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Standard Guide for Personal Samplers of Health-Related Aerosol Fractions¹

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1. Scope

1.1 This guide defines conventions for personal samplers of specific particle-size-dependent fractions of any given non-fibrous airborne aerosol. Such samplers are used for assessing health effects and in the setting of and testing for compliance with permissible exposure limits in the workplace and ambient environment. The conventions have been adopted by the International Standards Organization (Technical Report ISO TR 7708), the Comité Européen de Normalisation (CEN Standard EN 481), and the American Conference of Governmental Industrial Hygienists (ACGIH) (1).² The conventions were developed (2) in part from health-effects studies reviewed (3) by the ACGIH and in part as a compromise between definitions proposed by the ACGIH (3) and by the British Medical Research Council (BMRC) (4). Conventions are given here for inhalable, thoracic, and respirable fractions.

1.2 This guide is complementary to Test Method D4532, which describes the performance of a particular instrument, the 10-mm cyclone, and operational procedures for use. The procedures, specifically the optimal flow rate, are still valid although the estimated accuracy differs somewhat from use with previous aerosol fraction definitions. Details on this instrument and also the Higgins-Dewell cyclone have recently been published (5-7).

1.3 Limitations:

1.3.1 The definitions given here were adopted by the agencies listed in 1.1 in part on the basis of expected health effects of the different size fractions, but in part allowing for available sampling equipment. The original adoption by CEN was, in fact, for the eventual setting of common standards by the EC countries while permitting the use of a variety of instrumentation. Deviations of the sampling conventions from health-related effects are as follows:

1.3.1.1 The inhalable fraction actually depends on the specific air speed and direction, on the breathing rate, and on

whether breathing is by nose or mouth. The values given in the inhalable convention are for representative values of breathing rate and represent averages over all wind directions.

1.3.1.2 The respirable and thoracic fractions vary from individual to individual and with the breathing pattern. The conventions are approximations to the average case.

1.3.1.3 Each convention applies strictly to a fraction penetrating to a region, rather than depositing. Therefore, samples collected according to the conventions may only approximate correlations with biological effects. For example, the respirable convention overestimates the fraction of very small particles deposited in the alveolar region of the respiratory system because some of the particles are actually exhaled without being deposited (8). In many workplaces, these very small particles contribute insignificantly to the sampled mass. Furthermore, the large variability between individuals and the details of clearance may be as important as this type of effect.

1.3.1.4 The thoracic convention applies to mouth breathing, for which aerosol collection is greater than during nose breathing.

1.4 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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 and health 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

¹ This guide is under the jurisdiction of ASTM Committee D22 on Air Quality and is the direct responsibility of Subcommittee D22.04 on Workplace Air Quality.

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² The boldface numbers in parentheses refer to a list of references at the end of this standard.

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.

D4532 Test Method for Respirable Dust in Workplace Atmospheres Using Cyclone Samplers

2.2 International Standards:

ISO TR 7708 Technical Report on Air Quality—Particle Size Fraction Definitions for Health-Related Sampling, Brussels, 1993⁴

CEN EN 481 Standard on Workplace Atmospheres. Size Fraction Definitions for the Measurement of Airborne Particles in the Workplace, Brussels, 1993⁵

3. Terminology

3.1 Many terms used in this guide are defined in Terminology **D1356**.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *aerodynamic diameter, D*, (μm)—the diameter of a sphere of density of 10³ kg/m³ with the same stopping time as a particle of interest.

3.2.2 *inhalable convention, E_I*—the target specification for sampling instruments when the inhalable fraction is the fraction of interest. Specifically, E_I is taken (Technical Report ISO TR 7708, CEN Standard EN 481, and the ACGIH threshold limit values **(1)**) as follows:

$$E_I = 0.50 (1 + \exp[-0.06 D]), D < 100 \mu\text{m} \quad (1)$$

defined in terms of aerodynamic diameter, D.

3.2.2.1 *Discussion*—The inhalable convention E_I is illustrated in **Fig. 1**. Note that E_I → 0.50 (50 %) at large D. **Eq 1** approximates the inhalable fraction when averaged over all wind directions for windspeeds v < 4 m/s. At higher wind speeds, the following convention has been tentatively suggested as follows **(9)**:

$$E_I = 0.50 (1 + \exp[-0.06 D]) + 10^{-5} v^{2.75} \exp[0.055 D], \quad (2)$$

$$4 \text{ m/s} < v < 9 \text{ m/s}$$

3.2.3 *inhalable fraction*—the total airborne particle mass fraction inhaled through the nose and mouth, that is, which enters the respiratory system.

3.2.4 *respirable convention, E_R*—the target sampling curve for instruments approximating the respirable fraction. E_R is defined (Technical Report ISO TR 7708, CEN Standard EN 481, and the present ACGIH Threshold Limit Values **(1)**) in terms of the cumulative normal function **(10)** Φ as follows:

$$E_R = E_I \cdot \Phi[1n[D_R/D]/\sigma_R] \quad (3)$$

where the indicated constants are D_R = 4.25 μm and σ_R = ln[1.5]. The cumulative normal function Φ is easily approximated using the algorithm given in **Appendix X1**.

3.2.4.1 *Discussion*—For protecting the sick or infirm or children, a quantity D_R = 2.5 μm has been suggested (Technical Report ISO TR 7708). This accounts for the fact that in children and in adults with certain chest diseases, the tracheo-bronchial region is more effective at collecting particles of small aerodynamic diameter than it is in healthy adults. The

respirable convention E_R is illustrated in **Fig. 1**. Note that 50 % of total airborne particles with D = 4.0 μm are in the respirable fraction.

3.2.5 *respirable fraction*—the mass fraction of total airborne particles penetrating to the alveolar region of the respiratory system.

3.2.6 *sampling convention*—a target specification that approximates to a specific health-related fraction of aerosol of given aerodynamic diameter. A sampling convention is specified in terms of the sampling efficiency E, the fraction of particles at given aerodynamic diameter collected by an ideal instrument.

3.2.7 *thoracic convention, E_T*—the target sampling curve for instruments approximating the thoracic fraction. E_T is defined (Technical Report ISO TR 7708, CEN Standard EN 481, and the present ACGIH Threshold Limit Values **(1)**) in terms of the cumulative normal function **(10)** Φ as:

$$E_T = E_I \cdot \Phi[1n[D_T/D]/\sigma_T] \quad (4)$$

where the indicated constant parameters are D_T = 11.64 μm and σ_T = ln[1.5].

3.2.7.1 *Discussion*—The thoracic convention E_T is illustrated in **Fig. 1**. Note that 50 % of total airborne particles with D = 10 μm are in the thoracic fraction.

3.2.8 *thoracic fraction*—the mass fraction of total airborne particles penetrating beyond the larynx.

3.3 Symbols and Abbreviations:

3.3.1 D (μm)—aerosol aerodynamic diameter.

3.3.2 D_R (μm) —respirable sampling convention parameter equal to 4.25 μm in the case of healthy adults, or 2.5 μm for the sick or infirm or children.

3.3.3 D_T (μm) —thoracic sampling convention parameter equal to 11.64 μm.

3.3.4 E—sampling convention in general.

3.3.5 E_I—inhalable sampling convention.

3.3.6 E_R—respirable sampling convention.

3.3.7 E_T—thoracic sampling convention.

3.3.8 v (m/s)—wind speed.

3.3.9 σ_R—respirable sampling convention parameter equal to ln[1.5].

3.3.10 σ_T—thoracic sampling convention parameter equal to ln[1.5].

3.3.11 Φ[x]—cumulative normal function defined, given argument x.

4. Significance and Use

4.1 The convention to be used is not always straightforward, but generally depends on what part of the respiratory system is affected by the aerosol particles. For example, if an aerosol (for example, silica) is expected to be hazardous mainly in the alveolar regions of the respiratory system, then the respirable convention applies. On the other hand, if an aerosol is extremely soluble (for example, KCN), then the inhalable convention should be used for monitoring or setting exposure

⁴ Available from International Organization for Standardization, Caisse Postale 56, CH-1211, Geneva 20, Switzerland.

⁵ Available from CEN Central Secretariat: rue de Stassart 36, B-1050 Brussels, Belgium.