



Designation: D8405 – 21

# Standard Test Method for Evaluating PM<sub>2.5</sub> Sensors or Sensor Systems Used in Indoor Air Applications<sup>1</sup>

This standard is issued under the fixed designation D8405; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method uses a chamber system to evaluate the performance of stationary PM<sub>2.5</sub> sensors (sensors) and particle sensor systems (sensor systems) subjected to various test conditions, including temperature, relative humidity, PM<sub>2.5</sub> concentration, and coarse PM interferent concentration.

1.1.1 This test method covers sensors and sensor systems that can be continuously powered and continuously operated for the duration of any test described in this method through line power or an internal battery of sufficient output. This test method is not meant to evaluate sensors or sensor systems without these capabilities.

1.1.2 This test method evaluates the performance of sensors and sensor systems that allow users to collect data in a systemic manner to assess the capabilities and limitations of these devices.

1.1.3 This test method is not meant to evaluate sensors or sensor systems without data storage and recording capabilities.

1.1.4 This test method is not intended to evaluate indoor air quality sensors and sensor systems for purposes of regulation of outdoor air, homeland security, law enforcement or forensic activity.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.3 The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *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.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standard-*

*ization 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:<sup>2</sup>

**D1356** Terminology Relating to Sampling and Analysis of Atmospheres

**D3670** Guide for Determination of Precision and Bias of Methods of Committee D22

**D6330** Practice for Determination of Volatile Organic Compounds (Excluding Formaldehyde) Emissions from Wood-Based Panels Using Small Environmental Chambers Under Defined Test Conditions

**E691** Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

**E3080** Practice for Regression Analysis with a Single Predictor Variable

### 2.2 International Standards Organization (ISO) Standards:<sup>3</sup>

**ISO 8573-1** Requirements for the purity of compressed air with respect to particles, water, and oil

**ISO 12103-1** Road vehicles — Test contaminants for filter evaluation — Part 1: Arizona test dust

**ISO 17025** General requirements for the competence of testing and calibration laboratories

### 2.3 United States (U.S.) Code of Federal Regulations (CFR):<sup>4</sup>

**Title 40 Part 53** Requirements for ambient particulate instruments to attain U.S. Environmental Protection Agency (EPA) Federal Equivalent Method (FEM) designations

**Title 40 Part 58** Terminology relating to particulate matter fractions

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

<sup>4</sup> Available from U.S. Government Publishing Office (GPO), 732 N. Capitol St., NW, Washington, DC 20401, <http://www.gpo.gov>.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.05 on Indoor Air.

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## 2.4 U.S. EPA Standards:<sup>5</sup>

**Method IP-10A Determination of respirable particulate matter in indoor air**

## 2.5 U.S. Department of Energy (DOE) Standards:<sup>4</sup>

**DOE-STD-3020 Specification for HEPA filters used by DOE contractors**

## 3. Terminology

**3.1 Definitions**—For definitions of terms used in this test method, refer to Terminology **D1356**.

### 3.2 Definitions of Terms Specific to This Standard:

**3.2.1 indoor air, *n***—air within an enclosed space (structure or vehicle), which is (1) intended for habitation, employment, leisure, retail, transport, or any other forms of occupation by humans and (2) conditioned for temperature or relative humidity (RH), or both, or does not allow for free air change with outdoor air other than through unintentional leakage or filtered mechanical ventilation.

**3.2.2 indoor air quality particle sensors, *n***—sensors used to measure and report particle content of indoor air and intended for use in indoor air quality applications.

**3.2.3 intra-model, *adj***—within a group of sensor systems of the same make, model, and firmware version. Intra-model results are developed by applying a mathematical operation to a data set developed from testing multiple test sensors or test sensor systems of the same make, model, and firmware version.

**3.2.4 intra-unit, *adj***—within an individual unit. Intra-unit results are developed by applying a mathematical operation to a data set developed from testing one test sensor or test sensor system.

**3.2.5 particle-negligible air, *n***—purified air for which particles, moisture and other substances that can interfere with a measurement are reduced to meet or exceed purity as specified in ISO 8573-1 for Class 2.4.1 air, that is: solid particulate number concentrations not exceeding (1) 400 000 per m<sup>3</sup> for 0.1–0.5 µm diameter particles, (2) 6000 per m<sup>3</sup> for 0.5–1 µm diameter particles, and (3) 100 per m<sup>3</sup> for 1–5 µm diameter particles; water vapor content not exceeding a vapor pressure dewpoint of 3°C; and total oil content not exceeding 0.01 mg/m<sup>3</sup>.

**3.2.5.1 Discussion**—For the purposes of this standard, particle-negligible air has particles reduced to concentrations at or below the limit of detection of PM<sub>2.5</sub> mass concentration reference monitor being used in this test method.

**3.2.6 PM<sub>10</sub>, *n***—particles collectable by a sampler with an upper 50 % cut point of 10 µm in aerodynamic diameter, along with other conditions as defined in the U.S. CFR Title 40, Part 58.

**3.2.7 PM<sub>2.5</sub>, *n***—particles collectable by a sampler with an upper 50 % cut point of 2.5 µm in aerodynamic diameter, along with other conditions as defined in the U.S. CFR Title 40, Part 58.

**3.2.8 PM<sub>2.5</sub> sensor, *n***—a device capable of reporting the concentration of PM<sub>2.5</sub> in the air without additional manipulation of the data.

**3.2.9 PM<sub>c</sub>, *n***—particles with an aerodynamic diameter less than or equal to 10 µm and greater than 2.5 µm, often referred to as “coarse” PM; equivalent to the difference between PM<sub>10</sub> and PM<sub>2.5</sub>; equivalent to the definition of PM<sub>10–2.5</sub> as defined in the U.S. CFR Title 40, Part 58.

**3.2.10 reference monitor, *n***—an instrument with a U.S. EPA performance designation of Class III FEM for PM<sub>2.5</sub>, excluding those using beta attenuation techniques, measuring particle mass concentration or particle mass size distribution, or both, against which test sensors or test sensor systems are compared.

**3.2.10.1 Discussion**—The U.S. EPA FEM designation (**1**)<sup>6</sup> is only applicable to, and valid for, stationary ambient monitoring applications. However, FEM designation is required for reference monitors used within this test method to provide a reasonable level of confidence in the acceptability of the reference monitor’s accuracy and precision.

**3.2.11 sensor system, *n***—a collection of sensors with integrated power, integrated communication to a user interface, and a user interface.

**3.2.12 test characterization chamber, *n***—a chamber into which test sensors or test sensor systems are placed, into which particles are introduced to evaluate the performance of the test sensor or test sensor system, and from which the reference monitor(s) is (are) sampling.

**3.2.13 test sensor, *n***—a single sensor evaluated according to this test method.

**3.2.14 test sensor system, *n***—a sensor system evaluated according to this test method.

**3.2.15 test system, *n***—a system including a test characterization chamber, reference monitor(s), particle systems, and other equipment needed to generate the conditions required for this test method.

## 4. Summary of Test Method

**4.1** This test method uses a test characterization chamber system to evaluate indoor air quality particle sensors and sensor systems on their capabilities to detect and measure particles against reference PM monitors.

**4.2** PM<sub>2.5</sub> is introduced into the test characterization chamber, and test sensors or test sensor systems are tested at prescribed, steady-state concentrations. The test system uses instruments that meet performance criteria demonstrating equivalence with established reference methods, along with ancillary instruments, to evaluate the performance of the test sensors or test sensor systems.

**4.3** The test sensor’s or test sensor system’s capabilities are evaluated based on the following parameters: Average; Standard Deviation (SD); Relative Standard Deviation (RSD); Bias; Precision; Intra-Model Variability (IMV); Mean Error; Pearson Linear Coefficient of Determination (*R*<sup>2</sup>); Climate

<sup>5</sup> Available from United States Environmental Protection Agency (EPA), William Jefferson Clinton Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, <http://www.epa.gov>.

<sup>6</sup> The boldface numbers in parentheses refer to the list of references at the end of this standard.