(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
The purposes of 41.7-2021 Addendum a are to (a) make it easier for the higher-tier ASHRAE standards to adopt this standard by reference, (b) update the uncertainty requirements, and (c) update the steady-state criteria sections.

Note: In this addendum, changes to the current standard are indicated in the text by underlining (for additions) and strikethrough (for deletions) unless the instructions specifically mention some other means of indicating the changes.

Addendum a to Standard 41.7-2021

Section 3, Definitions: Revise or add the definitions as shown below.

3. DEFINITIONS

accuracy: the degree of conformity of an indicated value to the corresponding true value. the difference between the observed value of the measurand and its corresponding true value.

post-test uncertainty: an analysis to establish the uncertainty of a test result after conducting the test.

pre-test uncertainty: an analysis to establish the expected uncertainty interval for a test result before conducting the test.

steady-state criteria: the criteria that establish negligible change of gas flow with time.

uncertainty: a measure of the potential error in a measurement that reflects the lack of confidence in the result to a specified level. the limits of error within which the true value lies.

Section 5, Requirements: Revise Section 5.1 as shown below.

5.1 Test Plan. A test plan shall specify the gaseous mass flow rate measurement system accuracy. The test plan shall also include the test points, targeted set points, and corresponding operating tolerances to be performed. The test plan shall be one of the following options:

a. A document provided by the person or the organization that authorized the tests and calculations to be performed.
c. A rating standard.
d. A regulation or code.
e. Any combination of items a. through d.
The test plan shall specify:

a. The maximum allowable value for either the accuracy or the measurement uncertainty of the gas flow measurement system.

b. The values to be determined and recorded are selected from this list: gas mass flow, pretest gas mass flow measurement uncertainty, post-test gas mass flow measurement uncertainty, gas volumetric flow, pretest gas volumetric flow measurement uncertainty, and post-test gas flow measurement uncertainty, gas density, gas density pretest uncertainty, and gas density post-test uncertainty.

c. Any combination of test points and targeted set points to be performed together with operating tolerances.

Section 5.2, Values to Be Determined and Reported: Revise as shown below to make it easier for MOT/MOR standards to adopt this standard by reference.

5.2 Values to be Determined and Reported. If specified in the test plan in Section 5.1, the test values to be determined and reported shall be as shown in Table 1. Use the unit of measure in the Table 1 unless otherwise specified in the test plan in Section 5.1.

<table>
<thead>
<tr>
<th>Table 1 Measurement Values and Units of Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Units of Measure</strong></td>
</tr>
<tr>
<td>Quantity</td>
</tr>
<tr>
<td>Gas mass flow rate and uncertainty</td>
</tr>
<tr>
<td>Gas mass flow rate uncertainty</td>
</tr>
<tr>
<td>Gas volumetric flow rate and uncertainty</td>
</tr>
<tr>
<td>Gas volumetric flow rate and uncertainty</td>
</tr>
<tr>
<td>Gas density and uncertainty</td>
</tr>
<tr>
<td>Gas density uncertainty</td>
</tr>
</tbody>
</table>

Section 5.3.1, Accuracy: Revise Section 5.3.1 as shown

5.3.1 Accuracy or Measurement Uncertainty. A selected gas flowmeter shall meet or exceed the required gas flow measurement system accuracy maximum allowable value for either the accuracy or the
measurement uncertainty of the gas flow rate measurement specified in the test plan in Section 5.1 over the full range of operating conditions.

Section 5.3.2, Uncertainty: Replace Section 5.3.1 with a new Section 5.3.1 and a new Section 5.3.2, and then renumber the subsequent sections as appropriate.

5.3.2 Uncertainty. The uncertainty in each gas flow measurement shall be calculated using the method in Section 8 for each test point, unless otherwise stated in the test plan in Section 5.1. Alternatively, the worst-case uncertainty for all test points shall be estimated and the same value reported for each test point.

5.3.2 Pretest Uncertainty Analysis. If required by the test plan in Section 5.1, perform an uncertainty analysis to establish the expected uncertainty for each gas flow rate test point prior to the conduct of that test in accordance with the pretest uncertainty analysis procedures in ASME PTC 19.1.

5.3.3 Post-test Uncertainty Analysis. If required by the test plan in Section 5.1, perform an uncertainty analysis to establish the gas flow rate measurement uncertainty for each gas flow test point in accordance with the post-test uncertainty analysis procedures in ASME PTC 19.1. Alternatively, if specified in the test plan, the worst-case uncertainty for all test points shall be estimated and the same value reported for each test point.

Section 5.3.3, Steady-State Test Criteria for Gas Mass Flow Rate Measurements: Revise as shown below to define the steady-state criteria requirements under laboratory and field test conditions.

5.3.3 Steady-State Test Criteria for Gas Mass Flow Rate Measurements. Gas mass flow rate test data shall be recorded at steady-state conditions unless otherwise indicated in the test plan in Section 5.1. If the test plan requires gas mass flow rate test data points to be recorded at steady-state test conditions and provides the operating condition tolerance but does not specify the steady-state criteria, then determine that steady-state test conditions have been achieved using one of the following methods:

a. Apply the steady-state criteria in Section 5.3.3.1 if the test plan provides test points for gas mass flow rate measurement.

b. Apply the steady-state criteria in Section 5.3.3.2 if the test plan provides targeted set points for gas mass flow rate measurement.

5.3.3.1 Steady-State Test Criteria for Gas Mass Flow Rate Measurements Under Laboratory Test Conditions. If the test plan requires gas flow test data points to be recorded at steady-state test conditions and provides the operating condition tolerance but does not specify the steady-state criteria, then determine that steady-state test conditions have been achieved using one of the following methods:

a. Apply the steady-state criteria in Section 5.3.3.3 if the test plan provides test points for gas mass flow rate measurement.

b. Apply the steady-state criteria in Section 5.3.3.4 if the test plan provides targeted set points for gas mass flow rate measurement.

5.3.3.2 Steady-State Test Criteria for Gas Mass Flow Rate Measurements Under Field Test Conditions. If the test plan requires gas flow test data points to be recorded at steady-state test
conditions and provides the operating condition tolerance but does not specify the steady-state criteria, the methods in Section 5.3.3.1 are optional.

*(Informative Note: The steady-state methods in Section 5.3.3.1 are likely to be impractical under field test conditions. Under these circumstances, the user may want to select another method to determine the conditions for field test data to be recorded.)*

Section 5.3.3.1, Steady-State Gas Mass Flow Rate Criteria for Test Points: Replace Figure 1 with a new Figure 1 and revise the text shown below.

5.3.3.3 Steady-State Gas Mass Flow Rate Criteria for Test Points

[...]

[replace the publication version of Figure 1]

![Graph showing steady-state gas mass flow rate criteria](image)
\(\bar{m}\), as determined by Equation 5-5, represents the steady-state mean gas mass flow rate provided that one of the following criteria is satisfied:

a. Apply Equation 5-6 if \(2\sigma \geq m_L\) where \(m_L\) is the specified operating tolerance limit for gas mass flow rate, and if Equation 5-6 is satisfied by not less than 95% of the sampled gas mass flow rates.

\[
|\bar{m} - \mu| \leq 2\sigma \text{, kg/s (lbm/min)} \quad (5-6)
\]

The horizontal dotted lines, that are located \(2\sigma\) above and below \(\mu\), are the boundaries of the 95% sampled gas mass flow rate scatter envelope.

b. Apply Equation 5-7 if \(m_L \geq 2\sigma\) where \(m_L\) is the specified operating tolerance limit for gas mass flow rate, and if Equation 5-7 is satisfied by not less than 95% of the sampled gas mass flow rates.

\[
|\bar{m} - \mu| \leq m_L \text{, kg/s (lbm/min)} \quad (5-7)
\]

The horizontal dashed lines, that are located \(m_L\) above and below \(\mu\), are the boundaries of the 95% sampled gas mass flow rate scatter envelope.

Section 5.3.3.2, Steady-State Gas Mass Flow Rate Criteria for Targeted Set Points: Replace Figure 2 with a new Figure 2 and revise Equation 5-16 shown below.

5.3.3.2 5.3.3.4 Steady-State Gas Mass Flow Rate Criteria for Targeted Set Points
[...]
5.3.5 Steady-State Test Criteria for Gas Volumetric Flow Rate Measurements. Gas volumetric flow rate test data shall be recorded at steady-state conditions unless otherwise specified in the test plan in Section 5.1. If the test plan requires gas volumetric flow rate test data points to be recorded at steady-state test conditions and provides the operating condition tolerance but does not specify the steady-state criteria, then determine that steady-state test conditions have been achieved using one of the following methods:

c. Apply the steady-state criteria in Section 5.3.5.1 if the test plan provides test points for gas volumetric flow rate measurement.

d. Apply the steady-state criteria in Section 5.3.5.2 if the test plan provides targeted set points for gas volumetric flow rate measurement.

5.3.5.1 Steady-State Test Criteria for Gas Volumetric Flow Rate Measurements Under Laboratory Test Conditions. If the test plan requires gas flow test data points to be recorded at steady-state test conditions and provides the operating condition tolerance but does not specify the steady-state criteria, then determine that steady-state test conditions have been achieved using one of the following methods:

c. Apply the steady-state criteria in Section 5.3.5.3 if the test plan provides test points for gas volumetric flow rate measurement.

d. Apply the steady-state criteria in Section 5.3.5.4 if the test plan provides targeted set points for gas volumetric flow rate measurement.

5.3.5.2 Steady-State Test Criteria for Gas Volumetric Flow Rate Measurements Under Field Test Conditions. If the test plan requires gas flow test data points to be recorded at steady-state test conditions and provides the operating condition tolerance but does not specify the steady-state criteria, the methods in Section 5.3.5.1 are optional.

(Informative Note: The steady-state methods in Section 5.3.5.1 are likely to be impractical under field test conditions. Under these circumstances, the user may want to select another method to determine the conditions for field test data to be recorded.)

5.3.5.3 Steady-State Gas Volumetric Flow Rate Criteria for Test Points

[replace the publication version of Figure 3]
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[with the new Figure 3]
\( \bar{Q} \), as determined by Equation 5-21, represents the steady-state mean gas volumetric flow rate provided that one of the following criteria is satisfied:

a. Apply Equation 5-22 if \( 2\sigma \geq Q_L \) where \( Q_L \) is the specified operating tolerance limit for gas volumetric flow rate, and if Equation 5-22 is satisfied by not less than 95% of the sampled gas volumetric flow rates.

\[
|Q_i - \mu| \leq 2\sigma, \text{ m}^3/\text{s (cfm)} \tag{5-22}
\]

The horizontal dotted lines, that are located \( 2\sigma \) above and below \( \mu \), are the boundaries of the 95% sampled gas volumetric flow rate scatter envelope.

b. Apply Equation 5-23 if \( Q_L \geq 2\sigma \) where \( Q_L \) is the specified operating tolerance limit for gas volumetric flow rate, and if Equation 5-23 is satisfied by not less than 95% of the sampled gas volumetric flow rates.

\[
|Q_i - \mu| \leq Q_L, \text{ m}^3/\text{s (cfm)} \tag{5-23}
\]

The horizontal dashed lines, that are located \( Q_L \) above and below \( \mu \), are the boundaries of the 95% sampled gas volumetric flow rate scatter envelope.

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**Section 5.3.5.2, Steady-State Gas Volumetric Flow Rate Criteria for Targeted Set Points: Replace Figure 4 and revise Equation 5-32 as shown below.**

**5.3.5.2 5.3.5.4 Steady-State Gas Volumetric Flow Rate Criteria for Targeted Test Points**

[...]

[replace the publication version of Figure 4]
First Public Review Draft

[with the new Figure 4]
\[ b \Delta t \leq 0.50 Q_L, \text{ m}^3/\text{s (cfm)} \]  
\[ |b \Delta t| \leq 0.50 Q_L, \text{ m}^3/\text{s (cfm)} \]

Section 7.1, Constraint on all Gas Flow Rate Measurement Methods: Revise the text and delete Equation 7-1 as shown below.

**7.1 Constraint on All Gas Flow Rate Measurement Methods.** A selected gas flow measurement plane shall exceed 7.5 inside pipe diameters geometrically equivalent diameters downstream of an obstruction or any change in the gas flow airflow direction and shall exceed 3 inside pipe diameters geometrically equivalent diameters upstream of an obstruction or change in the gas flow direction unless otherwise specified by the gas flow airflow measurement instrument manufacturer. For a rectangular duct with interior width and height dimensions equal to \(a\) and \(b\) respectively, the geometrically equivalent diameter shall be obtained from Equation 7-1. For a round duct, the geometrically equivalent diameter \(D_e\) is equal to the interior diameter \(D\).

\[
D_e = \sqrt{\frac{4ab}{\pi}} \tag{7-1}
\]

where
- \(D_e\) = geometrically equivalent diameter, m (ft)
- \(a\) = interior width, m (ft)
- \(b\) = interior height, m (ft)

Section 7.4.2.1, Measurements: Revise the text as shown below.

**7.4.2.1 Measurements:** Measurements required for this nozzle gas flow shall be:
- **a.** Inlet pipe inside diameter \(D\), duct geometrically equivalent diameter \(D_e\), that is defined in Equation 7-1, m (ft)
- **b.** Nozzle throat diameter \(d\), m (ft)
- **c.** Nozzle inlet absolute pressure \(p_1\), Pa (in. of water) (psia)
- **d.** Nozzle throat absolute pressure \(p_2\), Pa (in. of water) (psia)
- **e.** Nozzle differential pressure \(\Delta p = (p_1 - p_2)\), Pa (in. of water) (psid)
- **f.** Nozzle inlet temperature \(t_1\), °C (°F)
Section 7.4.2.2, Nozzle Inlet Duct Hydraulic Diameter: Delete the text and delete Equation 7-3 as shown below.

7.4.2.2 Nozzle Inlet Duct Hydraulic Diameter. Nozzle inlet duct hydraulic diameter $D_h$ shall be obtained from dimensional measurements. For a round duct, $D_h$ is equal to the interior inlet diameter. For a rectangular duct, the hydraulic diameter shall be obtained from Equation 7-3.

$$D_h = \frac{ab}{(a+b)} \quad (7-3)$$

where
- $D_h$ = hydraulic diameter, dimensionless
- $a$ = interior width, m (ft)
- $b$ = interior height, m (ft)

Section 7.4.2.3, Nozzle Limits of Use and Reynolds Number: Revise the text and revise Equation 7-4 as shown below.

7.4.2.3 Nozzle Limits for Use and Reynolds Number. Limits for the use for long radius nozzle and Reynolds number are:

a. $50 \text{ mm (2 in.)} \leq D \leq 630 \text{ mm (25 in.)}$

b. $R_s/D \leq 3.2 \times 10^{-4}$ where $R_s$ is the mean of the surface roughness in the upstream duct

c. $1 \times 10^4 \leq Re_D \leq 1000 \times 10^7$ where $Re_D$ is defined in Equation 7-4.

$$Re_D = \frac{\rho_1 V_D D}{\mu} \quad (7-4)$$

where
- $\rho_1$ = gas density, kg/m$^3$ (lbm/ft$^3$)
- $V$ = average gas velocity $\left[\frac{4ab}{(a+b)}\right]$ m/s (ft/s)
- $V_D$ = average gas velocity, m/s (ft/s)
- $D_h$ = nozzle inlet hydraulic diameter, m (ft)
- $D$ = inlet pipe inside diameter, m (ft)
- $\mu$ = dynamic viscosity, Ns/m$^2$ (lbm/s-ft)

Section 7.4.2.4, Nozzle Beta Ratio: Revise the text and revise Equation 7-5 as shown below.

7.4.2.4 Nozzle Beta Ratio. The nozzle beta ratio shall be obtained from Equation 7-5. If gas flow operating temperatures are not within ±6ºC (±10ºF) of the ambient temperature during the dimensional measurements, parameters $d$, $D_h$, $D$, and $\beta$ shall be corrected to account for thermal expansion in compliance with ASME PTC 19.57 Section 3-10.
\( \beta = \left( \frac{d}{D} \right), \text{ dimensionless} \) \hfill (7-5)

\( \beta = \left( \frac{d}{D} \right), \text{ dimensionless} \) \hfill (7-5)

Section 7.4.2.6, Nozzle Gas Volumetric Flow Rates: Replace Equations 7-6 and 7-7 as shown below.

7.4.2.6 Nozzle Gas Volumetric Flow Rates.

[...]

In SI units:

\[
Q = C \varepsilon \left( \frac{\pi}{4} \right) d^2 K_1 \sqrt{\frac{2(\Delta p)}{\rho_1(1-\beta^2)E}} 
\]  \hfill (7-6)

where

\( Q = \) nozzle gas volumetric flow rate, \( m^3/s \)
\( C = \) nozzle discharge coefficient, dimensionless
\( \varepsilon = \) nozzle expansibility factor, dimensionless
\( d = \) nozzle throat diameter, \( m \)
\( K_1 = \) nozzle calibration coefficient, dimensionless
\( \rho_1 = \) nozzle inlet gas density, \( kg/m^3 \)
\( \Delta p = \) nozzle differential pressure, \( Pa \)
\( E = \) flow kinetic energy coefficient = 1.043^6

(Informative Note: The superscript “7” in “1.043^7” above is reference number, not an exponent.)

In I-P units:

\[
Q = 1097.8 C \varepsilon \left( \frac{\pi}{4} \right) d^2 K_2 \sqrt{\frac{(\Delta p)}{\rho_1(1-\beta^2)E}} 
\]  \hfill (7-7)

where

\( Q = \) nozzle gas volumetric flow rate, \( cfm \)
\( C = \) nozzle discharge coefficient, dimensionless
\( \varepsilon = \) nozzle expansibility factor, dimensionless
\( d = \) nozzle throat diameter, \( ft \)
\( K_2 = \) nozzle calibration coefficient, dimensionless
\( \rho_1 = \) nozzle inlet gas density, \( lbm/ft^3 \)
\( \Delta p = \) nozzle differential pressure, in. of water
\( E = \) flow kinetic energy coefficient = 1.043^6

\( \beta = \frac{d}{D_{g}} \), dimensionless
In I-P units:

\[ Q = 0.47268 \times C \varepsilon \left( \frac{\pi}{4} \right) d^2 K_1 \sqrt{\frac{2(\Delta p)}{\rho_1 (1 - \beta^2)}} \]  

(7-7)

where

- \( Q \) = nozzle gas volumetric flow rate, cfm
- \( C \) = nozzle discharge coefficient, dimensionless
- \( \varepsilon \) = nozzle expansibility factor, dimensionless
- \( d \) = nozzle throat diameter, ft
- \( K_1 \) = nozzle calibration coefficient, dimensionless
- \( \rho_1 \) = nozzle inlet gas density, lbm/ft³
- \( E \) = flow kinetic energy coefficient = 1.0437, dimensionless
- \( \Delta p \) = nozzle differential pressure, psid
- \( \beta = d/D \), dimensionless

0.47268 = units conversion coefficient, \( \sqrt{\frac{(lbm-ft^3)}{(psid-in^4-s^2)}} \)

(Informative Note: The superscript “7” in “1.0437” above is reference number, not an exponent.)

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**Section 8.1, Uncertainty Estimate: Revise as shown below to make it easier for MOT/MOR standards to adopt this standard by reference.**

**8.1 Post-Test Uncertainty Estimate Analysis.** If required by the test plan in Section 5.1, a post-test analysis of the measurement uncertainty performed in accordance with ASME PTC 19.1 shall accompany each gas flow measurement.

(Informative Note: Informative Annex B contains an example of uncertainty calculations.)

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**Section 9.6, Test Results: Revise Section 9.6 as shown below.**

**9.6 Test Results.** If specified in the test plan in Section 5.1, report the following test results:

**9.6.1 Gas mass flow rate unless otherwise specified by the test plan:**

a. Gas mass flow rate, kg/s (lbm/min).
b. Pretest uncertainty Uncertainty in gas mass flow rate, kg/s (lbm/min).
c. Post-test uncertainty in gas mass flow rate, kg/s (lbm/min).
9.6.2 Gas volumetric flow rate if required by the test plan:
   a. Gas volumetric flow rate, m³/s (cfm).
   b. Pretest uncertainty Uncertainty in gas volumetric flow rate, m³/s (cfm).
   c. Post-test uncertainty in gas volumetric flow rate, m³/s (cfm).

9.6.3 Density if required by the test plan:
   a. Density, kg/m³ (lbm/ft³).
   b. Pretest uncertainty Uncertainty in density, kg/m³ (lbm/ft³).
   c. Post-test uncertainty in density, kg/m³ (lbm/ft³).

Section 10, References: Renumber and revise the References as shown below.

10. REFERENCES

3. ANSI/ASHRAE Standard 41.3-2014, Standard Methods for Pressure Measurement. ASHRAE, Atlanta, GA. See Note 2.
4. ANSI/ASME PTC 19.5-2004 (R2013), Flow Measurement. ASME, New York, NY. (See Note 3.)

4. ANSI/ASHRAE Standard 41.3-2022, Standard Methods for Pressure Measurement. ASHRAE, Atlanta, GA. See Note 2.
5. ANSI/ASME PTC 19.5-2004 (R2013), Flow Measurement. ASME, New York, NY. (See Note 3.)

Note 1: Reference 12 is not required if there are no temperature measurements.

Note 2: Reference 23 is not required if there are no pressure measurements.

Note 3: References 4 and 5, 6, and 7 are only required if using an Orifice, Flow Nozzle, or Venturi Tube.
Informative Appendix B, An Uncertainty Example for a Coriolis Flowmeter: Revise as shown below.

Follow the step-by-step procedures outlined in Section 9 of ASME PTC 19.17, to estimate the uncertainty in SI units in Section B1 or in I-P units in Section B2. Note that, in general, using a commercial equation solver software, such as MATLAB or EES, significantly reduces the time and effort required to complete an uncertainty analysis.

[...]