Designation: E 1132 – 99a

Standard Practice for Health Requirements Relating to Occupational Exposure to Respirable Crystalline Silica[1]

This standard is issued under the fixed designation E 1132; 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.

INTRODUCTION

Silicon dioxide (silica, SiO_2) 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 which are amorphous by x-ray diffraction examination. Crystalline silica[2] exists in a number of forms or polymorphs. The three major forms, quartz, cristobalite, and tridymite, pertain to this practice. Quartz (or alpha quartz) is the more common form encountered as airborne particulates. Two of the polymorphs, cristobalite and tridymite are formed at elevated temperatures and are much less common in nature, but might be encountered in several occupations where silicas are fired (calcined) at high temperatures.[3] These silica materials have a broad range of physical and chemical properties.

1. Scope

1.1 This practice covers a description of several actions that could be taken to reduce the probability of harmful occupational exposures to humans in environments containing respirable crystalline silica.

1.2 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.

1.3 *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.* 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 *ASTM Standards:*[4]

E 1238 Specification for Transferring Clinical Observations Between Independent Computer Systems

E 1239 Guide or Description of Reservation/Registration-Admission, Discharge, Transfer (R-ADT) Systems for Automated Patient Care Information Systems

E 1384 Guide for Content and Structure of the Computer-Based Patient Record

E 1633 Specification for Coded Values Used in Computer-Based Patient Record

E 1715 Practice for an Object-Oriented Model for Registration, Admitting, Discharge, and Transfer (RADT) Functions in Computer-Based Patient Record Systems

2.2 *ANSI Standards:*[5]

Z9.2 1979 Fundamentals Governing the Design and Operation of Local Exhaust Systems

Z88.2 1992 American National Standard Practice for Respiratory Protection

2.3 *Code of Federal Regulations:*[6]

29 CFR 1910.134, Respiratory Protection

[1] This practice is under the jurisdiction of ASTM Committee E34 on Occupational Health and Safety and is the direct responsibility of Subcommittee E34.16 on Silicas.

Current edition approved Aug. 10, 1999. Published September 1999. Originally Published as E 1132 - 99. Last Previous edition E 1132 - 99.

[2] Smith, Deane K., Opal, cristobalite, and tridymite: Noncrystallinity versus crystallinity, nomenclature of the silica minerals and bibliography, *Powder Diffraction*, Vol 13, 1998, pp 1–18.

[3] Miles, W.J., Crystalline silica analysis of Wyoming bentonite by X-ray diffraction after phosphoric acid digestion, *Analytical Chemistry Acta*, Vol 286, 1994, pp 97–105.

[4] 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.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

29 CFR 1910.1000, Air Contaminants
29 CFR 1910.1200, Hazard Communication
42 CFR 84 Title 42, Part 84, Approval of Respiratory Protective Devices, Tests for Permissibility, Fees
30 CFR 56, Title 30, Subpart D, Air Quality, Radiation, and Physical Agents (MSHA)

2.4 *NIOSH Publications:*[7]

Manual of Analytical Methods, 4th Ed., DHHS (NIOSH), Publication No. 94-113 August 1994.
Method 7500 for Silica, Crystalline, Respirable (XRD)
Method 7601 for Silica, Crystalline Visible Absorption Spectrophotometry
Method 7602 for Silica, Crystalline (IR)
Method 7603 for Coal Mine Dust by IR

2.5 *Other Standards:*

ACGIH, Threshold Limit Values for Chemical Substances and Physical Agents; Biological Exposure Indices[8]
HealthLevel 7 Interface Standard, Version 2.3[9]

3. Significance and Use

3.1 These practices and criteria were developed for occupational exposures. They are intended to (*a*) protect against clinically significant lung or respiratory disease from exposure to respirable crystalline silica, (*b*) be measurable by techniques that are valid, reproducible, and readily available, and (*c*) be attainable with existing technology and protective practices.

4. General Requirements

4.1 *Occupational Exposure Limits*:

4.1.1 *Permissible Exposure Limit (PEL) – Occupational Health and Safety Administration (OSHA) General Industry (see 29 CFR 1910.1000)*—Workers shall not be exposed to respirable dust containing quartz exceeding 10/(% quartz + 2) mg/m^3 as an 8-h time weighted average in any 8-h work shift of a 40-h work week or, for total dust (respirable plus non-respirable), 30/(% quartz + 2). The PEL for respirable cristobalite and tridymite is one-half the value for quartz.

4.1.2 *PEL – Mine Safety and Health Administration (MSHA) (non-coal) (see 30 CFR 56.5001)*—Workers shall not be exposed to respirable dust containing quartz exceeding the PEL as determined for a time weighted 8-h workday and 40-h workweek based on the following formula: PEL = 10/(% quartz + 2) mg/m^3. The PEL for respirable cristobalite and tridymite is one-half the value for quartz.

4.1.3 The Threshold Limit Value (TLV) as established by the American Conference of Governmental Industrial Hygienists (ACGIH) for quartz is 0.1 mg/m^3 and the TLV is 0.05 mg/m^3 for cristobalite and tridymite.

4.1.4 The Recommended Exposure Limit (REL) (see NIOSH Criteria Document[10]) as established by the National Institute for Occupational Safety and Health (NIOSH), is 0.05 mg/m^3 as a time weighted average (TWA) for up to 10 h/day during a 40-h workweek.

4.1.5 Other industries or companies may adapt different exposure values to trigger protective actions and these values should be used as appropriate.

4.2 *Exposure Assessment and Monitoring*:

4.2.1 Risk can be assessed qualitatively based on visible dust in the air, proximity of airborne dust to workers, nature of the industrial process (example; wet work – low risk; dry work – higher risk), and location of workers (example; control room or at a crusher). Note that the absence of visible dust is not a guarantee of lack of risk.

4.2.2 Workers with a high relative risk of dust exposure should be sampled first. Sampling should then progress toward those individuals with low exposure risk. High relative risk can be assigned to any area where the process involved may generate respirable crystalline silica particles and persons are potentially exposed for most or all of a work shift.

4.2.3 Initial sampling of representative workers' exposures shall be made to characterize the exposure and its variability, to determine compliance with standards given in 4.1, and to establish a baseline exposure level in all areas where workers are or may be exposed to silica. Exposure sampling should be periodic and should occur frequently enough that a significant and deleterious change in the contaminant generation process or the exposure controls is not permitted to go undetected. This is particularly true for areas or operations where conditions can change dramatically within a short span of time.

4.2.4 Employers shall sample and maintain records of occupational exposures of workers exposed to respirable crystalline silica.

4.2.5 For workers engaged in dusty trades where overexposures to high silica concentrations are common and workers are placed inside of supplied air respirators or ventilated enclosures, such as in sandblasting, sampling should be conducted inside of the control device to determine employee exposure.

4.2.6 In areas where overexposures are persistent, an Exposure Control Plan shall be established to implement engineering, work practice, and administrative controls to reduce silica exposures to below the PEL as soon as feasible.

4.2.7 Sampling information is summarized in Table 1.

4.2.8 Because people have different work habits, sampling should be rotated among employees with a goal of sampling each individual at least once every three years or use statistical random sampling.

4.2.9 When monitoring indicates levels in excess of the PEL, appropriate NIOSH-approved respirators shall be worn until at least three consecutive measurements, taken on different days on the same worker and his/her replacement, or both whose sample exceeded the PEL, are below the PEL. A root cause analysis should be conducted for all exposures in excess of the PEL that can not be accounted for. Root cause analysis involves investigating cause(s) for the excessive exposure, providing remedies, and conducting follow-up sampling to document that exposures are below the PEL.

4.2.10 Measurement of worker occupational exposures shall be within the worker's breathing zone and shall meet the

[6] Available from Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.
[7] Available from National Institute for Occupational Safety and Health, Division of Physical Sciences and Engineering, Cincinnati, OH.
[8] Available from American Conference of Governmental and Industrial Hygienists, 1014 Broadway, Cincinnati, OH 45202.
[9] Available from HL7, 900 Victors Way, Ste 122, Ann Arbor, MI 48108.
[10] Criteria for a Recommended Standard: Occupational Exposure to Crystalline Silica, Publication No. 75-120, 1974.

TABLE 1 Sampling Information

Condition	Action
Qualitative assessment	Based on evaluation of process and materials used and visual review of dust generation potential.
Initial sampling	Conducted at representative job functions starting with assumed highest dust exposure levels. Results used to establish sampling plan.
Sampling results are below one half the PEL	No periodic sampling necessary but additional samples may be required due to process changes.
No PEL overexposures were found, but exposures exceed one half the PEL	These noted locations are to be included in a sampling plan. Noted job functions should be sampled at least annually with a goal of sampling each employee with that job function within a 3 year period.
PEL was exceeded and engineering, work practice, and administrative controls, or both are being applied to the work area to reduce exposures to below the PEL (see 4.2.6)	Sampling to be conducted before and after the remedy to assess the results of silica reduction efforts. If high levels persist institute workplace controls and include in sampling plan until levels are below one half the PEL.
Process materials, process equipment, engineering controls, or any other changes that occur which would tend to increase worker exposures	Sampling to be conducted as soon as feasible to assess the effects of workplace changes on worker exposures.
Ventilated protective enclosures are used because work area exposures are presumed or known to exceed the PEL	Sample at least annually to ensure that worker exposures do not exceed one-half the PEL.
Short duration (hours or less) silica dust generation operations such as drilling and cutting	Depend on workplace controls to reduce exposures. Sampling only provides historical data since the operation will have ended before sample analysis results are available.
Worker(s) or supervision express concerns that silica exposures have increased.	Review and discuss concerns and sample as soon as necessary to determine exposures.

criteria of this section. Such measurements should be representative of the worker's customary activity and should be representative of workshift exposure.

4.2.11 Respirable dust samples are to be collected according to accepted methods. See Appendix X1 for an example.

4.2.12 Sampling data records shall include employee identification, a log of the date and time of sample collection, sampling time duration, volumetric flow rate of sampling, documentation of pump calibration, description of the sampling location, and other pertinent information. See Figs. X1.1–X1.3 for example sampling record, calibration forms, and employee notification of dust sampling results.

4.3 *Methods of Compliance*:

4.3.1 The methods listed below are applicable where compliance is required because of personal exposures exceeding the PEL or when there is concern for exposure to respirable crystalline silica exceeding one-half the PEL.

4.3.2 *Engineering Controls*:

4.3.2.1 Use of properly designed engineering controls is the most desirable approach for controlling dust from crystalline silica-containing materials.

4.3.2.2 Adequate ventilation or other dust suppression methods shall be provided to reduce respirable crystalline silica concentrations to below the PEL, where feasible.

4.3.2.3 Enclosed workstations, such as control booths and equipment cabs, designed for protection against respirable crystalline silica dust, shall be under positive pressure and provided with clean make-up air. Recirculation of air is not preferred; however, properly designed and maintained recirculation systems are acceptable. Re-circulated air inside enclosed workstations should be in accordance with NIOSH guidance. See NIOSH publication No. 78-141.[11]

4.3.2.4 Engineering design of equipment shall include, where feasible, provisions to reduce exposure of workers to respirable crystalline silica dust to the PEL or below. If ventilation systems are used, they shall be designed and maintained to prevent the accumulation and re-circulation of respirable crystalline silica dust in the working environment (see ANSI Z9.2). If wet suppression systems are used, spray nozzles and associated piping shall be maintained to ensure that adequate wetting agent is applied where needed to control respirable crystalline silica dust.

4.3.2.5 All engineering controls shall be properly maintained and periodically evaluated and brought up to specifications, when needed.

4.3.3 *Work Practices and Administrative Controls*:

4.3.3.1 Workers should avoid working in areas of visible dust generated from respirable crystalline silica-containing materials without use of respiratory protection.

4.3.3.2 Workers are not to perform dry sweeping of respirable crystalline silica-containing materials.

4.3.3.3 Workers shall not use compressed air or any other gas to blow respirable crystalline silica-containing materials from surfaces or clothing.

4.3.3.4 Workers shall practice good housekeeping practices to minimize the generation and accumulation of dust.

4.3.3.5 Workers shall maximize the use of all means provided to reduce exposure to dust. These means may include the use of respirators, the use of control rooms or rest areas, the use of ventilation systems, the use of high efficiency particulate air (HEPA) vacuum cleaners or water spray, the use of wet floor sweepers, and rotation of personnel to minimize individual exposure.

4.4 *Respiratory Protection*:

4.4.1 Respirators shall be required in work situations in which engineering and work practice controls are not sufficient to reduce exposures of employees to or below the applicable PEL or TLV. Where the use of personal respiratory protection is required under this practice, the employer shall establish and enforce a program to include the following elements of a respiratory protection program for exposed workers. Respirators must comply with the requirements contained herein. Consideration should be given to wearing respirators at typical

[11] Symposium Proceedings – The Recirculation of Industrial Exhaust Air, NIOSH Publication No. 78-141.

concentrations above the REL, one-half the PEL, TLV, or at any time for comfort or individual concern.

4.4.2 When respirators are used by this practice, the employer shall select a respirator certified by NIOSH under the provisions of 42 CFR 84 that has an assigned protection factor (APF) greater than the hazard ratio (HR). The HR is defined as the ratio of the ambient concentration to the exposure limit. The APF values are given in Table 2. All respirators must be approved for use against silica type dusts. Respirators must comply with requirements of ANSI Z88.2. See Table 2 for recommended respiratory protection.

4.4.3 Employers shall perform respirator fit tests in accordance with ANSI Z88.2 at the time of initial fitting and at least annually, thereafter, for each worker wearing negative pressure respirators. The tests shall be used to select respirators that provide the required protection.

4.4.4 The employer shall institute a respiratory protection program that includes worker training in the use and limitations of respirators, routine air monitoring, and the inspection, cleaning, maintenance, selection, and proper storage of respirators. This training shall be done at first employment and annually as refresher training. Any respiratory protection must, at a minimum, meet the requirements of 29 CFR 1910.134 and ANSI Z88.2. Respirators should be used according to the manufacturer's instructions.

TABLE 2 Recommended Respiratory Protection for Workers Exposed to Respirable Crystalline Silica

APF[A]	Minimum Respiratory Protection for Crystalline Silica[B]
10	Any air-purifying respiratory with any Part 84 particulate filter (N,R, or P, as appropriate).
25	Any powered, air-purifying respirator with a high-efficiency particulate filter, or any supplied-air respirator equipped with a hood or helmet and operated in a continuous-flow mode (for example, type CE abrasive blasting respirators operated in the continuous-flow mode)
50	Any air-purifying, full-facepiece respirator with a 100 series (N,R, or P) Part 84 particulate filter, or any powered, air-purifying respirator with a tight-fitting facepiece and a high-efficiency particulate filter
1000	any supplied-air respirator equipped with a half-mask and operated in a pressure-demand or other positive-pressure mode
2000	any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode (for example, a type CE abrasive blasting respirator operated in a positive-pressure mode)
Planned or emergency entry into environments containing unknown concentrations or concentrations 10 000	any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode, or any supplied-air respirator equipped with a full facepiece and operated in a pressure-demand or other positive-pressure mode in combination with an auxiliary self-contained breathing apparatus operated in a pressure-demand or other positive-pressure mode
Firefighting	any self-contained breathing apparatus equipped with a full facepiece and operated in a pressure-demand or other positive pressure mode
Escape only	any air-purifying, full facepiece respirator with a high-efficiency particulate filter, or any appropriate escape-type, self-contained breathing apparatus

[A]Assigned protection factor (APF). The APF is the minimum anticipated level of protection provided by each type of respirator.

[B]Only NIOSH/MSHA approved equipment should be used. These recommendations are intended to protect workers from silicosis.

4.4.5 Workers who smoke should be encouraged to participate in a smoking cessation program. When smoking is allowed, workers should be counseled about their increased risk, due to the additive effects of smoking and dust exposures, of developing occupational respiratory diseases.

4.5 *Hygiene Facilities*:

4.5.1 Some operations with exposure to crystalline silica, such as abrasive blasting, also involve exposure to heavy metals (for example, lead, zinc, cadmium). Where employees are exposed to combinations of crystalline silica and heavy metals above permissible exposure limits, the employer shall comply with the provisions of this section. This 4.5 applies to workplaces with combined exposure to crystalline silica and heavy metals above the PEL without regard to the use of respirators as a control measure.

4.5.2 In areas with combined exposures food or beverage shall not be present or consumed, tobacco products shall not be present or used, and cosmetics are not to be applied, except in change rooms, lunchrooms, and showers required by 4.5.

4.5.3 *Change Rooms*—The employer shall provide clean change rooms for workers who work in areas with combined exposures. Change rooms are to be equipped with separate storage facilities for protective work clothing and equipment, and for street clothes that prevent cross-contamination.

4.5.4 *Showers*—Workers who work in areas with combined exposures shall shower at the end of the work shift. Showers shall be provided for each sex and supplied with hot and cold water. Clean individual towels, body soap, and other appropriate cleansing agents are to be provided for workers.

4.5.5 *Lunchrooms*—The employer shall provide lunchroom facilities for workers who work in areas with combined exposures. Facilities will have temperature controlled, positive pressure and filtered air supply, and be readily accessible to workers. Workers shall wash their hands and face prior to using lunchroom facilities. Workers shall not enter the lunchroom with protective work clothing or equipment unless surface contamination has been removed by vacuuming or other cleaning methods.

4.5.6 *Lavatories*—The employer shall provide adequate lavatory facilities for workers who work in areas with combined exposures. Lavatories shall be equipped with hot and cold water, hand soap or appropriate cleaning agents, hand towels, paper towels, or warm air blowers.

4.6 *Respiratory Medical Surveillance*:

4.6.1 The employer shall institute a respiratory medical surveillance program for all workers who work in areas, for 30 days per year or more, where the TWA concentration of respirable crystalline silica dust exceeds one-half the PEL.

4.6.2 All medical examinations and medical procedures as required under 4.6 are to be performed by or under the direction of a licensed physician, and are provided without cost to the worker.

4.6.3 The employer shall provide the required medical surveillance to the workers and at a reasonable time and place.

4.6.4 Persons other than licensed physicians who administer the pulmonary function testing required by 4.6 shall have completed a NIOSH approved training course in spirometry.

4.6.5 Medical examinations shall be made prior to placement of new workers, within six months of the adoption of this practice for workers already employed, and no less than once every three years, thereafter. These examinations shall include as a minimum:

4.6.5.1 Medical and occupational history to elicit information on respiratory symptoms, smoking history, and prior exposures to dust and agents affecting the respiratory system. See Fig. X1.4 for example.

4.6.5.2 A posterior-anterior (PA) chest roentgenogram on a film no less than 14 by 17 in. and no more than 16 by 17 in. at full inspiration. The roentgenogram shall be classified according to the 1980 *Guidelines for the Use of ILO International Classification of Radiographs of Pneumoconioses* by NIOSH certified "B" readers. NIOSH "B" readers are physicians that have demonstrated proficiency in the classification of roentgenograms according to the ILO system by successfully completing a practical examination.

4.6.5.3 A tuberculosis intradermal skin test using purified protein derivative for new hires at the time of the baseline examination and for workers with roentgenographic evidence of silicosis who have not been tested.

4.6.5.4 Spirometry is an OPTIONAL component of this practice. Experience has shown that most abnormalities on screening spirometry are not due to work-related disorders. Smoking, non-occupational pulmonary disease, and other variables are more common causes of alterations in pulmonary function. Provided spirometry is conducted, pulmonary function measurements including a determination of forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_1), and forced expiratory volume in 1 s as a percentage of total forced vital capacity (FEV_1/FVC%). Spirometry results should be compared with the 95^{th}–percentile lower limit of normal (LLN) values obtained from Knudson's reference equations to identify workers with abnormal patterns of obstruction and restriction. LLN values from Knudson's equations are listed in Fig. X1.5.

4.6.6 The employer shall provide the following information to the health care provider:

4.6.6.1 A copy of this practice with appendices,

4.6.6.2 A description of the affected worker's duties as they relate to the worker's exposure,

4.6.6.3 The worker's representative exposure level or anticipated exposure level to respirable crystalline silica,

4.6.6.4 A description of any personal protective and respiratory protective equipment used or to be used by the worker, and

4.6.6.5 Information from previous medical examinations of the affected worker that is not otherwise available to the health care provider.

4.6.7 The employer shall obtain a written signed opinion from the physician. This written opinion shall contain the results of the medical examination and shall include:

4.6.7.1 The physician's opinion as to whether the worker has any detected medical conditions that would place the worker at an increased risk of material health impairment from exposure to respirable crystalline silica,

4.6.7.2 Any recommended limitations on the worker or upon the use of personal protective equipment such as clothing or respirators; for example, the fact that worker is medically or emotionally unable to wear a respirator,

4.6.7.3 A statement that the worker has been informed by the physician of the results of the medical examination and of any medical conditions resulting from respirable crystalline silica exposure that require further examination or treatment, and

4.6.7.4 The employer shall provide a copy of the physician's written opinion to the affected employee within 30 days from its receipt.

4.7 *Medical Protection*:

4.7.1 Workers with profusion equal to or greater than 1/0 shall be evaluated at a frequency as determined by a physician qualified in pulmonary disease. Recommendations provided by the examining physician regarding placement of the worker in the workplace will be followed for affected workers.

4.7.2 Workers with profusion equal to or greater than 1/0 will be counseled by a physician or other person qualified in pulmonary disease, at least annually, about silicosis prevention, safe work practices, respiratory protection, personal habits, smoking cessation, and other items and areas that could contribute to the betterment of their respiratory health.

4.8 *Worker Training and Education*:

4.8.1 *Training*—The employer shall provide training for each worker exposed or potentially exposed to respirable crystalline silica dusts at any level of exposure, including supervisors. Training shall be provided at no cost to the worker.

4.8.2 *Frequency*—Training shall be provided as follows:

4.8.2.1 Annually for all current workers covered in 4.8.1,

4.8.2.2 Prior to the initial job assignment for new workers exposed to respirable crystalline silica dusts,

4.8.2.3 Whenever a worker is assigned to a new or unfamiliar task or operation involving respirable crystalline silica dust exposure, and

4.8.2.4 Whenever a worker demonstrates unsafe job performance which may result in increased respirable crystalline silica dust exposures.

4.8.3 *Content*—At a minimum, training shall consist of the following elements:

4.8.3.1 The content of this practice and its appendix,

4.8.3.2 The specific nature of operations which could result in exposures to respirable crystalline silica dust above the PEL,

4.8.3.3 An explanation of engineering, work practice, hygiene, administrative and personal protection equipment (PPE) controls used in each of the above operations to eliminate or reduce respirable crystalline silica dust exposures, and

4.8.3.4 The purpose and description of the medical surveillance program and the medical protection program, including information concerning the following.

4.8.3.4.1 The purpose of silicosis diagnostic exam elements such as work histories, chest X-rays, lung function tests, and TB screening,

4.8.3.4.2 The adverse health effects associated with excessive exposures to respirable crystalline silica dusts including silicosis, tuberculosis, and the possible association with lung cancer, and

4.8.3.4.3 The relationship between smoking and exposure to respirable crystalline silica dusts in producing silicosis.

4.8.3.5 The purpose, proper selection, fitting, use, and limitations of respirators if they are used to supplement engineering, administrative, and work practice controls to reduce respirable crystalline silica dust exposures.

4.8.4 *Competency*—Prior to assignment to new or unfamiliar respirable crystalline silica dust-exposing tasks and operations, the employer shall ensure that workers demonstrate proficiency in the use of all applicable exposure control measures for that operation such as PPE, engineering, administrative, work practice, and hygiene controls.

4.8.5 *Training Methods*—The employer shall present all training required by 4.8 in a manner that the worker is able to understand.

4.8.6 *Certification of Training*—The employer shall verify that training required by 4.8.6 has been completed by preparing a written certification record. The written certification record shall contain the name or other identity of the worker trained, the date(s) of the training, and the signature of the person who conducted the training or the signature of the employer. The most recent training certification shall be maintained.

4.8.7 *Access to Information and Training Materials*—The employer shall provide upon request by any worker or their designated representative, a copy of this practice and its appendices, and materials relating to the employer's silica training, medical, and exposure monitoring programs.

4.8.8 Information concerning silicosis and other aspects of crystalline silica are available from OSHA, MSHA, and NIOSH.

4.9 *Warning Signs and Labels*:

4.9.1 In areas where respirable crystalline silica concentrations in the atmosphere are likely to exceed the standard, appropriate danger signs, barricades, or work practices should be employed to restrict access to unauthorized persons. The method must alert anyone entering an exposure area as to the hazards and what actions or precautions should be taken.

4.9.2 A suitable warning label, in addition to or in combination with labels required by other statutes, regulations, or ordinances, shall be affixed to containers used for shipping material having a crystalline silica content that is capable of release which exceeds 0.1 % by weight or volume.

4.10 *Record Keeping*:

4.10.1 The employer shall establish and maintain an accurate record of all medical and exposure monitoring required by this practice. These records shall include, as a minimum, the following details:

4.10.2 Name, identification number, and job classification of each worker monitored for dust exposure. The exposure monitoring result, work location, and monitoring date for each worker monitored, and the method for determining other workers whose exposure the measurement is intended to represent, and their identities.

4.10.2.1 A description of the sampling procedure used for each worker monitored to include sampling pump calibration data.

4.10.2.2 A description of the analytical methods used and evidence of their accuracy,

4.10.2.3 The type of respiratory protection worn by each worker monitored, if any, and fit testing records.

4.10.2.4 Where relevant, environmental variables that may have affected the measurement of worker exposure for each worker measurement.

4.10.3 Medical evaluation results and records of all sampling schedules, including sampling methods, analytical methods, breathing zone, and work area respirable crystalline silica dust concentrations shall be kept for the duration of employment of an individual plus 30 years.

4.10.3.1 Medical records to include medical histories, radiographic films and any pulmonary function results shall be maintained according to standards of confidentiality and kept for the duration of employment of an individual plus 30 years.

4.10.4 In recording examination data in an electronic health record system, described in Guides E 1239, E 1384, Specification E 1633, and Practice E 1751, capture the essential demographic data elements needed to uniquely identify the individual and the attributes of the health history, the examination, the encounter and the diagnostic tests administered. If the data are communicated to other electronic information systems, the conventions in Specification E 1238 and HL7 V2.3 should be used since the message formats can be related to the data documented in the above guides, specification, and practice.

4.10.5 Each worker shall have access to records of that worker's occupational exposure and medical examination records in accordance with regulatory provisions.

4.10.6 Employees will be informed as to the results of medical and sampling results within 30 days of receipt of this data. An acknowledgment record, signed by the employee, attesting to being so informed, should be maintained along with medical records for 30 years past employment of each individual. Sampling history and medical records, with employee's consent and in accordance with standards of confidentiality, will be forwarded to their next employment if this employment is known.

4.11 *Observation of Exposure Monitoring*:

4.11.1 *Employee Observation*—The employer shall provide affected employees or their designated representatives an opportunity to observe any monitoring of employee exposure to silica and provide an explanation of the sampling procedure.

4.11.2 *Monitoring Procedures*—Whenever observation of the monitoring of employee exposure to respirable crystalline silica requires entry into an area where the use of respirators, protective clothing, or equipment is required, the employer shall provide and ensure the use of such personal protective

equipment and shall require compliance with all other applicable safety and health procedures.

4.11.3 Monitoring Results. Observers shall be entitled to:

4.11.3.1 Receive an explanation of the measurement and analytical procedures,

4.11.3.2 Observe all steps related to the monitoring of respirable crystalline silica performed at the place of exposure, and

4.11.3.3 Record the results obtained for any real-time measurements, and receive copies of the results when returned by the laboratory.

4.12 *Practice Evaluation*:

4.12.1 Periodic review and evaluation of workplace respirable silica exposure and medical records shall be performed to determine the effectiveness of control measures.

5. Physical and Chemical Properties

5.1 The physical and chemical properties of the crystalline silica (quartz) dusts and its polymorphs, cristobalite and tridymite, that are the subject of this practice vary over ranges characteristic of purity and the particle size distribution.

5.1.1 Crystalline silica or quartz (CAS No 14808-60-7):

Specific gravity (20 C)	2.65
Melting point	1610 C
Boiling point	2230 C
Appearance	White to dark gray
X-Ray characteristics	Principal d-spacings and relative intensities 3.34 4.26 1.82

5.1.2 Cristobalite (CAS No. 14464-46-1):

Specific gravity (20 C)	2.33
Melting point	1713 C
Boiling point	2230 C
Appearance	White to yellowish
X-Ray characteristics	Principal d-spacings and relative intensities 4.05 2.48 2.84 3.13

5.1.3 Tridymite (CAS No. 15468-32-3)

Specific gravity (20 C)	2.26
Melting point	1703 C
Boiling point	2230 C
Appearance	White
X-Ray characteristics	Principal d-spacings and relative intensities 4.10 4.32 3.81 2.97

6. Laboratory Analysis

6.1 *General Requirements*:

6.1.1 The concentration of respirable crystalline silica dust in the air sampled with a gravimetric personal sampler shall be determined by NIOSH Methods 7500 (XRD), 7602 (IR), 7601 (visible absorption spectrophotometry) or 7603 (IR). Breathing zone sampling shall be as required in the method using a cyclone separator and the required filter. The employer shall ensure that the methods used to perform exposure monitoring produce results that are accurate to a confidence level of 95 %, and are within plus or minus 25 % for airborne concentrations of respirable crystalline silica above the 8-h TWA PEL. See Appendix X1 for an sampling example. Air samples should be accompanied with a settled-dust or bulk sample.

NOTE 1—Each of the NIOSH methods include sections on applicability, interferences, accuracy, and evaluation. Generally, Method 7500 (XRD) is to be preferred, but recently there is increased use of Method 7602 (IR), particularly for coal mine dust samples. An advantage of Method 7500 is its ability to distinguish between crystalline silica and cristobalite, and tridymite. Method 7601 does not distinguish between these three. Method 7602 (IR) can distinguish between crystalline silica and cristobalite, but only at some loss of sensitivity. However, tridymite can be determined only in absence of the other two polymorphs. Interferences should be considered when selecting an analytical method, especially when silicates are involved. To assist the laboratory in identifying interferences, information should be provided along with the sample concerning the potential presence of aluminum phosphate, feldspars, graphite, iron carbide, lead sulfate, micas, montmorillonite, potash, sillimanite, silver chloride, talc, and zircon.

7. Keywords

7.1 crystalline silica dust; cristobalite; dust; occupational exposure; permissible exposure limits; quartz dust; respirators; respiratory protection; tridymite

APPENDIX

(Nonmandatory Information)

X1. RESPIRABLE SAMPLING TECHNIQUE

X1.1 *Respirable Sampling*—Respirable dust samples can be collected using a two-stage, 10-mm nylon cyclone size-selective sampler that meets American Conference of Governmental Industrial Hygienists (ACGIH) criteria. The cyclone assembly is connected to a two-piece 37-mm cassette containing a collecting medium that consists of a pre-weighed 37-mm, low-ashing polyvinyl chloride (PVC) filter with a 5.0-µm pore size. A battery-operated pump, calibrated to a flow rate of 1.7 L of air per minute, will be used as the vacuum or pump source. For each day of sampling, one blank (unused) filter or a number equal to approximately 10 % of the total number of filters, all of the same lot, submitted for analysis, whichever is greater, should be sent to the laboratory. Sampling duration should be sufficient for laboratory detection at one-half the PEL at 5 % crystalline silica.

X1.2 See Figs. X1.1-X1.19.

Respirable-Dust/Silica Sampling Data Sheet

Location _____ Sample Number _____

Type of Sample: ☐ Personal breathing zone ☐ Work Area ☐ Other
If breathing-zone sample; was respirator used? ☐ Yes ☐ No
Employee _____ Social Security No. _____
Date of sample _____ Obtained by _____
Description of job activity/work area: _____

_____

Weather conditions: ☐ Clear ☐ Overcast ☐ Rain/Snow ☐ Windy
Filter No. _____ Pump No. _____ Calibration date _____
Time: Start _____ Stop _____
Rotameter reading (liters per minute): Start _____ Stop _____
Filter blank no. _____
Average flow rate (liters per minute) x Duration of sample (minutes) x 0.001 = Volume of air sampled (cubic meters)
_____ x _____ x 0.001 = _____
Temperature _____ °C Barometric Press _____ mmHg
Air Volume Sampled (m^3) = Pump Flow Rate $\left[\frac{\text{liters}}{\text{min}}\right]\left[\frac{\text{mmHg}}{°C}\right]\left[\frac{298}{760}\right]\left[\frac{\text{sampling min}}{\text{time}}\right]\left[\frac{}{1}\right]$ (0.001) = cubic meters

Analytical Results:
Respirable dust _____(mg) Respirable silica _____(mg) or _____(%)
Analytical method _____ Name of Lab _____

$$\% \text{ Respirable silica} = \frac{\text{Respirable silica (milligrams)}}{\text{Respirable dust (milligrams)}} \times 100 = \_\_\_\_\_\%$$

$$\text{Respirable dust concentration} = \frac{\text{Respirable dust (mg)}}{\text{Volume of air samples } (m^3)} = \frac{\text{mg}}{m^3}$$

$$\% \text{ Exposure} = \frac{\text{Respirable dust concentration}}{\text{Exposure Limit}} \times 100 = \_\_\_\_\_\%$$

Exposure Limit: 0.1 mg/m^3 for OSHA
$\frac{10}{2 + \% \text{ Respirable silica}}$ mg/m^3 for MSHA

(If result exceeds 100%, the exposure limit is exceeded)

Mixtures:

$$\text{PEL} = \frac{10\ mg/m^3}{\% \text{ Respirable silica} + 2\ (\% \text{ respirable cristobalite}) + 2\ (\% \text{ respirable tridymite}) + 2}$$

Name of Person Conducting Sampling _____

Signature _____ Date Form Completed _____

FIG. X1.1 Sampling Data Sheet

Pump Calibration Record

Location _____ Pump Number _____

Date	Calibrated Flow Rate	Calibration Method	Sampling Location	Person Performing Calibration

FIG. X1.2 Pump Calibration Record

GUIDE FOR EMPLOYEE NOTIFICATION

OF

DUST SAMPLING RESULTS

This document provides notification guidelines for informing employees of dust sampling results. Notification is primarily directed at personal sample results; those samples collected by both government regulators and the company or its designated agent.

You are encouraged to report ALL sample results to affected employees, especially those sample results that exceed the Permissible Exposure Limit. Notification should be accomplished within 15 calendar days following receipt of personal dust sampling results.

The following paragraph constitutes guidelines for notification:

"The results of your dust sampling for [date] showed a result of [XXXXX mg/m³]. The Exposure Limit is [XXXXX mg/m³] and therefore your exposure was in excess of [or within] this limit, resulting in [ ] percent exposure. During the sampling period, your activity log indicated that you were doing [work activity description]. The following actions [for excessive exposures] are being investigated to help reduce future exposures to yourself [list actions]. Continue to wear your respirator. [This statement applies if the exposure exceeds the Exposure Limit or the company required respirator use exposure value]."

For documentation purposes the above notification should be delivered orally and in writing.

FIG. X1.3 Employee Notification