Controls Validation Method for Variable Speed Air Conditioners and Heat Pumps

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Prepared for the IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E TCP)

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Controls Validation Method for Variable Speed Air Conditioners and Heat Pumps

Section 1 Purpose

This controls validation method aims to provide a uniform method of test which will validate native control operation and performance criteria for residential air conditioners and heat pumps with variable speed compressors. This method is intended to be used as a confirmation against regulatory tests in which modulating component(s) are overridden.

Section 2 Scope

a) This Standard specifies the methodology for validation of controls used to determine capacity and efficiency ratings of electrically driven, vapor compression, air source or air-cooled systems rated at or below 19KW capacity.

b) This standard includes validation methods for the following:

   i) Room air conditioners (i.e. through-the-wall air conditioner)

   ii) Room Heat Pumps (i.e. through the wall heat pump)

   iii) Non-Ducted split air conditioners

   iv) Non-Ducted split Heat Pumps

   v) Short Ducted split air conditioners

   vi) Short Ducted split Heat Pumps

   vii) Central Ducted split air conditioners

   viii) Central Ducted split Heat Pumps

   ix) Single package air conditioners

   x) Single package Heat Pumps

   xi) Single split matched air conditioner systems

   xii) Single split matched heat pump systems

Section 3 Nomenclature/Definitions

3.1 Definitions Incorporated by Reference

The definitions contained in ASHRAE 16-2016, ASHRAE 37-2009, and ISO 5151 – 2017 shall be incorporated by reference with the following exceptions and modifications:

3.1.1 ASHRAE 16-2016

3.1.1.1 The following definitions shall be excluded: air conditioner, equilibrium, conditions, heating coil, room air conditioner, packaged terminal air conditioner, packaged terminal heat pump, indoor air enthalpy test method, standard air I-P, standard air SI, and UUT stability.

3.1.1.2 The following definitions shall be modified as follows:
Unit under test (UUT): the air-cooled air conditioner or air-source heat pump system under test.

3.1.2 ASHRAE 37-2009

3.1.2.1 The following definitions shall be excluded: equipment, indoor side, and outdoor side.

3.2 Additional Definitions

Table 1 lists the additional definitions used throughout this standard.

Table 1. Additional Definitions

Term	Definition
Control Device	A thermostat or remote controller shipped with or specified by the manufacturer in the installation instructions.
Native Controls	Configuration of the unit under test to operate with applicable settings specified for field use (i.e. removing the unit from any test mode that may be used for regulatory tests where modulating components are overridden.)
Target Compensation Load	The load applied to the indoor room/side at the desired indoor conditions.

Section 4 Unit Configurations

This standard is applicable to the configurations listed in Table 2.

Table 2. Unit Configurations

Configuration	Heat Rejection	Indoor Arrangement	
Single Package System & Single Split System	Air Cooled	Blower Coil	Ducted
			Non-ducted
	Air Source		Ducted
			Non-ducted

Section 5 Instruments and Measurement Apparatus

5.1 General

Follow the requirements contained in ASHRAE 16-2016, ASHRAE 37-2009, and ISO 5151 – 2017 incorporated by reference with the following clarifications:

Instruments and data acquisition systems shall meet the measurement system accuracy specified in this section.

5.1.1 Calibration

Measurements from the instruments shall be traceable to primary or secondary standards calibrated by either the United States National Institute of Standards and Technology (NIST[1]) or to the Bureau International des Poids et Mesures (BIPM[2]) if a National Metrology Institute (NMI) other than NIST is used. Instruments shall be recalibrated on regular intervals that do not exceed the intervals prescribed by the instrument manufacturer, and calibration records shall be maintained. Instruments shall be installed in accordance with the instrument manufacturer's requirements, or the manufacturer's accuracy does not apply.

5.1.2 Applicable Standards

Instruments shall be applied and used in accordance with their respective method of measurement standards unless otherwise noted in section 5 of this document.

[1] https://www.nist.gov/
[2] https://www.bipm.org/

5.1.2.1 Precedence

Where there are differences between this document and respective method of measurement standards, this document shall prevail.

5.1.3 Accuracies

Instrument accuracies shall be as indicated in Table 3.

Table 3. Instrument Accuracy

Type of Measurement	Purpose	Required Accuracy
Temperature	Wet Bulb for Water Vapor Content	+/- 0.1 ºC (0.2 ºF)
	Air Dry bulb	+/- 0.1 ºC (0.2 ºF)
	Volatile Refrigerant	+/- 0.6 ºC (1 ºF)
	Water or nonvolatile refrigerant	+/- 0.1 ºC (0.2 ºF)
Dew Point Hygrometer	Water Vapor Content	+/- 0.2 ºC (0.4 ºF)[3]
Relative Humidity	Water Vapor Content	+/- 1.2 percent RH[3]
Pressure	Barometric Pressure	+/- 100 pa (0.030 inHg)
	Refrigerant and Liquid	±1.0 percent of the reading, or 3.4 kPa (0.5 psig) whichever is greater
	Nozzle pressure difference and nozzle exit velocity pressure	+/-1 percent of reading
	Duct static pressure	±2.5 Pa (±0.01 in. of water)
Electric Power Input	System Components[4]	+/- 1 percent of reading
Electric Energy Input (Wh) or Average Electric Power Input (W)	Total System Energy/Power Input	+/- 0.5 percent of reading
Voltage	Equipment Input Voltage	+/- 1.0 percent of reading
Flow	Volatile Refrigerant	+/- 1.0 percent of reading
	Liquid	+/- 1.0 percent of reading
Rotational Speed	Fan Speed	+/- 1.0 percent of reading
Time	Any	+/- 1 second
Mass	Condensate	±1.0 percent of the reading, or 22.68 g (0.05 lb) whichever is greater

5.2 Pressure Measurement

Pressure measurements and differential pressure measurements shall be made with electronic pressure transducers.

[3] Accuracy at 27/19°C (80/67 °F)
[4] For example, fan motors, compressor motors, or other equipment accessories.

5.3 Electrical Measurement

Electrical input voltage, frequency, power and/or energy shall be measured by digital power instruments. Voltages shall be measured at the equipment terminals. When using a non-integrating (W) measurement instrument, measurements shall be recorded at each second. When using an integrating (Wh) measurement instrument, measurements shall be recorded at intervals of 10 seconds or less.

5.4 Air Measurement

5.4.1 Air measurement apparatus.

An air sampling device shall collect a sample of air at the inlet and outlet locations of the unit under test. When the outdoor air enthalpy method is not used, an air sampling device at outdoor outlet location is not required. Measure the dry-bulb and water vapor content of the sampled air.

5.4.1.1 Air Sampling Tree Requirements

5.4.1.1.1 Construction

The air sampling tree is intended to draw a sample of the air at the critical locations of a unit under test. An example configuration for the air sampling tree is shown in Figure 1. It shall be constructed of stainless steel, plastic or other durable materials. It shall have a main flow trunk tube with a series of branch tubes connected to the trunk tube. Holes shall be on the side of the sampler facing the upstream direction of the air source. Other sizes and rectangular shapes are allowed, and shall be scaled accordingly with the following requirements:

1. Minimum hole density of 6 holes per 0.093 m2 (1 ft2) of area to be sampled
2. Sampler branch tube pitch (spacing) of 15.2 ± 7.6 cm (6 ± 3in)
3. Manifold trunk to branch diameter ratio having a minimum of 3:1 ratio
4. Hole pitch (spacing) shall be equally distributed over the branch (1/2 pitch from the closed end to the nearest hole)
5. Maximum individual hole to branch diameter ratio of 1:2
   Informative Note: 1:3 individual hole to branch diameter ratio preferred

5.4.1.1.2 Air Velocity

The minimum average velocity through the air sampling tree holes shall be 0.76 m/s (2.5 ft/s).

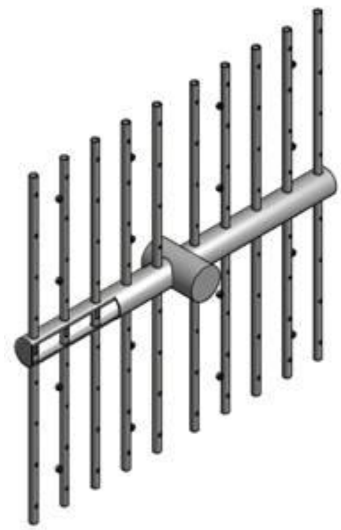

Figure 1. Example Air Sampling Tree

5.4.1.2 Aspirating Psychrometer Requirements

5.4.1.2.1 General

The aspirating psychrometer consists of a flow section and a fan to draw air through the flow section and measures an average value of the sampled air stream. At a minimum, the flow section shall have a means for measuring the air dry-bulb temperature and a means for measuring the water vapor content. The aspirating psychrometer shall include a fan that can either be adjusted manually or automatically to maintain required velocity across the sensors. An example configuration for the aspirating psychrometer is shown in Figure 2. In typical applications, there are two sets of measurements for temperature and water vapor content, one for the rough room control, and the other for the fine control and actual measurement.

5.4.1.2.2 Construction

The aspirating psychrometer shall be made of plastic (such as polycarbonate), aluminum or other metallic materials. Outside diameters shall be between 5 cm (2 in) and 15 cm (6 in). Aspirating psychrometers shall be designed such that radiant heat from the motor does not affect sensor measurements. For aspirating psychrometers with wet-bulb sensors, velocity across the wet bulb sensor shall be 5.0 ± 1.0 m/s (1000 ± 200 ft/min). For all other aspirating psychrometers, velocity shall be as specified by the sensor manufacturer. The aspirating psychrometer shall discharge sampled air back into the duct downstream of the sampler.

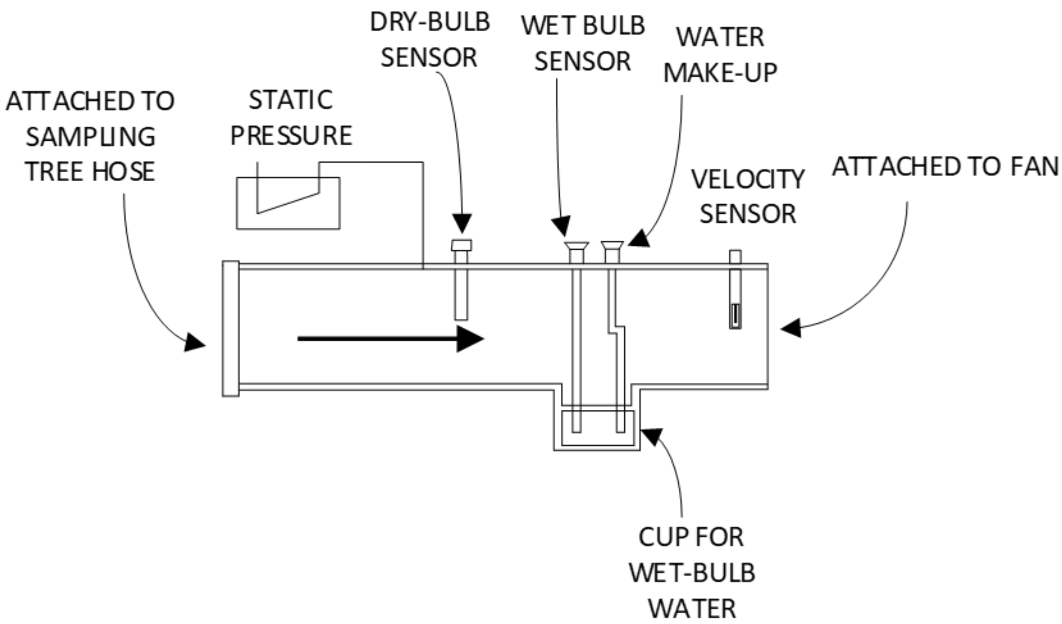

Figure 2. Aspirating Psychrometer

5.4.1.3 Chilled Mirror Dew-point Hygrometer Requirements

5.4.1.3.1 General

If used, apply chilled mirror dew-point hygrometers as specified in Section 7.1 of ASHRAE Standard 41.6–2014. The sampled air shall be discharged into the duct downstream of the sampler. Applying a chilled mirror with a sensor that measures the dewpoint directly within the psychrometer will minimize the time lag observed by pulling the air sample separately out of the psychrometer into a remote sensor located elsewhere in the laboratory. Mounting the sensor in a horizontal orientation also allows for the accumulated condensate to drain from the sensor rather than building up on the mirror causing potential flooding.

5.4.1.4 Air Property Measurement

5.4.1.4.1 General

Air properties shall be calculated using dry-bulb temperature and pressure at the air sampler location, and the humidity ratio calculated for the measurement location of the water vapor content. When dry-bulb temperature at the measurement location of the water vapor content deviates from dry-bulb temperature at the air sampling location (for example, when a sampling tree is separated from the sensor by long lengths of interconnecting tubing) by more than 0.3ºC (0.5ºF), the dry-bulb temperature shall be measured at both locations.

5.4.1.4.2 Pressure Correction

Pressure at location of the water vapor content (wet bulb measurement, dew-point hygrometer, or RH sensor) shall be measured or corrected to ensure humidity ratio is calculated using the pressure measured at the sensor location. The use of room barometric pressure is acceptable when deviations are less than 120 pa (0.5 in. of water).

5.4.1.4.3 Humidity Ratio

The humidity ratio shall be calculated using the pressure measured at the water vapor content sensor location if the 120 pa (0.5 in. of water) threshold is exceeded and using the air dry-bulb temperature measured at the water vapor content sensor location if the 0.3ºC (0.5ºF) threshold is exceeded.

5.5 Thermopile grid and Thermocouple grid

The sampling tree shall be equipped with a thermopile grid or grid of individual thermocouples to measure the average temperature of the airflow over the sampling tree.

5.5.1 Uniformity

A grid of individual thermocouples shall be used to validate temperature uniformity and mixing. To ensure adequate air distribution, thorough mixing, and uniform air temperature, it is important that the room and test setup is properly designed and operated. Air distribution at the test facility point of supply to the unit shall be reviewed and may require remediation prior to the beginning of testing. Mixing fans can be used to ensure adequate air distribution in the test room. If used, mixing fans shall be oriented such that they are pointed away from the air intake so that the mixing fan exhaust cannot be directed at or away from the air entrance to the air inlet. Particular attention should be given to prevent recirculation of condenser fan exhaust air back through the unit. Uniformity of inlet air is adequate when no individual thermocouple deviates from the mean air dry-bulb temperature by more than 1.11°C (2.0°F).

5.6 Nozzle Airflow Measuring Apparatus

The nozzle airflow measuring apparatus is the assembly used to collect the necessary inputs for airflow calculations. There are slight differences between reference standards. For the purposes of these tests, follow the requirements of the associated reference standards used during regulatory testing.

5.6.1 Construction

As shown in Figure 3, the nozzle airflow measuring apparatus consists of a receiving chamber and a discharge chamber separated by a partition containing one or more nozzles. Air from the equipment under test is conveyed through a duct to the receiving chamber, passes through the nozzle or nozzles, and is then exhausted to the test room or channeled to the reconditioning equipment.

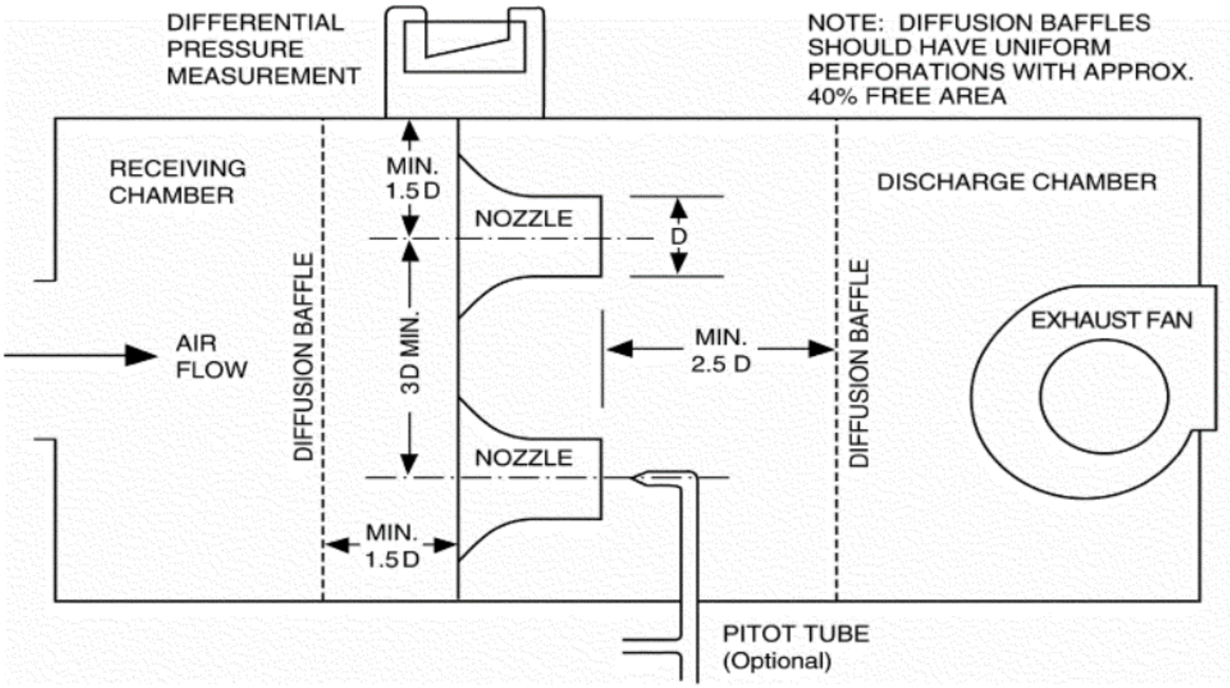

Figure 3. Nozzle Airflow Measuring Apparatus

Section 6 Test Methods Applicability and Test Facility Arrangements

Ducted and non-ducted units shall be tested in different arrangements. The following section describes the test measurement method that applies to each type of unit.

For the initial cooling and initial heating maximum speed or full-load tests performed, two of the methods in Table 4 shall be conducted simultaneously. The primary measurement method is denoted by "1" and all allowable secondary measurements method by "2". For any tests other than initial cooling and initial heating maximum speed or full-load, the secondary measurement measuring instruments shall remain in place, however, the capacity agreement or heat balance requirements are not applicable. (When using outdoor air enthalpy as a secondary measurement, ensure the outdoor airflow measurement apparatus is disconnected for any tests other than maximum speed or full-load.)

Table 4. Applicable Test Methods

Unit Under Test		Applicable Test Method					
Equipment component arrangement(s)	Type of Unit	Indoor air enthalpy	Outdoor air enthalpy	Indoor calorimeter	Outdoor calorimeter	Refrigerant enthalpy method	Loop Air Enthalpy
Single Package System	Ducted	1	2	-	2	-	1
		1	2	-	2	-	1
	Non-Ducted	-	2	1	2	-	-
		-	2	1	2	-	-
Single Split System metering device in outdoor unit	Ducted	1	2	-	2	-	1
		1	2	-	2	-	1
	Non-Ducted	-	2	1	2	-	-
		-	2	1	2	-	-
Single Split System metering device in Indoor unit	Ducted	1	2	-	2	2	1
		1	2	-	2	2	1
	Non-Ducted	-	2	1	2	2	-
		-	2	1	2	2	-

6.1 Indoor Air Enthalpy

The Indoor Air Enthalpy method is applicable to ducted blower coil systems- both single split (see Figure 4) and single package (Figure 5) systems. Space conditioning capacity is determined by measuring airflow rate and the dry-bulb temperature and the water vapor content of the air that enters and leaves the indoor unit. An airflow measuring apparatus is attached to the air outlet of the indoor unit. The discharge air from the reconditioning apparatus provides desired dry-bulb temperatures and the water vapor content in the indoor conditioned space. The indoor air enthalpy method shall follow the requirements of ASHRAE 37-2009 with the following modifications.

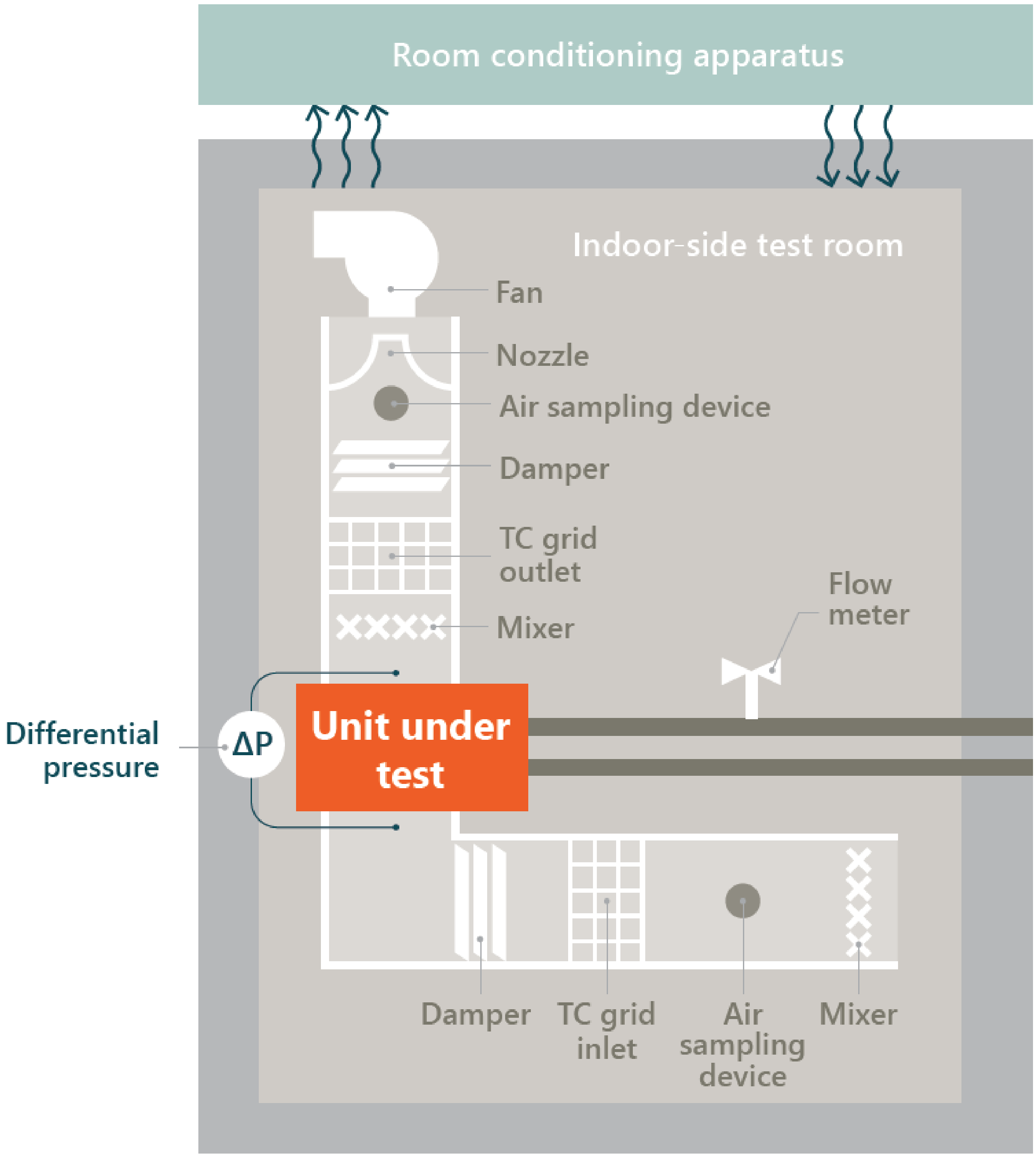

Figure 4. Indoor Air Enthalpy Measurement for Single Split Ducted Systems

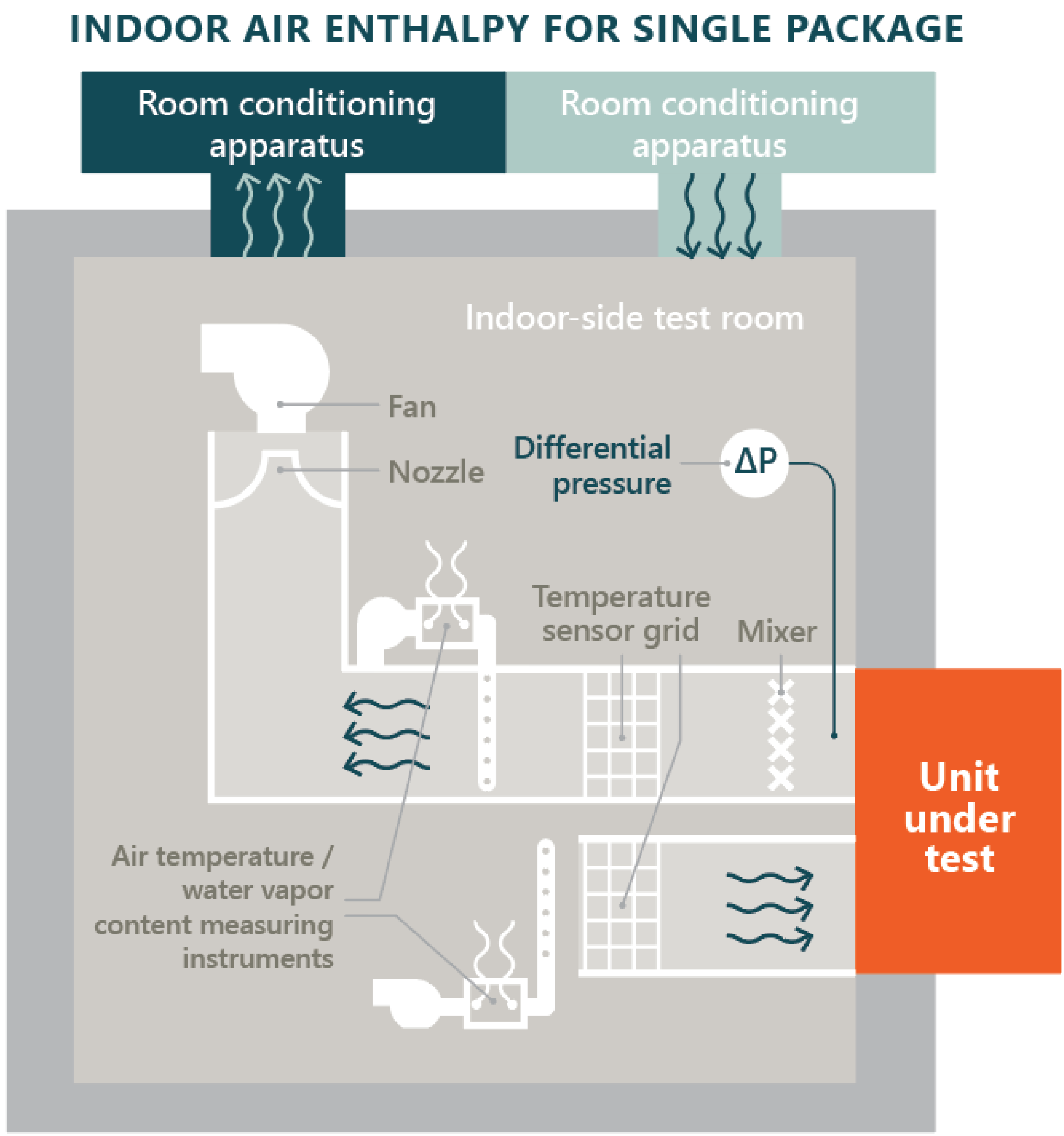

Figure 5. Indoor Air Enthalpy Measurement for Single Package Ducted Systems

6.1.1 External Static Pressure Measurement Apparatus

Recommended configurations for the test apparatus are provided in this section. In all cases, suitable means for determining the airflow and differential pressure shall be provided. The recommended practices for static pressure measurements shall follow requirements of ASHRAE 37- 2009 section 6.5 with the following modifications:

6.1.1.1 Location of Taps
Revise ASHRAE 37- 2009 section 6.5.1 as follows: A tap shall be located at the center of each face of each plenum, if rectangular, or at four evenly distributed locations along the perimeter of an oval or round plenum with a 10% tolerance on the location measurement.

6.1.1.2 Static Pressure Manifold
Revise ASHRAE 37- 2009 section 6.5.3 as follows: Static pressure taps should be manifolded using one of the recommended connection options shown in Figure 6 . Letters A-N indicate where equal tube lengths are required.

6.1.1.3 Manifold Connection
Add the following: Connect one side of the differential pressure instrument to the manifolded pressure taps installed in the outlet plenum. Connect the other side of the instrument to the manifolded pressure taps located in the inlet plenum.

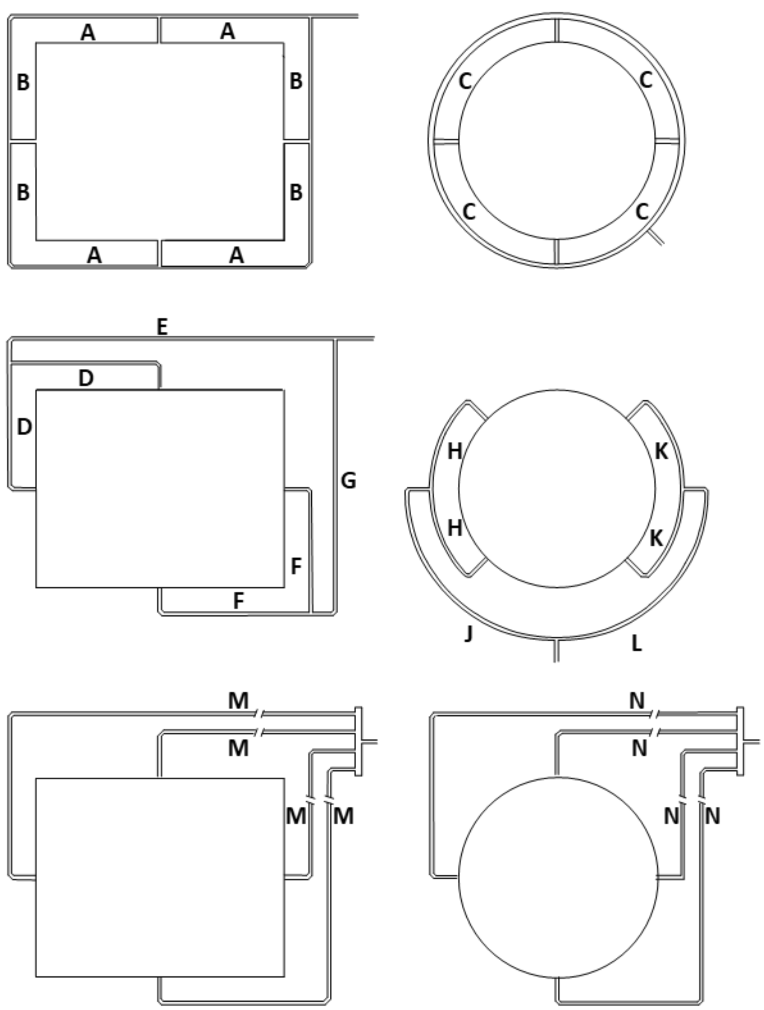

Figure 6. Recommended Connection Options for Static Pressure Taps

6.1.2 Inlet Plenum

6.1.2.1 Full Inlet Plenum

If space within the test room permits, a full inlet duct connection shall be installed. If used, the inlet duct shall have cross-sectional dimensions equal to those of the equipment and should otherwise be fabricated with a length of at least 1.5 equivalent diameters, $1.5 \cdot \sqrt{\frac{\pi D_i^2}{4}}$ for circular ducts or $1.5 \cdot \sqrt{C \cdot D}$ for rectangular. The static pressure measurement plane is located 0.5 equivalent diameters, $0.5 \cdot \sqrt{\frac{\pi D_i^2}{4}}$for circular ducts or $0.5 \cdot \sqrt{C \cdot D}$ for rectangular ducts upstream of the unit inlet connection with a tolerance of ± 10%.

6.1.2.2 Space-limited Inlet Plenum

If space within the test room does not permit the full inlet plenum connection, an abbreviated inlet plenum shall be installed. The inlet plenum shall have cross-sectional dimensions equal to those of the equipment and a minimum length of 15 cm (6 inches). Four static pressure taps shall be located in the center of each face with a tolerance of ± 10%. This inlet duct shall be connected directly to the inlet of the unit.

6.1.3 Outlet Plenum

6.1.3.1 Full Outlet Plenum

A full outlet plenum shall be attached to the outlet of the discharge side of the equipment. This plenum shall have cross-sectional dimensions equal to the dimensions of the equipment outlet and should otherwise be fabricated as shown by the setups given in Figure 7, Figure 8, and Figure 9 and discharge into the mixer (if used) prior to the air sampling section upstream of the airflow measurement device.

The discharge plenum duct shall be at least 2.5 equivalent diameters,

$2.5 \cdot \sqrt{\frac{\pi D_O^2}{4}}$ for circular ducts, or $2.5 \cdot \sqrt{A \cdot B}$ for rectangular ducts.

The static pressure measurement plane is located 2.0 equivalent diameters,

$2.0 \cdot \sqrt{\frac{\pi D_O^2}{4}}$ or circular ducts or $2.0 \cdot \sqrt{A \cdot B}$ for rectangular ducts downstream of the unit inlet connection with a tolerance of ± 10%.

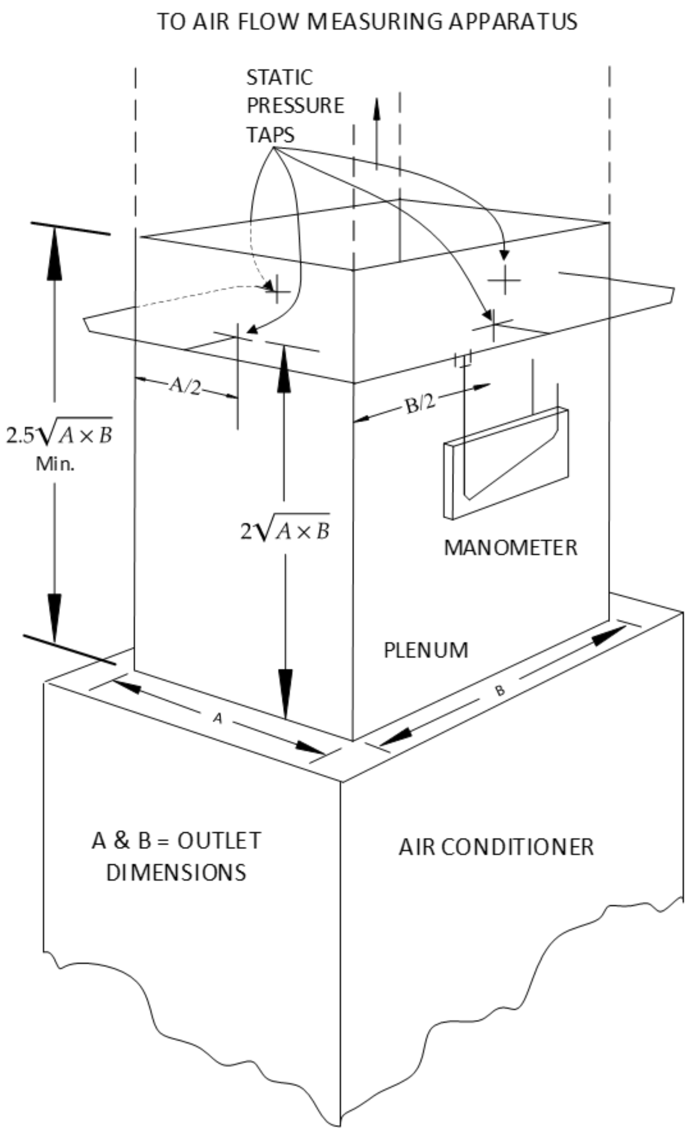

Figure 7. Example External Static Pressure Measurement (Outlet)

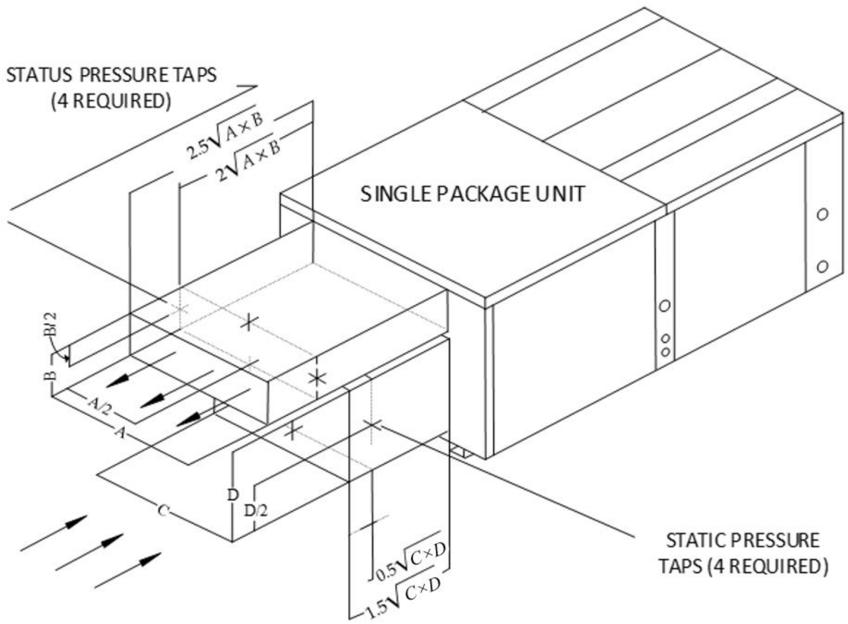

Figure 8. Example External Static Pressure Measurement (Inlet and Outlet)

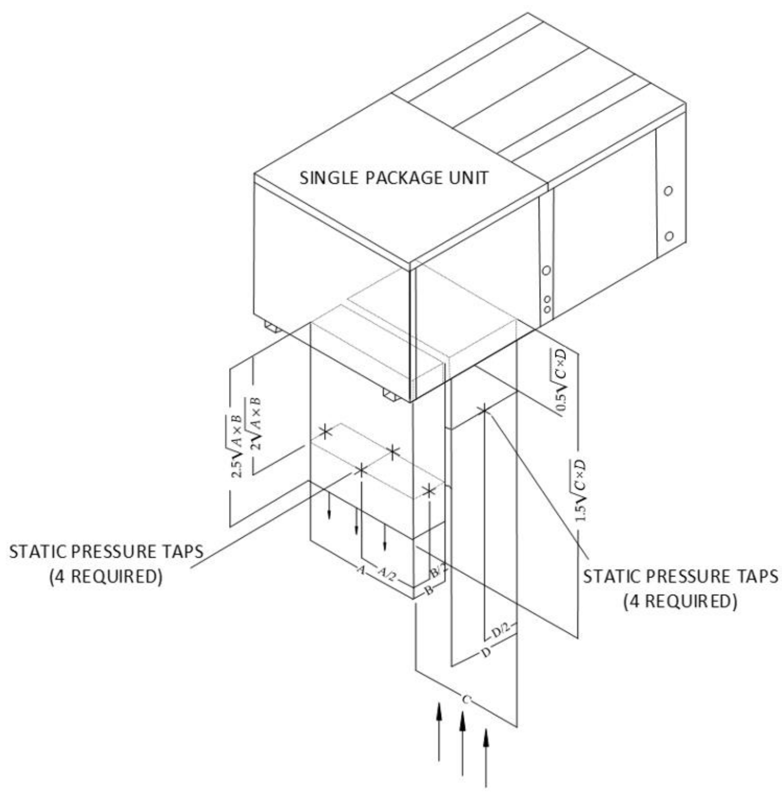

Figure 9. Example External Static Pressure Measurement (Inlet and Outlet)

6.1.4 Small-duct, High-velocity Systems

6.1.4.1 Outlet Plenum

For Small-duct, High-velocity Systems, install an outlet plenum that has a diameter that is equal to or less than the value listed in Table 5. The limit depends only on the Cooling Full-Load Air Volume Rate and is effective regardless of the flange dimensions on the outlet of the unit (or an air supply plenum adapter accessory, if installed in accordance with the manufacturer's installation instructions).

Table 5. Maximum Diameter of Outlet Plenum for Small-duct, High-velocity

Cooling Full-Load Air Volume Rate Standard L/s (scfm)	Maximum Diameter* of Outlet Plenum cm (in)
≤ 236 (500)	15 (6)
>236 (501) to 330 (700)	18 (7)
>330 (701) to 425 (900)	20 (8)
>425 (901) to 519 (1100)	23 (9)
>519 (1101) to 661 (1400)	25 (10)
>661 (1401) to 826 (1750)	28 (11)

*If the outlet plenum is rectangular, calculate its equivalent diameter using (4A)/P, where A is the area and P is the perimeter of the rectangular plenum, and compare it to the listed maximum diameter.

6.2 Outdoor Air Enthalpy

The outdoor air enthalpy is applicable to all blower coil systems- both single package and single split systems (see Figure 10). Space conditioning capacity is determined by measuring airflow rate and the dry-bulb temperature and the water vapor content of the air that enters and leaves the outdoor unit. An airflow measuring apparatus is attached to the air outlet of the outdoor unit. The discharge air from the reconditioning apparatus provides the desired dry-bulb temperatures and the water vapor content in the outdoor conditioned space. The outdoor air enthalpy method shall follow the requirements of ASHRAE 37-2009 with the following modifications.

6.2.1 Outdoor Air Temperatures

For the outdoor air inlet location, multiple temperature measurements shall be used to determine acceptable air distribution and the mean air temperature. The outdoor air inlet air sampling tree shall also be equipped with a thermocouple, thermopile grid or individual thermocouples to measure the average temperature of the airflow over the air sampling tree. The air sampling trees shall be placed within 15 – 30 cm (6-12 in) of the unit to minimize the risk of damage to the unit while ensuring that the air sampling tubes are measuring the air going into the unit rather than the room air around the unit and care shall be taken to assure that the upper sampling holes are not pulling in the discharge air leaving the outdoor section of the unit under test. Any sampler holes directly exposed to condenser discharge air shall be blocked to prevent sampling.

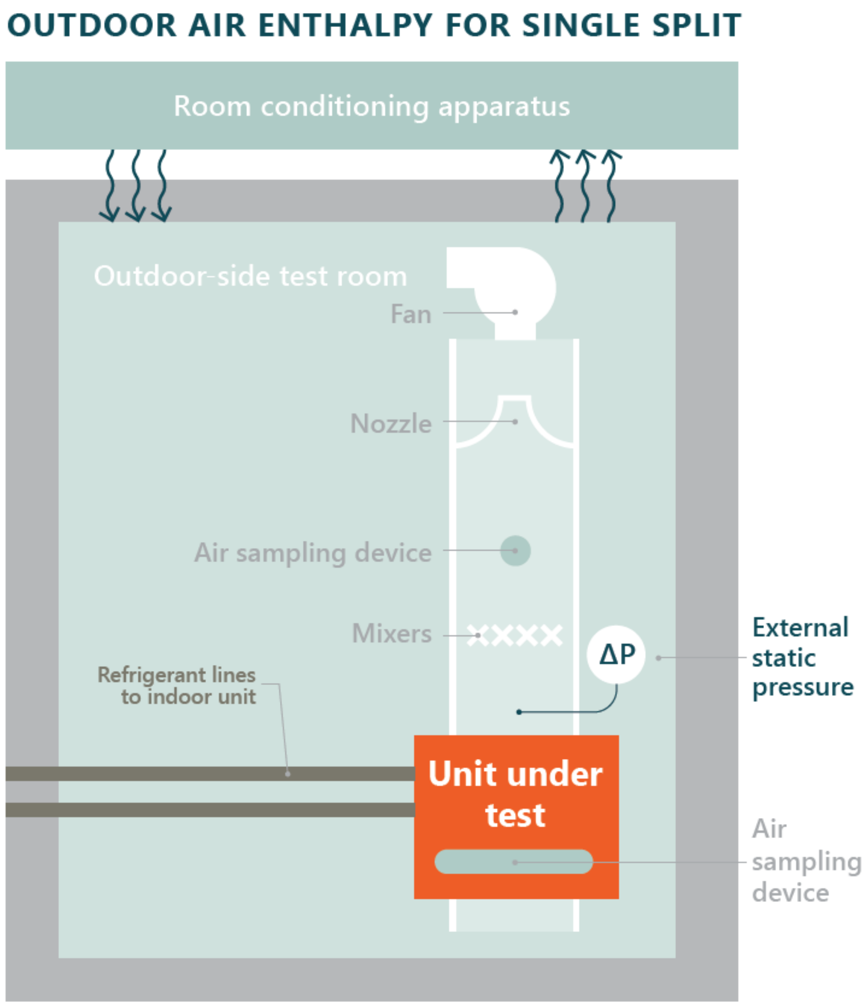

Figure 10. Outdoor Air Enthalpy

6.3 Indoor Calorimeter

Indoor Calorimeter encompasses both balanced ambient and calibrated room types. The Indoor Calorimeter method is applicable to non-ducted both single package and single split blower coil systems. The indoor calorimeter method may be utilized inside existing psychrometric facilities.

6.3.1 Cooling Capacity

For cooling capacity, space conditioning capacity is determined by balancing the cooling and dehumidification effects of the unit under test against the measured energy and water inputs used to maintain the chamber conditions. The discharge air from the reconditioning apparatus provides desired dry-bulb temperatures and water vapor content in the Indoor conditioned space. By measuring the amount of energy and water inputs used to recondition the chamber air, the system capacity is calculated.

6.3.2 Heating Capacity

For heating capacity, space conditioning capacity is determined by balancing the heating effects of the unit under test against the measured amount of cooling medium and heat input to the indoor room. The discharge air from the reconditioning apparatus provides desired dry-bulb temperatures and water vapor content in the Indoor conditioned space. By measuring the amount of energy and cooling medium used to recondition the chamber air, the system capacity is calculated.

6.3.3 Pressure Equalizing Device

For single package equipment a pressure equalizing device shall be provided in the partition wall between the room-side and outdoor-side compartments to maintain a balanced pressure between these compartments and to permit measurement of leakage, exhaust and ventilation air. The pressure equalizing device shall follow the requirements of ISO 5151-2017 appendix C section C1.3 (ASHRAE-16 Section 6.1.1.5)

6.3.4 Air Sampling Device

The air sampling device locations shall meet the requirements defined in ASHRAE 16 section 8.2.7 and 8.2.8 which includes the requirements specified in section 8.2.7.1 through 8.2.7.4.

6.3.5 Calibrated Room Type Calorimeter

When using a calibrated room type calorimeter the requirements of ISO 5151-2017 appendix C section C2 (ASHRAE 16 section 6.1.2) shall be met. Figure 11 shows an example of a calibrated room type calorimeter set up with a single package unit.

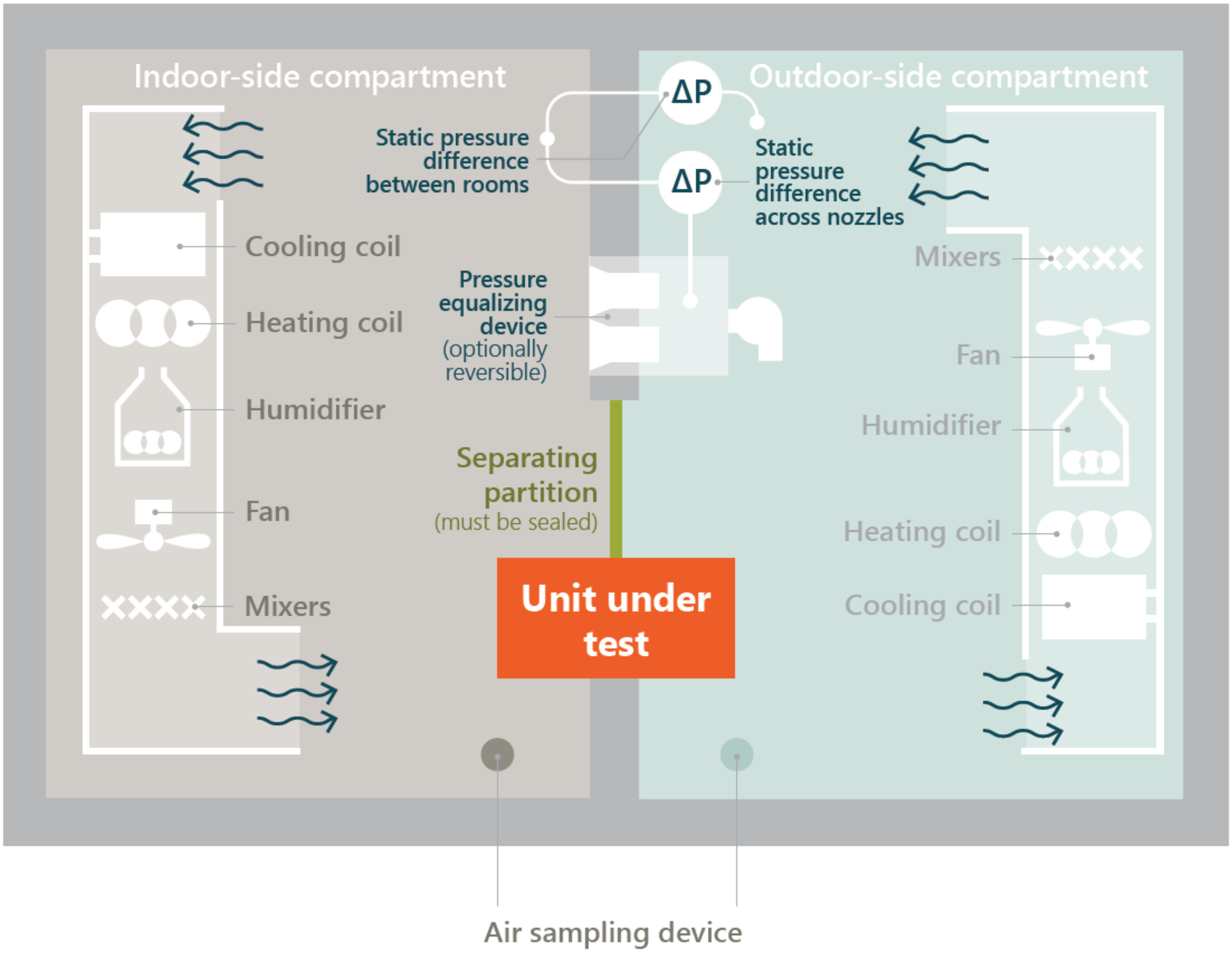

Figure 11. Calibrated Room Type Calorimeter with Single Package Unit

6.3.6 Balanced Ambient Calorimeter

When using a balanced ambient room type calorimeter requirements of ISO 5151-2017 appendix C section C3 (ASHRAE 16 section 6.1.3) shall be met.

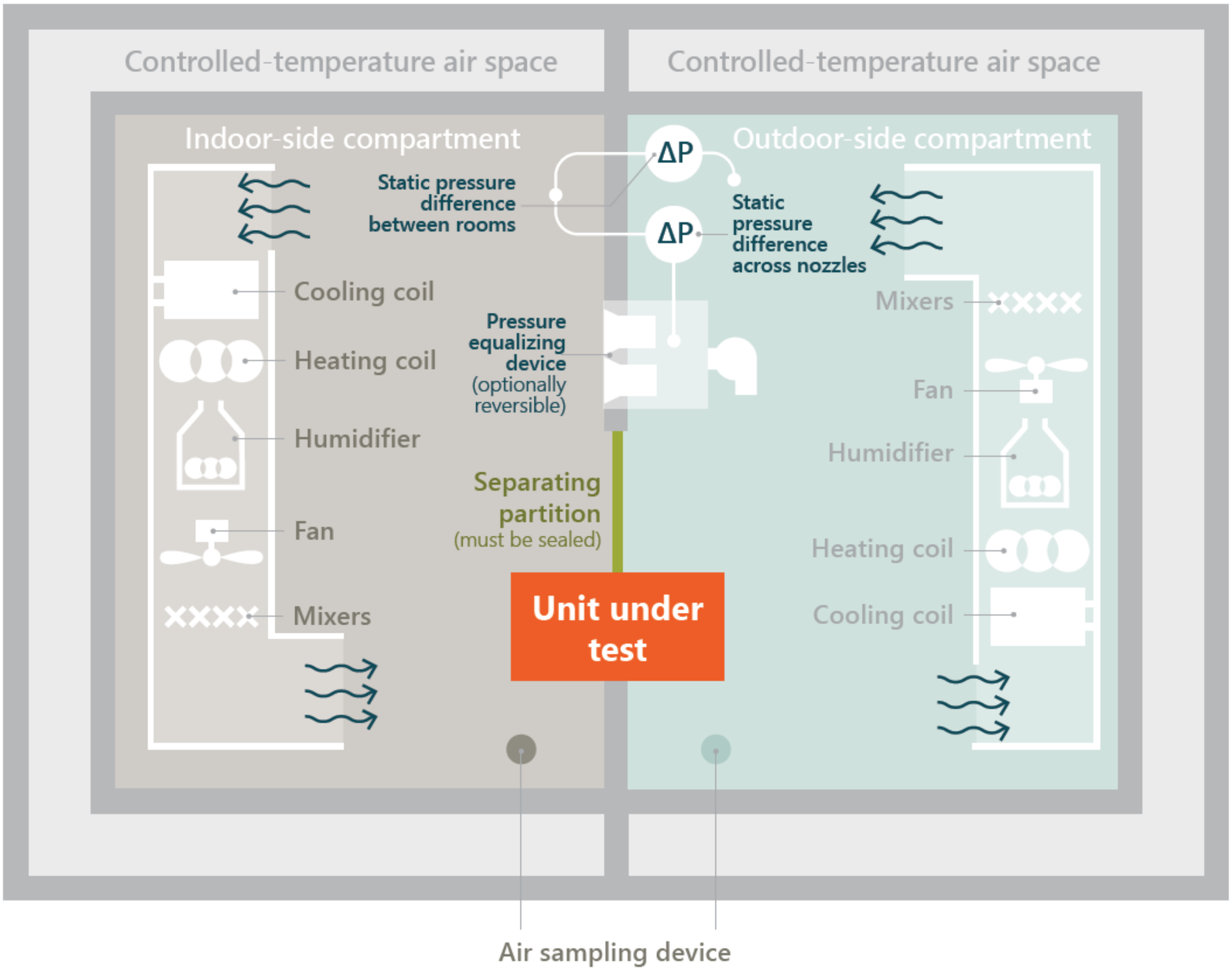

Figure 12. Balanced Ambient Calorimeter set up to test a single package unit.

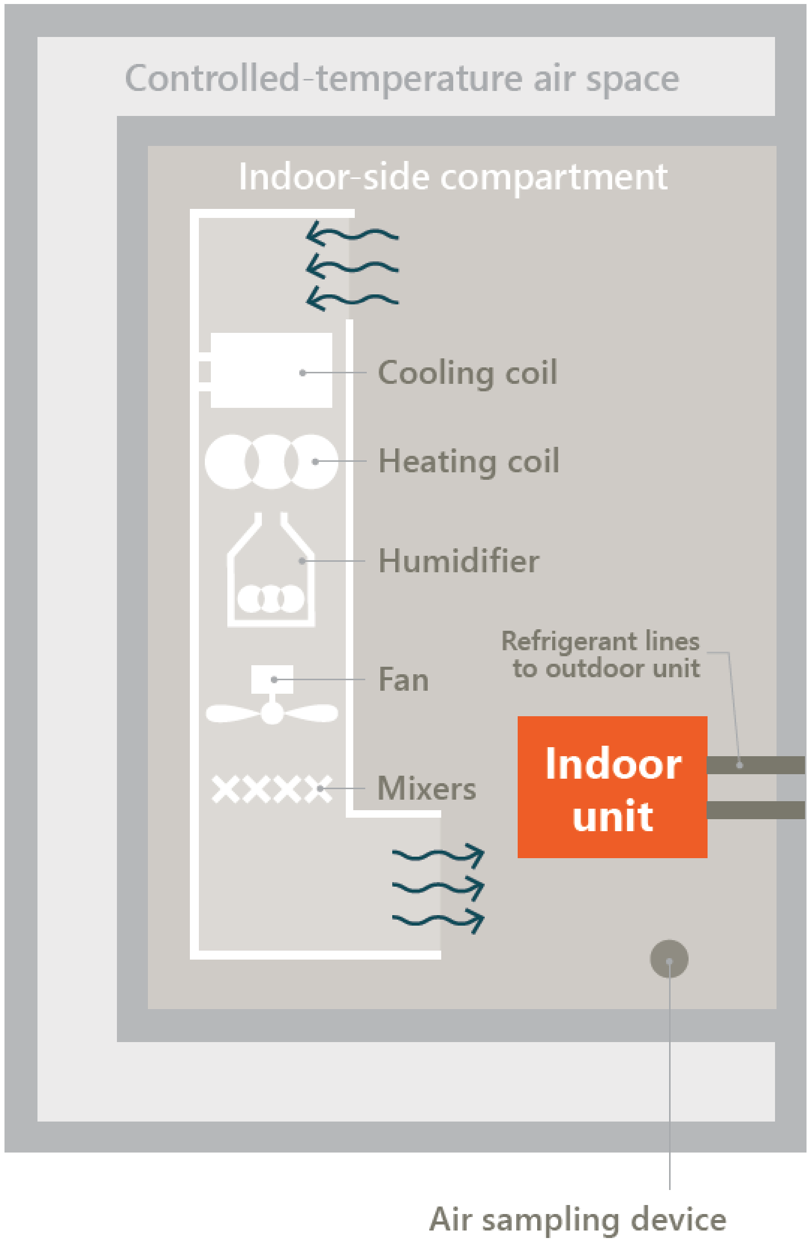

Figure 13. Indoor Side of a Balanced Ambient Calorimeter with a Single Split Unit

6.4 Outdoor Calorimeter

Outdoor Calorimeter encompasses both balanced ambient and calibrated room types. The Outdoor Calorimeter method is applicable to package and split blower coil systems operating above 0°C (32°F).

6.4.1 Cooling Mode Capacity

When the unit under test is in cooling mode the outdoor space conditioning capacity is determined by balancing heat and water vapor rejection of the unit under test against the measured cooling and water inputs used to maintain the chamber conditions. The discharge air from the reconditioning apparatus provides desired dry-bulb temperatures and water vapor content in the Indoor conditioned space.

6.4.2 Heating Mode Capacity

When the unit under test is in heating mode, the outdoor space conditioning capacity is determined by balancing the cooling and dehumidification effects of the unit under test against the measured amount of heat and water vapor inputs used to maintain the chamber conditions. The discharge air from the reconditioning apparatus provides desired dry-bulb temperatures and water vapor content in the outdoor conditioned space.

6.4.3 Pressure Equalizing Device

For single package equipment a pressure equalizing device shall be provided in the partition wall between the room-side and outdoor-side compartments to maintain a balanced pressure between these compartments and to permit measurement of leakage, exhaust and ventilation air. The pressure equalizing device shall follow the requirements of ISO 5151-2017 appendix C section C1.3 (ASHRAE-16 Section 6.1.1.5)

6.4.4 Air Sampling Device

The air sampling device locations shall meet the requirements defined in ASHRAE 16 section 8.2.7 and 8.2.8 which includes the requirements specified in section 8.2.7.1 through 8.2.7.4.

6.4.5 Calibrated Room Type Calorimeter

When using a calibrated room type calorimeter the requirements of ISO 5151-2017 appendix C section C2 (ASHRAE 16 section 6.1.2) shall be met. Figure 11 shows an example of a calibrated room type calorimeter set up with a single package unit.

6.4.6 Balanced Ambient Calorimeter

When using a balanced ambient room type calorimeter requirements of ISO 5151-2017 appendix C section C3 (ASHRAE 16 section 6.1.3) shall be met.

6.5 Refrigerant Enthalpy

Refrigerant enthalpy is applicable to ducted and non-ducted single split blower coil systems with metering device located in the indoor unit. Capacity is determined from the refrigerant enthalpy change and flow rate. Enthalpy changes are determined from measurements of entering and leaving pressures and temperatures of the refrigerant, and the flow rate is determined by a suitable flow meter in the liquid line. The temperature and pressure of the refrigerant leaving the indoor section or side and either entering the indoor section or side (heating mode) or entering the expansion device (cooling mode) shall be measured. The temperatures, pressures and flow are used to calculate the refrigerant enthalpy capacity with the equipment operating at the desired test conditions.

6.5.1 Specification

The specification of this method detailed in either ISO 5151-2017 Appendix E or ASHRAE 37-2009 section 7.5 shall be followed when using this method.

6.5.2 Applicability

This method may be used for tests of equipment in which the refrigerant charge is not critical and where normal installation procedures involve the field connection of refrigerant lines.

6.5.3 Restrictions

This method shall not be used for tests in which the refrigerant liquid leaving the flow meter is subcooled less than 2°C (3°F) or for tests in which any instantaneous measurement of the superheat of the vapor leaving the indoor section is less than 3°C (5°F).

6.6 Loop air enthalpy

Loop air enthalpy is applicable to ducted blower coil systems- both single package and single split systems. Space conditioning capacity is determined by measuring airflow rate and the dry-bulb temperature and the water vapor content of the air that enters and leaves the indoor unit. An air-measuring device is attached to the air outlet and inlet ducts of the indoor unit to measure the air flow. The supply air temperature and the water vaper content are measured using an air sampling tree, then sent through a reconditioning loop to provide the proper air temperature, water vaper content and air flow to test unit return duct where an air sampling tree to determine the air temperature and the water vaper content entering the tests unit. Air-sampling trees and pressure sensors at the indoor air inlet and indoor air outlet measure the dry-bulb temperatures, the water vapor content and absolute pressure to calculate enthalpy difference.

6.6.1 Specification

The specification detailed in ISO 5151-2017 Appendix D section D 5.3 shall be followed when using this method.

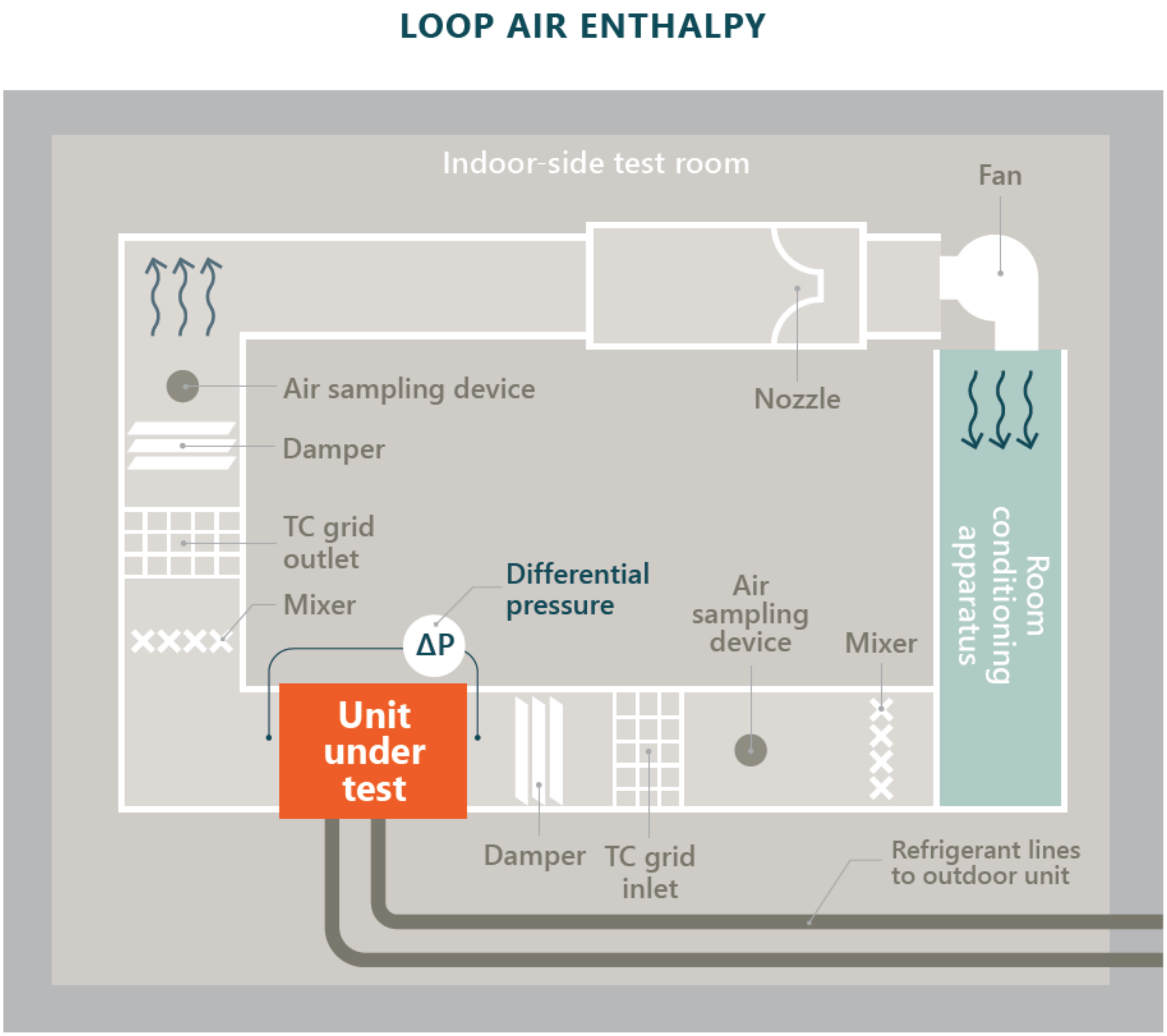

Figure 14. Loop Air Enthalpy

Section 7 Test Procedures

The controls validation test procedure complements regulatory tests that utilize overrides for modulating components in variable speed compressor systems. This procedure consists of identifying a Target Compensation Load that corresponds to the selected regulatory test conditions. The unit under test shall operate under its own Native Controls to validate operation and system performance characteristics overridden during regulatory tests. An example flow-chart of the test procedure process is included in Figure 15 below. Detailed descriptions of the procedure requirements are provided in this section.

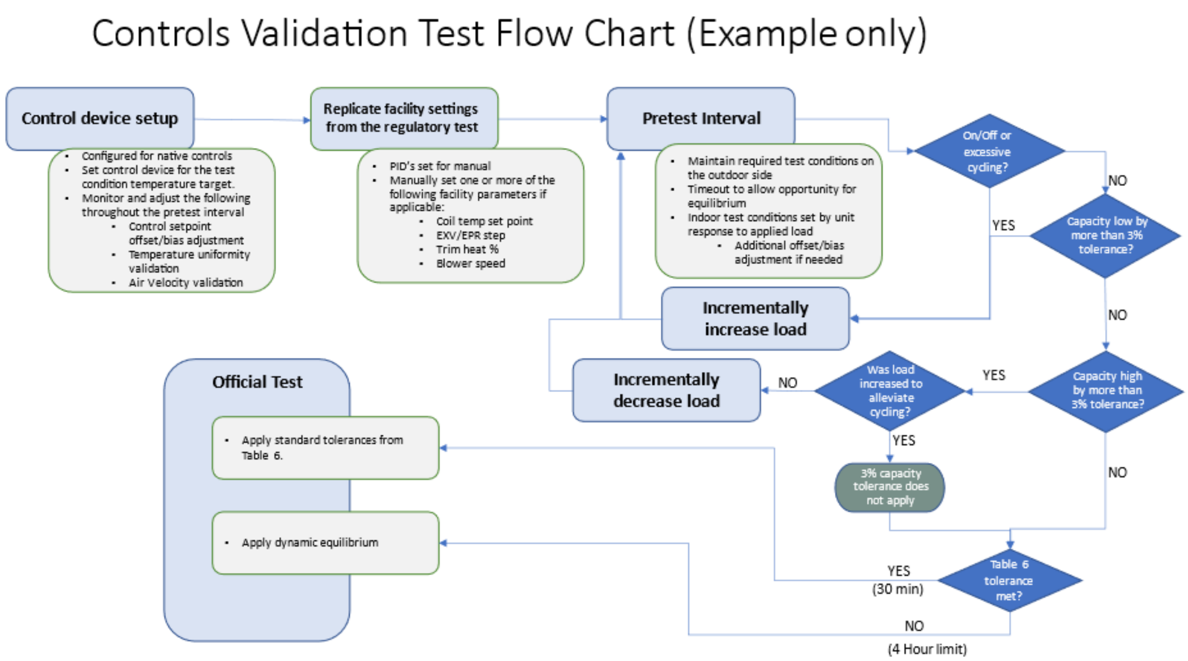

Figure 15. Controls Validation Test Method Flow Chart

7.1 General

The applicable test methods listed in Table 4 above shall be consistent with the test methods used in regulatory tests, except as described in this document, to measure capacity and power and/or energy consumption.

7.1.1 Test Conditions

The indoor room/side shall subject the unit under test to a Target Compensation Load corresponding to the regulatory test measured capacity. The unit under test responds accordingly to maintain the indoor test conditions. The outdoor room/side shall maintain constant conditions corresponding to the appropriate regulatory test conditions.

7.2 Control Device and Configuration

The Control Device (i.e. thermostat or remote controller) is considered an integral component of Native Control. For units shipped with a Control Device, that Control Device shall be used for testing. For units intended to be used with a communicating Control Device (i.e., communicates the difference between set point temperature and room temperature to the compressor speed controller) but the Control Device is not shipped with the unit, the test shall utilize the Control Device that is most commonly installed with the unit. For units intended to be used with multiple Control Device types including communicating and non-communicating (i.e., 24-volt or digital on/off signals) any generic thermostat shall be allowed for testing.

7.2.1 Control Device Installation

Install the Control Device on a flat surface (i.e., wood or insulation) extending 12" from the nearest edge on all sides. A thermocouple shall be installed at the return air sensor on the Control Device (within 2" of the inlet opening on Control Device). An additional thermocouple shall be installed at the return air thermistor (within 2" of the return air thermistor provided on the test unit), if present. If both thermocouples are installed, they shall agree within 0.5°C (1°F) of each other. Each thermocouple shall also agree with the air entering dry-bulb sensor within 0.5°C (1°F). Mixing fans may be used to ensure temperature uniformity. If used, the mixing fans shall not be directed at the Control Device. Air velocity at the Control Device shall not exceed 0.25 meters per second (50 feet per minute). Baffles or a perforated-plate box may be used to reduce air velocity at the Control Device to this limit.

7.2.2 Control Device Offset Adjustment

Adjustments for the thermostat set point for offsets **at each load point** may be required and shall be made prior to collecting test measurements. The Control Device set point of the system under test shall initially be set at the air entering dry-bulb temperature specified for the appropriate test conditions for the corresponding regulatory test. Then, identify and correct the Control Device setpoint by the difference between the displayed return/ambient air temperature on the Control Device and the thermocouple(s) specified in the Control Device Installation section.

7.3 Control Settings

7.3.1 Control Settings

Control settings shall be identical to those used in the associated regulatory test except that modulating component overrides are not allowed. The available control settings shall be determined from the installation instructions manual shipped with the unit. Control settings shall be divided into group A, B, C and D according to Table 6. Example Control Settings

7.3.1.1 Control Group Descriptions and Determination

Group A control settings shall be specified by the associated regulatory test (i.e. cooling for cooling tests and heating for heating tests). Auto Changeover and Troubleshooting/Refrigerant Charging shall not be used.

Group B control settings shall be defined in the associated regulatory test and consistent with the regulatory test requirements such as static limits, air volume rate per capacity limits and required adjustments if the resultant airflow values are invalid.

Group C control settings shall be defined by the authority having jurisdiction or the regulatory test. The authority having jurisdiction may require certain settings such as defrost, dehumidification, dry cooling or eco/energy save function as climate region specific to better align with the regulatory test and anticipated field installed operation. If the group C control settings are not defined by the authority having jurisdiction, the settings shall be set to “off” or “disabled”.

Group D control settings includes anything not explicitly grouped in the other three categories. The group D control settings shall be defined by the authority having jurisdiction or the regulatory test. If the group D control settings are not defined by the authority having jurisdiction, the test shall be conducted with the group D control settings set to the default setting listed in the installation instructions. If no default settings are provided in the installation instructions, the test shall be conducted using the as-shipped settings. In the event that control settings do not allow the unit under test to operate continuously in order to complete the test (e.g. occupancy sensor set to on), the settings shall be modified as minimally as possible to complete the test.

Table 6. Example Control Settings and corresponding groups

Operating Modes – Group A	Cooling
	Heating
	Auto Changeover
	Troubleshooting/Refrigerant Charging
Airflow – Group B	Auto
	High
	Medium-High
	Medium
	Medium-Low
	Low
	Quiet

	Fan Energy Save
	On
	Circulate/Stir
Function – Group C	Dehumidification
	Eco/Energy Save
	Jet/Turbo
	Dry Cooling
	Louver Position/Louver Swing
	Defrost Configuration
Special features – Group D	Low Noise
	Skin moisturize
	Anti-mosquito
	Air purify

7.3.2 Test Facility Settings (Informative)

Test facility reconditioning equipment, hardware and software automation may vary by location. If advanced controls (shown in Figure 16) do not exist such that a test facility can automate the Target Compensation Load injection, the test facility settings from the corresponding regulatory test shall be replicated, to the extent possible, to initially set the indoor room load. Manual settings for some test facility parameters may be required, as shown in Figure 17, Figure 18, and Figure 19.

7.4 Pretest Interval

7.4.1 Pretest Setup

Initially, set up operation at the Target Compensation Load by setting the chamber conditioning equipment at the conditioning levels used for the corresponding regulatory test on the indoor room/side or an advanced control feedback loop from the measured load. Maintain the required outdoor test conditions within the tolerances listed in Table 7. Once the unit under test and chamber conditioning system are running, allow time for system to adjust to the load that is being applied to the indoor section and achieve equilibrium. Equilibrium is determined in the pretest interval when the unit under test is no longer cycling its compressor on and off. Additional adjustment to the thermostat setpoint to account for offset/bias may be needed to achieve equilibrium at the proper indoor temperature.

7.4.2 Steady-state determination during pretest interval

Steady-state shall be considered to have been met when the test operating and test condition tolerances listed in Table 7 are met for at least 30 minutes and the average capacity shall be achieved within +/-3% of the corresponding regulatory test capacity.

7.4.2.1 System that cycles in cooling mode
For cooling tests, if the system is unable to operate within +/-3% of the corresponding regulatory test capacity with no compressor on/off cycling, incrementally increase the total heating (sensible and latent to maintain the sensible to total cooling capacity ratio within 3% of the regulatory test) addition to the indoor room until there is no on/off compressor cycling and steady-state requirements are achieved. Steady state shall be considered to have been met when the test operating and test condition tolerances listed in Table 7 are met for at least 30 minutes. If cooling tests require increased loads to achieve steady state conditions, the 3% tolerance of the corresponding regulatory test capacity does not apply.

7.4.2.2 System that cycles in heating mode
For heating tests, if the system is unable to operate within +/-3% of the corresponding regulatory test capacity with no compressor on/off cycling, increase incrementally the sensible cooling addition to the indoor room until there is no on/off compressor cycling and steady-state requirements are achieved. Steady state shall be considered to have been met when the test operating and test condition tolerances listed in Table 7 are met for at least 30 minutes. If heating tests require increased loads to achieve steady state conditions, the 3% tolerance of the corresponding regulatory test capacity does not apply.

7.4.2.3 Dynamic Equilibrium
If the system is unable to achieve steady-state requirements within four (4) hours after the last incremental adjustment of the load addition to the indoor room, the pretest interval is complete and dynamic equilibrium criteria (described in section 7.5.2 below) shall apply during the official test period.

Table 7. Operating and Condition Tolerances for Target Compensation Load

	Test operating tolerance[5]	Test condition tolerance[6]
Indoor/Sampler dry-bulb:		
Entering temperature	0.56°C (1.0°F)	1.11°C (2.0°F)
Leaving temperature	2.22°C (4.0°F)	-
Indoor/Sampler wet-bulb:		
Entering temperature	0.56°C (1.0°F)	-
Outdoor dry-bulb:		
Entering temperature	0.56°C (1.0°F)	1.11°C (2.0°F)

[5] Test operating tolerance is the maximum permissible variation of the observed range.
[6] Test condition tolerance is the maximum permissible variation of the mean average from the specified test condition.

	Test operating tolerance[5]	Test condition tolerance[6]
Leaving temperature	-	-
Outdoor wet-bulb:		
Entering temperature	0.56°C (1.0°F)	0.56°C (1.0°F)
Leaving temperature	-	-
Air temperature surrounding calorimeter		
Dry bulb	1.11°C (2.0°F)	0.56°C (1.0°F)
Wet bulb	0.56°C (1.0°F)	0.28°C (0.5°F)
External resistance to airflow	12.44 Pa (0.05" H2O)	
Electrical voltage, % of reading	2.0	1.5
Nozzle pressure drop, % of reading	8.0	

7.5 Official Test Period

7.5.1 Test Duration

The official test period shall be one hour for systems that attain steady-state determination during the pretest interval and can maintain tolerances throughout the official test period. For systems that were unable to meet the steady-state determination in the pretest interval and utilize the dynamic equilibrium criteria, the official test period duration is described in section 7.5.2. Once the official test period begins, continuously monitor all instrumentation at intervals that span 10 seconds or less, except for power which shall be recorded each second unless using an integrating power meter.

7.5.2 Dynamic Equilibrium Criteria

Dynamic equilibrium is attained when both average capacity and average system power input measured in successive test period intervals are within 2 percent of each other.

7.5.2.1 If regular cycling occurs, the test periods intervals shall be at least 30 minutes in duration and comprise a whole number of system cycles.

7.5.2.2 If regular cycling does not occur, the intervals shall be 30 minutes in duration.

7.5.2.3 The official test measurements for dynamic equilibrium shall be the average values measured during these two successive intervals.

Section 8 Calculations

The calculations contained in ASHRAE 16-2016, ASHRAE 37-2009, and ISO 5151 – 2017 shall be incorporated by reference and applied as required by the respective test method listed in section 6. Capacity and input shall be calculated for each test condition and compared to the corresponding regulatory test. Permissible deviations from the regulatory tests shall be defined by the authority having jurisdiction.

Section 9 Symbols and Subscripts

The symbols and subscripts contained in ASHRAE 16-2016, ASHRAE 37-2009, and ISO 5151 – 2017 shall be incorporated by reference and applied as required by the respective test method listed in section 6.

Section 10 Data Recording and reporting requirements

The data to be recorded contained in ASHRAE 16-2016, ASHRAE 37-2009, and ISO 5151 – 2017 shall be incorporated by reference and applied as required by the respective test method listed in section 6. Table 8 includes additional parameters required for controls validation tests. Items indicated by an "x" under the test method columns, or their equivalents are required when that test method is employed.

Table 8. Data to be Recorded

Item	Indoor Air Enthalpy Method	Outdoor Air Enthalpy Method	Indoor Calorimeter Method	Outdoor Calorimeter Method	Refrigerant Enthalpy Method	Loop Air Enthalpy Method
Test interval times	X	X		X	X	X
Fan speed(s), setting	X	X	X	X	X	X
Temperature within 2" of Control Device °C [°F]	X		X			X
Temperature within 2" of return air thermistor (if present) °C [°F]	X		X			X
Air velocity within 2" of Control Device, m/s [fpm]	X		X			X

Section 11 References

11.1 ANSI/ASHRAE Standard 16-2016

ANSI/ASHRAE Standard 16-2016, Method of Testing for Rating Room Air Conditioners, Package Terminal Air Conditioners, and Package Terminal Heat Pumps for Cooling and Heating Capacity

11.2 ANSI/ASHRAE Standard 37-2009

ANSI/ASHRAE Standard 37-2009, Method of Testing for Rating Electrically Driven Unitary Air-Conditioners and Heat Pump Equipment

11.3 ISO 5151_2017

ISO 5151_2017, Non-ducted Air Conditioners and Heat Pumps – Testing and Rating for Performance

Section 12 Appendix: Informative Examples of Test Room Controls

The following images are provided as informative examples of test facility programmable logic. Test facilities vary widely in construction, reconditioning equipment, hardware and software automation. The examples shown below are indicative of how existing software automation could potentially be modified to accommodate Target Compensation Load testing.

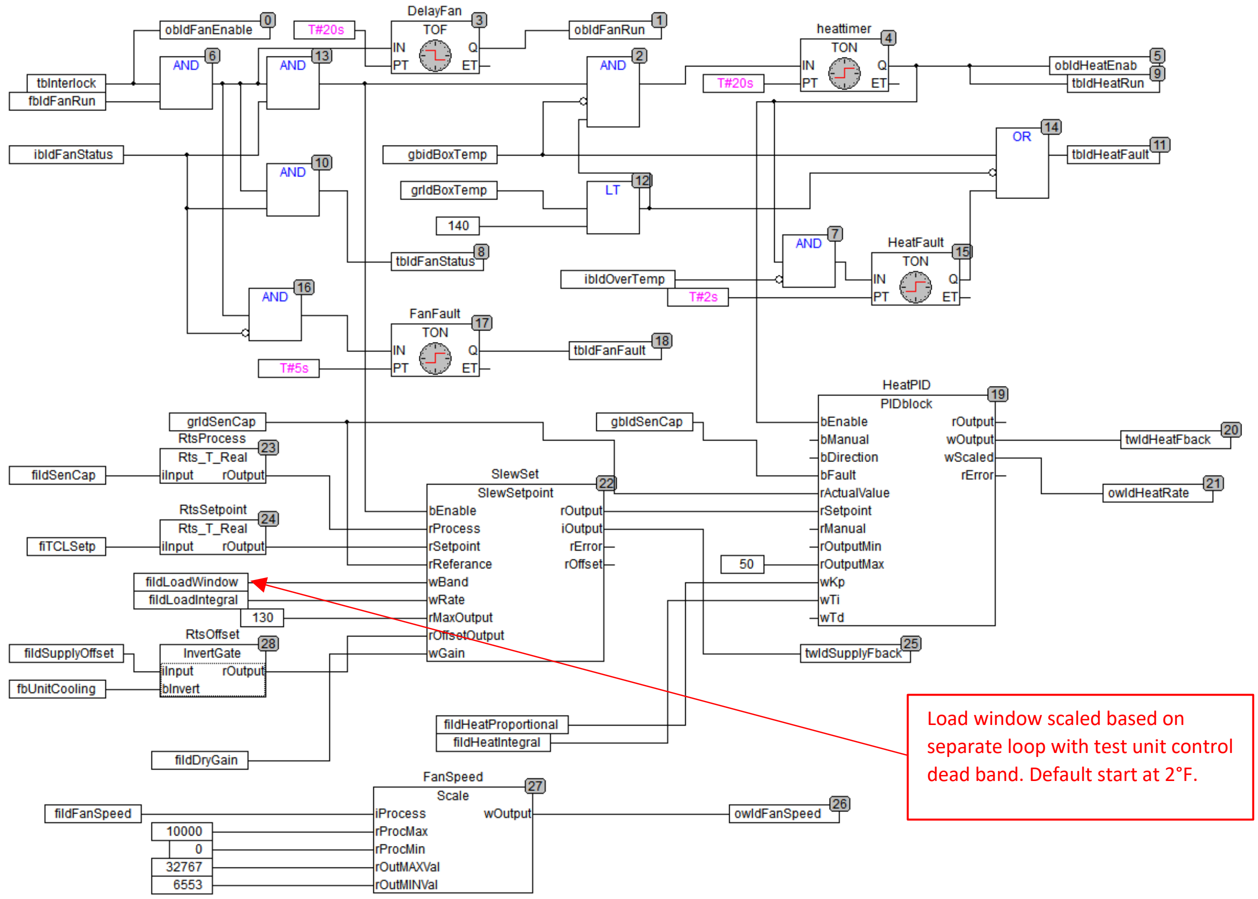

Figure 16. Advanced Load Control

The advanced load control shown in Figure 16 uses the measured capacity feedback as the process value for the outer PID loop. The Target Compensation Load is the process set point and an additional load window (scaled value based on the unit under test control dead band) feeds into the logic to allow the heater control to modulate to obtain the Target Compensation Load and reduce hysteresis between the room and the unit prior to achieving equilibrium.

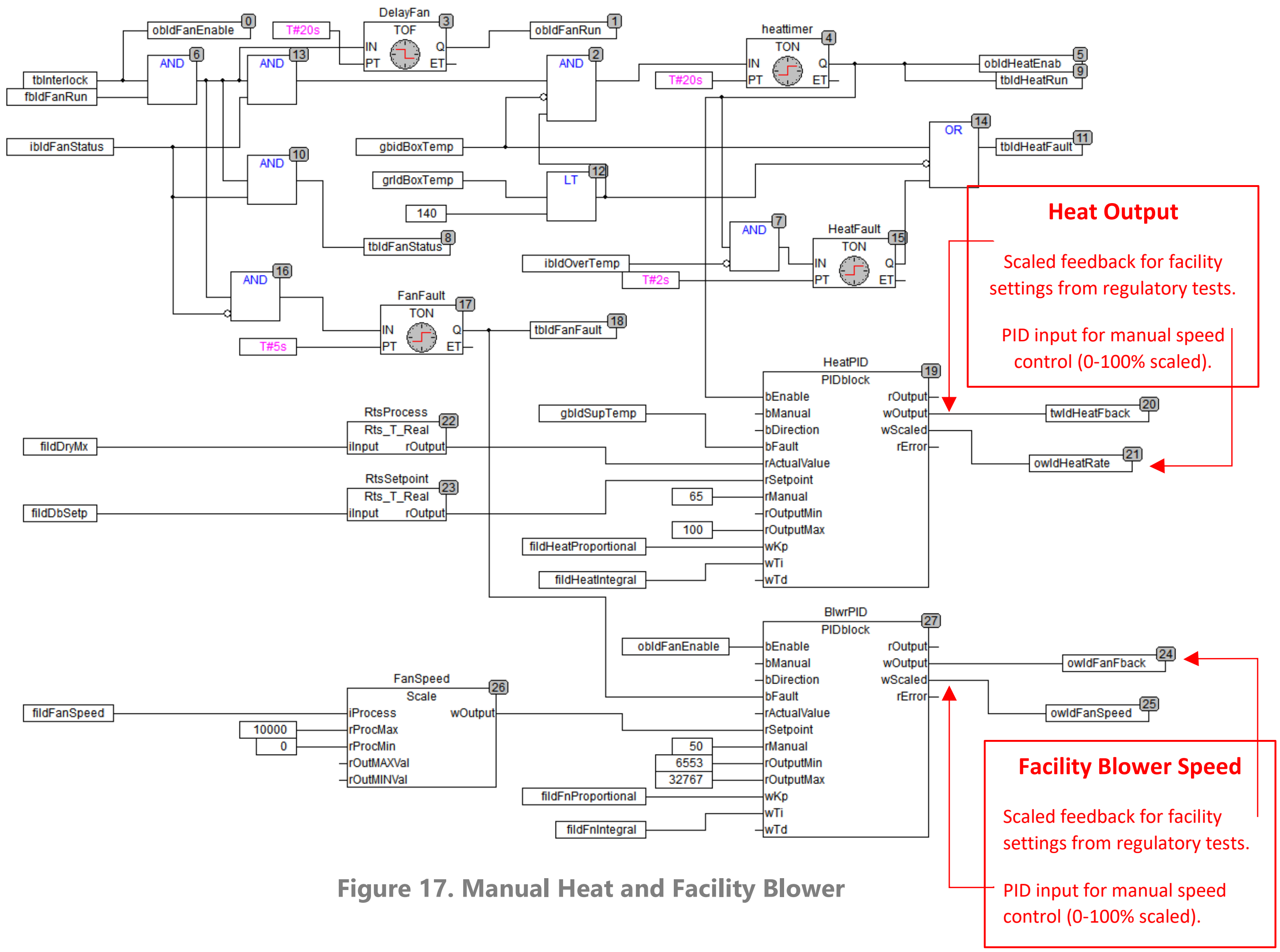

Figure 17. Manual Heat and Facility Blower

The manual control option for heat and facility blower shown in Figure 17 uses the facility settings from the regulatory tests as the process set point when the software or hardware PID controller is set in manual mode for the Target Compensation Load test. Aggressive unit controllers may require manual intervention to eliminate hysteresis in the return air temperature swings to achieve equilibrium.

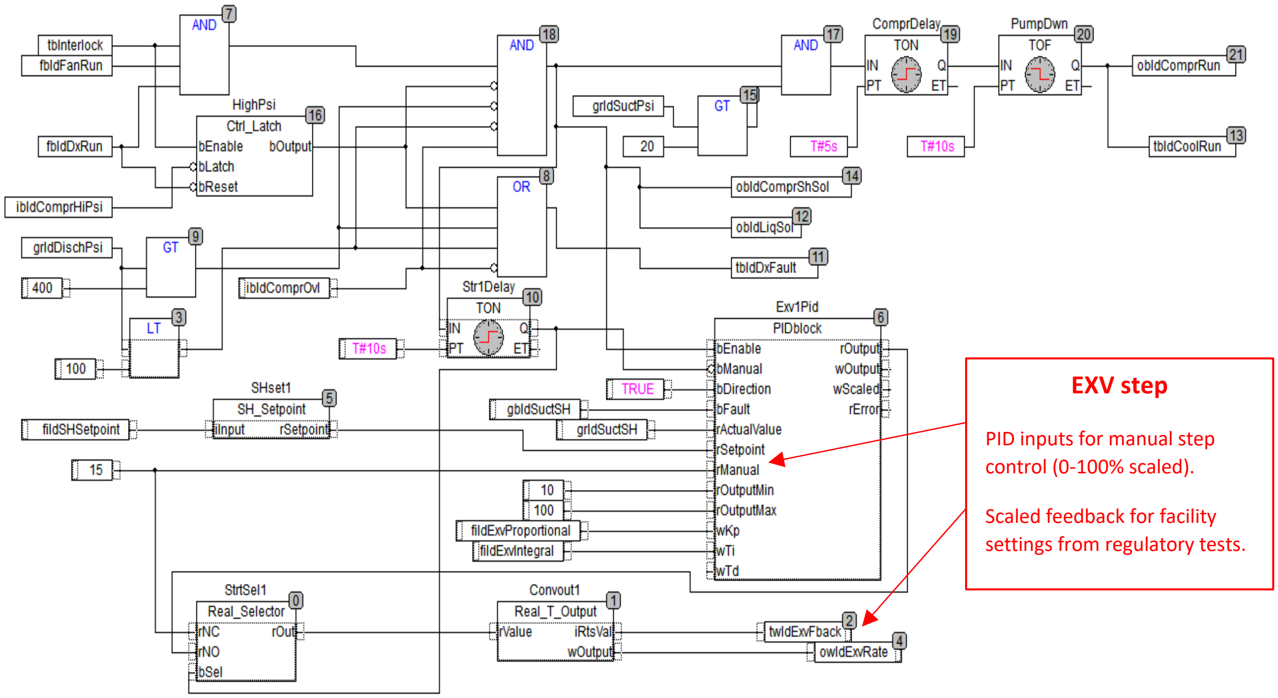

Figure 18. Manual Electronic Expansion Valve

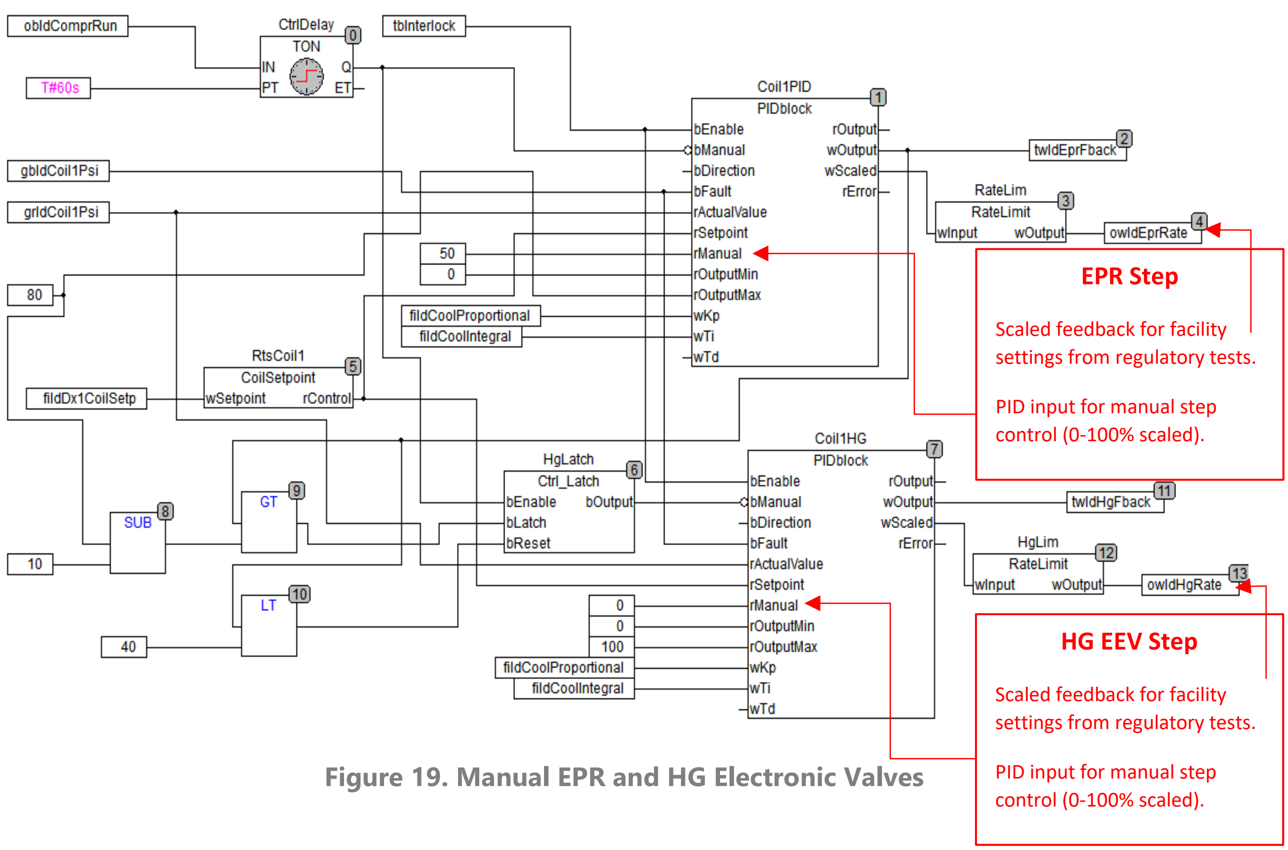

Figure 19. Manual EPR and HG Electronic Valves

For test facilities utilizing electronic step control valves for cooling coils or steam injection, the manual control option for the valves is shown in Figure 18 and Figure 19. Similar to the manual heat and blower logic, it uses the facility settings from the regulatory tests as the process set point when the software or hardware PID controller is set in manual mode for the Target Compensation Load test.