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# Standard Practice for Health Requirements for Occupational Exposure to Synthetic Amorphous Silica<sup>1</sup>

This standard is issued under the fixed designation E 1156; 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.

<sup>ε1</sup>NOTE—Keywords were added in May 1993.

## INTRODUCTION

Silicon dioxide (silica, SiO<sub>2</sub>) is encountered in nature and industry in a wide variety of forms. These range from essentially anhydrous types with or without a very high degree of crystallinity, to highly hydroxylated or hydrated types that are amorphous by x-ray diffraction examination. Quartz is the most common of the crystalline polymorphs encountered as airborne particles. Two other crystalline polymorphs, cristobalite, and tridymite, are much less common in nature, but might be encountered in several occupations where silicas, kaolin clays, ceramic clays, etc., are fired (calcined) at high temperatures. These silica materials have a broad range of physical and chemical properties.

This practice is intended for synthetic amorphous silicas produced by three distinct processes: (1) vapor phase hydrolysis (fumed), (2) wet process precipitation (precipitated), and (3) wet process gelation (gelled). All other processes are excluded.

### 1. Scope

1.1 This practice is designed to protect the health and safety of workers exposed to the specific synthetic amorphous silica dusts, or mixtures thereof.

1.2 Actions recommended in subsequent sections of this practice apply where the time-weighted average (TWA) occupational exposure to the silicas is in excess of the permissible exposure limit (PEL) of 5 mg/m<sup>3</sup> of respirable dust (see 5.1.1), as determined by monitoring in 5.7.

1.3 Nothing in this practice shall be interpreted as requiring any action that violates any statute or requirement of any federal, state, or other regulatory agency.

1.4 *This standard does not purport to address all of the safety problems, 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.* It is the responsibility of the user to consult all material safety data sheets and labels pertaining to any hazardous materials used in this standard.

### 2. Referenced Documents

#### 2.1 ANSI Standards:

Z9.2 1979 Fundamentals Governing the Design and Operation of Local Exhaust Systems<sup>2</sup>

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee E-34 on Occupational Health and Safety and is the direct responsibility of Subcommittee E34.16 on Silicas.

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<sup>2</sup> Available from American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

Z88.2 1980 Practices for Respiratory Protection<sup>2</sup>

#### 2.2 Code of Federal Regulations:

29 CFR Part 1910.134 Respiratory Protection<sup>3</sup>

29 CFR Part 1910.1000 Air Contaminants<sup>3</sup>

30 CFR Part 11 Respiratory Protective Devices; Test for Permissibility<sup>3</sup>

### 3. Terminology

#### 3.1 Descriptions of Terms Specific to This Standard:

3.1.1 *aerodynamic diameter*—the diameter of a hypothetical sphere of unit density having the same terminal settling velocity in air at standard temperature and pressure as a particle in question, regardless of its geometric size, shape, and true density.

3.1.2 *occupational exposure*—the air volume concentration, expressed as mass of quartz dust particles per unit volume of air within a specified aerodynamic diameter range, to which a worker is exposed as measured by a gravimetric personal sampler located in the breathing zone of the worker.

3.1.3 *respirable dust*—that portion of an inhaled dust that is deposited in the nonciliated portions of the lung. Respirable particles are considered to be those having an aerodynamic diameter of less than 10.0  $\mu$ m.

3.1.4 *silica class*—applies only to those synthetic amorphous silica dusts produced by vapor phase hydrolysis (fumed), wet process precipitation (precipitated), or wet process gelation (gelled) processes.

3.1.5 *time-weighted average (TWA)*—the time-weighted

<sup>3</sup> Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

**TABLE 1 Respiratory Protection at Synthetic Amorphous Silica Dust Concentrations Exceeding the PEL**

| Airborne Concentrations of Respirable Synthetic Amorphous Silica Dust   | Respirator Type <sup>A,B</sup>  |
|---|---|
| Less than or equal to 10 × PEL  | Any dust, mist, or fume respirator.   |
| Less than or equal to 25 × PEL  | Any powered air purifying respirator.   |
| Less than or equal to 100 × PEL   | Any dust, mist, or fume respirator with a full facepiece.<br>Any supplied-air respirator with a full facepiece, helmet, or hood.<br>Any self-contained breathing apparatus with a full facepiece.<br>Any powered air-purifying respirator with a high efficiency particulate filter and a tight fitting facepiece.        |
| Less than or equal to 1000 × PEL  | Any Type C supplied-air respirator operated in a positive-pressure mode.  |
| Greater than 1000 × PEL or entry and escape from unknown concentrations | Any combination respirator that includes a Type C supplied-air with a full facepiece operated in a positive-pressure mode and an auxiliary, self-contained breathing apparatus operated in a positive-pressure mode.<br>Any self-contained breathing apparatus with full facepiece, operated in a positive-pressure mode. |

<sup>A</sup> For respirators used, maintained, and fitted in accordance with ANSI Z88.2.

<sup>B</sup> Refer to 30 CFR 11 for a description of respirator types.

average concentration of synthetic amorphous silica for a normal 8-h workday and a 40-h workweek.

#### 4. Significance and Use

4.1 These criteria were not developed for the population at large and any extrapolation beyond general occupational exposures is not warranted. They are intended to assure that the results of practices based thereon will (1) protect against possible adverse health effects from exposure to synthetic amorphous silica; (2) be measurable by techniques that are valid, reproducible, and available to industry and official agencies; and (3) be attainable with existing technology.

#### 5. General Requirements

##### 5.1 Environmental:

5.1.1 Occupational exposure to synthetic amorphous silica so that workers shall not be exposed to a respirable dust concentration greater than a PEL of 5 mg/m<sup>3</sup> synthetic amorphous silica determined as a TWA concentration for up to an 8-h workshift and a 40-h workweek. (The total dust concentration of substances not assigned a lower PEL shall not exceed 15 mg/m<sup>3</sup>. (See OSHA Standard 29 CFR 1910.1000, Table Z-3.))

5.1.2 Synthetic amorphous silicas have higher oil and water absorption values and, therefore, skin exposure should be minimized. Skin exposures should be minimized.

##### 5.2 Medical:

5.2.1 A preplacement medical examination and medical surveillance shall be made available to all workers subject to occupational exposure to synthetic amorphous silica. Medical examinations shall include as a minimum:

5.2.1.1 Comprehensive medical and work histories with special emphasis directed to respiratory systems, symptoms of respiratory disease, and prior exposure to dusts, mists, and vapors. The medical and work histories should include consideration of skin problems.

5.2.1.2 Comprehensive physical examination, with particular attention to the skin, mucous membranes, and pulmonary and cardiac systems.

5.2.1.3 Clinical tests including a 14 by 17-in. posterior-anterior chest roentgenogram (classified according to the 1980 ILO International Classification of Radiographs of

Pneumoconioses<sup>4</sup>), electrocardiogram, and pulmonary function tests including forced vital capacity (FVC) and forced expiratory volume in 1 s FEV<sub>1</sub>, in accordance with the methods given in the American Review of Respiratory Diseases (1).<sup>5</sup>

5.2.1.4 A judgment of the worker's ability to use negative or positive pressure respirators.

5.2.1.5 During examinations, applicants or employees found to have medical conditions, such as chronic upper or lower respiratory irritation, that could be directly or indirectly aggravated by exposure to synthetic amorphous silica dust shall be counseled as to the possible increased risk of impairment of their health from working with the dust.

##### 5.3 Labeling (Posting):

5.3.1 In areas where synthetic amorphous silica dust concentrations may exceed the permissible exposure limit, appropriate warning signs, barricades, or work practices shall be employed to restrict access by unauthorized persons. The technique chosen shall alert anyone entering the area as to what action must be taken.

5.3.2 The following minimal labeling, in addition to, or in combination with, labeling required by statutes, regulations, or ordinances, shall be affixed to all containers containing synthetic amorphous silica powders:

**CAUTION  
CONTAINS SYNTHETIC  
AMORPHOUS SILICA  
AVOID BREATHING DUST**

5.4 *Personal Protective Equipment*—When the limit of exposure given in 5.1.1 cannot be met by limiting the airborne concentration of synthetic amorphous silica in the work environment, the employer shall establish and enforce a program of respiratory protection to provide the required protection of exposed workers.

##### 5.4.1 Respiratory Protection:

5.4.1.1 The employer shall provide respirators meeting the requirements of Table 1 and ANSI Z88.2 and shall ensure that employees use the respirators provided when the use of respirators is the only means of reducing the worker exposure below the PEL.

<sup>4</sup> Available from International Labor Office, 1750 New York Ave., NW, Washington, DC.

<sup>5</sup> The boldface numbers in parentheses refer to the list of references at the end of this practice.

5.4.1.2 The requirements prescribed in this section shall apply for all operations including nonroutine operations such as brief exposure to dusts in excess of the requirements of 5.1.1 as a result of maintenance or repair activities, or in emergency situations.

5.4.1.3 A respiratory protection program meeting the applicable requirements of ANSI Z88.2 shall be established and enforced by the employer.

5.4.1.4 Initial selection and assignment of negative pressure respirators shall be made at least on the basis of qualitative or quantitative facepiece fit test. The employer shall ensure that respirators are properly used, cleaned, maintained, and stored when not in use.

5.4.1.5 For the purpose of determining the type of respirator to be used (see Table 1), the employer shall measure the atmospheric concentration of synthetic amorphous silica dust in the working environment, and thereafter whenever process, worksite, climate, or control changes occur that are likely to affect the concentrations of the airborne dust.

5.4.1.6 Employees who are routinely required to wear a respirator shall be medically examined annually to determine their fitness to wear the respirator and a record kept of the results of the examination.

#### 5.5 Employee Training and Education:

5.5.1 Each worker exposed or who might be potentially exposed to synthetic amorphous silica dust shall be informed in appropriate language of the potential hazards, proper methods for safe use, and precautions to minimize exposure.

5.5.2 Each worker shall be informed as to the location of information given in 5.5.1. Required information shall be recorded on a Material Safety Data Sheet or on a similar form and shall be kept on file, readily accessible to employees.

5.5.3 Each worker using a respirator shall be properly trained in its maintenance, cleaning, and use.

#### 5.6 Work Practices:

##### 5.6.1 Engineering Controls:

5.6.1.1 *Process Location*—In areas where exposure in excess of the PEL is likely (for example, packaging), the work shall be performed in areas with limited access and adequate ventilation.

5.6.1.2 *Exhaust or Other Systems*—Engineering design of equipment shall include, where feasible, provisions to reduce exposure of workers to synthetic amorphous silica dust to the PEL or below. If a local exhaust ventilation system is used, it shall be designed and maintained to prevent the accumulation and recirculation of synthetic amorphous silica dusts in the working environment (see ANSI Z9.2). Suitable air filtration systems shall be employed.

5.6.1.3 *Equipment Design*—Proper design of equipment for the handling and processing of dusty materials is the most desirable technique of dust control.

5.6.2 *General Maintenance*—The employer shall undertake and maintain a program of periodic inspection and servicing of equipment.

5.7 *Monitoring and Recordkeeping Requirements*—Records of industrial hygiene surveys, including data showing occupational exposures to be below the PEL given in 5.1, shall be retained by the employer as required by statute or corporate practice, or both. The following require-

ments are recommended for synthetic amorphous silica exposures:

#### 5.7.1 Sampling and Recording:

5.7.1.1 *Initial Monitoring*—Initial monitoring shall be performed to determine compliance with the PEL (5.1.1).

5.7.1.2 *Routine Monitoring*—When monitoring of the worker's exposure indicates a synthetic amorphous silica concentration in excess of the PEL, suitable controls shall be initiated to reduce the exposure level to or below the limit. Repeat monitoring shall be performed with a frequency and pattern that reflects with reasonable accuracy the level of employee exposure to synthetic amorphous silica. Sampling shall also be performed whenever process, worksite, climate, or control changes occur that may alter airborne synthetic amorphous silica concentrations.

5.7.1.3 Periodic review and evaluation of environmental and medical data shall be performed to determine the effectiveness of control measures.

5.7.2 Records of all sampling schedules, including sampling methods, analytical methods, breathing zone, and work area synthetic amorphous silica dust concentrations shall be kept for at least 30 years. Records showing the details of the applicable respiratory protection program shall be kept for the same period of time.

5.7.3 All worker medical records shall be kept for at least 30 years following the last occupational exposure to synthetic amorphous silica.

5.7.4 Each worker shall have access to records of his/her occupational exposure and medical examinations in accordance with regulatory provisions.

## 6. Chemical and Physical Properties of Synthetic Amorphous Silicas

6.1 The silicas of this practice are chemically prepared synthetic materials that are amorphous, in that no crystalline pattern is detectable by x-ray diffraction irrespective of particle size. These forms of silica are virtually insoluble in water and organic solvents but dissolve in hydrofluoric acid solutions and in hot solutions of strong alkalis. They are otherwise inert. Most properties and all the methods for their determination are as given in the monograph on silicon dioxide in the *U.S. Food Chemicals Codex* (2).

6.1.1 *Precipitated Silica*—Synthetic amorphous silica (silicon dioxide) produced in a "wet" process in a finely divided hydrated form by precipitation from aqueous alkali metal silicate solutions. It is supplied as a fine white powder or as beads or granules.

Properties: SiO<sub>2</sub> not less than 94 % after ignition

Loss on drying—Not more than 7 %

Loss on ignition—Not more than 8.5 % after drying

Soluble ionizable salts (ignited basis and as Na<sub>2</sub>SO<sub>4</sub>)—Not more than 5 %

Arsenic (as As)—Not more than 3 ppm

Heavy metals (as Pb)—Not more than 30 ppm

Lead (as Pb)—Not more than 10 ppm

6.1.2 *Gel Silica or Silica Gel*—Synthetic amorphous silica (silicon dioxide) produced by a "wet" process by reacting an aqueous alkali metal silicate solution and an acid, so that an extensive three-dimensional hydrated silica structure, or "gel," is formed. It is supplied as granules, beads or tablets, or as a fine white powder after comminution. Silica gel, silica