BSR/ASHRAE Standard 195-2024R

Public Review Draft

Method of Test for Rating Air Terminal Unit Controls

First Public Review (September 2025)
(Complete Draft for Full Review)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at https://www.ashrae.org/technical-resources/standards-and-guidelines/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

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FOREWORD

Standard 195 specifies instrumentation and facilities, test installation methods, and procedures for determining the accuracy and stability of airflow control systems for terminal units at various airflow setpoints.

One motivation for this standard is to save energy. Minimum ventilation rates for many zones (e.g., perimeter office zones) are on the order of 10% or less of the design airflow rates. Many engineers are hesitant to specify VAV box minimum flow rates below 20% or 30% of the design flow rate because of concerns that the VAV box (and associated controller) will not be able to stably and accurately maintain a lower flow setpoint. During many hours of the year (even summer), the minimum airflow rates exceed what is needed to satisfy the cooling demand, and as a result, VAV boxes operate with active airflow setpoints that are pegged at the minimum setpoint while driving the space temperature down to the zone heating setpoint, necessitating reheat operation to prevent further overcooling. High zone airflow minimums result in significant wasted fan energy, heating energy, and cooling energy, as the excess airflow must be conditioned and delivered through the associated air handler and terminals. The Standard Project Committee (SPC) expects that performance data based on Standard 195 tests will show that zone minimums of 10% or lower can be stably and accurately maintained by many commonly available products. Once this data is widely available, then engineers should have the confidence they need to specify low zone minimum flow rates.

In order to ensure performance data is widely available, the SPC intends to submit a proposal to SSPC 90.1 to require that 90.1 compliance documentation include Standard 195 performance data for all VAV box controllers used on a project. For example: "Each controller used shall have a Ctrlr-Only Total Rating Score per ASHRAE Standard 195 Appendix A."

The SPC anticipates that once performance data is available from several controls manufacturers, that poorly performing manufacturers will be highly incentivized to improve the performance of their products.

The SPC also anticipates that once Ctrlr-Only Total Rating Scores are available from several controls manufacturers, that VAV box manufacturers will update their catalogs to list minimum VAV box flows that are significantly lower than the values currently in their catalogs, which are based on conservative assumptions of controller performance. This will help give engineers the confidence they need to specify low zone minimum flow rates.

Other potential applications of this standard include the following scenarios:

- *An HVAC system specifier indicates performance requirements for airflow control for a given project. The requirements are specified in terms of nominal flow rates, accuracy, stability, operating pressures, and other relevant conditions. Contractors or suppliers document performance of proposed equipment based on tests run and reported in accordance with this standard.*

- *A supplier of airflow controls wishing to publish the capabilities of a product executes tests and reports results in accordance with this standard. The supplier chooses the operating conditions to test and report.*

The SPC does not envision application of this standard to field tests or acceptance tests in construction projects.

This edition of Standard 195 includes several modifications based on a detailed research project conducted by Taylor Engineers and PG&E in 2023/2024. These modifications are intended to both reduce the testing burden and to more accurately determine controller-only accuracy and stability. Modifications include:

1. *The Accuracy Test and Zero Drift Test are combined into the Accuracy Test to reduce the test burden. The new Accuracy Test includes testing over a range of temperatures to capture temperature-related zero drift.*
2. *Previously, the accuracy/zero drift tests basically consisted of the controller modulating to a commanded airflow setpoint while a fixed ΔP is held across the system under test (SUT) with error determined by comparing the reference flow to the setpoint. In this version, the accuracy test basically consists of locking the damper open and comparing the airflow reported by the controller to the reference flow. This change was made to more easily collect accuracy data over a wide range of setpoints and because controller modulation is already included in the Stability Test and thus does not also need to be included in the accuracy tests. This change also addresses a critical flaw in the current MOT: if the controller has a wide deadband within which it will not move the damper, then the tester can tweak the fan speed to get the reference airflow closer to setpoint without triggering the controller to move the damper.*
3. *Previously, the tester was encouraged to repeat the tests at different setpoints in order to determine the lowest airflow rate at which the test is passed, but the testing burden also discouraged repeating tests. Now the tests require taking readings over a defined range of setpoints in order to determine the lowest airflow rate at which the test is passed.*
4. *Previously, the Controller-Only test results were the same as the SUT test results, i.e., they included any error introduced by the flow probe as well as errors introduced by the controller. This was based on two previous research projects that indicated that the flow probe had negligible contribution to SUT error. The 2023/2024 research indicates that the flow probe error may not be a negligible contribution to SUT error. Explicitly removing any flow probe error from the Controller-Only ratings improves the validity of the Controller-Only results.*
5. *Previously, the stability tests allowed the tester to manually adjust the fan speed to achieve the dP setpoint, then the 50% of dP setpoint and the 200% of dP setpoint. This has the same critical flaw as noted above for the accuracy test: if the controller has a wide deadband within which it will not move the damper, then the tester can tweak the fan speed (while staying within the allowed tolerance on the dP targets) to get the reference airflow closer to setpoint without triggering the controller to move the damper. To address this, flaw the stability test now requires the fan speed to be automatically controlled by a controller to exact speed setpoints, including 50% and 200% of the initial speed observed at dP setpoint.*
6. *All references to standard cfm (scfm) have been changed to actual cfm (acfm). This is to reduce the testing burden (no need to measure humidity and pressure) and to make the results more applicable to real world applications that typically use acfm. For example, terminal unit calibration is typically done with acfm reference readings, terminal unit controllers typically measure acfm (not scfm), and airflow setpoints (for ventilation, pressurization, heating/cooling, etc.), are typically stated in acfm.*

7. *Fan requirements have been added to the test setup to ensure the selected fan can perform all required tests.*

The controller-only test only evaluates systems using velocity pressure sensing. To compare systems using other sensing technology, the full system test is appropriate.

This standard method of test (MOT) reports performance as a pass/fail rating with respect to a control accuracy tolerance. It also reports numerical accuracy at various setpoints.

The stability and accuracy of an SUT using velocity pressure sensing relies on the stability and accuracy of the flow probe signal as well as the stability and accuracy of the pressure sensor, damper actuator, and algorithms included in the controller. The flow probe, which generates the flow probe signal, is typically supplied by the terminal unit manufacturer. The controller, which includes the pressure sensor, actuator, and algorithms, is typically provided by a controls manufacturer, not the terminal unit manufacturer. This MOT includes procedures for evaluating the total SUT error and for breaking the SUT error into its two components: flow probe error and controller-only error.

This standard MOT pertains to some of the same equipment as Standard 130[1] and measures some of the same quantities.

For example, Standard 130-2025 Section 5.4 Pressure-Compensating Volume Controller Performance is similar to the SUT Stability Test herein but applies to the rated airflow, i.e., max flow. Standard 130 does not differentiate between flow probe error and controller error. The Stability tests herein apply to both SUT and Controller-Only stability and are intended to identify the lowest flow rate that meets the rating condition error tolerance.

Standard 130 also includes tests that measure flow probe amplification (i.e., K-factor) over a range of airflows.

This standard MOT describes procedures that apply to single-duct air terminals without fans. Future versions may include procedures that apply to other air terminals.

1 PURPOSE

This standard specifies instrumentation and facilities, test installation methods, and procedures for determining the accuracy and stability of airflow control systems for terminal units at various airflow setpoints.

2 SCOPE

This standard applies to electronic and/or pneumatic control systems used for pressure independent airflow control in terminal units for VAV and CV air moving systems.

3 DEFINITIONS

3.1 This section provides definitions of key terms used in this standard. For terms not defined, refer to the definitions listed in *ASHRAE Terminology of Heating, Ventilation, Air Conditioning, and Refrigeration.*[2]

accuracy: degree of conformity of an indicated value to an accepted standard value, or true value. The degree of inaccuracy is known as "total measurement error" and is the sum of bias error and precision error.

air terminal: see air terminal unit

air terminal unit. device that automatically modulates the volume of air delivered to or removed from a defined space.

airflow: for the purpose of this test method, airflow is the actual unit volume displacement of air per unit time at the current drybulb temperature, humidity, air pressure. It is measured in actual cubic feet per minute (acfm) or liters per second (L/s), not in standard cfm (scfm), which is based on standard temperature, humidity, and pressure.

auto-zero feature: any automatic means of adjusting the zero calibration point of a pressure or velocity transducer.

controller-only test: this is used to measure the performance of a controller and actuator independent from the air terminal unit.

cross-sectional area: the area of the air terminal inlet perpendicular to the direction of airflow. Note: the cross-sectional area is calculated based on the geometry of the inlet duct, not on the actual free area.

Informative Note: for example, a round inlet duct, the cross-sectional area may be calculated from duct diameter D as:

$$A = \frac{\pi D^2}{4}$$

differential pressure: difference in pressure between any two locations in a system.

equivalent diameter: the diameter of a circular-duct equivalent that will have a cross-sectional area that is equal to that of a particular rectangular duct.

Informative Note: The equivalent diameter is calculated from cross-sectional area A as:

$$D = \sqrt{\frac{4A}{\pi}}$$

flow coefficient (K or K-Factor): actual airflow divided by the square root of the flow probe signal.

flow probe signal (P_{vm}): output of a velocity pressure flow probe, in. of water (Pa).

full-system test: this measures the combined performance of a controller, actuator, and *air terminal unit.*

national measurement standard: measurement standard recognized by national authority to serve in a state or economy as the basis for assigning quantity values to other measurement standards.

pressure: force exerted per unit area.

reference airflow measuring system: combination of sensing devices and data acquisition hardware and software that produces the airflow value against which the system under test (SUT) is compared.

shall: where *shall* and *shall not* are used for a specified provision, that provision is mandatory if compliance with this test method is claimed.

stability: (1) independence or freedom from changes in one quantity as the result of a change in another; (2) absence of drift.

system under test (SUT): the combination of components whose performance is the subject of the test, as distinct from the components that serve as the test facility or test equipment.

test specifier: individual or organization that calls out details for a test conforming to this MOT. The test specifier may designate products to be tested, airflow rates and pressure drops, ambient temperatures, calibration procedure, and pass/fail criteria.

tolerance: the level of accuracy desired in the airflow control system under test; the criterion by which the SUT is judged to pass or fail the accuracy test.

velocity pressure (P_v): in a moving fluid, the pressure due to the velocity (V) and density (ρ) of the fluid, expressed by the velocity squared times the fluid density, divided by two ($\rho V^2/2$).

voltmeter: a device used to measure differences in electrical potential between points in an electrical circuit.

zero drift: change in sensor output at zero flow with the passage of time, change in temperature, or both.

3.2 The following nomenclature is used throughout this test method:

Table 1. Nomenclature

Symbol	Quantity	I-P Units	SI Units
A	Internal cross section of duct	ft^2	m^2

D_e	Equivalent diameter	ft	m
P	Absolute static pressure	in. of water	Pa
P_a	Atmospheric pressure	in. Hg	Pa
P_v	Velocity pressure	in. of water	Pa
P_{vm}	Flow probe signal	in. of water	Pa
P_s	Static pressure	in. of water	Pa
P_t	Total pressure	in. of water	Pa
ΔP	Differential pressure	in. of water	Pa
ΔP_t	Total differential pressure	in. of water	Pa
Q_a	Airflow at actual test conditions	ft^3/min (cfm)	L/s
V	Air velocity	ft/min (fpm)	m/s

4 INSTRUMENTATION

4.1 Temperature Measurement

Temperature measuring instruments shall meet the requirements of *ASHRAE Standard 41.1-2024 (RA 2006)*[3] and the following:

4.1.1 Accuracy of the temperature measuring instruments shall be within ±0.2°F (0.1°C). The smallest scale division or output resolution of the temperature measuring device shall not exceed the specified accuracy.

4.1.2 Temperature measuring instruments shall be calibrated, on an annual basis, in the range of use by comparison to a national measurement standard, with uncertainties traceable to that national measurement standard, and shall be certified to provide the accuracies listed in 4.1.1.

4.2 Pressure Measurement

Pressure measuring instruments shall meet the requirements of *ASHRAE Standard 41.3-2014*[4] and the following:

4.2.1 Accuracy of the duct pressure measuring instruments shall be within 5% of the measured pressure. The smallest scale division or output resolution of the pressure measuring device shall not exceed the specified accuracy.

4.2.2 Accuracy of the sensor recording the flow probe signal (if the SUT includes flow probe pressure taps) shall be within 5% of the reading.

4.2.3 Pressure measuring instruments shall be calibrated annually, in the range of use, by comparison with a national measurement standard (e.g., a NIST standard). Instruments shall be calibrated directly against the national standard, or through a traceable chain of not more than two intermediary instruments. Measurement uncertainty, based on that calibration, shall satisfy the accuracies listed.

4.3 Airflow Measurement

Airflow measurement shall be in accordance with ASHRAE Standard 130-2016.

Separate reference airflow measuring systems may be used for the high flow and low flow accuracy subtests in 6.2.1.

4.4 Automatic Data Acquisition

Test data shall be automatically gathered from the prescribed sensors or instruments and logged for analysis and reporting purposes.

5 TEST SETUP

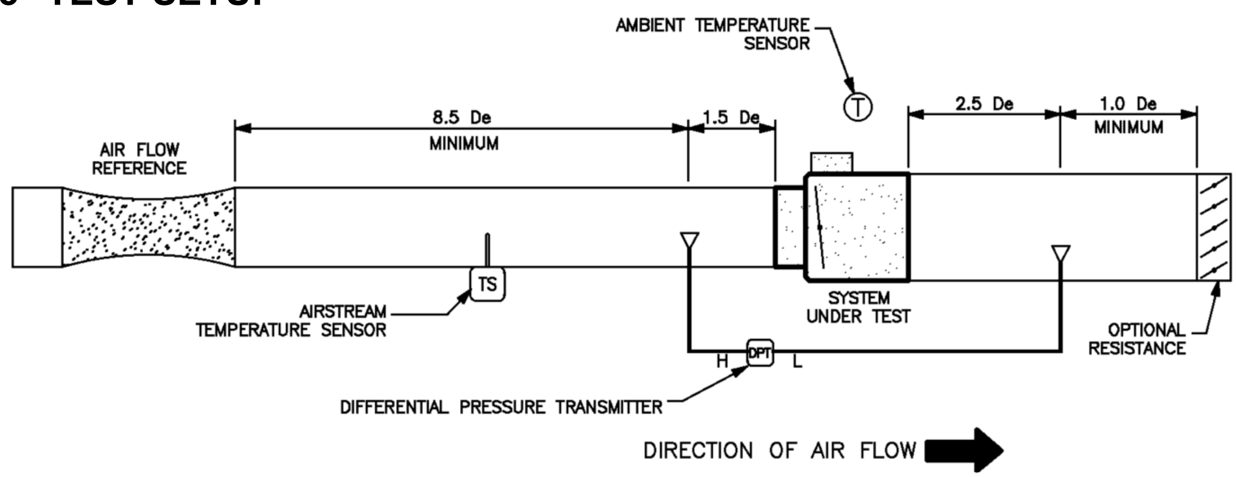

Figure 1 Required Test Setup.

Figure 1 illustrates the required test setup. The following sections describe the components and their relationship.

5.1 Inlet to Terminal

The nominal test condition is a straight, hard inlet to the terminal. Minimum of 10 duct diameters. The inlet duct dimensions shall be the same size as terminal inlet, i.e., no transitions.

5.2 Outlet from Terminal

Minimum of 3.5 straight duct diameters. Downstream duct size shall match the terminal unit outlet, i.e., no transitions. A flow resistance (e.g., damper) may be installed downstream of this duct.

5.3 Airflow Reference

A reference airflow measuring system, conforming to Section 4.3, shall be installed a minimum of 10 duct diameters upstream of the air terminal.

5.4 Fan

A fan is required for testing. The fan must be sized to achieve the airflow and total static pressure required for all tests, without operating in the surge region. For example, for the stability test at max flow, the cfm setpoint might be 609 cfm (based on 1800 fpm and actual inlet area). The stability test includes testing at approximately 1.0 in. of water (250 Pa) differential static pressure (ΔSP) across the SUT. The total static on the fan includes this 1.0” plus any additional pressure drop through the reference flow meter, ductwork, etc. So, the fan must be capable of achieving this condition outside of the surge region.

The fan may be located upstream of the airflow reference, integral to the airflow reference, or downstream of the outlet from the terminal. During the stability test, all flow through the fan shall flow through the SUT. During the stability test, the fan speed shall be automatically controlled by a controller program, not modulated manually.

5.5 Ambient Air Temperature Sensor

Ambient air temperature sensor shall not be in the airstream. It shall be located within 12” (30 cm) of the controller and shall be representative of the temperature of air surrounding the controller.

5.6 Airstream Temperature Sensor

The airstream temperature sensor shall be located in the airstream of the air terminal. It shall be located between 3 and 8 diameters upstream of the air terminal.

5.7 Differential Static Pressure (ΔSP)

The differential static pressure across the air terminal shall be measured. The high pressure port shall be located 1.5 equivalent duct diameters upstream of the air terminal. The low pressure port shall be located 2.5 equivalent duct diameters downstream of the air terminal.

5.8 Flow Probe Signal (for systems that include a velocity pressure flow probe)

If tees are available in the tubing between the flow probe and the controller, then they shall be used in order to measure the flow probe signal with a reference pressure sensor. The reference sensor needs to use a pressure sensor that has a dead end so it does not disrupt the pressure seen by the controller under test.

5.9 Controller

The controller shall be mounted and connected per the manufacturer’s instructions. All control and measurement tubing and connections shall be tested for leakage. Maintain integrity of tubing throughout the test.

The controller programming shall be the default programming provided by the manufacturer and shall not be edited or customized for testing.

5.10 Ductwork Leakage

Every joint of the ductwork between the reference airflow station and the unit under test must be sealed and tested. A duct pressure test shall be conducted at 6.0 in. w.c (1500 Pa). The measured leakage rate shall be less than 10 cfm (5 L/s).

6 TEST METHODS

To ensure the highest level of comparability between the test results of two different SUTs, regardless of the documented accuracy of the comparison references involved, the test specifier shall require that the tests be performed in the same lab, using the same equipment, reference, and setup.

6.1 Calibration

The SUT is calibrated on the test installation, with the intention that the calibration process used in the lab represents the one that will be used in a field installation. The reference airflow measuring system, used for the System Performance Tests, shall also be used for calibration.

The SUT shall be calibrated in the test installation according to the procedures recommended by the manufacturer.

6.2 System Performance Test Methods

The test specifier may specify that all of the following Test Methods be performed or only one or more of the Test Methods. For each Test Method specified, the method must be followed in its entirety and all other requirements of this standard must be followed (e.g., Instrumentation, Calibration, etc.)

6.2.1 Accuracy Test Method

This test is intended to measure the accuracy of the system as installed on an airflow terminal unit.

The terminal unit/control assembly to be tested shall be installed per Section 1.

6.2.1.1 Calibration

1. Calibrate the airflow control at the minimum (Qmin) and maximum (Qmax) airflow setpoints of interest. (see Appendix A for Rating Conditions)
2. The ambient temperature and airstream temperature during calibration shall be 72.5°F ± 2.5°F (22.5°C ± 1.4°C)
3. The SUT damper shall be full open during calibration. Flow rates of Qmin ± 5% and Qmax ± 5% as measured by the reference flow meter shall be achieved by adjusting fan speed and/or external resistance.
4. If controller does not read at Qmin, then raise Qmin until it reads
5. Record:
    a. the ambient temperature at which the controller was calibrated, Tcal.

b. The barometric pressure

c. Qmin Calibration:
   i. Reference airflow, Qref-min
   ii. Reference flow probe signal, Pvm-ref-min

d. Qmax Calibration:
   i. Reference airflow, Qref-max
   ii. Reference flow probe signal, Pvm-ref-max

6. Calculate
   a. K-factors: K-Qmin-cal, K-Qmax-cal from reference airflow and reference flow probe signal at Qmin and Qmax, using
      i. K-Qmin-cal = Qref-min / sqrt(Pvm-ref-min)
      ii. K-Qmax-cal = Qref-max / sqrt(Pvm-ref-max)
   b. OPTIONAL: Probe errors:
      i. Nominal Probe-error-min = -1 *(1 – K-Qmin-cal / Knominal)
      ii. Nominal Probe-error-max = -1 *(1- K-Qmax-cal / Knominal)
      iii. where Knominal is the K-factor of the flow cross provided by the terminal unit manufacturer and determined in accordance with ASHRAE Standard 130-2016.

Informative Note: *While the probe error is not directly used in determining the rated minimum flow probe signals for the controller and SUT, it useful for validating the controller-only error and SUT errors (both of which are directly used to determine the rated flow probe minimums). As the calculated SUT error should be roughly equal to the sum of the controller-only error and the probe error, instances in which this equality does not hold true could serve to flag areas in which calculation errors were made or testing conditions were not properly maintained (e.g., flow and/or static pressure not properly controlled).*

6.2.1.2 Subtests

1. Without recalibrating the airflow control, complete all of the following Subtests.

2. Subtest – Qmax

   a. The ambient temperature and airstream temperature shall be Tcal ± 2°F (1°C)

   b. SUT Damper shall be full open throughout the Accuracy Test, i.e. the controller is not modulating the damper.

   c. Adjust fan speed and/or optional resistance to achieve airflow of Qmax ± 5% at the reference flow meter.

   d. Begin recording with data acquisition system. Record at least 5 samples at regular intervals of between 10 and 60 seconds. Data collected shall include:

      i. Reference airflow rate, Qref

      ii. Ambient dry-bulb temperature

      iii. Airstream dry-bulb temperature

      iv. Flow rate indicated by product under test (if available) (Qctrlr)

v. Reference Flow probe signal (Pvm-ref) for systems that include velocity pressure sensors (note: Controller-Only Tests include velocity pressure sensors).

e. For each sample calculate:

i. Observed K-factor: K-Qmax-obs = Qref / sqrt (Pvm-ref)

ii. Adjusted Airflow for Controller-Only accuracy:

a. Qadj = K-Qmax-cal * sqrt (Pvm-ref)

iii. SUT Error = 1- Qctrlr / Qref

iv. Ctrlr-Only Error: 1- Qctrlr / Qadj

v. OPTIONAL: Probe Error: = 1 – Qadj / Qref

f. For all samples calculate:

i. Average SUT error, average Ctrlr-Only error

3. Qmin Subtest 1 (Tcal).

a. The ambient temperature and airstream temperature shall be Tcal ± 2°F (1°C)

b. SUT Damper shall be full open

c. Adjust fan speed and/or optional resistance to achieve each of the Pvm setpoints +/- 10%, as measured by the ref probe signal, and take at least 5 steady state readings at regular intervals of between 10 and 60 seconds at each Pvm setpoint

d. Data collected shall include:

i. Reference airflow rate, Qref

ii. Ambient dry-bulb temperature

iii. Airstream dry-bulb temperature

iv. Flow rate indicated by product under test (if available) (Qctrlr)

v. Reference Flow probe signal (inches w.c.) (Pvm-ref) for systems that include velocity pressure sensors.

g. For each sample calculate:

vi. Observed K-factor: Kobs = Qref / sqrt (Pvm-ref)

vii. Adjusted Airflow for Controller-Only accuracy:

a. Qadj = K-Qmin-cal * sqrt (Pvm-ref)

viii. SUT Error = 1- Qctrlr / Qref

ix. Ctrlr-Only Error = 1- Qctrlr / Qadj

x. OPTIONAL: Probe Error = 1 – Qadj / Qref

Informative Note: *While the probe error is not directly used in determining the rated minimum flow probe signals for the controller and SUT, it's useful for validating the controller-only error and SUT errors (both of which are directly used to determine the rated flow probe minimums). As the calculated SUT error should be roughly equal to the sum of the controller-only error and the probe error, instances in which this equality does not hold true could serve to flag areas in which calculation errors were made or testing conditions were not properly maintained (e.g., flow and/or static pressure not properly controlled).*

   h. For each Pvm setpoint calculate:
      ii. Average SUT error, average Ctrlr-Only error

4. Qmin Subtest 2 (High Temp, Pre-Auto-Zero)
   a. This subtest is optional. The intent is to demonstrate the benefit of auto-zero.
   b. The controller shall not be auto-zero'ed between Subtest 1 and Subtest 2.
   c. Subtest 2 is a repeat of Subtest 1 with ambient temperature and airstream temperature of 85°F ± 2°F (30°C ± 1°C).
   d. See Subtest 1 for required data collection and calculations.
5. Qmin Subtest 3 (High Temp, Post-Auto-Zero, if available)
   a. If the controller has an autozero feature, then shut off fan and command controller to execute autozero
   b. Subtest 3 is a repeat of Subtest 1 with ambient temperature and airstream temperature of 85°F ± 2°F (30°C ± 1°C)
   c. See Subtest 1 for required data collection and calculations.

6.2.2 Stability Test Method

1. If the test specifier specifies both the Accuracy Test and Stability Test, then perform the System Accuracy Test first and then proceed to the Stability Test without recalibrating the controller. If only the Stability Test is specified, then calibrate the controller per Section 6.1.
2. Adjust ambient temperature and airstream temperature to Tcal ± 2°F (1°C).
3. If the controller has an autozero feature, then shut off the fan and command controller to execute autozero.
4. Command the controller to hold a fixed airflow setpoint of Qstpt (see Appendix A for Rating Conditions). The controller will then modulate the damper using its standard control algorithm to maintain its measured airflow at setpoint.
5. Manually or automatically adjust fan speed to achieve steady state (damper not modulating) with ∆SP within 0.05" of ∆SP setpoint (see Appendix A for Rating Conditions). Fan speed at this condition shall be called Spd0.
6. Begin recording data.

7. After 4 minutes at fixed Spd0, fan speed shall automatically modulate at a rate of 1% every 15 seconds from Spd0 to 50% of Spd0, i.e. 12.5 minutes to smoothly modulate from Spd0 to 50% of Spd0. NOTE: % Speed must be scaled such that 0% speed is at 0 Hz or 0 RPM, and not scaled such that 0% speed is at some minimum speed setpoint of say 10 Hz. For example, if Spd0 = 1000 RPM then 50% of Spd0 = 500 RPM.
8. After 4 minutes fixed at 50% of Spd0, fan speed shall automatically modulate at a rate of 1% every 10 seconds to 200% of Spd0, i.e. 25 minutes to smoothly modulate from 50% to 200% of Spd0.
9. Wait 4 minutes with fan speed fixed at 200% of Spd0 .
10. Stop recording data. (45.5 minutes of data)
11. Recorded data at 1 minute intervals:
    a. Fan speed in % Speed and in Hz or RPM
    b. Reference airflow rate (Qref)
    c. Reference Flow probe signal (inches w.c.) (Pvm-ref)
    d. Pressure drop across the flow control device
    e. Ambient and airstream temperature
12. For each sample calculate:
    a. Observed K-factor: Kobs = Qref / sqrt (Pvm-ref)
    b. Adjusted Airflow Setpoint for Controller-Only stability:
        i. Qstpt-adj = Kobs * sqrt(Pvm-stpt-stability)
    c. SUT Error = 1 – Qref / Qstpt
    d. Ctrlr-Only Error = 1 – Qref / Qstpt-adj
    e. OPTIONAL: Probe Error = -1*(1 – Qref-adj/Qref)
13. OPTIONAL: Damper Start/Stops
    a. Record output command from the controller to the damper actuator every 5 seconds (~546 recordings).
        a. Analog: For controllers using analog output, damper position shall be recorded as 0%-100%, where 0% is full closed and 100% is full open, with a resolution of at least 0.01%.
        b. Floating Point: If the controller uses floating point control, rather than analog control, then position shall be recorded as COMMAND-OPEN, COMMAND-CLOSE, NO-COMMAND.
    b. Calculate the number of damper actuator starts and stops during the recording period.

a. Analog:

    i. Damper is stopped if consecutive recordings are within 0.02%.

    ii. Damper is started if damper is stopped in the previous recording and current recording differs from previous recording by 0.02% or more.

b. Floating Point:

    i. Damper is stopped if there is NO-COMMAND in a recording and previous recording was either COMMAND-OPEN or COMMAND-CLOSE.

    ii. Damper is started if current command is different from previous command.

Informative Note: *While the probe error is not directly used in determining the rated minimum flow probe signals for the controller and SUT, it's useful for validating the controller-only error and SUT errors (both of which are directly used to determine the rated flow probe minimums). As the calculated SUT error should be roughly equal to the sum of the controller-only error and the probe error, instances in which this equality does not hold true could serve to flag areas in which calculation errors were made or testing conditions were not properly maintained (e.g., flow and/or static pressure not properly controlled). Note that for stability tests, the sum of the controller-only error and probe error may not always be equal to the calculated SUT error during the parts of the test in which the static pressure is being increased or decreased. However, the equality should hold true while the static pressure is constant.*

7 CONTROLLER-ONLY TESTS

The *controller-only tests* isolate the error introduced by the controller from the error introduced by the flow probe by adjusting the airflow setpoints used to measure controller-only error. The adjustments are made by removing the measured error introduced by the flow probe.

The SUT for the controller-only test is the same as the SUT for the full-system test, except that the air terminal is replaced with a standard air terminal that meets the requirements listed in Normative Appendix B.

8 TEST REPORT

The report shall not present average accuracy values that indicate better than 4 times the accuracy of the reference airflow measuring system.

The test report shall include information on the test equipment used, including names, model numbers, serial numbers, and calibration records.

The test report shall include all data required to be recorded and calculated for all subtests used to determine Rating Scores, including SUT Error and Controller-Only Error.

9 REFERENCES

1. *ANSI/ASHRAE Standard 130-2025, Laboratory Methods of Testing Air Terminal Units.* Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers Inc.
2. *ASHRAE Terminology of Heating, Ventilation, Air Conditioning, and Refrigeration.* Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers Inc.
3. *ANSI/ASHRAE Standard 41.1-2024 (RA 2006), Standard Methods for Temperature Measurement*. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers Inc.
4. *ANSI/ASHRAE Standard 41.2-1987 (RA 1992), Standard Methods for Airflow Measurement*. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers Inc.
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APPENDIX A – RATING CONDITIONS (NORMATIVE)

A.1 System Performance Test

A.1.1 Accuracy Rating

- Qmax = flow rate corresponding to an inlet velocity of 1,800 feet/min, or mfg suggested maximum flow, whichever is lower
- Qmin = flow rate calculated from flow probe signal (P_{vm}) of 0.005” and the nominal K-factor of the flow cross provided by the terminal unit manufacturer using Qmin = Knominal * sqrt(Pvm)
- If the controller does not provide a stable steady state reading at Qmin, then slowly raise Pvm in the Qmin calculation until the controller does provide a stable steady state reading.
- Pvm Setpoints:
    - 0.100"
    - 0.050"
    - 0.025"
    - 0.013"
    - 0.008"
    - 0.005"
    - 0.004"
    - 0.003"
    - 0.002”

SUT Accuracy Rating Score

The Subtest-Qmax is passed if:

1. no sample has an SUT Error > 20% or < -20%.
2. The average SUT Error is between -10% and 10%.

A Pvm setpoint passes a MIN subtest if

1. no sample has an SUT Error > 20% or < -20%.
2. The average SUT Error is between -10% and 10%.

To receive a SUT Accuracy Rating Score the Subtest-Qmax must pass.

The SUT Accuracy Rating Score is the lowest Pvm setpoint that passes both Qmin Subtest 1 and Qmin Subtest 3

Controller-Only Accuracy Rating Score

To receive a Ctrlr-Only Accuracy Rating Score, the terminal unit must meet the requirements for a Standard Terminal Unit listed in Normative Appendix B.

The Subtest-Qmax is passed if:

1. no sample has a Ctrlr-Only Error > 20% or < -20%.
2. The average Ctrlr-Only Error is between -10% and 10%.

A Pvm setpoint passes a MIN subtest if

1. no sample has an Ctrlr-Only Error > 20% or < -20%.
2. The average Ctrlr-Only Error is between -10% and 10%.

To receive a Ctrlr-Only Accuracy Rating Score, the Subtest-Qmax must pass

The Ctrlr-Only Accuracy Rating Score is the lowest Pvm setpoint that passes both Qmin Subtest 1 and Qmin Subtest 3

A.1.2 Stability Rating

Stability shall be tested at Max Flow and at Min Flow

Max Flow Conditions

ΔSPstpt = 0.50”

Qstpt = flow rate corresponding to an inlet velocity of 1,800 feet/min, or mfg suggested maximum flow, whichever is lower

Min Flow Conditions

ΔSPstpt = 0.50”

Qstpt = K-Qmin-cal * sqrt (Pvm-stpt-stability)

For SUT testing: Pvm-stpt-stability = SUT Accuracy Rating Score

For Ctrlr-Only testing: Pvm-stpt-stability = Ctrlr-Only Accuracy Rating Score

The SUT Stability test is passed if the following tolerance conditions are met during all subtests:

1. No individual reference airflow reading is more than 30% above or below Qstpt.
2. The average reference airflow reading is within 10% of Qstpt.

The Ctlr-Only Stability test is passed if the following tolerance conditions are met during all subtests:

3. No individual reference airflow reading is more than 30% above or below Qstpt-adj.
4. The average reference airflow reading for each subtest is within 10% of Qstpt-adj.

If the Min Flow Stability Test is not passed at the initial Pvm-stpt-stability, then repeat the Stability test at the airflow setpoint calculated from the next highest Pvm setpoint listed in Section A.1.1. Continue repeating at higher Pvm setpoint until the Stability test is passed.

Optional: If the Min Flow Stability Test is passed at the initial Pvm-stpt-stability, then repeat the Stability test at lower airflow setpoint(s) to determine the lowest Pvm setpoint that passes the Stability Test.

To receive a SUT Stability Rating Score, the SUT Max Flow Stability Test must pass.

The SUT Stability Rating Score is the lowest Pvm setpoint that passes the SUT Min Flow Stability Test.

To receive a Ctrlr-Only Stability Rating Score, the Ctrlr-Only Max Flow Stability Test must pass.

The Ctrlr-Only Stability Rating Score is the lowest Pvm setpoint that passes the Ctlr-Only Min Flow Stability Test.

A.1.3 Total Rating

The SUT Total Rating Score is the higher of the SUT Accuracy Rating Score and the SUT Stability Rating Score.

The Ctrlr-Only Total Rating Score is the higher of the Ctrlr-Only Accuracy Rating Score and the Ctrlr-Only Stability Rating Score.

The Total Rating Score shall be “no passing score” if the Accuracy Subtest-Qmax fails or the Stability Max Flow test fails..

APPENDIX B – STANDARD TERMINAL UNIT (NORMATIVE)

The Standard Terminal unit shall consist of a multi-point velocity pressure flow probe mounted in an 8” duct, with a butterfly damper and uninsulated casing. Dimensions and location of components shall match Figure B.1.

The flow probe shall be a differential pressure airflow device measuring total and static pressures.

Control tubing shall be protected by grommets at the wall of the housing.

The flow probe shall have K-factor between 800 and 1000 (corresponding to an amplification factor between 3.05 and 1.95)

Figure B.1. Standard Terminal Unit Dimensions and Tolerances

	A	B	C	D	L
IP (in)	8 +/- 0.25	12 +/- 1	10 +/- 1	8 +/- 1	20 +/- 1
SI (mm)	203 +/- 6	305 +/- 25	254 +/- 25	203 +/- 25	508 +/- 25