BSR/ASHRAE Standard 195-2024R

Public Review Draft

Method of Test for Rating Air Terminal Unit Controls

Second Public Review – Independent Substantive Change (July 2026)
(Draft shows Proposed Changes to First Public Review Draft)

(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).

This document may not be distributed in whole or in part in either paper or electronic form outside of the PC without the express permission of the MOS and shall include a statement indicating such.

The appearance of any technical data or editorial material in this public review document does not constitute endorsement, warranty, or guaranty by ASHRAE of any product, service, process, procedure, or design, and ASHRAE expressly disclaims such.

ASHRAE, 180 Technology Parkway NW, Peachtree Corners, GA 30092

TABLE OF CONTENTS

(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

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 Standard 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 controller-only Total Rated Minimum 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 controller-only Total Rated Minimum Scores are available from several controls manufacturers, 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 Airflow Reference 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 Airflow Reference 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 130-2016 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.

Independent Substantive Changes Since Previous Public Review

This is a review of Independent Substantive Changes that were made since the last public review. Text that was removed from the public review draft is provided for reference but is shown in strikeout, and text that has been added is shown with underlines.

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.

Informative Note: This standard includes the test methods in Sections 6.2 and 6.3. Completion of both methods is not required unless specified by the party referencing this standard. For example, if only the Rated Minimum Test Method in Section 6.2 is specified, only the tests in Section 6.2 need to be completed.

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~~volumetric flow rate of air ~~per unit time~~ at the current ~~drybulb~~dry-bulb temperature, humidity, and air pressure. It is measured in actual cubic feet per minute (acfm) or liters per second (L/s), not in standard ~~cfm~~cubic feet per minute (scfm), which is based on standard temperature, humidity, and pressure.

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

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

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

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

Informative Note: for example, for 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-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, expressed in in. of water (Pa).

full-system test: ~~this measures~~test used to measure 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.

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
ΔSP	Differential static pressure across the SUT	in. of water	Pa
$\cancel{P}\Delta SP_{stpt}$	~~Absolute~~Differential static pressure setpoint	in. of water	Pa
$\cancel{P_a}\Delta SP_{stpt\text{-}max}$	~~Atmospheric~~Differential static pressure setpoint corresponding to $Q_{max\text{-}cal}$	in. ~~Hg~~ of water	Pa
$\cancel{P_v}\Delta SP_{stpt\text{-}min}$	~~Velocity~~Differential static pressure setpoint corresponding to $Q_{min\text{-}cal}$	in. of water	Pa
A	Cross-sectional area	ft^2	m^2
D_e	Equivalent diameter	ft	m
$FanSpd_{Qmax}$	Fan speed corresponding to $Q_{max\text{-}cal}$ at $\Delta SP_{stpt\text{-}max}$	% speed, Hz, or rpm	% speed, Hz, or rpm
$FanSpd_{Qmin}$	Fan speed corresponding to $Q_{min\text{-}cal}$ at $\Delta SP_{stpt\text{-}min}$	% speed, Hz, or rpm	% speed, Hz, or rpm
$\cancel{P_{vm}}K_{nominal}$	~~Flow probe signal~~Nominal K-factor provided by the terminal unit manufacturer	cfm/(in. of water)$^{1/2}$	~~Pa~~L/s/Pa$^{1/2}$
$\cancel{P_s}K_{obs}$	~~Static pressure~~Observed K-factor	cfm/(in. of water)$^{1/2}$	~~Pa~~L/s/Pa$^{1/2}$
$K_{Qmax\text{-}cal}$	K-factor at $Q_{max\text{-}cal}$	cfm/(in. of water)$^{1/2}$	L/s/Pa$^{1/2}$
$K_{Qmin\text{-}cal}$	K-factor at $Q_{min\text{-}cal}$	cfm/(in. of water)$^{1/2}$	L/s/Pa$^{1/2}$
$\cancel{P_t}P_{vm}$	~~Total pressure~~Flow probe signal	in. of water	Pa
$\cancel{\Delta P}P_{vm\text{-}ref}$	~~Differential pressure~~Reference flow probe signal	in. of water	Pa
$\cancel{\Delta P_t}P_{vm\text{-}stpt\text{-}stability}$	~~Total differential pressure~~Flow probe signal used to define the minimum-flow stability setpoint	in. of water	Pa
Q_{adj}	Adjusted airflow used for controller-only accuracy calculations	cfm	L/s
Q_{ctrlr}	Airflow indicated by the controller	cfm	L/s
$Q_{max\text{-}cal}$	Maximum calibration airflow	cfm	L/s
$Q_{min\text{-}cal}$	Minimum calibration airflow	cfm	L/s
$Q_{min\text{-}stability}$	Minimum-flow stability airflow setpoint	cfm	L/s

Q_{ref}	Airflow reference rate	cfm	L/s
Q_{stpt}	Airflow setpoint	cfm	L/s
$Q_{stpt\text{-}adj}$	Adjusted airflow setpoint used for controller-only stability calculations	cfm	L/s
RampTime	Time between step changes during the full-range accuracy test	min	min
Spd0	Baseline fan speed for the stability test	% speed, Hz, or rpm	% speed, Hz, or rpm
~~Q_a~~ *SteadyStateTime*	~~Airflow~~Hold time at ~~actual~~each step during the full-range accuracy test ~~conditions~~	~~ft³/~~min ~~(cfm)~~	~~L/s~~min
T_{cal}	Ambient temperature at calibration	°F	°C
V	Air velocity	ft/min ~~(fpm)~~	m/s

4 INSTRUMENTATION

4.1 Temperature Measurement

Temperature measuring instruments shall meet the requirements of *ASHRAE Standard 41.1-2013 (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 airflow 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

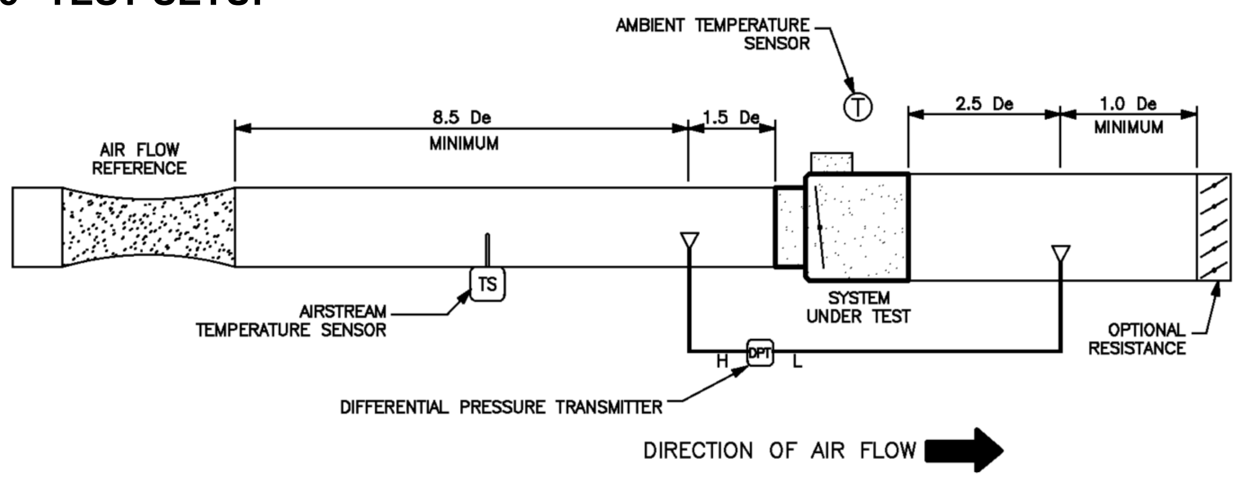

Figure 1 Required Test Setup.

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~~shall include a straight, hard inlet to the terminal~~. Minimum~~ with a minimum length of 10 duct diameters. The inlet duct dimensions shall ~~be~~match the ~~same size as~~ terminal inlet~~, i.e., no~~; transitions shall not be used.

5.2 Outlet from Terminal

~~Minimum~~A minimum of 3.5 straight duct diameters~~. Downstream~~ shall be provided downstream of the terminal unit outlet. The downstream duct size shall match the terminal unit outlet~~, i.e., no~~; transitions~~.~~ shall not be used. A flow resistance device (e.g., damper) may be installed downstream of this duct.

5.3 Airflow Reference

~~A~~An airflow 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~~shall be provided for testing. The fan ~~must~~shall 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~~maximum airflow, the ~~cfm~~airflow setpoint ~~might~~may be 609 cfm ~~(~~, based on 1800 fpm and the actual inlet area~~)~~. The stability test includes ~~testing~~operation at approximately 1.0 in. of water (250 Pa) differential static pressure (ΔSP) across the SUT. The required fan total static ~~on the fan~~pressure includes this 1.0~~"~~ in. of water plus any additional pressure drop through the airflow reference ~~flow meter~~measuring system, ductwork, ~~etc. So, the fan must~~and other components. The fan shall therefore be capable of achieving this condition outside ~~of~~ the surge region.

The fan may be located upstream of the airflow reference measuring system, integral to the airflow reference measuring system, or downstream of the ~~outlet from the~~ terminal outlet. During the stability test, all ~~flow~~airflow through the fan shall ~~flow~~pass through the SUT. During the stability test, ~~the~~ fan speed shall be automatically controlled by a controller program~~,~~ and shall not be 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~~shall have a dead-end connection so that it does not ~~disrupt~~disturb the pressure ~~seen~~measured 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 duct joint ~~of the ductwork~~ between the airflow reference ~~airflow~~ station and the unit under test ~~must~~shall 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~~shall be calibrated on the test installation~~, with the intention that the~~ using a calibration process intended to represent the process used in ~~the lab represents the one that will be used in a~~ a field installation. The airflow reference ~~airflow~~ measuring system used for the ~~System Performance Tests,~~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 for Rated Minimum

The test specifier may ~~specify that all of the following Test Methods be performed or only~~ require one or more of the ~~Test Methods.~~following test methods for rated minimum performance. For each ~~Test Method~~ specified~~, the~~ test method ~~must~~, the method shall be ~~followed~~completed in its entirety and all other applicable requirements of this standard ~~must~~shall be ~~followed~~met (e.g., ~~Instrumentation,~~ instrumentation and calibration). For example, if only an SUT Accuracy Rated Minimum Score, as described in Appendix A, is required, only the Sensing Accuracy Test Method need be performed. If an SUT Total Rated Minimum Score, as described in Appendix A, is required, both the Sensing Accuracy Test Method and the Stability Test Method shall be performed. 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. These adjustments are made by removing the measured error introduced by the flow probe.~~, etc.~~)

In order to receive any of the controller-only Rated Minimum Scores in Appendix A, the SUT must meet the requirements listed in Normative Appendix B.

6.2.1 Sensing Accuracy Test Method for Rated Minimum

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.~~5.

6.2.1.1 Calibration

1. Calibrate the airflow control at the minimum ($Q_{min\text{-}cal}$) and maximum ($Q_{max\text{-}cal}$) airflow setpoints of interest~~.~~ (see Appendix A for ~~Rating Conditions)~~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~~may be ~~full open~~at any position during calibration. Flow rates of $Q_{min\text{-}cal}$ ± 5% and $Q_{max\text{-}cal}$ ± 5% as measured by the reference flow meter shall be achieved by adjusting fan speed and/or external resistance.

4. If the controller does not ~~read~~provide a stable reading at Q_{min}~~, then raise~~$_{\text{-}cal}$, increase $Q_{min\text{-}cal}$ until ~~it reads~~a stable reading is obtained.

5. Record~~:~~ the following:

    a. ~~the ambient~~Ambient temperature at ~~which the controller was calibrated~~calibration, T_{cal}~~.~~

    b. ~~The barometric~~Barometric pressure

    c. Q_{min} ~~Calibration~~$_{\text{-}cal}$ calibration:
        i. ~~Reference airflow~~Airflow reference rate, $Q_{ref,min}$
        ii. Reference flow probe signal, $P_{vm\text{-}ref,min}$

    d. Q_{max} ~~Calibration~~$_{\text{-}cal}$ calibration:
        i. ~~Reference airflow~~Airflow reference rate, $Q_{ref,max}$
        ii. Reference flow probe signal, $P_{vm\text{-}ref,max}$

6. Calculate:

    a. K-factors: ~~K-Qmin~~$K_{Qmin\text{-}cal}$~~, K-Qmax~~ and $K_{Qmax\text{-}cal}$, calculated from the airflow reference ~~airflow~~ and reference flow probe signal at $Q_{min\text{-}cal}$ and $Q_{max\text{-}cal}$, respectively, using
        i. ~~K-Qmin~~$K_{Qmin\text{-}cal} = Q_{ref,min} / \mathrm{sqrt}(P_{vm\text{-}ref,min})$
        ii. ~~K-Qmax~~$K_{Qmax\text{-}cal} = Q_{ref,max} / \mathrm{sqrt}(P_{vm\text{-}ref,max})$

    b. ~~OPTIONAL~~Optional: Probe errors:
        i. ~~Nominal~~ Probe~~-~~ error~~-min = -~~ at $Q_{min\text{-}cal}$ = absolute value of (1 ~~*(1 – K-Qmin~~− $K_{Qmin\text{-}cal} / K_{nominal}$)
        ii. ~~Nominal~~ Probe~~-~~ error~~-max = -1 *(1- K-Qmax~~ at $Q_{max\text{-}cal}$ = absolute value of (1 − $K_{Qmax\text{-}cal} / K_{nominal}$)

iii. where $K_{nominal}$ is the nominal K-factor of the flow ~~cross~~probe 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 is 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~~subtests.

2. Subtest ~~–~~$Q_{max\text{-}cal}$

   a. The ambient temperature and airstream temperature shall be T_{cal} ± 2°F (1°C~~)~~).

   b. The SUT ~~Damper~~damper shall be fixed at the full-~~-~~open ~~throughout the Accuracy Test, i.e.~~position for this subtest; the controller ~~is~~shall not ~~modulating~~modulate the damper.

   c. Adjust fan speed and/or ~~optional~~external resistance to achieve a reference airflow of $Q_{max\text{-}cal}$ ± 5~~% at the reference flow meter.~~%.

   d. Begin ~~recording with~~ data acquisition ~~system~~. Record at least ~~5~~20 samples at ~~regular~~constant 10 second intervals ~~of between 10 and 60 seconds. Data collected~~. The data shall include the following:

      i. ~~Reference airflow~~Airflow reference rate, Q_{ref}

      ii. Ambient dry-bulb temperature

      iii. Airstream dry-bulb temperature

      iv. ~~Flow rate~~Airflow indicated by ~~product under test (~~the controller (Q_{ctrlr}), if available~~) (Qctrlr)~~

      v. Reference ~~Flow~~flow probe signal ($P_{vm\text{-}ref}$~~)~~), for systems that include a velocity pressure ~~sensors (note: Controller-Only Tests include velocity pressure sensors).~~flow probe

   e. For each sample calculate:

i. Observed K-factor: ~~K-Qmax-obs~~K_{obs} = Q_{ref} ~~-~~/ sqrt~~-~~($P_{vm\text{-}ref}$)

ii. Adjusted ~~Airflow~~airflow for ~~Controller-Only~~controller-only accuracy:

1. Q_{adj} = ~~K-Qmax~~$K_{Qmax\text{-}cal}$ ~~*~~× sqrt~~-~~($P_{vm\text{-}ref}$)

iii. SUT ~~Error = ~~error = 1~~-~~ − Q_{ctrlr} / Q_{ref}

iv. ~~Ctrlr-Only Error:~~Controller-only error = 1~~-~~ − Q_{ctrlr} / Q_{adj}

v. ~~OPTIONAL~~Optional: Probe ~~Error:~~error = 1 ~~–~~− Q_{adj} / Q_{ref}

f. For all samples calculate:

i. Average SUT error~~,~~ and average ~~Ctrlr-Only~~controller-only error

3. Q_{min} Subtest 1 (T_{cal}~~).~~)

a. The ambient temperature and airstream temperature shall be T_{cal} ± 2°F (1°C~~)~~).

a. ~~SUT Damper shall be full open~~

b. The SUT damper shall be fixed at the full-open position or at a fixed position corresponding to no more than 0.1 in. of water differential static pressure (ΔSP) across the SUT. The damper position shall remain constant throughout all Q_{min} subtests.

c. Adjust fan speed and/or ~~optional~~external resistance to achieve each ~~of the~~ P_{vm} ~~setpoints +/-~~ setpoint within ±10%, as measured by the ~~ref~~reference flow probe signal, and ~~take~~record at least ~~5 steady state~~20 readings at ~~regular~~constant 10 second intervals ~~of between 10 and 60 seconds~~ at each P_{vm} setpoint.

d. ~~Data collected~~The data shall include the following:

i. ~~Reference airflow~~Damper position

ii. ΔSP across the SUT

iii. Airflow reference rate, Q_{ref}

iv. Ambient dry-bulb temperature

v. Airstream dry-bulb temperature

vi. ~~Flow rate~~Airflow indicated by ~~product under test (~~the controller (Q_{ctrlr}), if available~~) (Qctrlr)~~

vii. Reference ~~Flow~~flow probe signal (~~inches w.c.) (~~$P_{vm\text{-}ref}$~~)~~), for systems that include a velocity pressure ~~sensors.~~flow probe

e. For each sample calculate:

b. ~~For each sample calculate:~~

i. Observed K-factor: $K_{obs} = Q_{ref}$ -/ sqrt-($P_{vm\text{-}ref}$)

ii. Adjusted ~~Airflow~~airflow for ~~Controller-Only~~ controller-only accuracy:

iii. Q_{adj} = ~~K-Qmin~~$K_{Qmin\text{-}cal}$ ~~*~~× sqrt-($P_{vm\text{-}ref}$)

iv. SUT ~~Error =~~ error = 1- − Q_{ctrlr} / Q_{ref}

v. ~~Ctrlr-Only Error~~ Controller-only error = 1- − Q_{ctrlr} / Q_{adj}

vi. ~~OPTIONAL~~Optional: Probe ~~Error~~error = 1 –− Q_{adj} / Q_{ref}

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~~it is 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).*

f. For each P_{vm} setpoint calculate:

i. Average SUT error~~,~~ and average ~~Ctrlr-Only~~controller-only error

4. Q_{min} 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~~zeroed between Q_{min} Subtest 1 and Q_{min} 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. Q_{min} Subtest 3 (High Temp, Post-Auto-Zero, if available)

   a. If the controller has an ~~autozero~~auto-zero feature, ~~then~~ shut off the fan and command the controller to execute ~~autozero~~auto-zero.

   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 for Rated Minimum

1. If the test specifier specifies both the Accuracy Test and the 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~~in accordance with Section 6.1.

2. Adjust ambient temperature and airstream temperature to T_{cal} ± 2°F (1°C).

3. If the controller has an ~~autozero~~auto-zero feature, then shut off the fan and command the controller to execute ~~autozero~~auto-zero.

4. Command the controller to ~~hold~~maintain a fixed airflow setpoint ~~of~~, Qstpt (see Appendix A for ~~Rating Conditions).~~ rating conditions). The controller ~~will then~~shall modulate the damper using its standard control algorithm to maintain ~~its~~the measured airflow at ~~setpoint~~Qstpt.

5. Manually or automatically adjust fan speed to achieve steady~~-~~-state conditions (damper not modulating) with ~~ΔSP~~ΔSP within 0.05~~"~~ in. of water of ~~ΔSP setpoint~~ΔSP_{stpt} (see Appendix A for ~~Rating Conditions). Fan~~rating conditions). The fan speed at this condition shall be ~~called~~designated Spd0.

6. Begin recording data.

7. After 4 minutes at fixed Spd0, the fan speed shall automatically modulate at a rate of 1% every 15 ~~seconds~~s from Spd0 to 50% of Spd0~~,~~; i.e~~.~~., 12.5 ~~minutes~~min to ~~smoothly~~ modulate from Spd0 to 50% of Spd0. ~~NOTE: % Speed must~~ Informative Note: % speed shall be scaled such that 0% speed ~~is at~~ corresponds to 0 Hz or 0 ~~RPM,~~rpm and not ~~scaled such that 0% speed is at some~~to a minimum speed setpoint ~~of say~~such as 10 Hz. For example, if Spd0 = 1000 ~~RPM~~rpm, then 50% of Spd0 = 500 ~~RPM~~rpm.

Informative Note: *Fan speed is automatically modulated, rather than adjusting ΔSP_{stpt}, to eliminate the risk of obtaining a favorable result by manually adjusting speed while remaining within the allowed tolerance on ΔSP_{stpt}.*

8. After 4 minutes ~~fixed~~ at 50% of Spd0, the fan speed shall automatically modulate at a rate of 1% every 10 seconds to 200% of Spd0~~,~~; i.e~~.~~., 25 ~~minutes~~min to ~~smoothly~~ modulate from 50% to 200% of Spd0.

9. ~~Wait 4 minutes with~~Maintain the fan speed ~~fixed~~ at 200% of Spd0 for 4 minutes.
10. Stop recording data. ~~-~~(45.5 minutes of data~~)~~.)
11. Recorded data at 1~~-~~-minute intervals shall include:
    a. ~~Reference airflow~~Fan speed in % Speed and in Hz or RPM
    b. Airflow reference rate (Q_{ref})
    c. Reference ~~Flow~~flow probe signal ~~(inches w.c.)~~ (P_{vm-ref})
    d. Pressure drop across the flow control device
    e. Ambient and airstream temperature
12. For each sample, calculate the following:
    a. Observed K-factor: $K_{obs} = Q_{ref}$ ~~-~~/ sqrt~~-~~(P_{vm-ref})
    b. Adjusted ~~Airflow Setpoint~~airflow setpoint for ~~Controller-Only~~controller-only stability:
        i. $Q_{stpt-adj} = K_{obs}$ ~~*~~× sqrt($P_{vm-stpt-stability}$)
    c. SUT ~~Error~~error = 1 ~~–~~− Q_{ref} / Q_{stpt}
    d. ~~Ctrlr-Only Error~~Controller-only error = 1 ~~–~~− Q_{ref} / $Q_{stpt-adj}$
    e. ~~OPTIONAL~~Optional: Probe ~~Error = -~~error = absolute value of (1~~*(1 – Qref~~ − $Q_{stpt-adj}$~~/Qref~~ / Q_{stpt})
13. ~~OPTIONAL~~Optional: Damper Start/Stops
    a. Record output command from the controller to the damper actuator every 5 seconds (~546 recordings).
        i. 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%.
        ii. 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.

i. Analog:

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

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

ii. Floating Point:

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

2. 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~~it is 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.*

6.3 System Performance Test Methods for Full Range Accuracy

6.3.1 Calibration

1. Calibrate the airflow control at $Q_{max\text{-}cal}$ and $Q_{min\text{-}cal.}$ Unless otherwise specified, $Q_{max\text{-}cal}$ shall correspond to inlet velocity of 1,800 fpm and $Q_{min\text{-}cal}$ shall be 20% of $Q_{max\text{-}cal.}$

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 may be at any position during calibration.

6.3.2 Accuracy and Stability Test Method for Full Range Accuracy

1. Adjust the ambient temperature and airstream temperature to 72.5°F ± 2.5°F (22.5°C ± 1.4°C). For this test method, $\Delta SP_{stpt\text{-}max}$ is the differential static pressure setpoint corresponding to $Q_{max\text{-}cal}$, with a default value of 1.0 in. of water, and $\Delta SP_{stpt\text{-}min}$ is the differential static pressure setpoint corresponding to $Q_{min\text{-}cal}$, with a default value of 0.5 in. of water.

2. Manually adjust the fan speed and damper position to achieve a reference airflow of $Q_{max\text{-}cal}$ ± 5% and a differential static pressure of $\Delta SP_{stpt\text{-}max}$ ± 0.05 in. of water. Record the corresponding fan speed as $FanSpd_{Qmax}$.

3. Manually adjust the fan speed and damper position to achieve a reference airflow of $Q_{min\text{-}cal}$ ± 5% and a differential static pressure of $\Delta SP_{stpt\text{-}min}$ ± 0.05 in. of water. Record the corresponding fan speed as $FanSpd_{Qmin}$.

4. During data acquisition, the SUT airflow setpoint and fan speed shall be automatically controlled as follows, where the time between steps RampTime = 10 min and the time at each step SteadyStateTime = 5 min.

    a. Time T0 (begin recording):

        i. Airflow Setpoint = $Q_{min\text{-}cal}$

        ii. Fan speed = $FanSpd_{Qmin}$

        iii. Hold for SteadyStateTime.

    b. Time T1:

        i. The airflow setpoint shall be linearly reset from $Q_{min\text{-}cal}$ to $Q_{max\text{-}cal}$ over RampTime.

        ii. The fan speed shall be linearly reset from $FanSpd_{Qmin}$ to $FanSpd_{Qmax}$ over RampTime.

    c. Time T2

        i. Airflow setpoint = $Q_{max\text{-}cal}$

        ii. Fan speed = $FanSpd_{Qmax}$

        iii. Hold for SteadyStateTime.

    d. Time T3

        i. The airflow setpoint shall be linearly reset from $Q_{max\text{-}cal}$ to $Q_{min\text{-}cal}$ over RampTime.

        ii. The fan speed shall be linearly reset from $FanSpd_{Qmax}$ to $FanSpd_{Qmin}$ over RampTime.

    e. Time T4

        i. Airflow setpoint = $Q_{min\text{-}cal}$

        ii. Fan speed = $FanSpd_{Qmin}$

        iii. Hold for SteadyStateTime.

   f. Stop recording.

5. During data acquisition, record the following at LoggingInterval, where LoggingInterval = 10 seconds:
   a. Fan speed in % Speed and in Hz or RPM
   b. Airflow setpoint (Q_{stpt})
   c. Airflow reference rate (Q_{ref})
   d. Pressure drop across the flow control device
   e. Optional:
      i. Flow rate indicated by product under test
      ii. Damper position command
      iii. Damper position feedback
6. For each sample, calculate the following:
   a. Airflow error = absolute value of ($Q_{ref} - Q_{stpt}$)
   b. Airflow percent error = airflow error / Q_{ref}
7. For all samples, calculate the following:
   a. Average airflow error and average airflow percent error
   b. Highest single airflow error and airflow percent error

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.~~

7 TEST REPORT

–The report shall not present average accuracy values ~~that indicate better~~with precision greater than ~~4~~four times the accuracy of the airflow 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~~all calculations required for ~~all~~the subtests used to determine ~~Rating Scores~~rating scores, including SUT ~~Error~~error and ~~Controller-Only Error~~controller-only error.

The test report shall include the make and model of all components of the SUT, including the controller and the airflow transducer.

8 REFERENCES

1. *ANSI/ASHRAE Standard 130-2016, 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 41.1-2013 (RA 2006), Standard Method 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.
5. *ANSI/ASHRAE Standard 41.3-2014, Standard Method for Pressure Measurement*. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers Inc.
6. *ASHRAE Handbook—Fundamentals*. Atlanta: American Society of Heating, Refrigerating and Air Conditioning Engineers Inc.
7. *ASHRAE Research Project RP-1353 -- Stability and Accuracy of VAV Box Control at Low Flows*
8. Pacific Gas and Electric Company, Emerging Technologies Program, Application Assessment Report #05xx, Stability and Accuracy of VAV Terminal Units at Low Flow, February 7, 2007. Prepared by Darryl Dickerhoff, Consultant, and Jeff Stein, Taylor Engineering.
9. *PG&E's Code Readiness Program: Final Project Report CR24PGE0001, Research Project in Support of ASHRAE Standard 195: Method of Test for Rating Air Terminal Unit Controls, Primary Authors: Jeff Stein and Pat Wendler, Taylor Engineers; S. Michael Daukoru and Mark Alatorre, Pacific Gas & Electric, Issued: June 26, 2024*

APPENDIX A – RATED MINIMUM RATING CONDITIONS (NORMATIVE)

A.1 System Performance Test

This appendix provides the rating conditions to be used in the System Performance Test Methods in Section 6.2 in order to receive any Standard 195 Rated Minimum Score as described below. No tests described in Section 6.3 are required to receive any Standard 195 Rated Minimum Score.

A.1.1 Accuracy Rating

- Q_{max} ~~= flow rate~~ $_{-cal}$ = airflow corresponding to an inlet velocity of ~~1,800 feet~~1800 ft/min~~,~~ or ~~mfg~~the manufacturer's suggested maximum ~~flow~~airflow, whichever is lower.
- Q_{min} ~~= flow rate~~ $_{-cal}$ = airflow calculated from the flow probe signal ~~(~~, P_{vm} ~~) of~~ = 0.005~~"~~ in. of water, and the nominal K-factor ~~of the flow cross~~ provided by the terminal unit manufacturer, using $Q_{min\text{-}cal} = K_{nominal}$ ~~*~~× sqrt(P_{vm}~~)~~).
- If the controller does not provide a stable ~~steady state~~ reading at Q_{min}~~, then slowly raise~~ $_{-cal}$, increase P_{vm} in the $Q_{min\text{-}cal}$ calculation until the controller ~~does provide~~provides a stable ~~steady state~~ reading.
- P_{vm} ~~Setpoints~~setpoints:
  - 0.100"
  - 0.050"
  - 0.025"
  - 0.013"
  - 0.008"
  - 0.005"
  - 0.004"
  - 0.003"
  - 0.002~~"~~"

SUT Accuracy ~~Rating~~Rated Minimum Score

~~The~~ Subtest~~-~~ $Q_{max\text{-}cal}$ is passed if:

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

A P_{vm} setpoint passes a ~~MIN~~ Q_{min} subtest if:

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

To receive ~~a~~an SUT Accuracy ~~Rating~~Rated Minimum Score~~ the~~, Subtest-~~ ~~Q_{max}~~ must~~$_{-cal}$ shall pass.

The SUT Accuracy ~~Rating~~Rated Minimum Score is the lowest P_{vm} setpoint that passes both Q_{min} Subtest 1 and Q_{min} Subtest 3.

Controller-~~Only~~only Accuracy ~~Rating~~Rated Minimum Score

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

~~The~~ Subtest-$Q_{max\text{-}cal}$ is passed if:

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

A P_{vm} setpoint passes a ~~MIN~~Q_{min} subtest if:

1. no sample has ~~an Ctrlr-Only Error~~a controller-only error > 20% or < -20%.
2. ~~The~~the average ~~Ctrlr-Only Error~~controller-only error is between -10% and 10%.

To receive a ~~Ctrlr-Only~~controller-only Accuracy ~~Rating~~Rated Minimum Score, ~~the~~ Subtest-Q_{max} ~~must~~$_{-cal}$ shall pass.

The ~~Ctrlr-Only~~controller-only Accuracy ~~Rating~~Rated Minimum Score is the lowest P_{vm} setpoint that passes both Q_{min} Subtest 1 and Q_{min} Subtest 3.

A.1.2 Stability ~~Rating~~Rated Minimum

Stability shall be tested at ~~Max Flow~~$Q_{max\text{-}cal}$ and ~~at Min Flow~~$Q_{min\text{-}stability}$.

~~Max Flow Conditions~~

Maximum-flow conditions

ΔSP_{stpt} ~~= 0.50”~~$_{-max}$ = 1.0 in. of water.

~~Qstpt = flow rate~~ $Q_{max\text{-}cal}$ = airflow corresponding to an inlet velocity of ~~1,800 feet~~1800 ft/min, or ~~mfg~~the manufacturer’s suggested maximum ~~flow~~airflow, whichever is lower.

~~Min Flow Conditions~~

Minimum-flow conditions

$\Delta SP_{stpt\text{-}min}$ = 0.50~~”~~ in. of water.

~~Qstpt = K~~ $Q_{min\text{-}stability} = K_{Qmin\text{-}cal}$ ~~*~~× sqrt(~~(~~$P_{vm\text{-}stpt\text{-}stability}$~~)~~).

For SUT testing~~:~~, $P_{vm\text{-}stpt\text{-}stability}$ = SUT Accuracy ~~Rating~~Rated Minimum Score.

For ~~Ctrlr-Only~~controller-only testing~~:~~, $P_{vm\text{-}stpt\text{-}stability}$ = ~~Ctrlr-Only~~controller-only Accuracy ~~Rating~~Rated Minimum Score.

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

1. No individual airflow reference ~~airflow~~ reading is more than 30% above or below Q_{stpt}.
2. The average airflow reference ~~airflow~~ reading for each subtest is within 10% of Q_{stpt}.

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

3. No individual airflow reference ~~airflow~~ reading is more than 30% above or below $Q_{stpt\text{-}adj}$.
4. The average airflow reference ~~airflow~~ reading for each subtest is within 10% of $Q_{stpt\text{-}adj}$.

If the Min Flow Stability Test is not passed at the initial $P_{vm\text{-}stpt\text{-}stability}$, ~~then repeat~~ the Stability ~~test~~ Test shall be repeated at the airflow setpoint calculated from the next ~~highest~~higher P_{vm} setpoint listed in Section A.1.1. ~~Continue repeating~~The test shall continue to be repeated at higher P_{vm} ~~setpoint~~setpoints until the Stability ~~test~~Test is passed.

Optional: If the Min Flow Stability Test is passed at the initial $P_{vm\text{-}stpt\text{-}stability}$, ~~then repeat~~ the Stability ~~test~~Test may be repeated at lower airflow ~~setpoint(s)~~setpoints to determine the lowest P_{vm} setpoint that passes the Stability Test.

To receive ~~a~~an SUT Stability ~~Rating~~Rated Minimum Score, the SUT Max Flow Stability Test ~~must~~shall pass.

The SUT Stability ~~Rating~~Rated Minimum Score is the lowest P_{vm} setpoint that passes the SUT Min Flow Stability Test.

To receive a ~~Ctrlr-Only~~controller-only Stability ~~Rating~~Rated Minimum Score, the ~~Ctrlr-Only~~controller-only Max Flow Stability Test ~~must~~shall pass.

The ~~Ctrlr-Only~~controller-only Stability ~~Rating~~Rated Minimum Score is the lowest P_{vm} setpoint that passes the ~~Ctlr-Only~~controller-only Min Flow Stability Test.

A.1.3 Total ~~Rating~~Rated Minimum

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

The ~~Ctrlr-Only~~controller-only Total ~~Rating~~Rated Minimum Score is the higher of the ~~Ctrlr-Only~~controller-only Accuracy ~~Rating~~Rated Minimum Score and the ~~Ctrlr-Only~~controller-only Stability ~~Rating~~Rated Minimum Score.

The Total ~~Rating~~Rated Minimum Score shall be "no passing score" if ~~the Accuracy~~ Subtest- $Q_{max\text{-}cal}$ fails or the Max Flow Stability ~~Max Flow test~~Test fails~~.~~.

APPENDIX B – STANDARD TERMINAL UNIT (NORMATIVE)

The Standard Terminal ~~unit~~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 a 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