Designation: D8406 – 22

Standard Practice for Performance Evaluation of Ambient Outdoor Air Quality Sensors and Sensor-based Instruments for Portable and Fixed-point Measurement[1]

This standard is issued under the fixed designation D8406; 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 establishes standardized tests for the performance evaluation of sensor-based continuous instruments for ambient outdoor air quality measurements. It describes both laboratory and field tests that provide information on candidate sensor repeatability, sensitivity, linearity, cross-interferences, drift, and comparability against reference instruments.

1.2 This practice does not apply to sensors or instruments that remotely measure atmospheric pollutants using open path, lidar, or imaging technology.

1.3 The evaluation procedures contained in this practice are for sensors that alone or in combination measure outdoor criteria pollutants in ambient air: particulate matter ($PM_{2.5}$ and PM_{10}), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO), or nitrogen dioxide (NO_2) at concentrations that are relevant to public health.

1.4 Testing is to be performed by a competent entity able to demonstrate that it operates in conformity with internationally accepted test laboratory quality standards such as ISO/IEC 17025.

1.5 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *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.*

1.7 *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:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D1914 Practice for Conversion Units and Factors Relating to Sampling and Analysis of Atmospheres

D3162 Test Method for Carbon Monoxide in the Atmosphere (Continuous Measurement by Nondispersive Infrared Spectrometry)

D3249 Practice for General Ambient Air Analyzer Procedures

D3824 Test Methods for Continuous Measurement of Oxides of Nitrogen in the Ambient or Workplace Atmosphere by Chemiluminescence

D5011 Practices for Calibration of Ozone Monitors Using Transfer Standards

D5110 Practice for Calibration of Ozone Monitors and Certification of Ozone Transfer Standards Using Ultraviolet Photometry

D6332 Guide for Testing Systems for Measuring Dynamic Responses of Carbon Monoxide Detectors to Gases and Vapors

D8405 Test Method for Evaluating $PM_{2.5}$ Sensors or Sensor Systems Used in Indoor Air Applications

E178 Practice for Dealing With Outlying Observations

E456 Terminology Relating to Quality and Statistics

E3080 Practice for Regression Analysis with a Single Predictor Variable

2.2 *Other References:*

29 CFR 1910.101 Compressed gases (general requirements)[3]

40 CFR Part 58 Ambient Air Quality Surveillance[3]

EN 14626:2012 Ambient air – Standard method for the measurement of the concentration of carbon monoxide by

[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.

Current edition approved Sept. 1, 2022. Published October 2022. DOI: 10.1520/D8406-22.

[2] 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.

[3] Available from U.S. Government Publishing Office (GPO), 732 N. Capitol St., NW, Washington, DC 20401, http://www.gpo.gov.

non-dispersive infrared spectroscopy[4]

EN 14625:2012 Ambient air – Standard method for the measurement of the concentration of ozone by ultraviolet photometry[4]

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe[4]

ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories[5]

ISO 6145-7:2018 Gas analysis – Preparation of calibration gas mixtures using dynamic methods Part 7: Thermal mass-flow controllers[5]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice other than those following, refer to Terminologies D1356 and E456.

3.1.2 *air quality sensor, n*—a physical device that uses one or more sensors to measure and report the concentration of one or more analytes (pollutants) in outdoor air.

3.1.3 *analyte, n*—the substance (air pollutant) measured by the air quality sensor or analyzer.

3.1.4 *full scale, n*—the designated maximum concentration for performance testing determined by either the measurement range of the sensor or the reference analyzer (whichever is lower).

3.1.5 *instrument, n*—see *air quality sensor*.

3.1.6 *interferent, n*—a substance other than the compound of interest that causes a bias in the sensor output.

3.1.7 *reading, n*—the analytical result obtained from a digital display or indicated on a scale or dial affixed to or recording output from a sensor or instrument.

4. Summary of Practice

4.1 This is a practice for evaluating ambient air quality sensor performance. This document contains definitions and terms, sampling information, calibration techniques, methods for validating results, and general comments related to ambient air sensors and sensor-based instruments. This practice is applicable to sensors and sensor-based instruments that sample ambient air through diffusion or passive sampling as well as through active sampling using a pump or fan. This practice comprises laboratory and field tests to evaluate performance of gas sensors and particulate matter sensors.

5. Significance and Use

5.1 This practice establishes standardized tests for the performance evaluation of sensor-based continuous instruments for ambient air quality measurements. Public and private air monitoring interests have manifested themselves as a driving force for the deployment of air quality sensors and instruments to quantify air pollutant concentrations in communities, around schools, around industrial facilities, and elsewhere. Users of air quality sensors require information on the performance and limitations of these devices so that informed decisions regarding their suitability for various purposes can be determined. This practice describes both laboratory and field tests that provide information on candidate instrument repeatability, sensitivity, linearity, cross-interferences, drift and comparability with more costly instruments typically used by entities such as government agencies. The air quality sensors are first evaluated in a laboratory chamber by comparing their response to a reference instrument and challenging the gas sensors with interferents. The sensors are then deployed outdoors for field testing at two sites with different climates against reference air quality instruments. This practice is intended to be referenced in standards and codes that establish minimum performance quality for sensor-based ambient outdoor air monitoring.

5.2 This practice is intended for air quality sensors that measure one or more of the criteria pollutants in ambient air (ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide, PM_{10} and $PM_{2.5}$) that can be operated in outdoor environments and can log a concentration reading. It is not intended for devices or transducers that require additional enclosures for deployment outdoors or post-processing to convert their output signal into a pollutant concentration reading.

5.3 It is anticipated that the main users of this practice will be manufacturers, developers, and distributors of outdoor air quality sensors, air quality agencies, and environmental consultants.

6. Apparatus

6.1 *Gas dilution and delivery system* for the continuous generation of test mixtures from gas standards and zero-air operated according to ISO 6145-7.

6.2 *Ozone analyzer* that is on the USEPA List of Designated Reference and Equivalent Methods for ozone or conforms to EN14625 or is on the MCERTS list of Certified Products: Continuous Ambient Air Monitoring System[6] or has been approved by a national standards body for ambient monitoring and has been calibrated according to Practices D5011.

6.3 *Sulfur dioxide analyzer* that is on the USEPA List of Designated Reference and Equivalent Methods for sulfur dioxide or conforms to EN14212 or is on the MCERTS list of Certified Products: Continuous Ambient Air Monitoring System[6] or has been approved by a national standards body for ambient monitoring.

6.4 *Nitrogen dioxide analyzer* that is on the USEPA List of Designated Reference and Equivalent Methods for nitrogen dioxide or conforms to EN14211 or is on the MCERTS list of Certified Products: Continuous Ambient Air Monitoring System[6] or conforms to Test Methods D3824 or has been approved by a national standards body for ambient monitoring.

[4] Available from European Committee for Standardization (CEN), Avenue Marnix 17, B-1000, Brussels, Belgium, http://www.cen.eu.

[5] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

[6] https://www.csagroupuk.org/services/mcerts/mcerts-product-certification/mcerts-certified-products/mcerts-certified-products-continuous-ambient-air-monitoring-system/ (Accessed 26 May 2021).