Designation: D5280 – 96 (Reapproved 2021)

Standard Practice for Evaluation of Performance Characteristics of Air Quality Measurement Methods with Linear Calibration Functions[1]

This standard is issued under the fixed designation D5280; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice[2] covers procedures for evaluating the following performance characteristics of air quality measurement methods: bias (in part only), calibration function and linearity, instability, lower detection limit, period of unattended operation, selectivity, sensitivity, and upper limit of measurement.

1.2 The procedures presented in this practice are applicable only to air quality measurement methods with linear continuous calibration functions, and the output variable of which is a defined time average. The linearity may be due to postprocessing of the primary output variable. Additionally, replicate values belonging to the same input state are assumed to be normally distributed. Components required to transform the primary measurement method output into the time averages desired are regarded as an integral part of this measurement method.

1.3 For surveillance of measurement method stability under routine measurement conditions, it may suffice to check the essential performance characteristics using simplified tests, the degree of simplification acceptable being dependent on the knowledge on the invariance properties of the performance characteristics previously gained by the procedures presented here.

1.4 There is no fundamental difference between the instrumental (automatic) and the manual (for example, wet-chemical) procedures, as long as the measured value is an average representative for a predefined time interval. Therefore, the procedures presented are applicable to both. Furthermore, they are applicable to measurement methods for ambient, workplace, and indoor atmospheres, as well as emissions.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E456 Terminology Relating to Quality and Statistics

2.2 *ISO Standard:*

ISO 6879:1983 Air Quality—Performance Characteristics and Related Concepts for Air Quality Measuring Methods[4]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology D1356.

3.2 *Definitions of Terms Specific to This Standard:*

NOTE 1—The statistical performance characteristics used throughout this practice are estimated, by convention, at the confidence level $1 - \alpha = 0.95$.

3.2.1 *averaging time, n*—predefined time interval length for which the air quality characteristic is made representative and $\Delta\theta$ the averaging time.

[1] This practice is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.03 on Ambient Atmospheres and Source Emissions.

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[2] This practice was adapted from International Standard ISO/DP 9169, prepared by ISO/TC 146/SC 4/WG 4, by the kind permission of the Chairman of ISO/TC 146 and the Secretariat of ISO/TC 146/SC 4.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

3.2.1.1 *Discussion*—Every measured value obtained is representative for a defined interval of time, τ, the value of which always lies above a certain minimum due to the intrinsic properties of the measuring procedure applied. In order to attain mutual comparability of data pertaining to comparable objects, a normalization to a common, predefined interval of time is necessary.

3.2.1.2 *Discussion*—By convention, this normalization is achieved by transformation by means of a simple, linear, and unweighted averaging process.

(a) Series of Discrete Samples:

$$\hat{c}(\theta \mid \Delta\theta) = \frac{1}{K}\sum_{k=1}^{K}\hat{c}(\theta_0 + (k-1)\,\tau \quad \mid \tau) \tag{1}$$

where:

θ_0 = θ – Δθ, and
Kτ = Δθ, τ << Δθ

(b) Continuous Time Series:

$$\hat{c}(\theta \mid \Delta\theta) = \frac{1}{\Delta\theta}\int_{\theta_0}^{\theta} d\theta\,\hat{c}(\theta \mid \tau) \tag{2}$$

In both cases (*a* and *b*), the original sample, described by $\hat{c}(t)$, is linked to a representative interval of time of length τ whereas $\hat{c}(\Delta\theta)$, the result after application of the averaging process, is made representative for the interval of time Δθ (just preceding θ), the averaging time.

3.2.1.3 *Discussion*—The averaging time, Δθ, is therefore the predefined and, by convention, common time interval length for which the measured variable $\hat{c}$ is made representative in a sense that the square deviation of the original values, attributed to time interval lengths τ << Δθ from $\hat{c}$ over Δθ is a minimum.

3.2.1.4 *Discussion*—The averaging process can alternatively be realized by means of a special sampling technique (averaging by sampling).

3.2.2 *continuously measuring system, n*—a system returning a continuous output signal upon continuous interaction with the air quality characteristic.

3.2.3 *influence variable, n*—a variable affecting the interrelationship between the (true) values of the air quality characteristic observed and the corresponding measured values; for example, variable affecting the slope or the intercept of or the scatter around the calibration function.

3.2.4 *noncontinuously measuring system, n*—a system returning a series of discrete output signals.

3.2.4.1 *Discussion*—The discretization of the output variable can be due to sampling in discrete portions or to inner function characteristics of the system components.

3.2.5 *period of unattended operation, n*—the maximum admissible interval of time for which the performance characteristics will remain within a predefined range without external servicing, for example, refill, calibration, adjustment.

3.2.6 *random variable, n*—a variable that may take any of the values of a specified set of values and with which is associated a probability distribution.

3.2.7 *randomization, n*—if, from a population consisting of the natural numbers 1 to *n*, these are drawn at random one by one successively without replacement until the population is exhausted, the numbers are said to be drawn in random order.

3.2.7.1 *Discussion*—If these numbers have been associated in advance with *n* distinct objects or *n* distinct operations that are then rearranged in the order in which the numbers are drawn, the order of the objects or operations is said to be randomized.

3.2.8 *reference conditions, n*—a specified set of values (including tolerances) of influence variables delivering representative values of performance characteristics.

3.2.9 *variance function, n*—a variance of the output variable as a function of the air quality characteristic observed.

3.2.10 *warm-up time, n*—the minimum waiting time for an instrument to meet predefined values of its performance characteristics after activating an instrument stabilized in a nonoperating condition.

3.2.10.1 *Discussion*—In practice, the warm-up time can be determined by using the performance characteristic that is expected to require the longest interval of time.

3.2.10.2 *Discussion*—In the case of the manual procedures, run-up time is used correspondingly.

3.3 *Symbols and Abbreviations:*

3.3.1 a_0, a_1, a_2—coefficients of the variance function model.

3.3.2 b_0, b_1—parameters of the estimate function for the calibration function.

3.3.3 *C*—air quality characteristic.

3.3.4 *c*—value of *C*.

3.3.5 $\hat{c}$—measured value at *c*.

3.3.6 c_i—value of *C* in the *i*-th sample; this sample may be generated from reference material.

3.3.7 c_0—normalization factor for air quality characteristics; in this case $|\,c_0\,| = 1$.

3.3.8 Δc_1—inaccuracy of *C* at c_1.

3.3.9 $\bar{c}_\omega$—weighted mean, with set of weights ω_k.

3.3.10 $D(b_0)$—drift (see ISO 6879:1983) of the intercept of the linear calibration function.

3.3.11 $D(b_1)$—drift of the slope of the linear calibration function.

3.3.12 $D(\hat{c})$—drift of the measured value, $\hat{c}$, at *c*.

3.3.13 $DEP(b_0)_{IVi}$—first order measure of dependence of the intercept on the influence variable labeled by *i*.

3.3.14 $DEP(b_1)_{IVi}$—first order measure of dependence of the slope on the influence variable labeled by *i*.

3.3.15 $DEP(\hat{c})_{IVi}$—first order measure of dependence of the measured value on the influence variable labeled by *i* at *c*.

3.3.16 $DEP(x)_{IVi}$—first order measure of dependence of the output signal on the influence variable labeled by *i*.

3.3.17 *F*—statistic (cf *F*-test).

3.3.18 F_x—*x*-quantile of the *F*-distribution.

3.3.19 I_{IVi}— selectivity with respect to the influence variable labeled by *i*.

3.3.20 IV_i— influence variable labeled by *i*.

3.3.21 iv_i— value of IV_i.