

*NG 4.3.8.4 Labeling requirements for tested systems*

A sticker shall be affixed to the exterior surface of the air handler access door with the following text in 14 point font:

**California Air Distribution Acceptance (Duct Leakage) Certification**

"The leakage of the air distribution ducts was found to be \_\_\_ CFM @ 25 Pascals or \_\_\_% of total fan flow.

This system (check one):

Has a leakage rate that is **equal to or lower** than the prescriptive requirement of 6% leakage for new duct systems or 15% leakage for alterations to existing systems. It meets the prescriptive requirements of California Title 24 Energy Efficiency Standards.

Has a leakage rate **higher than** 6% leakage for new duct systems or 15% leakage for altered existing systems. It does NOT meet the meet or exceed the prescriptive requirements of the Title 24 standards. However, all accessible ducts were sealed.

Signed: \_\_\_\_\_

Print name: \_\_\_\_\_

Print Company Name: \_\_\_\_\_

Print Contractor License No: \_\_\_\_\_

Print Contractor Phone No: \_\_\_\_\_

Do not remove sticker"

**8.6.11 NJ.8.1 Demand Control Ventilation Acceptance**  
**At-a-Glance**

<b>NJ.8.1 Demand Control Ventilation Acceptance</b> <b>Use Form MECH-6-A</b>	
<b>Purpose of the Test</b>	
	<p>The purpose of the test is to verify that systems required to employ demand control ventilation (refer to §121(c)3) can vary outside ventilation flow rates based on maintaining interior carbon dioxide (CO<sub>2</sub>) concentration setpoints. Demand control ventilation refers to an HVAC system’s ability to reduce outside air ventilation flow below design values when the space served is at less than design occupancy. CO<sub>2</sub> is a good indicator of occupancy load and is the basis used for modulating ventilation flow rates.</p>
<b>Benefits of the Test</b>	
	<p>The Standards state that all non-exempt HVAC systems can maintain a minimum ventilation flow rate no less than the value calculated per §121(c)4.E, as long as measured CO<sub>2</sub> concentrations do not exceed specified levels. Lowering ventilation airflow based on actual load (as indicated by CO<sub>2</sub> level) reduces energy usage associated with heating, cooling, or dehumidification of the outside ventilation air delivered to the space.</p>
<b>Instrumentation</b>	
	<p>To perform the test, it may be necessary to vary and possibly measure (if calibration is necessary) ambient CO<sub>2</sub> levels. The instrumentation needed to perform the task may include, but is not limited to:</p> <ul style="list-style-type: none"> <li>• Hand-held reference CO<sub>2</sub> probe calibrated to +/-10 ppm</li> </ul>
<b>Test Conditions</b>	
	<p>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 control ventilation strategy must be complete. To perform the test, it may be necessary to use BAS to override or temporarily modify the CO<sub>2</sub> sensor reading.                      Air-Side Economizer is disabled so that it will not interfere with outside 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.</p>

<b>Time to Complete</b>
<p><b>Construction inspection:</b> 0.5 to 1 hours (depending on CO<sub>2</sub> sensor calibration)</p> <p><b>Equipment testing:</b> 1 to 2 hours (depending on how ambient CO<sub>2</sub> concentration levels are manipulated, system response time to variations in CO<sub>2</sub>)</p>
<b>Acceptance Criteria</b>
<p>Each CO<sub>2</sub> sensor is factory calibrated (with calibration certificate) or field calibrated.</p> <p>Each CO<sub>2</sub> sensor is wired correctly to the controls to ensure proper control of the outdoor air damper.</p> <p>Each CO<sub>2</sub> sensor is located correctly within the space 1 to 6 feet above the floor.</p> <p>Interior CO<sub>2</sub> concentration setpoint is 600 ppm plus outside air CO<sub>2</sub> value if dynamically measured or 1000 ppm if no OSA sensor is provided.</p> <p>A minimum OSA setting is provided whenever the system is in Occupied mode per Standard §121(c)4E regardless of space CO<sub>2</sub> readings.</p> <p>A maximum OSA damper position for DCV control can be established per the exception to §121(c)4C, regardless of space CO<sub>2</sub> readings.</p> <p>The outside air damper modulates open when the CO<sub>2</sub> concentration within the space exceeds setpoint,</p> <p>The outside air damper modulates closed (toward minimum position) when the CO<sub>2</sub> concentration within the space is below setpoint.</p>
<b>Potential Issues and Cautions</b>
<p>Lock out the economizer control during the test. Outside air damper may not modulate correctly if the economizer control strategy is controlling damper operation.</p> <p>Overall test time may be reduced (especially for rooftop HVAC units) if two people perform the test - one to vary the CO<sub>2</sub> concentration while someone else verifies operation of the outside air dampers.</p> <p>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.</p>

### **8.6.12 Test Procedure: NJ.8.1 Demand Control Ventilation Acceptance, Use Form MECH-6-A**

#### *Test Comments and Applicability*

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

- Single-zone systems. The intent was to limit the demand control ventilation requirement to systems that primarily serve spaces with variable occupancy. Keep in mind, however, that 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 control 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 HVAC system must have an economizer. The reason for this requirement is that the system must have the ability to modulate outside airflow.
- Spaces served with specific use types or have the following occupancy densities, as described in the Uniform Building Code (UBC) Chapter 10, must utilize DCV control:
  - Assembly areas, concentrated use (without fixed seating); or
  - Auction rooms; or
  - Assembly areas, less concentrated use; or
  - Occupancy density of 40 square feet per person or less. Occupancy density is calculated using UBC Section 1003.2.2.2.2 for spaces without fixed seating and UBC Section 1003.2.2.2.3 for spaces with fixed seating. However, classrooms are exempt from the demand control ventilation requirement.

The Standards state that the system will maintain a minimum ventilation flow rate no less than the value calculated per §121(c)4.E. This doesn't necessarily require that the system deliver less than design minimum, but it can if §121(c)4.E. is satisfied.

### ***Construction Inspection***

- The CO<sub>2</sub> sensor is located within the control zone(s) between 1 ft and 6 ft above the floor. This is the critical range for measuring CO<sub>2</sub> since most occupants will be typically either sitting or standing within the space.
- CO<sub>2</sub> 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<sub>2</sub> measuring device and making proper adjustments through the sensor or ventilation controller.
- Sensor is wired correctly to the controls to ensure proper control of the outdoor air damper. For stand-alone economizer controller/actuators, this means that the CO<sub>2</sub> sensor lead wires are landed on the proper terminals and sensor polarity is correct. For DDC controlled systems, ensure CO<sub>2</sub> sensor value is being read – this will ensure that the sensor is connected to the DDC control panel correctly.
- Interior CO<sub>2</sub> concentration setpoint is 600 ppm plus outside air CO<sub>2</sub> value if outside concentration is measured dynamically. Else setpoint is 1000 ppm. Outside air CO<sub>2</sub> 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; or 3) measure outside concentration one time during system checkout and use this value continually to determine inside concentration setpoint.

### ***Equipment Testing***

#### ***Step 1: Defeat the economizer.***

Defeating the economizer will prevent the outside air damper from modulating during the test due to atmospheric conditions rather than CO<sub>2</sub> variations. The economizer can be defeated in a number of ways depending on the control strategy used to modulate the outside 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:

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

#### ***Step 2: Simulate a high CO<sub>2</sub> load.***

The intent of this test is to ensure the outside air damper modulates open when the CO<sub>2</sub> concentration within the space exceeds setpoint. Simulating a high CO<sub>2</sub> load can be accomplished by, but not limited to: 1) commanding the setpoint value to be slightly below current concentration level; 2) exposing the sensor to a known concentration of source gas (i.e. canister of CO<sub>2</sub> gas with a concentration greater than setpoint); or 3) exposing the sensor to an unknown concentration (i.e. breathing excessively onto the sensor – human breath will provide a very high concentration of CO<sub>2</sub>). Regardless of the method used to simulate a high CO<sub>2</sub> load, ensure the condition persists long enough for the HVAC system to respond.

#### ***Verify and Document***

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

#### ***Step 3: Simulate a low CO<sub>2</sub> load.***

The intent of this test is to ensure the outside air damper modulates towards minimum position when the CO<sub>2</sub> concentration within the space is below setpoint. Eventually the outside air damper should close to a position that

provides minimum ventilation flow rate per §121(c)4.E, regardless of how far the measured interior concentration is below setpoint. Simulating a low CO<sub>2</sub> load can be accomplished by, but not limited to: 1) commanding the setpoint value to be slightly higher than current concentration level; 2) exposing the sensor to a known concentration of source gas (i.e. canister of CO<sub>2</sub> gas with a concentration less than setpoint); or open doors and windows to reduce CO<sub>2</sub> concentration in the space.. Regardless of the method used to simulate a low CO<sub>2</sub> load, ensure the condition persists long enough for the HVAC system to respond.

*Verify and Document*

Ensure the outside air damper modulates towards minimum position. If setpoint is raised just above current concentration levels, the outside air damper will modulate closed and the reduced outside air should bring interior concentrations up to meet and maintain the new setpoint. If necessary, continue to adjust the setpoint upward until the outside air damper closes to a minimum position. If a known concentration of CO<sub>2</sub> gas was used to simulate a lowered concentration, then the outside air damper will most likely modulate to minimum position since the “measured” concentration will not be influenced by the decrease in outside 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.

### 8.6.13 NJ.9.1 Supply Fan Variable Flow Controls Acceptance At-a-Glance

## NJ.9.1 Supply Fan Variable Flow Controls Acceptance Use Form MECH-7-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:

- NJ.3.1 Variable Air Volume Systems Outdoor Air Acceptance

### Benefits of the Test

Using a VFD to reduce supply fan airflow as system loads decrease, is more energy efficient than modulation flow through other methods (i.e. inlet guide vanes or outlet dampers).

### Instrumentation

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

- Differential pressure gauge

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

Test Conditions
<p>BAS programming for the operation of the air handling unit and VAV boxes must be complete, including but not limited to:</p> <ul style="list-style-type: none"><li>• Supply fan VFD control</li></ul> <p>VAV box control (including zone temperature sensors and maximum/minimum flow rates)</p> <p>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.</p> <ul style="list-style-type: none"><li>• This test can and should be performed in conjunction with <b>NJ.3.1 Variable Air Volume Systems Outdoor Air Acceptance</b> test procedures.</li></ul>
Time to Complete
<p><b>Construction inspection:</b> 0.5 to 1.5 hours (depending on sensor calibration and minimum VFD speed verification)</p> <p><b>Equipment testing:</b> 1 to 2 hours (depending on how total fan power at design airflow is determined and system control stability)</p>

Acceptance Criteria
<p>Static pressure sensor(s) is factory calibrated (with calibration certificate) or field calibrated.</p> <p>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.</p> <p>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).</p> <p>At full flow:</p> <ul style="list-style-type: none"><li>• Supply fan maintains discharge static pressure within <math>\pm 10\%</math> of control static pressure setpoint</li><li>• Supply fan speed stabilizes within 15 minutes</li></ul> <p>At minimum flow (at least 30% of total design flow):</p> <ul style="list-style-type: none"><li>• VFD reduces supply fan speed to meet flow conditions</li><li>• Supply fan maintains discharge static pressure within <math>\pm 10\%</math> of control static pressure setpoint</li><li>• Control static pressure setpoint at minimum flow is no greater than control static pressure setpoint at full flow.</li><li>• System operation stabilizes within 15 minutes</li></ul>
Potential Issues and Cautions
<p>Ensure that all disabled reset sequences are enabled upon completion of this test.</p> <p>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.</p>

### **8.6.14 Test Procedure: NJ.9.1 Supply Fan Variable Flow Controls Acceptance, Use Form MECH-7-A**

#### ***Construction Inspection***

- Discharge static pressure sensor is factory calibrated or field calibrated. Calibration certificates from the manufacturer are acceptable. 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 (building automation system). If the value measured by the BAS is within 10% of the field-measured value, the sensor is considered calibrated.

#### ***Equipment Testing***

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

#### ***Step 1: Drive all VAV boxes to achieve full 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 in AUTO to discern this.

#### ***Verify and Document***

- Supply fan maintains discharge static pressure setpoint within  $\pm 10\%$ . Verification can be accomplished by simply reading the value measured by calibrated pressure sensor and comparing it to setpoint.
- System operation stabilizes within 15 minutes. The intent is to ensure the PID control loops are tuned properly so that the system does not hunt.

**Step 2: Drive all VAV boxes to the greater of the minimum airflow or 30% of total design airflow.**

The intent is to verify proper supply fan operation when the system is at or near minimum flow conditions. This typically occurs when all of the VAV boxes are operating at minimum cooling flow rate. 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 (may be accomplished by a global command or it may have to be done per individual box).
- Set maximum flow setpoint to be the same as minimum flow setpoint (may be accomplished by a global command or it may have to be done per individual box).
- Space temperature setpoint can be raised above current space conditions to force the VAV box into minimum cooling or heating mode (may be accomplished by a global command or it may have to be done per individual box or per zone thermostat).

Again, you cannot simply override the VFD as it would negate the purpose of the test.

*Verify and Document*

- VFD reduces supply fan speed to meet flow conditions.
- Supply fan maintains discharge static pressure setpoint within  $\pm 10\%$ . Verification can be accomplished by simply reading the value measured by calibrated pressure sensor and comparing it to setpoint.
- System operation stabilizes within 15 minutes. The intent is to ensure the PID control loops are tuned properly so that the system does not hunt.

**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.

## 8.6.15 NJ.10.1 Variable Hydronic Flow Controls Acceptance At-a-Glance

### NJ.10.1 Variable (Hydronic) Flow Controls Acceptance Use Form MECH-8-A

#### Purpose of the Test

The purpose of this test is to ensure that all chilled or heating water configurations with more than 3 control valves are designed and operated so that total system flow changes as load requirements fluctuate, i.e., the design incorporates two-way control valves at some if not all of the coils. A cooling and heating load is typically met by modulating the amount of water that flows through the respective coil using a control valve. The Standards require that total system flow rate vary as a function of load; that is, the flow rate should decrease when the system calls for less-than-design flow.

Related acceptance tests for these systems include the following:

- NJ.10.2 Automatic Isolation Controls Acceptance
- NJ.10.5 (Pump)Variable Frequency Drive Controls Acceptance
- Testing time will be greatly reduced if these acceptance tests are done simultaneously.

NOTE: There are two alternative tests applicable to this measure depending on system design: Alternate 1 – with flow measurement and Alternate 2 – without flow measurement. The Acceptance Agent may select either of these two tests to comply.

#### Benefits of the Test

Modulating the system flow rate to meet load – rather than maintaining a constant flow throughout the entire system – helps to reduce pumping energy and improve heating and cooling plant efficiencies.

#### Instrumentation

Performance of this test will require measuring total hydronic system flow rate. The instrumentation needed to perform the task may include, but is not limited to:

- Differential pressure gauge

#### 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.

<b>Time to Complete</b>
<p><b>Construction inspection:</b> 0.5 to 2 hours (depending on availability of construction documentation and complexity of the system.)</p> <p><b>Equipment testing:</b> 1 to 4 hours (depending on the complexity of the system)</p>
<b>Acceptance Criteria</b>
<p>Provisions have been made for variable flow:</p> <ul style="list-style-type: none"> <li>• System has no flow when all coils are closed and the pump is turned on.</li> <li>• At minimum flow, system achieves the greater of 1)50% or less design flow; or 2)minimum flow required by equipment manufacturer for proper operation of any unit.</li> <li>• On a change in flow, pumps achieve setpoint within 15 minutes without excessive hunting.</li> </ul>
<b>Potential Issues and Cautions</b>
<p>The Acceptance Agent will likely need access to the EMCS during testing</p> <p>Running a pump in a “deadhead” 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.</p> <p>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.</p>

**Scope of test**

This test is required for hydronic systems with more than 3 automatic control valves, typically systems with more than 3 coils.

**ALTERNATE 1- With Flow Measurement Test Procedure: NJ.10.1 Variable Hydronic Flow Controls, Use Form MECH-8-A**

**Construction Inspection**

- Ensure all valve and piping arrangements were installed per the design drawings in order to achieve the desired control. This refers to each heat exchanger or coil having its own two-way control valve, flow measuring devices, if applicable, are located adequately to achieve accurate measurements (i.e. sufficient straight-line piping before and after the meter), and the piping arrangements are correct (for example, there may be three-way valves located at one or more of the coils to ensure system minimum flow rates can be achieved).

**Equipment Testing**

**Step 1: Open all control valves.** The intent of this test is to ensure that the system operates at design conditions when the system calls for full flow. Opening the control valves can be achieved in a variety of ways, such as: 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.

### **Verify and Document**

- System operation achieves design conditions within  $\pm 5\%$ .

**Step 2: Close control valves.** The intent of this test is to ensure that system flow rate decreases when the system calls for less-than-design flow. This test must only be performed on hydronic systems that are exempt from the variable frequency drive control requirement per §144(j)6. Closing the control valves can be achieved in a variety of ways, 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.

### **Verify and Document**

- The design flow control strategy achieves required flow reductions. §144(j)1 requires that a variable flow system reduce system flow by the greater of: 1) minimum flow required by the equipment manufacturer for proper operation of the unit (i.e. chillers, boilers, etc) or 2) 50% or less of the design system flow rate. This number should be on the plans.
- Ensure each control valve closes completely under normal operating pressure. The intent is to make sure that the actuator-valve torque requirements are adequate to shut the valve under normal operating system pressure. Verifying complete closure can include, but is not limited to: 1) visually inspect for full valve stem travel and listen for leakage through the valve; 2) flow switches or meters, if installed, do not detect any flow; 3) differential pressure measured across the device (coil, heat exchanger, etc.) is zero; or 4) differential temperature across the device (coil, heat exchanger, etc.) is zero because if the valve were leaking, energy would be either added to or extracted from the fluid flowing through the device.

**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.

### **Alternate 2 – No Flow Measurement**

- Test Procedure: NJ.10.1 Variable Hydronic Flow Controls Acceptance, Use Form MECH-8-A)

### **Construction Inspection**

- Ensure all valve and piping arrangements were installed per the design drawings in order to achieve the desired control. This refers to each heat exchanger or coil having its own two-way control valve, flow measuring devices, if applicable, are located adequately to achieve accurate measurements (i.e. sufficient straight-line piping before and after the meter), and the piping arrangements are correct

(for example there may be three-way valves located at one or more of the coils to ensure system minimum flow rates can be achieved).

### ***Equipment Testing***

**Step 1: Deadhead One Pump.** The intent of this test is to establish a baseline pump pressure for use in checking the ability of all valves to close across the system. Use manual isolation or balance valves at the inlet or bypass of all three way valves and close it off. If a balance valve is used mark its current position so that it can be reset after the test.

Isolate one circulation pump and make sure that all chillers or boilers are off. Close off the isolation valve at the pumps discharge and turn the pump on for not more than 5 minutes. Measure and note the pressure across the pump at this “deadhead” condition. If the system is piped primary/secondary make sure this is a secondary pump. At the end of the measurement turn off the pump and open the discharge valve at the pump.

### ***Verify and Document***

**Step 2: Close control valves.** The intent of this test is to ensure that all two-way valves can modulate fully closed and have actuators that can fully close across an operating pump. With the chillers or boiler still off, start the same pump that was used in Step 1 and drive all HX or coil control valves closed. Closing the control valves can be achieved in a variety of ways, 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. Make sure that the pump operates for no more than 5 minutes in this “deadhead” condition.

### ***Verify and Document***

- Ensure each control valve closes completely under normal operating pressure. The intent is to make sure that the actuator-valve torque requirements are adequate to shut the valve under normal operating system pressure. Verifying complete closure shall be done by measuring the pressure across the operating pump. If the pressure is more than 5% less than that previously measured the test fails as one or more valves have not fully closed. Diagnose and fix the problem then retest.

**Step 3: Return system back to normal operating condition.** Ensure all schedules, setpoints, isolation and balance valves, operating conditions, and control parameters are placed back at their initial conditions.

**8.6.16 NJ.10.2 Automatic Isolation Controls Acceptance****At-a-Glance****NJ.10.2 Automatic Isolation Controls Acceptance****Use Form MECH-8-A****Purpose of the Test**

Many HVAC systems are served by central chilled water and heating hot water plants that consist of multiple pieces of equipment that work cooperatively to meet total system load. Often, each piece of equipment is sized so that only a particular unit will operate at a given time based on the performance characteristics of that unit and its ability to serve the load. For example, a 600-ton cooling load may be served by two 300-ton chillers, with one unit operating when the load is less than 300 tons and both operating to satisfy higher loads.

The purpose of the test is to verify that each piece of equipment is automatically isolated from the condenser, chilled or hot water flow when it is not in operation; that is, the isolation valves serving each piece of equipment open fully before the equipment is started and close fully once the equipment is turned off. Note for equipment with dedicated pumps and check valves, automatic isolation valves and this test are not required.

Related acceptance tests for these systems include the following:

- NJ.10.1 Variable (Hydronic) Flow Controls Acceptance

**Benefits of the Test**

Ensuring that automatic equipment isolation controls are operating correctly will avert excess pump energy and control problems due to the bypass of unconditioned water.

**Instrumentation**

To perform the test, it will be necessary to verify correct operation of the isolation valves during start-up and shutdown and that the valves close completely. There is no instrumentation needed to perform this task.

**Test Conditions**

Each piece of equipment, along with the respective isolation valve, must be installed and started up.

If using the BAS to enable “start” and “stop” commands for the equipment, then programming of the start/stop sequences and control valves must be complete.

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.

Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.

<b>Time to Complete</b>
<b>Construction inspection:</b> 0.5 to 1 hours (depending on availability of construction documentation – i.e. plumbing drawings, material cut sheets, specifications, etc.) <b>Equipment testing:</b> 0.5 to 1 hours (depending on familiarity with BAS, method employed to verify tight valve closure, and time delay between equipment shutdown and valve closure)
<b>Acceptance Criteria</b>
The isolation valve(s) associated with the respective equipment opens fully upon start-up and closes fully upon shutdown. Isolation valve does not leak when fully closed.
<b>Potential Issues and Cautions</b>
Problems could be encountered with manipulating the BAS. Therefore, a controls contractor should be on-site to assist with completing the “start” and “stop” sequences.

**Test Procedure: NJ.10.2 Automatic Isolation Controls Acceptance, Use Form MECH-8-A**

*Construction Inspection*

- Ensure all valve and piping arrangements were installed per the design drawings in order to achieve the desired control. If the pumps are dedicated to the chillers or boilers, each piece of equipment must have its own isolation valve and is mounted in such a manner that process water cannot flow through the equipment when that unit is not operating.

*Equipment Testing*

**Step 1: Deadhead One Pump.** The intent of this test is to establish a baseline pump pressure for use in checking the ability of isolation valves to close across the system

Isolate one circulation pump and make sure that all chillers or boilers are off. Close off the isolation valve at the pumps discharge and turn the pump on for not more than 5 minutes. Measure and note the pressure across the pump at this “deadhead” condition. If the system is piped primary/secondary make sure this is a primary pump. At the end of the measurement turn off the pump and open the discharge valve at the pump.

**Verify and Document**

- Note the “deadhead” pressure of the circulation pump. This will be used in the next test.

**Step 2: Open manual isolation valve and shut down all chillers or boilers.** The intent of this test is to ensure that all two-way valves can modulate fully closed and have actuators that can fully close across an operating pump. With the chiller or boiler off, make sure that the pump operates for no more than 5 minutes in this “deadhead” condition.

**Verify and Document**

- As each chiller or boiler is started visually verify that the isolation valve(s) open fully.
- Ensure each isolation valve closes completely under normal operating pressure. The intent is to make sure that the actuator-valve torque requirements are adequate to shut the valve under normal operating system pressure. Verifying complete closure shall be done by measuring the pressure across the operating pump. If the pressure is more than 5% less than that previously measured, the test fails as one or more valves have not fully closed. Diagnose and fix the problem, then retest.

**Step 3: Return system back to normal operating condition.** Ensure all schedules, setpoints, isolation and balance valves, operating conditions, and control parameters are placed back at their initial conditions.

**8.6.17 NJ.10.3 Supply Water Temperature Reset Controls Acceptance At-a-Glance**

<p><b>NJ.10.3 Supply Water Temperature Reset Controls Acceptance</b>  <b>Use Form MECH-8-A</b></p>
<p><b>Purpose of the Test</b></p>
<p>The intent of the test is to ensure that both the chilled water and hot water supply temperatures are automatically reset based on either building loads or outside 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.</p> <p>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 MBh (thousand BTU's per hour).</p>

<b>Instrumentation</b>
<p>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:</p> <ul style="list-style-type: none"> <li>• Hand-held temperature probe</li> </ul>
<b>Test Conditions</b>
<p>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, boilers, air handling units, and pumps must be complete, including but not limited to:</p> <ul style="list-style-type: none"> <li>• Supply water temperature control</li> <li>• Equipment start-stop control</li> <li>• All control sensors installed and calibrated</li> <li>• Control loops are tuned</li> </ul> <p>All systems must be installed and ready for system operation, including:</p> <ul style="list-style-type: none"> <li>• Chillers, boilers, pumps, air handling units, valves, piping, etc.</li> <li>• All piping is pressure tested, flushed, cleaned, and filled with water</li> <li>• Control sensors (temperature, humidity, flow, pressure, etc.)</li> <li>• Electrical power to all equipment</li> <li>• Start-up procedures for all pieces of equipment are complete, per manufacturer's recommendations</li> </ul> <p>Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.</p>
<b>Time to Complete</b>
<p><b>Construction inspection:</b> 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.)</p> <p><b>Equipment testing:</b> 1 to 2 hours (depending on familiarity with BAS, method employed to vary operating parameters, and time interval between control command and system response)</p>
<b>Acceptance Criteria</b>
<p>Supply water temperature sensors are either factory calibrated (with calibration certificates) or field calibrated.</p> <p>Sensor performance complies with specifications.</p> <p>Supply water reset works.</p>
<b>Potential Problems and Cautions</b>
<p>If the heating hot water temperature reset is tested 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 could 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.</p> <p>Where humidity control is required, chilled water supply water reset is not recommended.</p>

**Test Procedure: NJ.10.3 Supply Water Temperature Reset Controls Acceptance, Use Form MECH-8-A***Test Comments*

The most common control variables used to reset supply water temperature setpoint include, but are not limited to: coil valve position; outside air temperature; and space conditioning parameters like humidity. Examples of each control strategy 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. If all heating valves are less than 94% open, then the hot water supply temperature will be incrementally lowered until one valve opens to 94% and then the setpoint is maintained. If any valve opens to more than 98% open, then the hot water supply temperature will be incrementally raised and maintained until one valve drops back down to 94% open. A similar control strategy can be used to reset the chilled water supply temperature. The chilled and hot water temperature setpoint values will be determined by the designer and should be available from either the design narrative, specifications, or control drawings.
- **Outside air temperature.** Another very common control strategy is to reset supply water temperature based on outside 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 outside air temperatures. For example, hot water temperature may be reset linearly between 90°F and 140°F when outside air temperature is above 50°F and below 35°F, respectively. Actual supply water and outside air temperatures will be determined by the designer and should be available from either 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. Actual chilled water temperature setpoint reset schedule will be determined by the designer and should be available from either the design narrative, specifications, or control drawings.

### ***Construction Inspection***

- Temperature sensors are either factory calibrated or field calibrated. Depending on the control strategy used to reset supply water temperature, sensors can include, but are not limited to: 1) supply water temperature sensor; and outside air temperature sensor (if used for reset). Calibration certificates from the manufacturer are acceptable. Field calibration requires using either a secondary temperature reference or placing the sensor in a known temperature environment (typically either ice water or a calibrated dry-well bath). 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).
- Sensor locations are adequate to achieve accurate measurements. Water temperature sensors will typically be located in immersion wells on the supply side of each piece of equipment, and the equipment will be controlled accordingly to meet supply temperature setpoint. Location of the outside air temperature sensor is much more critical. The sensor should not be exposed to direct sun (preferably mounted on a north-facing wall with a protective cover) or any other heat sources like exhaust streams, cooling towers, or generation equipment.
- Sensors comply with specifications. Proper control depends on the installation of good sensors. Review all sensor cut sheets and verify installed sensors meet all performance requirements as detailed in the specifications.

### ***Equipment Testing***

**Step 1. Achieve maximum supply water temperature setpoint (coldest for chilled water and warmest for heating water).** Manually change the control variable in order to reset supply water temperature. For a valve position control strategy, command at least one coil valve to 100% open. An alternate method would be to adjust discharge air temperature or zone temperature setpoints to drive a valve into a 100% open condition. For an outside air temperature control strategy, override actual outside air sensor to exceed maximum water temperature boundary value. For example, if the control strategy calls for 42°F chilled water when outside 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% 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 meet the new setpoint. It may take a few minutes for the water temperature to change depending on system conditions and equipment operation.

**Step 2. Achieve minimum supply water temperature setpoint (warmest for chilled water and coldest for heating water).** 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% open, command all valves to be 90% 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 outside air temperature control strategy, override actual outside air sensor to exceed minimum water temperature boundary value. For example, if the control strategy calls for 90°F heating water when outside air temperature is above 50°F, command the sensor to read 52°F.

***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 meet the new setpoint. It may take a few minutes for the water temperature to change depending on system conditions and equipment operation.

**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.

**8.6.18 NJ.10.4 Water-loop Heat Pump Controls Acceptance**  
**At-a-Glance**

<b>NJ.10.4 Water-loop Heat Pump Controls Acceptance</b>	
<b>Use Form MECH-8-A</b>	
<b>Purpose of the Test</b>	
<p>For water-loop heat pump systems with total loop pump capacity greater than 5 hp, two-way isolation valves are required at each heat pump. These valves close when the heat pump's compressor has cycled off. This causes the flow through the loop to vary which saves energy. In addition, each individual loop pump with a motor greater than 5 hp is required to have a VSD to control it's capacity (smaller pumps may ride the pump curve).</p> <p>Related acceptance tests for these systems include the following:</p> <p>NJ.10.5 (Pump) Variable Frequency Drive Controls Acceptance</p> <ul style="list-style-type: none"><li>• Note that this test should be performed in conjunction with NJ.10.5 (Pump) Variable Frequency Drive Controls Acceptance test if a VFD is required.</li><li>• NOTE: There are two alternative tests for this measure: Alternate 1 – with flow measurement and Alternate 2 – without flow measurement. The Acceptance Agent may select either of the two tests to perform.</li></ul>	
<b>Benefits of the Test</b>	
<p>By adjusting the overall system flow rate to match operating load, pumping energy can be reduced at part-load operating condition.</p>	
<b>Instrumentation</b>	
<p>Performance of this test will require measuring total hydronic system flow rate and pump power. The instrumentation needed to perform the task may include, but is not limited to:</p> <ul style="list-style-type: none"><li>• Differential pressure gauge</li></ul>	

<b>Test Conditions</b>
<p>To perform the test, the control system will be used to manipulate system operation to achieve the desired control. At a minimum, the control system for the operation of the heat pumps, control valves, and water pumps must be complete, including:</p> <ul style="list-style-type: none"> <li>• Equipment start-stop control</li> <li>• Thermostatic control of zones</li> <li>• Interlock control of isolation valves</li> <li>• Circulation pump controls including start-stop and flow controls</li> </ul> <p>All systems must be installed and ready for system operation, including:</p> <ul style="list-style-type: none"> <li>• Heat pumps, cooling towers, boilers, pumps, control valves, piping, etc.</li> <li>• All piping is pressure tested, flushed, cleaned, and filled with water</li> <li>• Control sensors (temperature, flow, pressure, etc.)</li> <li>• Electrical power to all equipment</li> <li>• Start-up procedures for all pieces of equipment are complete, per manufacturer's recommendations</li> </ul> <p>Document the initial conditions before overrides or manipulation of the control system. All systems must be returned to normal at the end of the test.</p>
<b>Time to Complete</b>
<p><b>Construction inspection:</b> 1 to 2 hours (depending on the number of heat pumps and the quality of the documentation.)</p> <p><b>Equipment testing:</b> 2 to 4 hours (depending on familiarity with BAS, method employed to vary operating parameters, verification method for tight valve closure, VFD test if applicable)</p>
<b>Acceptance Criteria</b>
<p>All equipment installed per drawings (two-way control valves, sensors)</p>
<b>Potential Issues and Cautions</b>
<p>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 commanding the heat pumps and adjusting system operation.</p>

**Test Procedure: NJ.10.4 Water-loop Heat Pump Controls Acceptance, Use Form MECH-8-A, (Alternate 1 – with flow measurement)**

*Test Comments*

A typical water-loop heat pump system may consist of the following equipment: 1) water-source heat pumps; 2) one or more circulation pumps (possibly with VFDs); 3) cooling tower (used to dissipate excess heat from the loop); and 4) hot water heating unit (used to add heat to the loop as necessary). A common strategy for controlling the circulation pump VFD would be to maintain a constant system pressure, or differential pressure between supply and return, within the water circuit with the greatest pressure drop (typically the most remote

heat pump in the loop). This control strategy would require the installation of a differential pressure sensor preferably far down the loop. The boilers and towers may have a by-pass line and primary pumps to ensure minimum loop flow is maintained. If the water-loop circulating pump is controlled by a VFD, the VFD performance tests are executed in NJ10.5 (Pump) Variable Frequency Drive Controls procedures.

### ***Construction Inspection***

- Ensure all valve and piping arrangements were installed per the design drawings in order to achieve the desired control. This refers to each heat pump having its own two-way control valve and is mounted in such a manner that process water cannot flow through the unit when it is not operating.
- Verify all valve and hydronic connection pressure ratings meet specifications. Verification includes reviewing equipment specification cut sheets.

### ***Equipment Testing***

**Step 1. Start all heat pumps.** Command all heat pumps to be enabled, which can be accomplished by simply commanding each unit to operate or by adjusting space temperature setpoints to be outside the existing space temperature.

### ***Verify and Document***

- System operation achieves design conditions within  $\pm 5\%$ . All of the two-way control valves should automatically open when the corresponding heat pump is operating, and the system should operate at or near design flow rate.

**Step 2. Adjust system to test two-way control valves.** Command several heat pumps to be disabled, which can be accomplished by simply commanding each unit OFF or by adjusting space temperature setpoints to be within the existing space temperature.

### ***Verify and Document***

- For the units commanded OFF, the two-way control valves should automatically close upon compressor shut down.
- Ensure each two-way control valve closes completely under normal operating pressure. The intent is to make sure that the actuator-valve torque requirements are adequate to shut the valve under normal operating system pressure. Complete closure can be verified if measured system flow has reduced by an amount equivalent to the cumulative flow of the disabled heat pumps.

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.

**Test Procedure: NJ.10.4 Water-loop Heat Pump Controls Acceptance, Use Form MECH-8-A, (Alternate 2 – without flow measurement) Construction Inspection**

- Ensure all valve and piping arrangements were installed per the design drawings in order to achieve the desired control. This refers to each heat pump having its own two-way control valve and is mounted in such a manner that process water cannot flow through the unit when it is not operating.

**Equipment Testing**

**Step 1: Deadhead One Loop Pump.** The intent of this test is to establish a baseline pump pressure for use in checking the ability of all isolation valves to close across the system.

Isolate one loop pump and make sure that all towers, boilers and heat pumps are off. Close off the isolation valve at the pumps discharge and turn the pump on for not more than 5 minutes. Measure and note the pressure across the pump at this “deadhead” condition. If the system is piped primary/secondary, make sure this is a secondary pump. At the end of the measurement turn off the pump and open the discharge valve at the pump.

**Verify and Document**

- Note the “deadhead” pressure of the circulation pump. This will be used in the next test.

**Step 2: Close all heat pump control valves.** Temporarily disable all heat pumps so that their two-way isolation valves close. The intent of this test is to ensure that all two-way valves can modulate fully closed and have actuators that can fully close across an operating pump. With the towers and boilers still off, start the same pump that was used in Step 1. Closing the heat pump isolation valves can be achieved in a variety of ways, examples of which include: resetting all thermostats to put them into the dead band (where no heating or cooling is called for); or commanding the heat pumps directly using the DDC control system (i.e., building automation system). Make sure that the pump operates for no more than 5 minutes in this “deadhead” condition.

**Verify and Document**

- Ensure each control valve closes completely under normal operating pressure. The intent is to make sure that the actuator-valve torque requirements are adequate to shut the valve under normal operating system pressure. Verifying complete closure shall be done by measuring the pressure across the operating pump. If the pressure is more than 5% less than that previously measured the test fails as one or more valves have not fully closed. Diagnose and fix the problem, then retest.

**Step 3: Return system back to normal operating condition.** Ensure all schedules, setpoints, isolation and balance valves, operating conditions, and control parameters are placed back at their initial conditions.

**8.6.19 NJ.10.5 Pump Variable Frequency Drive Controls Acceptance**  
**At-a-Glance**

<b>NJ.10.5 (Pump) Variable Frequency Drive Controls Acceptance</b> <b>Use Form MECH-8-A</b>	
<b>Purpose of the Test</b>	
<p>All hydronic variable flow chilled water and water-loop heat pump systems with circulating pumps larger than 5 hp shall vary system flow rate by modulating pump speed using a variable frequency drive (VFD) or equivalent. 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 will be closed when that unit is 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.</p> <p>Note, this is not required on heating hot water systems with variable flow designs or for condensing water serving only water cooled chillers.</p> <p>Related acceptance tests for these systems include the following:</p> <ul style="list-style-type: none"> <li>• NJ.10.1 Variable (Hydronic) Flow Controls Acceptance (if applicable)</li> <li>• NOTE: There are two possible tests applicable to this measure depending on system design: Alternate 1 – with Flow Meters and Alternate 2 – Without Flow Meters. The person conducting the acceptance test must select one of the two tests to perform depending on system configuration.</li> </ul>	
<b>Benefits of the Test</b>	
<p>Modulating the system flow rate to meet load – rather than maintaining a constant flow throughout the entire system –reduces pumping energy and improves heating and cooling plant efficiencies.</p>	
<b>Instrumentation</b>	
<p>The instrumentation needed to perform the task may include, but is not limited to:</p> <ul style="list-style-type: none"> <li>• Differential pressure gauge</li> </ul>	

<b>Test Conditions</b>
<p>To perform the test, it will be necessary to 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 be complete, including, but not limited to:</p> <ul style="list-style-type: none"> <li>• Equipment start-stop control</li> <li>• All control sensors installed and calibrated</li> <li>• Control loops are tuned</li> </ul> <p>All systems must be installed and ready for system operation, including:</p> <ul style="list-style-type: none"> <li>• Heat pumps, cooling towers, boilers, pumps, control valves, piping, etc.</li> <li>• All piping is pressure tested, flushed, cleaned, and filled with water</li> <li>• Control sensors (temperature, flow, pressure, etc.)</li> <li>• Electrical power to all equipment</li> <li>• Start-up procedures for all pieces of equipment are complete, per manufacturer's recommendations</li> </ul> <p>Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.</p>
<b>Time to Complete</b>
<p><b>Construction inspection:</b> 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)</p> <p><b>Equipment testing:</b> 2 to 4 hours (depending on familiarity with BAS, method employed to vary operating parameters, verification method for system flow and VFD power)</p>
<b>Acceptance Criteria</b>
<p>Differential pressure sensor is either factory calibrated (with calibration certificates) or field calibrated.                  Pressure sensor is located at or near the most remote HX or control valve.                  System controls to the setpoint stably.</p>
<b>Potential Problems and Cautions</b>
<p>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.</p>

**Test Procedure: NJ.10.5 (Pump) Variable Frequency Drive Controls Acceptance, comments and construction inspection common to both Alternative 1 (without flow meters) and Alternative 2 (with flow meters)**

*Test Comments*

§144(j)6 permits two general VFD control strategies: one based on system flow; and the other based on differential system pressure. The most common control strategy employed to control the pump VFD is to maintain constant differential pressure between supply and return within the water circuit with the greatest

pressure drop (typically the most remote heat exchanger or coil in the loop). A flow-based control strategy would require either the calculation or direct measurement of system flow in order to control the pump speed effectively. Regardless of the control strategy employed, the intent of the test is to ensure that as each control valve modulates, the pump VFD responds accordingly to meet system water flow requirements.

- It is recommended that minimum VFD speed setpoint be verified. If the minimum speed is too low, equipment may not operate correctly. However, if the minimum speed is too high, the system will not be allowed to turn down and the full energy savings of the VFD will not be achieved. Guidance for setting minimum speed setpoint is provided below:
  1. The VFD minimum speed setpoint should meet the equipment manufacturer's requirements, including pump motors, hot water heating unit, and cooling tower. Typically most motor manufacturers do not recommend operating for extended periods of time below a designated speed because heat build-up in the motor can adversely effect winding insulation and motor efficiency. Chillers and heating hot water units may also require a specific flow rate through the unit to ensure proper operation. For example, in a primary-only chilled water system, the chiller manufacturer will dictate the minimum flow rate of chilled water through the evaporator.
  2. VFD minimum setpoint should not be below the point where energy use increases. Both the drive and motor efficiencies decrease at reduced load and eventually a point is reached where a continued reduction in load (i.e., speed) results in an increase in energy usage. Depending on the system characteristics and equipment served, other factors may dictate minimum VFD speed (i.e., equipment manufacturer's requirements), but the minimum speed maintained by the VFD should never be set below this power inflection point. Many VFDs can measure and display power usage on its control screen and it is a simple process of reducing system speed and watching power consumption to determine the inflection point. If the VFD cannot measure power, measuring motor amperage would be a good substitute – inflection point is reached when motor amperage starts to increase.

#### *Construction Inspection*

- Sensor location is adequate to achieve the desired control. System pressure or differential pressure sensor must be located near the most distant heat exchanger or coil. Verify actual sensor location matches design drawings.
- The differential pressure sensor (if applicable) is either factory calibrated or field calibrated. Calibration certificates from the manufacturer are acceptable. Field calibration would require measuring system pressure, or differential 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.

**Test Procedure: NJ.10.5 (Pump) Variable Frequency Drive Controls Acceptance, Use Form MECH-8-A, (Alternate 1 – for systems without flow meters)**

It is acceptable to use this method to verify VFD operation even if the control does have a flow meter. This method compares VFD speed and pressure at full and minimum flow. If at minimum flow, VFD speed is decreased and system pressure is no greater than at full flow, the system is compliant.

**Equipment Testing**

**Step 1. Open all control valves.** Ensure all control valves are 100% open. Opening the control valves can be achieved in a variety of ways, such as: 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.

**Verify and Document**

- Make note of VFD output – it should be close to 100% speed
- Record system pressure at loop pressure sensor control point
- System pressure should stabilize within 5 minutes.

**Step 2. Modulate control valves closed.** Closing control valves can be accomplished by simply commanding each valve to a specific position or by adjusting temperature setpoints to be within the existing temperature range.

**Verify and Document**

- Spot check to ensure that valves are closed.
- As the control valves close, the VFD should reduce pump speed. Reduction in pump speed should be commensurate with the expected decrease in water flow.
- Record system pressure at loop pressure sensor control point
- System pressure can be no greater at minimum flow than at full flow.
- Ensure system operation stabilizes within 5 minutes after initiating a valve closure procedure. The intent is to verify that the VFD control PID loop is tuned properly so that changes in system pressure (differential pressure-based control strategy), or flow (flow-based control strategy) due to valve position do not cause excessive hunting of the VFD to achieve proper system flow.

**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.

**Test Procedure: NJ.10.5 (Pump) Variable Frequency Drive Controls Acceptance, Use Form MECH-8-A, (Alternate 2 – for systems with flow meters)**

This test assures that power draw of the VFD and pump at 50% flow is no greater than 30% of power draw at full flow.

### **Equipment Testing**

**Step 1. Open all control valves.** Ensure all control valves are 100% open. Opening the control valves can be achieved in a variety of ways, such as: 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.

### **Verify and Document**

- System operation achieves design conditions within  $\pm 5\%$ . All of the two-way control valves should open fully and the system should operate at or near design flow rate. Verifying system flow rate can be accomplished by reading flow measured with installed flow meter.

**Step 2. Modulate control valves closed.** Closing control valves can be accomplished by simply commanding each valve to a specific position or by adjusting temperature setpoints to be within the existing temperature range.

### **Verify and Document**

- Ensure each two-way control valve closes completely under normal operating pressure. The intent is to make sure that the actuator-valve torque requirements are adequate to close the valve under normal operating system pressure. Complete closure can be verified by reading the measured system flow has reduced by an amount equivalent to the cumulative flow of the closed coils.
- As the control valves close, the VFD should reduce pump speed. Reduction in pump speed should be commensurate with the expected decrease in water flow.
- Ensure system operation stabilizes within 5 minutes after initiating a valve closure procedure. The intent is to verify that the VFD control PID loop is tuned properly so that changes in system pressure (differential pressure-based control) or flow (flow-based control strategy) due to valve position do not cause excessive hunting of the VFD to achieve proper system flow.

**Step 3. Adjust system operation to achieve 50% flow.** The intent of this test is to verify pump input power meets the required reduction stipulated in §144(j)6 at 50% design flow. Review all heat exchanger and coil flow rates and vary valve position as necessary to achieve a 50% flow condition.

### **Verify and Document**

- The input power consumption for the pump motor/VFD does not exceed 30% of full-load power at a 50% flow condition. Input power can be verified by reading power (kW) directly from the drive if the system has the capability, or a power meter can be used. Otherwise, measure voltage and amperage at each leg of the VFD, assume a reasonable part-load system power factor, and calculate power based on:  $1.73 * \text{Volt}_{ave} * \text{Amp}_{ave} * \text{power factor}$ . At 30% of full-load

power, the power factor may range from 50%-70%. It is preferable to verify power factor using motor manufacturer performance data.

- Note: If there are any large imbalances ( $\pm 10\%$  or greater for voltage and  $\pm 20\%$  or greater for amperage) between each leg, this may be indicative of an electrical system problem which could impact system operation and equipment life.

**Step 4. Adjust system operation to verify system minimum flow.** There may be situations where the water flow rate required by the heat exchangers or coils could be far less than the minimum flow rate programmed into the VFD (refer to the discussion in the Test Comments section). The intent of this test is to verify the VFD maintains minimum pump speed, regardless of actual flow requirements. To execute this test, command all but a few of the heat exchangers or coils fully closed. The cumulative flow rate through the coils still open should be much less than minimum flow set at the VFD.

#### ***Verify and Document***

- The VFD maintains pump speed at minimum programmed value.

**Step 5: Return system back to normal operating condition.** Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions.

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### ***8.7 Test Procedures for Lighting Equipments***

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

- Form LTG-3-A
- NJ6.1 Automatic Daylighting Controls Acceptance
- Form LTG-2-A
- NJ6.2 Occupancy Sensor Acceptance
- NJ6.3 Manual Daylight Controls Acceptance
- NJ6.4 Automatic Time Switch Control Acceptance

**8.7.1 NJ.6.1 Automatic Daylighting Control Acceptance**  
**At-a-Glance**

<b>NJ.6.1 Automatic Daylighting Control Acceptance</b> <b>Use Form LTG-3-A</b>	
<b>Purpose of the Test</b>	
<p>The purpose of this test is to ensure that spaces mandated to have automatic daylighting control (refer to Standards Section 131(c)2) are capable of achieving the required reduced lighting levels. Automatic lighting controls can include continuous dimming, stepped dimming, and stepped switching. Automatic daylighting controls under skylights are mandatory and must have multiple stages of control that reduce lighting power to no greater than 35% of full power. Automatic daylighting controls by windows are for a credit, do not have to be multi-stage and need only control lights to no greater than 50% of full power.</p>	
<b>Benefits of the Test</b>	
<p>Reducing artificial light output when adequate daylight is available improves overall light quality and reduces energy usage.</p>	
<b>Instrumentation</b>	
<p>To perform the test, it will be necessary to measure ambient light level and validate overall power reduction. The instrumentation needed to perform the task may include, but is not limited to:</p> <ul style="list-style-type: none"> <li>• Light meter</li> <li>• Hand-held amperage and voltage meter</li> <li>• Power meter</li> <li>• Manufacturer’s light versus power curve for dimming ballasts</li> </ul>	
<b>Test Conditions</b>	
<p>All luminaires in the daylit area must be wired and powered.</p> <p>Lighting control system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer’s recommendations.</p> <p>Simulating a bright condition can be difficult; therefore, performing the test under natural sunny conditions is preferable.</p> <p>Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.</p>	

<b>Time to Complete</b>
<p><b>Construction Inspection:</b> 1 to 3 hours (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.)</p> <p><b>Equipment Test:</b> 2 to 5 hours (depending on ability to manipulate ambient light levels, familiarity with lighting control programming language, and method employed for verifying required power reduction)</p>
<b>Acceptance Criteria</b>
<p>Lighting is correctly circuited so that only fixtures in the daylight area are on the controlled circuit and lighting in the area can be reduced uniformly.</p> <p>Photosensor has been located properly within the daylight area.</p> <p>Photosensor is factory calibrated (with calibration certificate) or field calibrated.</p> <p>Illuminance setpoint is maintained continually.</p> <p>Light level from each fixture is delivered to the space uniformly.</p> <p>The controlled fixtures reduce lighting power by at least 35% of full-load power under fully dimmed and/or stepped conditions.</p> <p>For the continuous and stepped dimming control systems, the lamps do not “flicker” at a reduced light output condition.</p> <p>For the stepped dimming and switching control systems, there is at least one intermediate step between full light output and minimum light output that reduces lighting power to between 70% and 50% of full-load power.</p> <p>For the stepped dimming and switching control systems, there is documentation of a minimum time delay of three minutes or greater between each step change.</p> <p>Under dark conditions, the control system increases the amount of light delivered to the space to full light output for each fixture.</p>
<b>Potential Issues and Cautions</b>
<p>Check fixture circuiting while access to wiring is relatively easy (i.e. while lift is available or before obstructions are installed).</p> <p>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.</p> <p>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 three minutes).</p>

### **8.7.2 Test Procedures: NJ.6.1 Automatic Daylighting Control Acceptance, Use Form LTG-3-A**

#### ***Construction Inspection***

- All photosensors have been properly located. Per the Standards, an individual photosensor must be located within the daylight area and

control only those fixtures in that zone. A lamp is considered to be in the daylit area if at least 1/2 of the lamp is in the zone. With long pendant fixtures that cross into the daylit area, the lamps that are in the daylit area must be controlled separately from those not in the daylit area. For example, multiple enclosed offices may not be controlled by a single photosensor. In addition the photosensor must be either ceiling mounted or located where it will measure light levels adequately and is inaccessible to unauthorized personnel. Correct photosensor location within the daylit space is critical. For vertical glazing, the typical daylit area is estimated by multiplying window width by a nominal 15 feet depth and the photosensor should be located within this depth range. For horizontal glazing (skylights), the daylit area is estimated by the dimensions of the skylight added to the lesser of 70% of the floor-to-ceiling height, distance to nearest 60 inch high partition, or half the distance to the next skylight or window in all directions. The photosensor should be located within this daylit area.

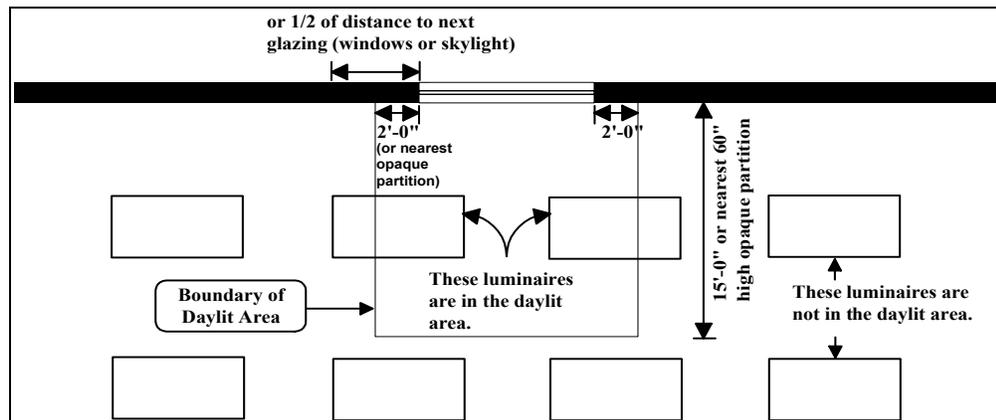


Figure 8-1 – Window Daylit Area

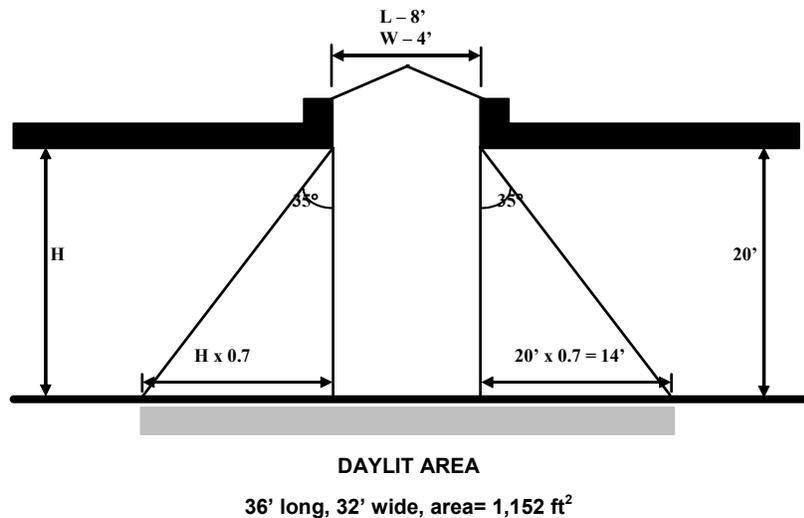


Figure 8-2 – Elevation View of Daylit Area under Skylight

- All photosensors have been either factory calibrated or field calibrated. A calibration certificate provided from the manufacturer for each sensor will be acceptable. Field calibration check will require following manufacturer's calibration instructions, required per §119(a), which may include measuring ambient light levels and comparing the resulting light output of the controlled luminaires.
- Verify installer has provided adequate documentation pertaining to illuminance level setpoints, settings, and programming for each zone being controlled. Examples include, but are not limited to:
- Sufficient time delays are programmed for stepped dimming or switching controls to prevent short cycling of light output from the lamps. Time delay between steps should be three minutes or greater.
- Illuminance level to be maintained within each control zone is reasonable for the space and tasks served. The illumination setpoint should be provided by the lighting designer and may be found in the design narrative, specifications, or lighting control drawings. If the designer does not provide the information, contact the designer and ask for documentation of illumination setpoints for each daylighting control. These design setpoints should be attached to the as-built plans.
- Ensure only the luminaires located within the various daylit zones are controlled by the automatic daylighting system. This can be verified by reviewing the lighting control as-built drawings and electrical drawings.

### ***Equipment Testing***

**Step 1: Simulate bright conditions.** Ensure the lights within each daylit zone are controlled correctly. Simulating a bright condition can be accomplished by opening all shading devices to allow natural daylight into the space or shine a bright flashlight or other light source onto the photosensor if natural conditions are not adequate at the time of the test.

### ***Verify and Document***

#### ***All Automatic Daylight Control Strategies***

- Ensure only luminaires within the daylit zone are controlled. For example, if an enclosed zone has two fixtures and one is in the daylit area but the other is not, only the fixture closest to the daylight source is controlled.
- Measure ambient light level and document location of measurement within the control zone. Verify illuminance setpoint is maintained continually.
- Automatic daylighting controls under skylights are required to have multiple levels of light output and automatically reduce lighting power to no greater than 35% of full power. This could include turning all luminaires completely off.

- Automatic daylighting controls by windows do not necessarily have to have multiple steps, but they must reduce electric lighting in the daylit area to no greater than 50% of full power.

#### *Continuous Dimming Control Systems*

- Typically with a continuous dimming control strategy, a lighting controller will vary the control voltage sent to the ballasts in direct relation to the input signal received from the photosensor in order to maintain ambient light level setpoint. In some instances, the controller may turn the lights completely off if ambient light level far exceeds setpoint. However, some continuous dimming systems do not utilize a stand-alone controller and the ballasts are controlled directly from the output signal from the photosensor. In these applications, the ballasts will operate at a minimum output but will not turn off completely. Verify the controlled fixtures reduce lighting power to at least 35% of full-load power under fully dimmed conditions. Validating power reduction can include, but is not limited to:
  - Measuring minimum and maximum light output to calculate a percent output value and comparing this value with manufacturer's specified power input at that percent light output (some ballast cut sheets will provide a curve illustrating the ballast input power vs. percent light output). If input power at a fully-dimmed condition is 35% of full-load power at full light output or if the controller turns the lights off completely when ambient light level far exceeds setpoint, the system passes.
  - Measure the input current to a fixture or a circuit of controlled fixtures at both minimum and maximum dimming conditions and calculate power reduction as a ratio of current under minimum light output to the current at full light output.
  - Depending on the options available for the controller, it may be possible to view lighting circuit amperage or power consumption from the output display.
  - Ensure light level from each fixture is delivered to the space uniformly. This means that the light output from each fixture connected to the same control zone should be at the same illuminance level. Uniformity is considered to be acceptable when alternating lamps, luminaires or rows of luminaires are controlled by different stages of a switching control. Combined daylight plus electric light uniformity is also achieved if the light fixtures closest to windows or skylights are grouped together for turning off first before other light fixtures which are also in the daylit area but further away from the daylight source.
  - Verify that the lamps do not "flicker" at a reduced light output condition. 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.

### *Stepped Dimming Control Systems*

- Typically with a stepped dimming control strategy, a lighting controller will vary the control voltage sent to the ballasts in discrete “steps” as ambient light level deviates from setpoint. Most stepped dimming control systems will have at least two or three “steps” to ensure a more inconspicuous reduction in light level, with one of the steps turning off the lights completely if ambient light level far exceeds setpoint. Verify the controlled fixtures reduce lighting power to at least 50% of full-load power under fully dimmed conditions in daylight areas by windows and to no greater than 35% of full load power in daylight areas under skylights. Validating power reduction can include, but is not limited to:
- Make note if the lights dim. If they do, and there is only one step, make note of the fraction of power reduced according to the manufacturer’s cut sheet. If input power at a fully-dimmed condition is below the criteria described above or if the controller turns the lights off completely when ambient light level far exceeds setpoint, the system passes.
- Measure the input current to the controlled fixtures at both minimum and maximum dimming conditions and calculate power reduction as a ratio of current under minimum light output to the current at full light output.
- Depending on the options available for the controller, it may be possible to view lighting circuit amperage or power consumption from the output display.
- Verify that there is at least one intermediate step between full light output and minimum light output that reduces lighting power to between 70% and 50% of full-load power. The intent is to prevent drastic changes in light level as natural daylight levels fluctuate. The same procedures as those described above can be used to determine system power at this reduced light output level.
- Verify minimum time delay between each step change is three minutes to prevent short cycling of light output. It would be acceptable to shorten the time delay while performing the tests, but ensure the programmed time delay is at least three minutes and the system is returned to normal operating conditions when the test is complete.
- Ensure light level from each fixture is delivered to the space uniformly. The intent of this requirement is to prevent severe contrasts in illumination within the space because occupants may override the system if uneven light distribution is an annoyance. This means that the light output from each fixture connected to the same control zone should be at the same illuminance level. The designer may have more than one control zone within the total daylight areas of a space with the zone closest to the daylight source turning off at lower ambient daylight levels than those further away from the source.

- Verify that the lamps do not “flicker” at a reduced light output condition. 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.

#### *Stepped Switching Control Systems*

- Typically with a stepped dimming control strategy, a lighting controller will turn lamps ON and OFF in discrete “steps” as ambient light level exceeds setpoint. Most stepped switching control systems will have at least two or perhaps three “steps” to ensure a more inconspicuous reduction in light level, with one of the steps turning off the lights completely. Verify that the controlled fixtures reduce lighting power to no more than 50% of full-load power under lowest light output in daylight areas near windows and to no more than 35% of full-load power under lowest light output in daylight areas under skylights. Validating power reduction can include, but is not limited to, visual inspection of the lamps within the control zone. For example, turning off 2 of 3 lamps in a 3-lamp fixture will satisfy the requirement. In addition, turning the lights off completely also meets the intent of the requirement – this may be a typical control strategy for 2-lamp fixtures.
- Verify that there is at least one intermediate step between full light output and minimum light output that reduces lighting power to between 70% and 50% of full-load power. The intent is to prevent drastic changes in light level as natural daylight levels fluctuate. For example, turning off 1 of 3 lamps in a 3-lamp fixture or 2 of 4 lamps in a 4-lamp fixture will satisfy the requirement.
- Verify minimum time delay between each step change is three minutes to prevent short cycling of light output. It would be acceptable to shorten the time delay while performing the tests, but ensure the programmed time delay is at least three minutes and the system is returned to normal operating conditions when the test is complete.
- The amount of light delivered to the control zone is uniformly reduced. The intent of this requirement is to prevent severe contrasts in illumination within the space because occupants may override the system if uneven light distribution is an annoyance. For switch control, examples of uniform illuminance include: two of four lamps in a fixture are turned off; center lamp or two outside lamps in 3-lamp fixtures are turned off; or lamps in alternating fixtures are turned off.

**Step 2: Simulate dark conditions.** Ensure the lights within each daylight zone are controlled correctly. Simulating a dark condition can be accomplished by, but not limited to, closing all shading devices to block natural daylight into the space, performing tests when natural conditions are accommodating (i.e., dark outside), or shading the photosensor from the ambient light levels using portable shrouds.

## **Verify and Document**

### *All Automatic Daylight Control Strategies*

- Measure ambient light level and document location of measurement within the control zone. Verify illuminance setpoint is maintained continually.

### *Continuous Dimming Control Systems*

- Verify the control system increases the amount of light delivered to the space to full light output for each fixture.
- Verify that the lamps do not “flicker” at full light output condition. The intent of the requirement is to ensure the lights do not flicker because occupants may override the system if light flicker is an annoyance.

### *Stepped Dimming Control Systems*

- Verify the control system increases the amount of light delivered to the space to full light output for each fixture.
- Verify that the lamps do not “flicker” at full light output condition. The intent of the requirement is to ensure the lights do not flicker because occupants may override the system if light flicker is an annoyance.
- Verify minimum time delay between each step change is three minutes to prevent short cycling of light output. It would be acceptable to shorten the time delay while performing the tests, but ensure the programmed time delay is at least three minutes and the system is returned to normal operating conditions when the test is complete.

### *Stepped Switching Control Systems*

- Verify the control system increases the amount of light delivered to the space to full light output for each fixture.
- Verify minimum time delay between each step change is three minutes to prevent short cycling of light output. It would be acceptable to shorten the time delay while performing the tests, but ensure the programmed time delay is at least three minutes and the system is returned to normal operating conditions when the test is complete.

**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.

**8.7.3 NJ.6.2 Occupancy Sensor Acceptance**  
**At-a-Glance**

<b>NJ.6.2 Occupancy Sensor Acceptance</b> <b>Use Form LTG-2-A</b>	
<b>Purpose of the Test</b>	
	The purpose of the test is to ensure that occupancy sensors are located, adjusted, and wired properly to achieve the desired lighting control. There are three basic technologies utilized in most occupancy sensors: 1) infrared; 2) ultrasonic; and 3) a combination of infrared and ultrasonic.
<b>Benefits of the Test</b>	
	Occupancy 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). Automated lighting controls prevent energy waste from unnecessarily lighting an unoccupied space.
<b>Instrumentation</b>	
	This test verifies the functionality of installed occupancy sensors visually and does not require special instrumentation.
<b>Test Conditions</b>	
	Occupancy 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.
<b>Time to Complete</b>	
	<b>Construction Inspection:</b> 0.25 to 0.5 hours (depending on visual and audible inspection requirements) <b>Equipment Test:</b> 0.5 to 1 hours (depending on necessity to adjust time delay or mask sensor to prevent false triggers)
<b>Acceptance Criteria</b>	
	Standard occupancy sensor responds to "typical" occupant movement to turn the lights ON immediately. Manual ON occupancy sensor requires occupant to switch lighting on. Ultrasonic occupancy sensors do not emit audible sound. Lights controlled by the occupancy sensor turn OFF when the preset time delay is met. The maximum time delay is not greater than 30 minutes. Occupancy 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 30 minutes).

Plan sensor location 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).

Avoid detection of motion in adjacent areas and unwanted triggers by adjusting coverage pattern intensity or masking the sensor with an opaque material.

Educating the owner about furniture and partition placement in the spaces can avoid future problems with infrared sensor performance (which rely on "line-of-sight" coverage).

**8.7.4 Test Procedure: NJ.6.2 Occupancy Sensor Acceptance, Use form LTG-2-A*****Purpose (Intent) of the Test***

The purpose of the test is to ensure that an occupancy sensor is located, adjusted, and wired properly to achieve the desired lighting control. Occupancy sensors are used to automatically turn lights on and keeps 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 short cycling ON and OFF as spaces are occupied and unoccupied frequently. There are three basic technologies utilized in most occupancy sensors: 1) infrared; 2) ultrasonic; and 3) a combination of infrared and passive sonic detection.

***Construction Inspection***

Occupancy sensor has been located to minimize false signals (both false ON and OFF). False signals can include, but is not limited to:

- Detection of motion in adjacent areas outside of desired control area. Coverage pattern intensity adjustment or sensor masking may be needed to prevent detection outside of the desired control area. Occupancy sensors are positioned so they "look" across the doorway not through it.
- Detection of heavy airflow. This can be prevented by locating a sensor more than 6 feet away from an HVAC diffuser or other source of air movement (this is most critical with ultrasonic sensors). The sensitivity of the sensor can also be adjusted to minimize false signals due to air movement.
- Occupancy sensor does not encounter obstructions that could adversely affect desired performance, including but not limited to: walls, partitions (temporary or permanent), office furnishings (desks, book cases, filing cabinets, plants), or doors. Note that obstruction limitations are more critical when using infrared occupancy sensors

since this technology relies on “line-of-sight” coverage. Ultrasonic sensors are less susceptible to obstructions.

- Ultrasonic sensors do not emit audible sound. As the name implies, ultrasonic sensors emit ultrasonic sound waves at frequencies that should be imperceptible to the human ear. Ensure the sensor does not emit any sounds that ARE audible to the human ear at typical occupant location.
- Regular noise in the room (such as HVAC noise) does not result in passive sonic detection keeping lights on. The sensitivity of the sensor can also be adjusted to minimize false signals due to regularly occurring noises.

### ***Equipment Testing***

**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***

Lights controlled by the occupancy sensor turn off when the time delay is met. If the time delay was not adjusted prior to the test, ensure the maximum delay was not greater than 30 minutes. If the time delay was adjusted to minimize test time, ensure the sensor time delay setting does not exceed 30 minutes.

Occupancy 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
- Movement other than occupants (i.e. airflow from HVAC system or furnishing movement due to external forces)

**Step 2: For a representative sample of building spaces, simulate an occupied condition.** Enter the test space.

### ***Verify and Document***

Ensure the lights in the control zone turn on immediately. Note that some applications may use an occupancy sensor in conjunction with an automatic control switch, which allows the occupant to manually turn ON/OFF the lights or allow them to automatically turn off when the space is unoccupied (automatic OFF and manual ON control strategy). In this case, activation of the control switch should enable the lights and they should stay illuminated while the space is occupied. The occupancy sensors that are required to have “manual on” capability are identified on the Lighting Control Worksheet.

Signal sensitivity is adequate to achieve the desired control. Ensure occupancy sensor responds to “typical” occupant movement to trigger lights back on. This may require remaining in the space throughout the time delay period to ensure the occupancy sensor continues to recognize the space is occupied. “Typical” movement pertains to the activities one may expect for the space being served,

for example: light desk work; casual walking; athletic movement (i.e. fitness rooms); sitting at rest (i.e. lunch/break room).

Status indicator or annunciator operates correctly. Most occupancy sensors have an LED that will illuminate (typically flash) when motion is detected, where others may emit an audible sound.

**Step 3: Return system back to normal operating condition.** Ensure all schedules, setpoints, operating conditions, and control parameters (especially time delays) are placed back at their initial conditions.

**8.7.5 NJ.6.3 Manual Daylighting Control Acceptance**

**At-a-Glance**

<p><b>NJ.6.3 Manual Daylighting Control Acceptance</b>  <b>Use Form LTG-2-A</b></p>	
<b>Purpose of the Test</b>	<p>The purpose of this test is to ensure that spaces exempt from the automatic daylighting control requirements (refer to §131(c)2) are capable of achieving reduced lighting levels manually under bright conditions. Manual lighting controls can include, but are not limited to, switches and dimmers.</p>
<b>Benefits of the Test</b>	<p>Reducing artificial light output when adequate daylight is available improves overall light quality and reduces energy usage.</p>
<b>Instrumentation</b>	<p>To perform the test, it will be necessary to validate overall power reduction. The instrumentation needed to perform the task may include, but is not limited to:</p> <ul style="list-style-type: none"> <li>• Light meter</li> <li>• Hand-held amperage and voltage meter</li> <li>• Power meter</li> <li>• Dimming ballast manufacturer’s light versus power curve</li> </ul>
<b>Test Conditions</b>	<p>The luminaires within each space are wired to manual switches and/or dimmers.                      All luminaires are wired and powered.</p>

<b>Time to Complete</b>
<p><b>Construction Inspection:</b> 0.25 to 0.5 hours (depending on access to necessary construction documentation – i.e. electrical drawings, material cut sheets, etc.)</p> <p><b>Equipment Test:</b> 0.5 to 2 hours (depending on method employed for verifying required power reduction)</p>
<b>Acceptance Criteria</b>
<p>Manual switching or dimming achieves a lighting power reduction of at least 50% within the control zone.</p> <p>The amount of light delivered to the control zone is uniformly reduced.</p> <p>For the dimming controls, the lamps do not “flicker” at a reduced light output condition.</p>
<b>Potential Issues and Cautions</b>
<p>Verifying required power reduction can be difficult when using dimmers. One method is to measure power (either directly or by calculating power using measured volts and amps) at maximum and minimum dimmer positions. Another method would be to measure light level at maximum and minimum dimmer positions and compare these values with ballast manufacturer’s published data on input power vs. percent light output.</p> <p>Uniform reduction in light level is subjective when lights are controlled by switches. Switching two of four lamps in a 4-lamp luminaire or having the center lamp and two outside lamps in a 3-lamp luminaire on separate switches are reasonable examples of “uniform” lighting.</p>

**8.7.6 Test Procedures: NJ.6.3 Manual Daylighting Control Acceptance, Use form LTG-2-A**

***Purpose (Intent) of the Test***

When the total daylit area in an enclosed space is greater than 250 sf and has adequate daylight. Controls must be installed which are capable of reducing the amount of electric lighting in the daylit areas. The purpose of this test is to ensure that spaces not required to have automatic daylighting control are capable of achieving reduced lighting levels manually. Manual lighting control can include, but is not limited to, switches and dimmers. The lights must be controlled separately from lights outside the daylit area.

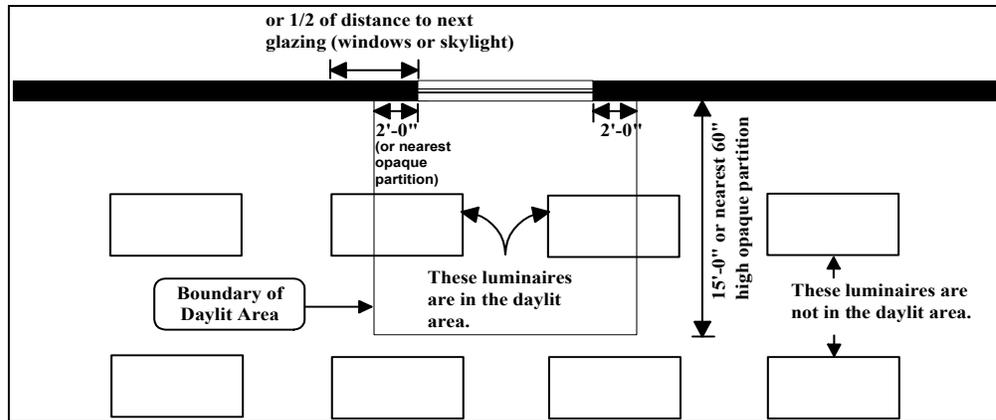


Figure 8-3 – Window Daylit Area

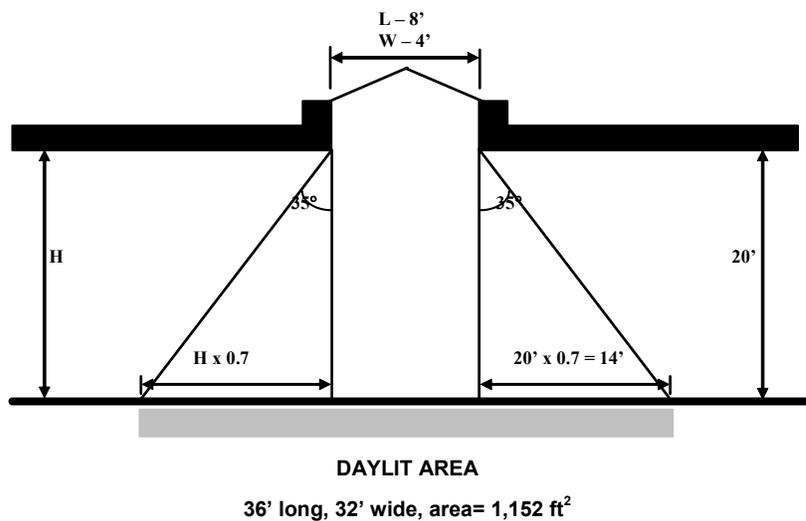


Figure 8-4 – Elevation View of Daylit Area under Skylight

**Construction Inspection**

If dimming ballasts are specified for light fixtures within the daylit area, ensure they meet all Standards requirements, including “reduced flicker operation” for manual dimming control systems. Flicker refers to a rapid fluctuation in light output that can be detected by the human eye.

**Equipment Testing**

**Step 1: Perform manual switching control.** Ensure the lights within each space are controlled correctly. Acceptable control includes, but is not limited to, toggle switches or dimmers.

**Verify and Document**

Manual switching or dimming achieves a lighting power reduction of at least 50% within the control zone. For toggle switch controls, this implies that at least 50% of the lamps (not necessarily fixtures) serving the control zone should be connected to common switches and can be turned off. It is implied that 50%

power reduction is achieved if 50% of the lamps have been turned off (i.e. two of four lamps in a 4-lamp fixture). For dimmers, it is more likely that all of the fixtures and lamps within the control zone will be controlled simultaneously. Verifying power reduction using dimmer control can include, but is not limited to:

- Measure maximum light output (minimum dimmer position) and minimum light output (maximum dimmer position) to calculate a percent output value and compare this value with manufacturer's specified power input at that percent light output. If lights are hard to reach, turn off lights to measure daylight footcandles and subtract daylight footcandles from maximum and minimum measurements of lights at full power and lights fully dimmed. Most ballast manufacturers will provide a curve illustrating the ballast input power vs. percent light output. If input power at maximum dimmer position achieves a 50% power reduction over minimum dimmer position, the system passes.
- Measure input power to the fixture at both full and minimum dimmer positions. The difference between the two measurements determines power reduction (it is acceptable to measure input amps and voltage and calculate power).

The amount of light delivered to the control zone is uniformly reduced. The intent of this requirement is to prevent severe contrasts in illumination within the space because occupants may override the system if uneven light distribution is an annoyance. For switch control, examples of uniform illuminance include: two of four lamps in a fixture are turned off; center lamp or two outside lamps in 3-lamp fixtures are turned off; or lamps closest to the daylight source turn off completely but those further away remain operating. As stated above, dimmer applications will typically control all of the lights in the control zone uniformly, but variation may occur depending on how the fixtures are actually wired.

**Step 2: Return system back to normal operating condition.** Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions.

## 8.7.7 NJ.6.4 Automatic Time Switch Control Acceptance At-a-Glance

### NJ.6.4 Automatic Time Switch Control Acceptance Use Form LTG-2-A

#### Purpose of the Test

The purpose of this test is to ensure that all non-exempt lights, per Standards Section 131(d)1, are automatically turned off at a predetermined time and individual lighting circuits can be manually enabled, if necessary, during scheduled OFF periods (i.e., a lighting “sweep”).

#### Benefits of the Test

Automated controls to turn off lighting during typically unoccupied periods of time 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.

Preferably, the space is unoccupied during the test to prevent conflicts with other trades.

Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.

#### 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 delay 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.
The battery back-up is installed and energized and is capable of retaining system programming for at least 10 hours if power is interrupted.
All lights can be turned ON manually or turn ON automatically during the occupied time schedule.
All lights turn OFF at the preprogrammed, scheduled times.
The manual override switch is functional and turns associated lights ON when activated.
Override time limit is no more than two hours, except for spaces exempt per §131(d)2.D.
Enunciator warning the occupants that the lights are about to turn OFF functions correctly.
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 two hours).
It is preferable to perform the test when the spaces are unoccupied. Turning the lights OFF when other occupants are present can cause problems and unsafe working conditions.

***Purpose (Intent) of the Test***

The purpose of this test is to ensure that all non-exempt lights per §131(a) are automatically turned off at a predetermined time and individual lighting circuits can be manually enabled, if necessary, during scheduled OFF periods. The most common term for this control strategy is a lighting “sweep”.

***Construction Inspection***

- Automatic time switch control is 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 have already left the space).
- Verify schedule and other programming parameter documentation was provided to the owner. This information will be used to verify system operation. The documentation should include weekday, weekend, and holiday schedules as well as sweep frequency and/or override time period. Sweep frequency or override time period refers to how often the OFF signal is sent through the system and commands the lights OFF again.
- 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.
- Verify the battery is installed and energized. Battery back-up should be capable of retaining system programming for at least 10 hours if power is interrupted.
- 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 consist of an override timer that will expire and turn off the lights that 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.

- 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.

### ***Equipment 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***

- 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.
- Verify the local lighting circuit switch only operates lights in the area in which the switch is located. 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.

**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 §131(d)2.D 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, it is recommended that the override time 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 two 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. See the example below.

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## 8.8 Mechanical Forms for Acceptance Requirements

There are eight forms used to document the completion of these procedures. Each form includes a series of check boxes relating to each test or verification that needs to be performed. When completing the forms, check the appropriate box on the form after each test or verification is completed. Where the form includes data entry locations other than check boxes, enter the data requested on the form. These forms are located in Appendix A:

- Certificate of Acceptance (3 pages)
- Ventilation System Acceptance Document
- Packaged HVAC Systems Acceptance Document
- Air Distribution Acceptance Document
- Air-Side Economizer Acceptance Document
- Demand Control Ventilation Acceptance Document
- Supply Fan Variable Flow Control Acceptance Document
- Hydronic System Control Acceptance Document

### ***MECH-1-A - Certificate of Acceptance Part 1 of 2***

The form is separated into three basic sections: project information; general information; and statement of acceptance. Each section consists of a combination of data entry requirements and check boxes.

#### *Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.

- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.

#### *General Information*

This section consists of a combination of data entry requirements and check boxes, all of which are self-explanatory. Complete check boxes and enter data as instructed.

#### *Statement of Acceptance*

This section consists of a combination of check boxes and data entry requirements, including signature; date; and license number. Complete check boxes and enter data as instructed.

### ***MECH-1-A - Certificate of Acceptance Part 2 of 2***

The form is used to document the overall final results of all acceptance test.

#### *Summary of Acceptance Tests*

- SYSTEM ACCEPTANCE DOCUMENT refers to the name of the test Form that has been completed. For example: "Ventilation System Acceptance document (AHU-1). This designates the acceptance test of outside air ventilation for air handling unit #1. Typically an individual form is completed for each piece of equipment tested.
- TESTING AUTHORITY is the person's name responsible for verifying all acceptance tests were performed and each system passed.
- DATE OF TEST is the date each test was actually performed.
- PASS/FAIL is the final outcome of the acceptance test.

### ***MECH-2-A - Ventilation System Acceptance Document***

This form is used to document results of the minimum outside air ventilation tests for both constant and variable air volume fan systems. A separate form should be completed for each system tested. The form is separated into six basic sections: project information; pre-test inspection; equipment testing; testing calculations and results; pass/fail evaluation; and certification statement. Each section consists of a combination of data entry requirements and check boxes.

*Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.
- VENTILATION SYSTEM NAME/DESIGNATION is the name or unique identifier for the system being tested. For example: AHU-1; AC-3; etc.

*Pre-test Inspection*

This section consists of check boxes for both constant and variable air volume systems. Complete only the check boxes associated with the appropriate system type.

*Equipment Testing*

This section consists of data entry requirements for both constant and variable air volume systems. Enter data associated with the appropriate system type as instructed.

*Testing Calculations and Results*

This section consists of data entry requirements for both constant and variable air volume systems. Enter data associated with the appropriate system type as instructed.

*Pass/Fail Evaluation*

Check the appropriate box.

*Certification Statement*

The statement of compliance is signed by the person responsible for performing the test and verifying system performance. The signatory provides the following: name; company name; signature and date signed; as well as license number and expiration date.

***MECH-3-A - Packaged HVAC System Acceptance Document***

This form is used to document results of packaged HVAC system operating tests. A separate form should be completed for each system tested. The form is separated into seven basic sections: project information; pre-test inspection;

operating modes; equipment testing requirements; testing results; pass/fail evaluation; and certification statement. Each section consists of a combination of data entry requirements and check boxes.

#### *Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.
- PACKAGED HVAC NAME/DESIGNATION is the name or unique identifier for the system being tested. For example: ACU-1; DX-3; etc.

#### *Pre-test Inspection*

This section consists of check boxes. Complete check boxes as instructed.

#### *Operating Modes*

This section documents the various operating modes for packaged HVAC systems under which they will be tested. Note that operating modes “F” and “G” are associated with systems that do not have an economizer and operating modes “H” and “I” are associated with systems that do have an economizer. The operating modes associated with these two equipment types are mutually exclusive – either the unit has or doesn’t have an economizer.

#### *Equipment Testing*

This section consists of check boxes arranged in a matrix pattern, with the various operating modes listed horizontally and expected system responses listed vertically. As the HVAC system is tested under each applicable operating mode, check the box associated with the expected system response. Again, note that operating modes “F” and “G” are mutually exclusive with operating modes “H” and “I”. If the unit does not have an economizer, only modes “F” and “G” should be checked. Conversely, “H” and “I” are used only for systems with an economizer.

#### *Testing Results*

This section consists of data entry requirements for all operating modes. Enter data associated with the appropriate operating mode as instructed.

*Pass/Fail Evaluation*

Check the appropriate box as instructed.

*Certification Statement*

The statement of compliance is signed by the person responsible for performing the test and verifying system performance. The signatory provides the following: name; company name; signature and date signed; as well as license number and expiration date.

***MECH-4-A - Economizer Acceptance Document***

This form is used to document results of both stand-alone and DDC controlled economizer operating tests. A separate form should be completed for each system tested. The form is separated into six basic sections: project information; pre-test inspection; equipment testing requirements; testing results; pass/fail evaluation; and certification statement. Each section consists of a combination of data entry requirements and check boxes.

*Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.
- AIR ECONOMIZER NAME/DESIGNATION is the name or unique identifier for the economizer being tested (typically associated with a particular HVAC system). For example: AC-1; AHU-3; etc.

*Pre-test Inspection*

This section consists of check boxes for both stand-alone and DDC controlled economizers. Complete the appropriate check boxes as instructed.

*Equipment Testing*

- This section consists of check boxes for each test procedure. Complete check boxes as instructed.

*Testing Results*

- This section consists of data entry requirements for all tests. Enter data as instructed.

*Pass/Fail Evaluation*

- Check the appropriate box as instructed.

*Certification Statement*

- The statement of compliance is signed by the person responsible for performing the test and verifying system performance. The signatory provides the following: name; company name; signature and date signed; as well as license number and expiration date.

**MECH-5-A - Air Distribution Acceptance Document**

This form is used to document results of duct leakage tests performed on specific packaged HVAC systems. A separate form should be completed for each system tested. The form is separated into five basic sections: project information; pre-test inspection; equipment testing requirements; pass/fail evaluation; and certification statement. Each section consists of a combination of data entry requirements and check boxes.

*Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.
- AIR DISTRIBUTOR NAME/DESIGNATION is the name or unique identifier for the ductwork being tested (typically associated with a particular HVAC system). For example: ACU-1 ductwork; etc.

*Construction Inspection*

- This section consists of check boxes. Complete check boxes as instructed.

*Certification Statement*

- The statement of compliance is signed by the person responsible for performing the test and verifying system performance. The signatory provides the following: name; company name; signature and date signed; as well as license number and expiration date.

This form is used to verify duct tightness by the installer and/or HERS rater (third-party). Compliance credit requires third-party field verification.

### ***Installer Certification***

#### ***NEW CONSTRUCTION***

- ENTER TEST LEAKAGE– enter the actual measured duct leakage value.
- FAN FLOW
  - CALCULATED FAN FLOW – enter the calculated fan flow either by multiplying 400cfm/ton times the number of tons of cooling or by entering 21.7 times the heating capacity of the unit being stalled in kBtu/h. In case of more than one separate fan flow unit calculate the fan flow for each separately and enter the value in the Measured Values column.
  - MEASURED FAN FLOW – enter the actual fan flow measured value in the Measured Values column.
- LEAKAGE PERCENTAGE – enter the leakage fraction by dividing the Test Leakage by either the calculated or measured fan flow. Enter the value in the Measured Values column.
  - PASS OR FAIL – check the “Pass” box if duct leakage is less than 6 %.

#### ***ALTERATIONS***

- ENTER PRE-TEST LEAKAGE FLOW - enter the actual measured duct leakage value for existing ductwork where the single-zone unit is being replaced or having a major component replaced (§149E) including:
  - Cooling coil
  - Furnace
  - Condenser coil (split system) or
  - Condensing unit (split system)

Different levels of leakage requirements apply to new and existing ductwork (see §149D).

- ENTER FINAL TEST FOR LEAKAGE - enter the actual measured duct leakage value after alterations are complete. There are three options for meeting the leakage requirements.
- The measured duct leakage shall be less than 15% of fan flow; or
  - The duct leakage shall be reduced by more than 60% relative to the leakage prior to the equipment having been replaced and a visual inspection shall demonstrate that all accessible leaks have been sealed; or
  - If it is not possible to meet the duct sealing requirements of Subsections a. or b., all accessible

leaks shall be sealed and verified through a visual inspection by a certified HERS rater.

**EXCEPTION to Section 149(b)1Dii:** Existing duct systems that are extended, which are constructed, insulated or sealed with asbestos.

Otherwise check the "Fail" box. See §149(b)1D for additional applicable information.

- ENTER REDUCTION IN LEAKAGE – This is option b. from above. If the leakage after the alteration is reduced by 60% then the system passes.
- NEW DUCTS – If all the ducts are new the leakage must not be over 6%. Enter this values here.
- TEST OR VERIFICATION STANDARDS
  - Leakage Percentage must be less than 15%. After the alteration the duct leakage must be less than 15% of fan flow.
  - Leakage Reduction - If a Pre-Test was conducted on the system before any alterations the final test after the alteration must less than 60%.
  - If none of the above options a HERS rater can test the duct system to verify by smoke test that all accessible leaks have been sealed.
- SIGNATURE AND DATE – enter the signature of the installer and date of the test.
- NAME OF INSTALLING CONTRACTOR OR SUBCONTRACTOR – enter the name of the company of the contractor of subcontractor.

### ***HERS Rater Compliance Statement***

The HERS rater fills out the following information:

- HERS RATER INFORMATION
  - HERS Rater – Rater prints name and telephone number.
  - CERTIFYING SIGNATURE – After tests passes the HERS Rater signs and dates form.
  - FIRM – Enter company name
  - SAMPLE GROUP NUMBER – Enter sample number here. Example, System 3 our of 7.
- ENTER TEST LEAKAGE– enter the actual measured duct leakage value.
- FAN FLOW
  - CALCULATED FAN FLOW – enter the calculated fan flow either by multiplying 400cfm/ton times the number of tons of cooling or by entering 21.7 times the heating

capacity of the unit being stalled in kBtu/h. In case of more than one separate fan flow unit calculate the fan flow for each separately and enter the value in the Measured Values column.

- MEASURED FAN FLOW – enter the actual fan flow measured value in the Measured Values column.
- LEAKAGE PERCENTAGE – enter the leakage fraction by dividing the Test Leakage by either the calculated or measured fan flow. Enter the value in the Measured Values column.
  - PASS OR FAIL – check the “Pass” box if duct leakage is less than 6 %.

#### ALTERATIONS

- ENTER PRE-TEST LEAKAGE FLOW - enter the actual measured duct leakage value for existing ductwork where the single-zone unit is being replaced or having a major component replaced (§149E) including:
  - Cooling coil
  - Furnace
  - Condenser coil (split system) or
  - Condensing unit (split system)

Different levels of leakage requirements apply to new and existing ductwork (see §149D).

- ENTER FINAL TEST FOR LEAKAGE - enter the actual measured duct leakage value after alterations are complete. There are three options for meeting the leakage requirements.
- The measured duct leakage shall be less than 15% of fan flow; or
- The duct leakage shall be reduced by more than 60% relative to the leakage prior to the equipment having been replaced and a visual inspection shall demonstrate that all accessible leaks have been sealed; or
- If it is not possible to meet the duct sealing requirements of Subsections a. or b., all accessible leaks shall be sealed and verified through a visual inspection by a certified HERS rater.

**EXCEPTION to Section 149(b)1Dii:** Existing duct systems that are extended, which are constructed, insulated or sealed with asbestos.

Otherwise check the “Fail” box. See §149(b)1D for additional applicable information.

- ENTER REDUCTION IN LEAKAGE – This is option b. from above. If the leakage after the alteration is reduced by 60% then the system passes.
- NEW DUCTS – If all the ducts are new the leakage must not be over 6%. Enter this value here.

- TEST OR VERIFICATION STANDARDS
  - Leakage Percentage must be less than 15%. After the alteration the duct leakage must be less than 15% of fan flow.
  - Leakage Reduction - If a Pre-Test was conducted on the system before any alterations the final test after the alteration must less than 60%.
  - If none of the above options a HERS rater can test the duct system to verify by smoke test that all accessible leaks have been sealed.

### ***MECH-6-A - Demand Control Ventilation Acceptance Document***

This form is used to document results of operational tests for HVAC systems required to utilize demand ventilation control. A separate form should be completed for each system tested. The form is separated into six basic sections: project information; pre-test inspection; equipment testing requirements; testing results; pass/fail evaluation; and certification statement. Each section consists of a combination of data entry requirements and check boxes.

#### *Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.
- DEMAND CONTROL VENTILATION NAME/DESIGNATION is the name or unique identifier for the HVAC unit utilizing ventilation control that is being tested. For example: AC-1; AHU-3; etc.

#### *Pre-test Inspection*

- This section consists of check boxes. Complete check boxes as instructed.

#### *Equipment Testing*

- This section consists of both check boxes and data entry for each test procedure. Complete all check boxes and enter data as instructed.

*Testing Results*

- This section consists of data entry requirements for all tests. Enter data as instructed.

*Pass/Fail Evaluation*

- Check the appropriate box as instructed.

*Certification Statement*

The statement of compliance is signed by the person responsible for performing the test and verifying system performance. The signatory provides the following: name; company name; signature and date signed; as well as license number and expiration date.

***MECH-7-A - Supply Fan Variable Flow Control Acceptance Document***

This form is used to document results of operational tests for HVAC supply fans required to utilize variable flow control. A separate form should be completed for each system tested. The form is separated into seven basic sections: project information; pre-test inspection; equipment testing requirements; test calculations; testing results; pass/fail evaluation; and certification statement. Each section consists of a combination of data entry requirements and check boxes.

*Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.
- VARIABLE FREQUENCY DRIVE NAME/DESIGNATION is the name or unique identifier for the supply fan that is being tested (typically associated with a particular HVAC system). For example: SF-1 in ACU-1; SF-2 in AHU-3 (multiple fan unit); etc.

*Pre-test Inspection*

- This section consists of check boxes. Complete check boxes as instructed.

*Equipment Testing*

- This section consists of data entry requirements for each test procedure. Enter data as instructed.

*Test Calculations*

- This section consists of data entry requirements for all tests. Enter data as instructed.

*Testing Results*

- This section consists of data entry requirements for all tests. Enter data as instructed.

*Pass/Fail Evaluation*

- Check the appropriate box as instructed.

*Certification Statement*

- The statement of compliance is signed by the person responsible for performing the test and verifying system performance. The signatory provides the following: name; company name; signature and date signed; as well as license number and expiration date.

***MECH-8-A - Hydronic System Acceptance Document***

This form is used to document the results for various hydronic system operating tests. The form was designed so that data from up to five hydronic systems (for example: chilled water; heating hot water; water-loop heat pump; etc.) could be recorded on one form. The form is separated into seven basic sections: project information; pre-test inspection; system type; select acceptance tests; equipment testing requirements; pass/fail evaluation; and certification statement. Each section consists of a combination of data entry requirements and check boxes.

*Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.

- HYDRONIC SYSTEM NAME/DESIGNATION is the name or unique identifier for the system(s) being tested. For example: Chilled water; heating hot water; water-loop heat pump; etc.

*Pre-test Inspection*

- This section consists of check boxes. Complete check boxes as instructed.

*System Type*

- This section documents the various system that will be tested. There are five columns under the "System ID" heading labeled 1 through 5 and are identified as follows: column 1 – chilled water systems; column 2 – heating hot water systems; column 3 – water-loop heat pumps; and column 4 and column 5 – other system types. Check each system type that is tested in the appropriate column.

*Select Acceptance Test*

- This section documents which of the various acceptance tests will be performed for each system type. Check the appropriate column for each test that applies to the respective system type.

*Equipment Testing*

- This section consists of check boxes and data entry requirements arranged by individual test. Check each box or enter data in each System ID column for which the specific test applies.

*Pass/Fail Evaluation*

- Check the appropriate box as instructed.

*Certification Statement*

- The statement of compliance is signed by the person responsible for performing the test and verifying system performance. The signatory provides the following: name; company name; signature and date signed; as well as license number and expiration date.

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## **8.9 Lighting Forms for Acceptance Requirements**

There are three forms used to document the completion of these procedures. Each form includes a series of check boxes relating to each test or verification that needs to be performed. When completing the forms, check the appropriate box on the form after each test or verification is completed. Where the form includes data entry locations other than check boxes, enter the data requested on the form.

These forms are located in Appendix A.

- Certificate of Acceptance (3 pages)
- Lighting Control Acceptance Document
- Automatic Daylighting Controls Acceptance Document

### ***LTG-1-A - Certificate of Acceptance Part 1 of 2***

The form is separated into three basic sections: project information; general information; and statement of acceptance. Each section consists of a combination of data entry requirements and check boxes.

#### *Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.

#### *General Information*

This section consists of a combination of data entry requirements and check boxes, all of which are self explanatory. Complete check boxes and enter data as instructed.

#### *Statement of Acceptance*

- This section consists of a combination of check boxes and data entry requirements, including signature; date; and license number. Complete check boxes and enter data as instructed.

### ***LTG-1-A - Certificate of Acceptance Part 2 of 2***

The form is used to document the overall final results of all acceptance tests.

#### *Summary of Acceptance Tests*

- SYSTEM ACCEPTANCE DOCUMENT refers to the name of the test form that has been completed. For example: "Lighting Control Acceptance" document, LTG-2-A. This designates the acceptance test of type of lighting control designated #1 or name of control. Typically an individual form is completed for each piece of control tested.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.

- DATE OF TEST is the date each test was actually performed.
- PASS/FAIL is the final outcome of the acceptance test.

### ***LTG-2-A - Lighting Control Acceptance Document***

This form is used to document the results for various lighting control tests. The form was designed so that data for three lighting control strategies (occupancy sensors, manual daylight control, and automatic time switch) could be recorded on one form. The form is separated into six basic sections: project information; pre-test inspection; select acceptance tests; equipment testing requirements; pass/fail evaluation; and certification statement. Each section consists of a combination of data entry requirements and check boxes.

#### *Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.
- LIGHTING CONTROL SYSTEM NAME/DESIGNATION is the name or unique identifier for the system(s) being tested. For example: "occupancy sensors and lighting sweep"

#### *Pre-test Inspection*

- This section consists of check boxes. Complete check boxes as instructed.

#### *Select Acceptance Test*

- This section documents which of the acceptance tests were performed. Check the appropriate box for each applicable test.

### *Equipment Testing*

- This section consists of data entry requirements arranged by individual test procedures. There are three columns under the “Applicable Lighting Control System” heading labeled 1 through 3 and are identified as follows: column 1 – occupancy sensors; column 2 – manual daylighting controls; and column 3 – automatic time switch controls. Note that the columns are shaded when test procedures do not apply to a particular control strategy. Enter data as instructed in each column.

### *Pass/Fail Evaluation*

- Check the appropriate box as instructed.

### *Certification Statement*

- The statement of compliance is signed by the person responsible for performing the test and verifying system performance. The signatory provides the following: name; company name; signature and date signed; as well as license number and expiration date.

## ***LTG-3-A - Automatic Daylighting Control Acceptance Document***

This form is used to document the results for automatic daylighting control tests. The form was designed so that data for three lighting control strategies (continuous dimming, stepped dimming, and stepped switching) could be recorded on one form. The form is separated into six basic sections: project information; pre-test inspection; control systems; equipment testing requirements; pass/fail evaluation; and certification statement. Each section consists of a combination of data entry requirements and check boxes.

### *Project Information*

- PROJECT NAME is the title of the project, as shown on the Code Compliance forms.
- DATE is the date of preparation of the compliance submittal package.
- PROJECT ADDRESS is the address of the project as shown on the Code Compliance forms.
- TESTING AUTHORITY is the person responsible for verifying all acceptance tests were performed and each system passed.
- TELEPHONE is the phone number where the testing authority can be reached during regular business hours.
- AUTOMATIC DAYLIGHTING CONTROL NAME/DESIGNATION is the name or unique identifier for the system(s) being tested. For example: “continuous dimming – whole building”.

*Pre-test Inspection*

- This section consists of check boxes. Complete check boxes as instructed.

*Control Systems*

- This section documents which control strategy has been tested. Check the appropriate box for each applicable strategy.

*Equipment Testing*

This section consists of data entry requirements arranged by individual test procedures. There are three columns under the “Applicable Control System” heading labeled 1 through 3 and are identified as follows: column 1 – continuous dimming; column 2 – stepped dimming; and column 3 – stepped switching. Note that the columns are shaded when test procedures do not apply to a particular control strategy. Enter data as instructed in each column.

*Pass/Fail Evaluation*

- Check the appropriate box as instructed.

*Certification Statement*

- The statement of compliance is signed by the person responsible for performing the test and verifying system performance. The signatory provides the following: name; company name; signature and date signed; as well as license number and expiration date