Appendix L

American National Standard

practices for respiratory protection

ANSI Z88.2-1980

american national standards institute, inc.
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Z88.2-1980
Revision of
ANSI Z88.2-1969

American National Standard Practices for Respiratory Protection

Secretariat

Mine Safety and Health Administration, U.S. Department of Labor

Approved May 22, 1980

American National Standards Institute, Inc

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American National Standard

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For word

(This Foreword is not part of American National Standard Practices for Respiratory Protection, ANSI Z88.2-1980.)

This is a revision of American National Standard Practices for Respiratory Protection, ANSI Z88.2-1969. The 1969 standard was a revision of the respiratory protection portions of American National Standard Safety Code for Head, Eye, and Respiratory Protection, ANSI Z2.1-1959.

The purpose of this standard is to help respirator users to establish, implement, and administer an effective respiratory protection program. It retains the format of the previous standard, while expanding certain sections and adding others to reflect the current state of the art. A more conservative approach toward selection and classification of respirators is taken in this revision. New techniques in respirator-fit testing have provided methods of measuring the fit quantitatively, making possible for the first time a method of establishing a protection factor for any respirator-wearer combination. Thus, a table of respirator protection factors is included in the section on respirator selection and represents a major new item in this revision.

This standard was processed and approved for submittal to ANSI by American National Standards Committee on Safety Standards for Respiratory Protection, Z88. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the Z88 Committee had the following members:

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Contents

Am rican National Standard Practic s for Respiratory Protection

1. Introduction

1.1 **Scope.** This standard sets forth accepted practices for respirator users, provides information and guidance on the proper selection, use, and care of respirators, and contains recommended requirements for establishing and regulating respirator programs. The standard covers the use of respirators to protect persons against the inhalation of harmful air contaminants and against oxygen deficient atmospheres in the workplace. The following are not covered by this standard: (1) underwater breathing devices, (2) aircraft oxygen systems, (3) military masks, and (4) medical inhalators and resuscitators.

1.2 **Purpose.** The purpose of this standard is to provide information and guidance on the proper selection and use of respirators that will help safeguard the health and life of the users. This standard is written for all persons concerned with respiratory protection, but especially for those primarily responsible for establishing and administrating an acceptable respirator program. The standard contains recommended requirements for use by enforcement authorities in establishing regulations or codes on respiratory protection.

1.3 **"Shall" and "Should."** The provisions of this standard are mandatory in nature where the word "shall" is used and advisory in nature where the word "should" is used.

1.4 **Exceptions.** Exceptions to this standard may be granted by an appropriate regulatory agency, provided that equally acceptable requirements are established.

2. Definitions

abrasive-blasting respirator. See *respirator.* A respirator designed to protect the wearer against inhalation of abrasive material and against impact and abrasion from rebounding abrasive material.

aerodynamic diameter. The diameter of a unit density sphere having the same settling velocity as the particle in question of whatever shape and density.

aerosol. A system consisting of particles, solid or liquid, suspended in air.

air-line respirator. See *respirator.*

air-purifying respirator. See *respirator.*

air-regulating valve. An adjustable valve used to regulate, but which cannot completely shut off, the airflow to the facepiece, helmet, hood, or suit of an air-line respirator.

air-supply device. A hand- or motor-operated blower for the hose mask, or a compressor or other source of respirable air for the air-line respirator.

approved. Tested and listed as satisfactory by the Bureau of Mines (BM) of the U.S. Department of Interior, or jointly by the Mining Enforcement and Safety Administration (MESA) of the U.S. Department of Interior and the National Institute for Occupational Safety and Health (NIOSH) of the U.S. Department of Health, Education, and Welfare, or jointly by the Mine Safety and Health Administration (MSHA) of the U.S. Department of Labor and the National Institute for Occupational Safety and Health (NIOSH) of the U.S. Department of Health, Education, and Welfare.

bioassay. A determination of the concentration of a substance in a human body by an analysis of urine, feces, blood, bone, or tissue.

breathing tube. A tube through which air or oxygen flows to the facepiece, mouthpiece, helmet, hood, or suit.

canister (air-purifying). A container with a filter, sorbent, or catalyst, or any combination thereof, which removes specific contaminants from the air drawn through it.

canister (oxygen-generating). A container filled with a chemical which generates oxygen by chemical reaction.

carcinogen. A substance known to cause cancer.

cartridge (air-purifying). A small canister.

catalyst. In respirator use, a substance which converts a toxic gas (or vapor) into a less-toxic gas (or vapor).

ceiling concentration. The concentration of an airborne substance that shall not be exceeded.

chemical-cartridge respirator. See *respirator.*

confined space. An enclosure – such as a storage tank, process vessel, boiler, silo, tank car, pipeline, tube, duct, sewer, underground utility vault, tunnel, or pit – having limited means of egress and poor natural ventilation and which may contain hazardous contaminants or be oxygen deficient.

contaminant. A harmful, irritating, or nuisance material that is foreign to the normal atmosphere.

corrective lens. A lens ground to the wearer's individual corrective prescription to permit normal visual acuity.

demand. See demand-type self-contained breathing apparatus and demand-type air-line respirator in Tables 3 and 4.

detachable coupling. A device which permits the respirator wearer, without using hand tools, to detach the air-supply line from that part of the respirator worn on the person.

dust. See Table 2.

emergency respirator use. Wearing a respirator when a hazardous atmosphere suddenly occurs that requires immediate use of a respirator either for escape from the hazardous atmosphere or for entry into the hazardous atmosphere to carry out maintenance or some other task.

exhalation valve. A device that allows exhaled air to leave a respirator and prevents outside air from entering through the valve.

eyepiece. A gas-tight, transparent window(s) in a full facepiece, helmet, hood, or suit, through which the wearer may see.

facepiece. That portion of a respirator that covers the wearer's nose and mouth in a quarter-mask (above the chin) or half-mask (under the chin) facepiece or that covers the nose, mouth, and eyes in a full facepiece. It is designed to make a gas-tight or particle-tight fit with the face and includes the headbands, exhalation valve(s), and connections for an air-purifying device or respirable gas source, or both.

face shield. A device worn in front of the eyes and a portion of, or all of, the face, whose predominant function is protection of the eyes and the face.

fibrosis-producing dust. Dust which, when inhaled, deposited, and retained in the lungs, may produce findings of fibrotic growth that may cause pulmonary disease.

filter. A media component used in respirators to remove solid or liquid particles from the inspired air.

filter respirator. See *respirator.*

fog. See Table 2.

full facepiece. See *facepiece.*

fume. See Table 2.

gas. An aeriform fluid which is in the gaseous state at ordinary temperature and pressure.

gas mask. See *respirator.*

goggle. A device, with contour-shaped eyecups with glass or plastic lenses, worn over the eyes and held in place by a headband or other suitable means for the protection of the eyes and eye sockets.

half-mask facepiece. See *facepiece.*

hazardous atmosphere. Any atmosphere, either immediately or not immediately dangerous to life or health, which is oxygen deficient or which contains a toxic or disease-producing contaminant exceeding the legally established permissible exposure limit (PEL) or, where applicable, the Threshold Limit Value (TLV) established by the American Conference of Governmental Industrial Hygienists (ACGIH).

head harness. That part of a facepiece assembly which secures the facepiece to the wearer.

helmet. That portion of a respirator which shields the eyes, face, neck, and other parts of the head.

high-efficiency filter. A filter which removes from air 99.97% or more of monodisperse dioctyl phthalate (DOP) particles having a mean particle diameter of 0.3 micrometer.

hood. That portion of a respirator which completely covers the head, neck, and portions of the shoulders.

hose mask. See *respirator.*

immediately dangerous to life or health (IDLH). Any atmosphere that poses an immediate hazard to life or produces immediate irreversible debilitating effects on health.

inhalation valve. A device that allows respirable air to enter a respirator and prevents exhaled air from leaving the respirator through the valve.

irrespirable. Unfit for breathing.

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maximum use limit of filter, cartridge, or canister. The maximum concentration of a contaminant for which an air-purifying filter, cartridge, or canister is approved for use.

mist. See Table 2.

mouthpiece. That portion of a respirator which is held in the wearer's mouth and is connected to an air-purifying device or respirable gas source, or both. It is designed to make a gas-tight or particle-tight fit with the mouth.

MPCa. Maximum permissible airborne concentration. These concentrations are set by the National Committee on Radiation Protection. They are recommended maximum average concentrations of radionuclides to which a worker may be exposed, assuming that he works 8 hours a day, 5 days a week, and 50 weeks a year.

negative pressure respirator. A respirator in which the air pressure inside the respiratory-inlet covering is positive during exhalation in relation to the air pressure of the outside atmosphere and negative during inhalation in relation to the air pressure of the outside atmosphere.

nonroutine respirator use. Wearing a respirator when carrying out a special task that occurs infrequently.

nose clamp. A device used with a respirator equipped with a mouthpiece that closes the nostrils of the wearer (sometimes called a nose clip).

not immediately dangerous to life or health. Any hazardous atmosphere which may produce physical discomfort immediately, chronic poisoning after repeated exposure, or acute adverse physiological symptoms after prolonged exposure.

odor theshold limit. The lowest concentration of a contaminant in air that can be detected by the olfactory sense.

oxygen deficiency – immediately dangerous to life or health. An atmosphere which causes an oxygen partial pressure of 100 millimeters of mercury column or less in the freshly inspired air in the upper portion of the lungs which is saturated with water vapor. See Appendix A10.

oxygen deficiency – not immediately dangerous to life or health. An atmosphere having an oxygen concentration below the minimum legal requirement (see Table 1) but above that which is immediately dangerous to life or health.

particulate matter. A suspension of fine solid or liquid particles in air, such as: dust, fog, fume, mist, smoke, or spray. Particulate matter suspended in air is commonly known as an aerosol.

permissible exposure limit (PEL). The legally established time-weighted average (TWA) concentration or ceiling concentration of a contaminant that shall not be exceeded.

pneumoconiosis-producing dust. Dust which, when inhaled, deposited, and retained in the lungs, may produce signs, symptoms, and findings of pulmonary disease.

positive-pressure respirator. A respirator in which the air pressure inside the respiratory-inlet covering is positive in relation to the air pressure of the outside atmosphere during exhalation and inhalation.

powered air-purifying respirator. See *respirator.*

pressure-demand. See pressure-demand-type self-contained breathing apparatus and pressure-demand-type air-line respirator in Tables 3 and 4.

protection factor. The ratio of the ambient concentration of an airborne substance to the concentration of the substance inside the respirator at the breathing zone of the wearer. The protection factor is a measure of the degree of protection provided by a respirator to the wearer. See Appendix A6.4.

rescue respirator use. Wearing a respirator for entry into a hazardous atmosphere to rescue a person(s) in the hazardous atmosphere.

resistance. Opposition to the flow of air, as through a canister, cartridge, particulate filter, orifice, valve, or hose.

respirable. Suitable for breathing.

respirator. A device designed to protect the wearer from the inhalation of harmful atmospheres. See Section 5, Classification, Description, and Limitations of Respirators, and Tables 3 and 4.

respiratory-inlet covering. That portion of a respirator which connects the wearer's respiratory tract to an air-purifying device or respirable gas source, or both. It may be a facepiece, helmet, hood, suit, or mouthpiece/nose clamp.

routine respirator use. Wearing a respirator as a normal procedure when carrying out a regular and frequently repeated task.

sanitization. The removal of dirt and the inhibiting of the action of agents that cause infection or disease.

self-contained breathing apparatus. See *respirator.*

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service life. The period of time that a respirator provides adequate protection to the wearer – for example, the period of time that an air-purifying device is effective for removing a harmful substance from inspired air.

smoke. See Table 2.

sorbent. A material which is contained in a cartridge or canister and which removes toxic gases and vapors from the inhaled air.

spray. See Table 2.

supplied-air respirator. See *respirator.*

supplied-air suit. A suit that is impermeable to most particulate and gaseous contaminants and that is provided with an adequate supply of respirable air.

time-weighted average (TWA). The average concentration of a contaminant in air during a specific time period.

valve (air or oxygen). A device which controls the pressure, direction, or rate of flow of air or oxygen.

vapor. The gaseous state of a substance that is solid or liquid at ordinary temperature and pressure.

welding helmet. A device designed to provide protection for the eyes and face against intense radiant energy and molten metal splatter encountered in the welding and cutting of metals.

window indicator. A device on a cartridge or canister that visually denotes the service life of the cartridge or canister.

3. Respirator Program Requirements

3.1 Purpose. This section establishes requirements for a program for the use of respirators. The following requirements are supplemented by recommended practices in subsequent sections of this standard.

3.2 Permissible Practice. In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fumes, sprays, mists, fogs, smokes, vapors, or gases, the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted or evaluated, appropriate respirators shall be used pursuant to the following requirements.

3.3 Employer Responsibility.

3.3.1 Respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee.

3.3.2 The employer shall provide the respirators which are applicable and suitable for the purpose intended.

3.3.3 The employer shall be responsible for the establishment and maintenance of a respiratory protection program which shall include the general requirements outlined in 3.5.

3.4 Employee Responsibility.

3.4.1 The employee shall use the provided respiratory protection in accordance with instructions and training received.

3.4.2 The employee shall guard against damage to the respirator.

3.4.3 The employee shall report any malfunction of the respirator to a responsible person designated by the written standard operating procedures.

3.5 Minimal Acceptable Respirator Program

3.5.1 Standard Operating Procedures. Written standard operating procedures covering a complete respirator program shall be established and implemented in conformance with 3.5.2 through 3.5.15.

3.5.2 Program Administration. The plant or company industrial hygiene, health physics, or safety engineering department shall administer the respirator program in close liaison with the medical department. Responsibility and authority for the respirator program shall be assigned to a single person. In small plants or companies having no formal industrial hygiene, health physics, or safety engineering department, the respiratory program shall be administered by an upper-level superintendent, foreman, or other qualified person responsible to the principal manager. The administrator shall have sufficient knowledge of respiratory protection to properly supervise the respirator program.

3.5.3 Physiological and Psychological Limitations for Respirator Wearers. A physician shall determine what physiological and psychological conditions are pertinent for the wearing of different types of respirators. The respirator program administrator or his designee, using guidelines established by the physician, shall determine whether or not a person may be assigned to a task requiring the use of a respirator. This determination shall be reviewed at least annually. (See 7.3.1, 7.3.2, 7.3.6, 7.3.7, and 7.3.8, and Appendix A4.)

3.5.4 Approved Respirators. Approved respirators shall be used. For exceptions, see 1.4. Any modification that is not authorized by the approval agencies of an approved respirator voids the approval.

3.5.5 Respirator Selection. The selection of the

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proper type of respirator shall be based upon (1) the nature of the hazardous operation or process, (2) the type of respiratory hazard (including physical properties, physiological effects on the body, concentration of toxic material or airborne radioactivity level, established permissible time-weighted average concentration for toxic material, established permissible airborne concentration for radioactive material, and established immediately dangerous to life or health concentration for toxic material), (3) the location of the hazardous area in relation to the nearest area having respirable air, (4) the period of time for which respiratory protection must be provided, (5) the activities of workers in the hazardous area, (6) the physical characteristics and functional capabilities and limitations of the various types of respirators, and (7) respirator protection factors. (See Section 6.)

3.5.6 **Training.** Each respirator wearer shall be given training which shall include explanations and discussions of (1) the respiratory hazard and what happens if the respirator is not used properly, (2) the engineering and administrative controls being used and the need for respirators to provide protection, (3) the reason for selecting a particular type of respirator, (4) the function, capabilities, and limitations of the selected respirator, (5) the method of donning the respirator and checking its fit and operation, (6) the proper wearing of the respirator, (7) respirator maintenance, and (8) recognizing and handling emergency situations. (See 7.2.3.)

3.5.7 **Respirator Fit.** Each respirator wearer shall be provided with a respirator fitted in accordance with 6.11. Each respirator wearer shall be required to check the seal of the respirator by appropriate means prior to entering a harmful atmosphere. (See 7.4.)

3.5.8 **Facial Hair, Contact Lenses, and Eye and Face Protective Devices.** A respirator equipped with a facepiece shall not be worn if facial hair comes between the sealing periphery of the facepiece and the face or if facial hair interferes with valve function. The wearer of a respirator equipped with a full facepiece, helmet, hood, or suit shall not be allowed to wear contact lenses. If a spectacle, goggle, face shield, or welding helmet must be worn with a facepiece, it shall be worn so as not to adversely affect the seal of the facepiece to the face. (See 7.3 and 9.1.)

3.5.9 **Issue of Respirators.** The proper type of respirator for each respiratory hazard shall be listed in written standard operating procedures. Only persons trained to ensure that proper respirators are issued shall be permitted to issue respirators to persons needing them. (See 7.2.2 and 7.5.)

3.5.10 **Respirator Inspection.** The respirator shall be inspected by the wearer prior to its use to ensure that it is in proper working condition. Each respirator stored for emergency or rescue use shall be inspected at least once a month. (See 7.6 and 8.3.)

3.5.11 **Monitoring Respirator Use.** Supervisory personnel shall periodically monitor the use of respirators to ensure that they are worn properly. (See 7.7.)

3.5.12 **Monitoring Respiratory Hazard.** The concentration or the airborne radioactivity level of the respiratory hazard in the work area shall be monitored initially prior to respirator selection and periodically during respirator use to ensure that the proper type of respirator is being utilized. (See 6.4 and 7.8.)

3.15.13 **Medical and Bioassay Surveillance.** When applicable, medical surveillance, including bioassay, shall be carried out periodically to determine if respirator wearers are receiving adequate respiratory protection. A physician shall determine the requirements of the surveillance program. (See 10.4.)

3.15.14 **Respirator Maintenance.** Respirator maintenance shall be performed regularly. Maintenance shall be carried out on a schedule which ensures that each respirator wearer is provided with a respirator that is clean and in good operating condition. Maintenance shall include: (1) washing, sanitizing, rinsing, and drying, (2) inspection for defects, (3) replacement of worn or deteriorated parts, (4) repair if necessary, and (5) storage to protect against dust, sunlight, excessive heat, extreme cold, excessive moisture, damaging chemicals, and physical damage. (See Section 8.)

3.5.15 **Respirator Program Evaluation.** An appraisal of the effectiveness of the respirator program shall be carried out at least annually. Action shall be taken to correct defects found in the program. (See Section 10.)

4. Classification of Respiratory Hazards

4.1 **Introduction.** The purpose of this section is to list and briefly describe various categories of respiratory hazards that might be encountered and that may require use of respirators. The information provides a general background for relating the guidance provided in subsequent sections to the type of hazard encountered. The respirator program administrator, however, may find it necessary to consult references on industrial hygiene and toxicology, and perhaps expert individuals as well, in order to develop the necessary comprehensive information on specific airborne contaminants.

Respiratory hazards, for the purpose of this standard, are classified as follows:

(1) Oxygen deficiency

(a) Immediately dangerous to life or health

(b) Not immediately dangerous to life or health

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(2) Gas and vapor contaminants
(a) Immediately dangerous to life or health
(b) Not immediately dangerous to life or health
(3) Particulate contaminants (aerosols including dust, fog, fume, mist, smoke, and spray)
(a) Immediately dangerous to life or health
(b) Not immediately dangerous to life or health
(4) Combination of gas, vapor, and particulate contaminants
(a) Immediately dangerous to life or health
(b) Not immediately dangerous to life or health

Respirators may afford some protection against high-temperature atmospheres. (See 9.6.) Further information on the hazards of and use of respirators in high temperatures is presented in a National Fire Protection Association publication, *Fire Officers Guide to Breathing Apparatus for the Fire Service*, published in 1975.

4.2 Classification and Description of Respiratory Hazards. The basic respiratory hazards listed in 4.1 are classified in Table 1 according to expected biological effects of the contaminants. Many respirators, particularly air-purifying respirators, are designed and selected on the basis of chemical and physical properties of the air contaminants. Therefore, gas, vapor, and particulate contaminants are presented in Table 2 according to their physical and chemical properties.

5. Classification, Description, and Limitations of Respirators

5.1 Introduction. The purpose of this section is to provide a description of the various types of respirators, including their limitations and capabilities, as a background for subsequent sections which discuss their selection, use, and maintenance. This information is presented in two tables. Table 3 covers the classification and description of respirators according to the general classifications concerning mode of operation. Table 4 covers capabilities and limitations of respirators arranged to correspond to the subject headings in Table 3.

Respirators fall into the following general classifications, according to mode of operation:
(1) Atmosphere-supplying respirators
(a) Self-contained
(b) Supplied-air
(c) Combination self-contained and supplied-air
(2) Air-purifying respirators
(a) Gas and vapor
(b) Particulate (aerosols including dust, fog, fume, mist, smoke, and spray)
(c) Combination gas, vapor, and particulate
(3) Combination atmosphere-supplying and air-purifying respirators

More detailed information on specific types of respirators can be obtained from respirator manufacturers and from the following manuals:

Respiratory Protective Devices Manual published by the American Industrial Hygiene Association and the American Conference of Governmental Industrial Hygienists in 1963 (out of print)

A Guide to Industrial Respiratory Protection published by the Los Alamos Scientific Laboratory in 1977

Energy Research and Development Administration, Division of Safety, Standards, and Compliance Respirator Manual published by the Los Alamos Scientific Laboratory in 1976

Manual of Respiratory Protection Against Airborne Radioactive Materials published by the U.S. Nuclear Regulatory Commission in 1976

The colors assigned to cartridges and canisters of air-purifying respirators are listed in the American National Standard for Identification of Cartridges and Canisters used in Air-Purifying Respirators, ANSI K13.1-1973.

5.2 Respirable Air and Oxygen for Self-Contained Breathing Apparatus and Supplied-Air Respirators. Compressed gaseous air, compressed gaseous oxygen, liquid air, and liquid oxygen used for respiration shall be of high purity. Compressed gaseous or liquid oxygen shall meet the requirements of the United States Pharmacopoeia for medical or breathing oxygen. Chemically generated oxygen shall meet the requirements of U.S. Department of Defense Military Specification MIL-E-83252 or Military Specification MIL-O-15633c. Compressed gaseous air shall meet at least the requirements of the specification for Type I – Grade D breathing air, and liquid air shall meet at least the requirements for Type II – Grade B breathing air as described in American National Standard Commodity Specification for Air, ANSI Z86.1-1973 (Compressed Gas Association Commodity Specification for Air, G-7.1, 1973).

Compressed gaseous air may contain low concentrations of oil. If high-pressure oxygen passes through an oil- or grease-coated orifice, an explosion or fire may occur. Therefore, compressed gaseous oxygen shall not be used in supplied-air respirators or in open-circuit-type self-contained breathing apparatus that have previously used compressed air.

Breathing air may be supplied to respirators from cylinders or air compressors. Cylinders shall be tested

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and maintained in accordance with applicable Department of Transportation specifications for shipping containers (Title 49, *Code of Federal Regulations*, Part 173, General Requirements for Shipments and Packagings, and Part 178, Shipping Container Specifications). A compressor shall be constructed and situated so as to avoid entry of contaminated air into the air-supply system and shall be equipped with a suitable in-line air-purifying sorbent bed and filter to further assure breathing air quality. If an oil-lubricated compressor is used, it shall be equipped with a high-temperature alarm or a carbon-monoxide alarm, or both.

Breathing air couplings shall be incompatible with outlets for nonrespirable plant air or other gas systems to prevent inadvertent servicing of air-line respirators with nonrespirable gases.

Breathing-gas containers shall be marked in accordance with American National Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained, ANSI Z48.1-1954 (R1971); Federal Specification BB-A-1034a, June 21, 1968, Air, Compressed for Breathing Purposes; or Interim Federal Specification GG-B-675d, September 23, 1976, Breathing Apparatus, Self-Contained. Further details on sources of compressed air and its safe use will be found in Compressed Gas Association Pamphlet G-7, 1976, Compressed Air for Human Respiration.

6. Selection of Respirators

6.1 Approved Respirators. Only approved respirators shall be selected. For exceptions, see 1.4. (See Appendix A3.)

6.2 General Considerations. The selection of a proper respirator for any given situation shall require consideration of the following factors:

(1) The nature of the hazard (see 6.3, 6.4, 6.9.1, 6.9.2, and 6.9.3)

(2) The characteristics of the hazardous operation or process (see 6.5)

(3) The location of the hazardous area with respect to a safe area having respirable air (see 6.6)

(4) The period of time for which respiratory protection may be provided (see 6.7)

(5) The activity of workers in the hazardous area (see 6.8)

(6) The physical characteristics, functional capabilities, and limitations of respirators of various types (see 6.9)

(7) The respirator-protection factors and respirator fit (see 6.10, 6.11, 6.12, 6.13, 6.14, and 6.15)

6.3 Nature of Hazard. The following factors concerning the nature of the hazard requiring the use of respirators shall be considered in respirator selection:

(1) Type of hazard
  (a) Oxygen deficiency
  (b) Contaminant

(2) Physical properties

(3) Chemical properties

(4) Physiological effects on the body

(5) Actual concentration of a toxic material or airborne radioactivity level
  (a) Average
  (b) Peak

(6) Established permissible time-weighted average or peak concentration of a toxic material, or both, or established maximum permissible airborne radioactivity level for radioactive substances

(7) Whether the hazard is an immediately-dangerous-to-life-or-health concentration of a toxic material

(8) Warning properties

See Section 4 for classification and discussion of respiratory hazards.

6.4 Initial Monitoring of Respiratory Hazard. Recognition and evaluation of the respiratory hazard [oxygen deficiency or contaminant(s)] shall be an essential part of selecting a respirator except in emergency or rescue operations. Initial monitoring of the respiratory hazard shall be carried out to obtain data needed for the selection of proper respiratory protection. The data should include:

(1) Identification of the type of respiratory hazard
  (a) Oxygen deficiency
  (b) Specific contaminant(s)

(2) Nature of contaminant(s)
  (a) Particulate matter
  (b) Vapor(s) or gas(es)

(3) Concentration of respiratory hazard

See Appendix A8 for a discussion of the monitoring of respiratory hazards.

6.5 Characteristics of Hazardous Operation or Process. The following factors concerning the hazardous operation or process shall be taken into account in selecting the proper respirator:

(1) Operation or process characteristics

(2) Work-area characteristics

(3) Materials, including raw materials, end products, and byproducts (actual and potential)

(4) Worker activities

Modification in the operation or process shall be taken into account, since this may change the hazard and hence require the selection of a different respirator.

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Table 1
Classification of Respiratory Hazards According to Their Biological Effect

Oxygen Deficiency

Minimum legal requirements: 19.5% by volume for respirable air at sea-level conditions. (See Note 1.)

Occurrence: Confined or unventilated cellars, wells, mines, ship holds, tanks, burning buildings, and enclosures containing inert atmospheres:

Atmospheric oxygen content (percent by volume) versus expected conditions:

20.9%: Oxygen content of normal air at sea-level conditions.

Oxygen Volume Percent at Sea Level	*Physiological Effects*
16%–12%	loss of peripheral vision, increased breathing volume, accelerated heartbeat, impaired attention and thinking, impaired coordination.
12%–10%	Very faulty judgment, very poor muscular coordination, muscular exertion causes fatigue that may cause permanent heart damage, intermittent respiration.
10%–6%	Nausea, vomiting, inability to perform vigorous movement, unconsciousness followed by death.
Less than 6%	Spasmatic breathing, convulsive movements, death in minutes.

Gas and Vapor Contaminants

Asphyxiants: Interfere with utilization of oxygen in the body.

Simple asphyxiants: Physiologically inert substances that dilute oxygen in the air (for example: nitrogen, hydrogen, helium, methane). See Oxygen Deficiency, Column 1.

Chemical asphyxiants: Low concentrations interfere with supply or utilization of oxygen in the body (for example: carbon monoxide, hydrogen cyanide, cyanogen, and nitriles).

Irritants: Corrosive in action. May cause irritation and inflammation of parts of the respiratory system (also skin and eyes) and pulmonary edema (for example: ammonia hydrogen chloride, formaldehyde, sulfur dioxide, chlorine, ozone, nitrogen dioxide, phosgene, and arsenic trichloride).

Anesthetics: Cause loss of feeling and sensation with unconsciousness and death possible (for example: nitrous oxide, hydrocarbons, and ethers). Some anesthetics injure body organs (for example: carbon tetrachloride [liver and kidneys], chloroform [liver and heart], benzene [bone marrow], and carbon disulfide [nervous system]).

Sensitizers: Cause increased probability of physiological reactions (for example: isocyanates, epoxy resin systems).

Systemic poisons: Damage organs and systems in the body (for example: mercury [nervous system and various organs], phosphorus [bone], hydrogen sulfide [respiratory paralysis], and arsine [red blood cells and liver]).

Carcinogens: Produce cancer in some individuals after a *latent period (for example: vinyl chloride, benzene).*

Particulate Contaminants
(Dust, fog, fume, mist, smoke, and spray)

Relatively inert: May cause discomfort and minor irritation, but generally without injury at reasonable concentrations (for example: marble, gypsum).

Pulmonary-fibrosis-producing: Produce nodulation and fibrosis in the lung, possibly leading to complications (for example: quartz, asbestos).

Carcinogens: Produce cancer in some individuals after latent period (for example: asbestos, chromates, radioactive particulates).

Chemical irritants: Produce irritation, inflammation, and ulceration in upper respiratory tract (for example: acidic mists, alkalies).

Systemic poisons: Produce pathologic reactions in various *systems of the body (for example: lead, manganese,* cadmium).

Allery-producing: Produce reactions such as itching, sneezing, and asthmas (for example: pollens, spices, and animal fur).

Febrile-reaction-producing: Produce chills followed by fever (for example: fumes of zinc and copper).

Combinations of Gas, Vapor, and Particulate Contaminants

Combinations of contaminants may occur simultaneously in the atmosphere. Contaminants may be entirely different substances (dusts and gases from blasting) or the particulate and vapor forms of the same substance. Synergistic effects (joint action of two or more agents that results in an effect which is greater than the sum of their individual effects) may occur. Such effects may require extraordinary protective measures.

NOTE 1: See definition in Section 2 for "oxygen deficiency – not immediately dangerous to life or heath" and "oxygen deficiency – immediately dangerous to life or health," and Appendix A10.

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Table 2
Classification of Respiratory Hazards According to Their Properties Which Influence Respirator Selection

Gas and Vapor Contaminants	Particulate Contaminants
Inert: Substances that do not react with other substances under most conditions, but create a respiratory hazard by displacing air and producing oxygen deficiency (for example: helium, neon, argon).	Particles are produced by mechanical means by disintegration processes such as grinding, crushing, drilling, blasting, and spraying; or by physiochemical reactions such as combustion, vaporization, distillation, sublimation, calcination, and condensation. Particles are classified as follows:
Acidic: Substances that are acids or that react with water to produce an acid. In water, they produce positively charged hydrogen ions (H^{+1}) and a pH of less than 7. They taste sour, and many are corrosive to tissues (for example: hydrogen chloride, sulfur dioxide, fluorine, nitrogen dioxide, acetic acid, carbon dioxide, hydrogen sulfide, and hydrogen cyanide).	**Dust:** A solid, mechanically produced particle with sizes varying from submicroscopic to visible or macroscopic.
Alkaline: Substances that are alkalies or that react with water to produce an alkali. In water, they result in the production of negatively charged hydroxyl ions (OH^{-1}) and a pH greater than 7. They taste bitter, and many are corrosive to tissues (for example: ammonia, amines, phosphine, arsine, and stibine).	**Spray:** A liquid, mechanically produced particle with sizes generally in the visible or macroscopic range.
Organic: The compounds of carbon. Examples are saturated hydrocarbons (methane, ethane, butane), unsaturated hydrocarbons (ethylene, acetylene), alcohols (methyl ether, ethyl ether), aldehydes (formaldehyde), ketones (methyl ketone), organic acids (formic acid, acetic acid), halides (chloroform, carbon tetrachloride), amides (formamide, acetamide), nitriles (acetonitrile), isocyanates (toluene diisocyanate), amines (methylamine), epoxies (epoxyethane, propylene oxide), and aromatics (benzene, toluene, xylene).	**Fume:** A solid condensation particle of extremely small particle size, generally less than one micrometer in diameter.
Organometallic: Compounds in which metals are chemically bonded to organic groups (for example: ethyl silicate, tetraethyl lead, and organic phosphate).	**Mist:** A liquid condensation particle with sizes ranging from submicroscopic to visible or macroscopic.
Hydrides: Compounds in which hydrogen is chemically bonded to metals and certain other elements (for example: diborane and tetraborane).	**Fog:** A mist of sufficient concentration to perceptibly obscure vision.
	Smoke: A system which includes the products of combustion, pyrolysis, or chemical reaction of substances in the form of visible and invisible solid and liquid particles and gaseous products in air. Smoke is usually of sufficient concentration to perceptibly obscure vision.

Table 3
Classification and Description of Respirators by Mode of Operation

Atmosphere-Supplying Respirators

A respirable atmosphere independent of the ambient air is supplied to the wearer.

Self-Contained Breathing Apparatus (SCBA)

A supply of air, oxygen, or oxygen-generating material is carried by the wearer. Normally equipped with full facepiece, but may be equipped with a quarter-mask facepiece, half-mask facepiece, helmet, hood, or mouthpiece and nose clamp.

(1) Closed-Circuit SCBA (oxygen only, negative pressure[a] or positive pressure[b]).

(a) Compressed or liquid oxygen type. Equipped with a facepiece or mouthpiece and nose clamp. High-pressure oxygen from a gas cylinder passes through a high-pressure reducing valve and, in some designs, through a low-pressure admission valve to a breathing bag or container. Liquid oxygen is converted to low-pressure gaseous oxygen and delivered to the breathing bag. The wearer inhales from the bag, through a corrugated tube connected to a mouthpiece or facepiece and a one-way check valve. Exhaled air passes through another check valve and tube into a container of carbon-dioxide removing chemical and reenters the breathing bag. Make-up oxygen enters the bag continuously or as the bag deflates sufficiently to actuate an admission valve. A pressure-relief system is provided, and a manual by-pass system and saliva trap may be provided depending upon the design.

Supplied-Air Respirators

(1) Hose Mask

Equipped with a facepiece, breathing tube, rugged safety harness, and large-diameter heavy-duty nonkinking air-supply hose. The breathing tube and air-supply hose are securely attached to the harness. The facepiece is equipped with an exhalation valve. The harness has provision for attaching a safety line.

(a) Hose mask with blower. Air is supplied by a motor-driven or hand-operated blower. The wearer can continue to inhale through the hose if the blower fails. Up to 300 feet (91 meters) of hose length is permissible.

(b) Hose mask without blower. The wearer provides motivating force to pull air through the hose. The hose inlet is anchored and fitted with a funnel or like object covered with a fine mesh screen to prevent entrance of coarse particulate matter. Up to 75 feet (23 meters) of hose length is permissible.

(2) Air-Line Respirator

Respirable air is supplied through a small-diameter hose from a compressor or compressed-air cylinder(s). The hose is attached to the wearer by a belt or other suitable means and can be detached rapidly in an emergency. A flow-control valve

Air-Purifying Respirators

Ambient air, prior to being inhaled, is passed through a filter, cartridge, or canister which removes particles, vapors, gases, or a combination of these contaminants. The breathing action of the wearer operates the nonpowered type of respirator. The powered type contains a blower – stationary or carried by the wearer – which passes ambient air through an air-purifying component and then supplies purified air to the respirator-inlet covering. The nonpowered type is equipped with a facepiece or mouthpiece and nose clamp. The powered type is equipped with a facepiece, helmet, hood, or suit.

Vapor- and Gas-Removing Respirators

Equipped with cartridge(s) or canister(s) to remove a single vapor or gas (for example: chlorine gas), a single class of vapors or gases (for example: organic vapors), or a combination of two or more classes of vapors or gases (for example: organic vapors and acidic gases) from air.

Particulate-Removing Respirators

Equipped with filter(s) to remove a single type of particulate matter (for example: dust) or a combination of two or more types of particulate matter (for example: dust and fume) from air. Filter may be a replaceable part or a permanent part of the respirator. Filter may be of the single-use or the reusable type.

Combination Particulate- and Vapor- and Gas-Removing Respirators

Equipped with cartridge(s) or canister(s) to remove particulate matter, vapors, and gases from air. The filter may be a permanent part or a replaceable part of a cartridge or canister.

(b) Oxygen-generating type. Equipped with a facepiece or mouthpiece and nose clamp. Water vapor in the exhaled breath reacts with chemical in the canister to release oxygen to the breathing bag. The wearer inhales from the bag through a corrugated tube and one-way check valve at the facepiece. Exhaled air passes through a second check valve/breathing tube assembly into the canister. The oxygen-release rate is governed by the volume of exhaled air. Carbon dioxide in the exhaled breath is removed by the canister fill.

(2) Open-Circuit SCBA (compressed air, compressed oxygen, liquid air, liquid oxygen). A bypass system is provided in case of regulator failure except on escape-type units.

(a) Demand type.[c] Equipped with a facepiece or mouthpiece and nose clamp. The demand valve permits oxygen or air flow only during inhalation. Exhaled breath passes to ambient atmosphere through a valve(s) in the facepiece.

(b) Pressure-demand type.[d] Equipped with a facepiece only. Positive pressure is maintained in the facepiece. The apparatus may have provision for the wearer to select the demand or pressure-demand mode of operation, in which case the demand mode should be used only when donning or removing the apparatus.

or orifice is provided to govern the rate of air flow to the wearer. Exhaled air passes to the ambient atmosphere through a valve(s) or opening(s) in the enclosure (facepiece, helmet, hood, or suit). Up to 300 feet (91 meters) of hose length is permissible.

(a) Continuous-flow class. Equipped with a facepiece, hood, helmet, or suit. At least 115 liters (four cubic feet) of air per minute to tight-fitting facepieces and 170 liters (six cubic feet) of air per minute to loose-fitting helmets, hoods, and suits is required. Air is supplied to a suit through a system of internal tubes to the head, trunk, and extremities through valves located in appropriate parts of the suit.

(b) Demand type.[c] Equipped with a facepiece only. The demand valve permits flow of air only during inhalation.

(c) Pressure-demand type.[d] Equipped with a facepiece only. A positive pressure is maintained in the facepiece.

Combination Air-Line Respirators with Auxiliary Self-Contained Air Supply

Include an air-line respirator with an auxiliary self-contained air supply. To escape from a hazardous atmosphere in the event the primary air supply fails to operate, the wearer switches to the auxiliary self-contained air supply. Devices approved for both entry into and escape from dangerous atmospheres have a low-pressure warning alarm and contain at least a 15-minute self-contained air supply.

Combination Atmosphere-Supplying and Air-Purifying Respirators

Provide the wearer with the option of using either of two different modes of operation: (1) an atmosphere-supplying respirator with an auxiliary air-purifying attachment which provides protection in the event the air supply fails or (2) an air-purifying respirator with an auxiliary self-contained air supply which is used when the atmosphere may exceed safe conditions for use of an air-purifying respirator.

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[a]Device produces negative pressure in respiratory-inlet covering during inhalation.

[b]Device produces positive pressure in respiratory-inlet covering during both inhalation and exhalation.

[c]Equipped with a demand valve that is activated on initiation of inhalation and permits the flow of breathing atmosphere to the facepiece. On exhalation, pressure in the facepiece becomes positive and the demand valve is deactivated.

[d]A positive pressure is maintained in the facepiece by a spring-loaded or balanced regulator and exhalation valve.

Table 4
Capabilities and Limitations of Respirators

Atmosphere-Supplying Respirators

(See 5.2 for specifications on respirable atmospheres.)

Atmosphere-supplying respirators provide protection against oxygen deficiency and toxic atmospheres. The breathing atmosphere is independent of ambient atmospheric conditions.

General limitations: Except for some air-line suits, no protection is provided against skin irritation by materials such as ammonia and hydrogen chloride, or against sorption of materials such as hydrogen cyanide, tritium, or organic phosphate pesticides through the skin. Facepieces present special problems to individuals required to wear prescription lenses (see 9.1). Use of atmosphere-supplying respirators in atmospheres immediately dangerous to life or health is limited to specific devices under specified conditions (see Table 5 and 9.3 and 9.4).

Self-Contained Breathing Apparatus (SCBA)

The wearer carries his own breathing atmosphere.

Limitations: The period over which the device will provide protection is limited by the amount of air or oxygen in the apparatus, the ambient atmospheric pressure (service life of open-circuit devices is cut in half by a doubling of the atmospheric pressure), and the type of work being performed. Some SCBA devices have a short service life (less than 15 minutes) and are suitable only for escape (self-rescue) from an irrespirable atmosphere.

Chief limitations of SCBA devices are their weight or bulk, or both, limited service life, and the training required for their maintenance and safe use.

(1) Closed-Circuit SCBA.
The closed-circuit operation conserves oxygen and permits longer service life at reduced weight. The negative-pressure type produces a negative pressure in the

Supplied-Air Respirators

The respirable air supply is not limited to the quantity the individual can carry, and the devices are lightweight and simple.

Limitations: Limited to use in atmospheres from which the wearer can escape unharmed without the aid of the respirator.

The wearer is restricted in movement by the hose and must return to a respirable atmosphere by retracing his route of entry. The hose is subject to being severed or pinched off.

(1) Hose Mask.
The hose inlet or blower must be located and secured in a respirable atmosphere.

(a) Hose mask with blower.
If the blower fails, the unit still provides protection, although a negative pressure exists in the facepiece during inhalation.

(b) Hose mask without blower.
Maximum hose length may restrict application of device.

Air-Purifying Respirators

General limitations: Air-purifying respirators do not protect against oxygen-deficient atmospheres nor against skin irritations by, or sorption through the skin of, airborne contaminants.

The maximum contaminant concentration against which an air-purifying respirator will protect is determined by the design efficiency and capacity of the cartridge, canister, or filter and the facepiece-to-face seal on the user. For gases and vapors, the maximum concentration for which the air-purifying element is designed is specified by the manufacturer or is listed on labels of cartridges and canisters.

Nonpowered air-purifying respirators will not provide the maximum design protection specified unless the facepiece or mouthpiece/nose clamp is carefully fitted to the wearer's face to prevent inward leakage (see 7.4). The time period over which protection is provided is dependent on canister, cartridge, or filter type; concentration of contaminant; humidity levels in the ambient atmosphere; and the wearer's respiratory rate.

The proper type of canister, cartridge, or filter must be selected for the particular atmosphere and conditions. Nonpowered air-purifying respirators may cause discomfort due to a noticeable resistance to inhalation. This problem is minimized in powered respirators. Respirator facepieces present special problems to individuals required to wear prescription lenses (see 9.1). These devices do have the advantage of being small, light, and simple in operation.

Use of air-purifying respirators in atmospheres immediately dangerous to life or health is limited to specific devices under specified conditions (see Table 5 and 9.3 and 9.4).

Vapor- and Gas-Removing Respirators

Limitations: No protection is provided against particulate contaminants. A rise in canister or cartridge temperature indicates that a gas or vapor is being removed from the inspired air.

An uncomfortably high temperature indicates a high concentration of gas or vapor and requires an immediate return to fresh air.

Use should be avoided in atmospheres

Particulate-Removing Respirators

Limitations: Protection against nonvolatile particles only. No protection against gases and vapors.

Not for use in atmospheres immediately dangerous to life or health unless the device is a powered-type respirator with escape provisions (see Table 5).

(1) Full Facepiece Respirator.
Provides protection against eye irritation in addition to respiratory protection.

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respiratory-inlet covering during inhalation, and this may permit inward leakage of contaminants; whereas the positive-pressure type always maintains a positive pressure in the respiratory-inlet covering and is less apt to permit inward leakage of contaminants.

(2) Open-Circuit SCBA.
The demand type produces a negative pressure in the respiratory-inlet covering during inhalation, whereas the pressure-demand type maintains a positive pressure in the respiratory-inlet covering during inhalation and is less apt to permit inward leakage of contaminants.

(2) Air-Line Respirator (Continuous Flow, Demand, and Pressure-Demand Types)

The demand type produces a negative pressure in the facepiece on inhalation, whereas continuous-flow and pressure-demand types maintain a positive pressure in the respiratory-inlet covering and are less apt to permit inward leakage of contaminants.

Air-line suits may protect against atmospheres that irritate the skin or that may be absorbed through the unbroken skin.

Limitations: Air-line respirators provide no protection if the air supply fails. Some contaminants, such as tritium, may penetrate the material of an air-line suit and limit its effectiveness.

Other contaminants, such as fluorine, may react chemically with the material of an air-line suit and damage it.

Combination Airline Respirators with Auxiliary SC Air Supply

The auxiliary self-contained air supply on this type of device allows the wearer to escape from a dangerous atmosphere. This device with auxiliary self-contained air supply is approved for escape and may be used for entry when it contains at least a 15-minute auxiliary self-contained air supply. (See Table 5).

where the contaminant(s) lacks sufficient warning properties (that is: odor, taste, or irritation at a concentration in air at or above the permissible exposure limit.) (Vapor- and gas-removing respirators are not approved for contaminants that lack adequate warning properties.)

Not for use in atmospheres immediately dangerous to life or health unless the device is a powered-type respirator with escape provisions (see Table 5).

(1) Full Facepiece Respirator.
Provides protection against eye irritation in addition to respiratory protection.

(2) Quarter-Mask and Half-Mask Facepiece Respirator. A fabric covering (facelet) available from some manufacturers shall not be used.

(3) Mouthpiece Respirator.
Shall be used only for escape applications. Mouth breathing prevents detection of contaminant by odor. Nose clamp must be securely in place to prevent nasal breathing.

A small lightweight device that can be donned quickly.

(2) Quarter-Mask and Half-Mask Facepiece Respirator. A fabric covering (facelet) available from some manufacturers shall not be used unless approved for use with respirator.

(3) Mouthpiece Respirator.
Shall be used only for escape applications. Mouth breathing prevents detection of contaminant by odor. Nose clamp must be securely in place to prevent nasal breathing.

A small, lightweight device that can be donned quickly.

Combination Particulate- and Vapor- and Gas-Removing Respirators

The advantages and disadvantages of the component sections of the combination respirator as described above apply.

Combination Atmosphere-Supplying and Air-Purifying Respirators

The advantages and disadvantages, expressed above, of the mode of operation being used will govern. The mode with the greater limitations (air-purifying mode) will mainly determine the overall capabilities and limitations of the respirator, since the wearer may for some reason fail to change the mode of operation even though conditions would require such a change.

6.6 Location of Hazardous Area. The location of the hazardous area with respect to a safe area having respirable air shall be considered in selecting a respirator, since this will permit planning for the escape of workers if an emergency occurs, for the entry of workers to perform maintenance duties, and for rescue operations.

6.7 Respirator Use Time Period. The period of time that a respirator must be worn is an important factor that shall be taken into account in selecting a respirator. Consideration shall be given to the type of respirator application, such as for routine, nonroutine, emergency, or rescue use. It would not be desirable, for example, to select respirators that are heavy or that offer high resistance to breathing for routine wearing for many hours each day.

6.8 Worker Activity. Worker activities and worker locations in hazardous areas shall be considered in selecting the proper respirator (for example, whether the worker is in the hazardous area continuously or intermittently during the work shift and whether the work rate is light, medium, or heavy).

6.9 Respirator Characteristics, Capabilities, and Limitations. The physical characteristics, the functional capabilities, and the performance limitations of the various types of respirators shall be considered in selecting a respirator. (See Section 5.)

6.9.1 Respirators for Oxygen-Deficient Atmosphere. Only respirators that provide an independent, respirable atmosphere shall be used in an oxygen-deficient atmosphere. Respirators for use in atmospheres that are oxygen deficient and immediately dangerous to life or health (see definition) and respirators for use in atmospheres that are oxygen deficient but not immediately dangerous to life or health (see definition) are listed in Table 5.

6.9.2 Respirators for Atmospheres Immediately Dangerous to Life or Health. Respirators for use in atmospheres that contain adequate oxygen but are immediately dangerous to life or health because of the presence of toxic contaminants are listed in Table 5.

6.9.3 Respirators for Atmospheres Not Immediately Dangerous to Life or Health. All types of respirators listed in Table 5 may be used in contaminated atmospheres that contain adequate oxygen and are not immediately dangerous to life or health.

6.10 Respirator Protection Factor (PF). Respirators shall be selected according to the characteristics of the hazards involved, the capabilities and limitations of the respirators, and the ability of each respirator wearer to obtain a satisfactory fit with a respirator. Taking into account the capabilities and limitations of respirators and the results of respirator-fitting tests, a table of respirator protection factors has been prepared (see Table 5).

A respirator protection factor is a measure of the degree of protection provided by a respirator to a wearer. Multiplying either (1) the permissible time-weighted average concentration or the permissible ceiling concentration, whichever is applicable, for a toxic substance, or (2) the maximum permissible airborne concentration for a radionuclide by a protection factor assigned to a respirator gives the maximum concentration of the hazardous substance in which the respirator can be used. Limitations of filters, cartridges, and canisters also shall be considered (see Table 5).

6.11 Respirator-Fitting Tests. A qualitative or quantitative respirator-fitting test shall be used to determine the ability of each individual respirator wearer to obtain a satisfactory fit with a negative-pressure respirator. (The National Institute for Occupational Safety and Health recommends that only a program of quantitative-fit testing can provide adequate worker protection.) The results of qualitative or quantitative respirator-fitting tests shall be used to select specific types, makes, and models of negative-pressure respirators for use by individual respirator wearers. A respirator-fitting test shall be carried out for each wearer of a negative-pressure respirator at least annually. Respirator-fitting tests shall not be required for positive-pressure respirators.

Qualitative Respirator-Fitting Test – A person wearing a respirator is exposed to an irritant smoke, an odorous vapor, or other suitable test agent. An air-purifying respirator must be equipped with an air-purifying element(s) which effectively removes the test agent from inspired air. If the respirator wearer is unable to detect penetration of the test agent into the respirator, the respirator wearer has achieved a satisfactory fit with the respirator. (See Appendix A5.)

Quantitative Respirator-Fitting Test – A person wears a respirator in a test atmosphere containing a test agent in the form of an aerosol, vapor, or gas. Instrumentation, which samples the test atmosphere and the air inside the respiratory-inlet covering of the respirator, is used to measure quantitatively the penetration of the test agent into the respiratory-inlet covering. (See Appendix A6.)

When carrying out a qualitative or quantitative respirator-fitting test, the respirator wearer shall carry out a series of exercises which simulate work movements. (See Appendix A5 and A6).

When carrying out respirator-fitting tests, it shall be acceptable procedure to make the following modifications to respirators provided that such modifications do not affect the seal of the respirators to wearers.

(1) When carrying out a qualitative or quantitative respirator-fitting test which uses an aerosol as the test

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Table 5
Respirator Protection Factors[a]

Type of Respirator	Permitted for Use in Oxygen-Deficient Atmosphere	Permitted for Use in Immediately-Dangerous-to-Life-or-Health Atmosphere[f]	Respirator Protection Factor	
			Qualitative Test	Quantitative Test
Particulate-filter, quarter-mask or half-mask facepiece[b,c]	No	No	10	As measured on each person with maximum of 100.
Vapor- or gas-removing, quarter-mask or half-mask facepiece[c]	No	No	10, or maximum use limit of cartridge or canister for vapor or gas, whichever is less.	As measured on each person with maximum of 100, or maximum use limit of cartridge or canister for vapor or gas[i,j], whichever is less.
Combination particulate-filter and vapor- or gas-removing, quarter-mask or half-mask facepiece[b,c]	No	No	10, or maximum use limit of cartridge or canister for vapor or gas, whichever is less.	As measured on each person with maximum of 100, or maximum use limit of cartridge or canister for vapor or gas[i,j], whichever is less.
Particulate-filter, full facepiece[b]	No	No	100	As measured on each person with maximum of 100 if dust, fume, or mist filter is used, or maximum of 1000 if high-efficiency filter is used.
Vapor- or gas-removing, full facepiece	No	No	100, or maximum use limit of cartridge or canister for vapor or gas, whichever is less.	As measured on each person with maximum of 1000, or maximum use limit of cartridge or canister for vapor or gas[i,j], whichever is less.
Combination particulate-filter and vapor- or gas-removing, full facepiece[b]	No	No	100, or maximum use limit of cartridge or canister for vapor or gas, whichever is less.	As measured on each person with maximum of 100 if dust, fume, or mist filter is used and maximum of 1000 if high-efficiency filter is used, or maximum use limit of cartridge or canister for vapor or gas[i,j], whichever is less.
Powered particulate-filter, any respiratory-inlet covering[b,c,d]	No	No (yes, if escape provisions are provided[d])	N/A	N/A
			No tests are required due to positive-pressure operation of respirator. The maximum protection factor is 100 if dust, fume, or mist filter is used and 3000 if high-efficiency filter is used.	
Powered vapor- or gas-removing, any respiratory-inlet covering[c,d]	No	No (yes, if escape provisions are provided[d])	N/A	N/A
			No tests are required due to positive pressure operation of respirator. The maximum protection factor is 3000, or maximum use limit of cartridge or canister for vapor or gas[i,j], whichever is less.	
Powered combination particulate-filter and vapor- or gas-removing, any respiratory-inlet covering[b,c,d]	No	No (yes, if escape provisions are provided[d])	N/A	N/A
			No tests are required due to positive-pressure operation of respirator. The maximum protection factor is 100 if dust, fume, or mist filter is used and 3000 if high-efficiency filter is used, or maximum use limit of cartridge or canister for vapor or gas[i,j], whichever is less.	

Table 5 (Continued)
Respirator Protection Factors[a]

Type of Respirator	Permitted for Use in Oxygen-Deficient Atmosphere	Permitted for Use in Immediately-Dangerous-to-Life-or-Health Atmosphere[f]	Respirator Protection Factor	
			Qualitative Test	Quantitative Test
Air-line, demand, quarter-mask or half-mask facepiece, with or without escape provisions[c,e]	Yes[f]	No	10	As measured on each person, but limited to the use of the respirator in concentrations of contaminants below the immediately-dangerous-to-life-or-health (IDLH) values.
Air-line, demand, full facepiece, with or without escape provisions[e]	Yes[f]	No	100	As measured on each person, but limited to the use of the respirator in concentrations of contaminants below the immediately-dangerous-to-life-or-health (IDLH) values.
Air-line, continuous-flow or pressure-demand type, any facepiece, without escape provisions[c]	Yes[f]	No	N/A	N/A
			No tests are required due to positive-pressure operation of respirator. The protection factor provided by the respirator is limited to use of the respirator in concentrations of contaminants below the immediately-dangerous-to-life-or-health (IDLH) values.	
Air-line, continuous-flow or pressure-demand type, any facepiece, with escape provisions[c,e]	Yes[g]	Yes	N/A	N/A
			No tests are required due to positive-pressure operation of respirator. The maximum protection factor is 10 000 plus.[h]	
Air-line, continuous flow, helmet, hood, or suit, without escape provisions	Yes[f]	No	N/A	N/A
			No tests are required due to positive-pressure operation of respirator. The protection factor provided by the respirator is limited to the use of the respirator in concentrations of contaminants below the immediately-dangerous-to-life-or-health (IDLH) values.	
Air-line, continuous-flow, helmet, hood, or suit, with escape provisions[e]	Yes[g]	Yes	N/A	N/A
			No tests are required due to positive-pressure operation of respirator. The maximum protection factor is 10 000 plus.[h]	
Hose mask, with or without blower, full facepiece	Yes[f]	No	10	As measured on each person, but limited to the use of the respirator in concentrations of contaminants below the immediately-dangerous-to-life-or-health (IDLH) values.
Self-contained breathing apparatus, demand-type open-circuit or negative-pressure-type closed-circuit, quarter-mask or half-mask facepiece[c]	Yes[f]	No	10	As measured on each person, but limited to the use of the respirator in concentrations of contaminants below the immediately-dangerous-to-life-or-health (IDLH) values.
Self-contained breathing apparatus, demand-type open-circuit or negative-pressure-type closed-circuit, full facepiece or mouthpiece/nose clamp[c]	Yes[f] (Yes[g], if respirator is used for mine rescue and mine recovery operations.)	No (yes, if respirator is used for mine rescue and mine recovery operations.)	100	As measured on each person, but limited to the use of the respirator in concentrations of contaminants below the immediately-dangerous-to-life-or-health (IDLH) values, except when the respirator is used for mine rescue and mine recovery operations.

Self-contained breathing apparatus, pressure-demand-type open-circuit or positive-pressure-type closed-circuit, quarter-mask or half-mask facepiece, full facepiece, or mouthpiece/nose clamp[c]	Yes[g]	Yes	N/A	N/A No tests are required due to positive-pressure operation of respirator. The maximum protection factor is 10 000 plus.[h]
Combination respirators not listed.	The type and mode of operation having the lowest respirator protection factor shall be applied to the combination respirator.			

N/A means not applicable since a respirator-fitting test is not carried out.

[a]A respirator protection factor is a measure of the degree of protection provided by a respirator to a respirator wearer. Multiplying the permissible time-weighted average concentration or the permissible ceiling concentration, whichever is applicable, for a toxic substance, or the maximum permissible airborne concentration for a radionuclide, by a protection factor assigned to a respirator gives the maximum concentration of the hazardous substance for which the respirator can be used. Limitations of filters, cartridges, and canisters used in air-purifying respirators shall be considered in determining protection factors.

[b]When the respirator is used for protection against airborne particulate matter having a permissible time-weighted average concentration less than 0.05 milligram particulate matter per cubic meter of air or less than 2 million particles per cubic foot of air, or for protection against airborne radionuclide particulate matter, the respirator shall be equipped with a high-efficiency filter(s).

[c]If the air contaminant causes eye irritation, the wearer of a respirator equipped with a quarter-mask or half-mask facepiece or mouthpiece and nose clamp shall be permitted to use a protective goggle or to use a respirator equipped with a full facepiece.

[d]If the powered air-purifying respirator is equipped with a facepiece, the escape provision means that the wearer is able to breathe through the filter, cartridge, or canister and through the pump. If the powered air-purifying respirator is equipped with a helmet, hood, or suit, the escape provision shall be an auxiliary self-contained supply of respirable air.

[e]The escape provision shall be an auxiliary self-contained supply of respirable air.

[f]For definition of "oxygen deficiency – not immediately dangerous to life or health" see Section 2.

[g]For definition of "oxygen deficiency – immediately dangerous to life or health" see Section 2 and A10.

[h]The protection factor measurement exceeds the limit of sensitivity of the test apparatus. Therefore, the respirator has been classified for use in atmospheres having unknown concentrations of contaminants.

[i]The service life of a vapor- or gas-removing cartridge or canister depends on the specific vapor or gas, the concentration of the vapor or gas in air, the temperature and humidity of the air, the type and quantity of the sorbent in the cartridge or canister, and the activity of the respirator wearer. Cartridges and canisters may provide only very short service lives for certain vapors and gases. Vapor/gas service life testing is recommended to ensure that cartridges and canisters provide adequate service lives. Reference should be made to published reports which give vapor/gas life data for cartridges and canisters.

[j]Vapor- and gas-removing respirators are not approved for contaminants that lack adequate warning properties of odor, irritation, or taste at concentrations in air at or above the permissible exposure limits.

NOTE: Respirator protection factors for air-purifying-type respirators equipped with a mouthpiece/nose clamp form of respiratory-inlet covering are not given, since such respirators are approved only for escape purposes.

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agent, it shall be acceptable procedure to equip an air-purifying respirator with a high-efficiency filter.

(2) When carrying out a qualitative or quantitative respirator-fitting test which uses a vapor or gas as the test agent, it shall be acceptable procedure to equip an air-purifying respirator with an appropriate cartridge or canister which removes the vapor or gas from air.

(3) When carrying out a quantitative respirator-fitting test, it shall be acceptable procedure to attach a sampling probe to the respirator which is connected by flexible tubing to an instrument which measures the penetration of the test agent into the respirator.

When carrying out quantitative respirator-fitting tests, it shall be an acceptable procedure to carry out a single test for each available make and model of respirator in order to select a respirator for use by a person. However, three additional quantitative respirator-fitting tests involving the wearing of the selected make and model of respirator by the person shall be carried out to determine a protection factor for that particular respirator and person. The lowest protection factor determined by these three tests shall be assigned to a particular person wearing a specific make and model of respirator.

If a qualitative respirator-fitting test has been used in respirator selection, a person shall be allowed to use only the specific make(s) and model(s) of respirator(s) for which the person obtained a satisfactory fit, and the respirator protection factor listed under "qualitative test" in Table 5 shall apply. Under no circumstances shall a person be allowed to use any respirator if the results of the qualitative respirator-fitting test indicates that the person is unable to obtain a satisfactory fit.

If a quantitative respirator-fitting test has been used in selecting a respirator, the test results shall be used to assign a respirator protection factor to each person for each specific make and model of respirator tested. The assigned respirator protection factor shall be applied when the person wears the specific respirator in a hazardous atmosphere, but it shall not exceed the respirator protection factor listed under "quantitative test" in Table 5 for the particular type of respirator.

6.12 **Respirator-Fitting-Test Records.** Records of respirator-fitting tests shall be kept for at least the duration of employment. These records shall include the following information:

(1) Type of respirator-fitting test used
(2) Specific make and model of respirator tested
(3) Name of person tested
(4) Name of test operator
(5) Date of test
(6) Results of respirator-fitting tests

(a) Success or failure of person to obtain satisfactory fit if a qualitative respirator-fitting test was carried out

(b) Respirator protection factor based upon test results if a quantitative respirator-fitting test was carried out

6.13 **Respirator Protection Factor Assignment.** When a group of persons wear respirators in a given work area, a single respirator protection factor shall be assigned to all respirator wearers in the group. When negative-pressure respirators are being used, this respirator protection factor shall correspond to the lowest value established by qualitative or quantitative respirator-fitting tests for any person of the group with the specific make and model of respirator which that person will wear in the given work area.

6.14 **Face Dimensions and Facepiece Sizes.** The wide range of face dimensions requires more than a single size of respirator facepiece to provide a proper fit to all respirator users. Therefore, respirator facepieces of more than one size shall be available in any respirator-selection program involving respirators equipped with facepieces.

6.15 **Employee Acceptance.** Employee acceptance of a particular respirator model within a class shall be considered in selecting a respirator since this may determine whether or not he wears the respirator properly. Acceptance factors to be considered include discomfort, breathing resistance, weight, and interference with vision or the work to be performed. If the results of respirator-fitting tests show that the person can obtain an acceptable fit with two or more respirator models of the selected class of respirator, then the person should be permitted to use the respirator model which he or she prefers.

7. Use of Respirators

7.1 **Standard Operating Procedures.** Written standard operating procedures shall cover a complete respirator program (see 3.5.1) and shall include information necessary for the proper use of respirators, including training of respirator wearers, respirator sealing tests, issuance of respirators, inspection of respirators prior to use, monitoring respirator use, monitoring respiratory hazard, and planning for routine, nonroutine, emergency, and rescue uses of respirators.

The written standard operating procedures shall include plans necessary to ensure the safe routine use and nonroutine use of respirators. Emergency and rescue uses of respirators shall be anticipated, and the writ-

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ten standard operating procedures shall include plans necessary to ensure the safe emergency and rescue uses of respirators. Persons who wear respirators routinely, who wear respirators nonroutinely, and who may be required to wear respirators for emergency and rescue work shall be given adequate information concerning plans covering these respirator uses to ensure the safe use of respirators.

7.1.1 **Standard Operating Procedures for Emergency and Rescue Use of Respirators.** It is recognized that it is not possible to foresee every emergency and rescue use of respirators for every kind of operation. Nevertheless, a wide variety of possible conditions requiring the emergency or rescue use of respirators can be envisioned and an adequate emergency and rescue respirator-response capability can be achieved through a serious effort to anticipate the worst possible consequences of particular malfunctions or mishaps.

The written standard operating procedures governing the emergency and rescue uses of respirators shall be developed in the following manner:

(1) An analysis of the emergency and rescue uses of respirators that may occur in each operation shall be made by careful consideration of materials, equipment, processes, and personnel involved. Such an analysis shall be reviewed by the person who is thoroughly familiar with the particular operation. Consideration shall be given to past occurrences requiring emergency or rescue uses of respirators as well as conditions which resulted in such respirator applications. The possible consequences of equipment or power failures, uncontrolled chemical reactions, fire, explosion, or human error shall be given consideration. All potential hazards which may result in emergency or rescue use of respirators shall be listed.

(2) Based upon the analysis, appropriate types of respirators shall be selected, an adequate number shall be provided for each area where they may be needed for emergency or rescue use, and these respirators shall be maintained and stored so that they are readily accessible and operational when needed.

7.2 **Training.** The supervisor, the person issuing respirators, and the respirator wearers shall be given adequate training by a qualified person(s) to ensure the proper use of respirators. Written records shall be kept of the names of persons trained and the dates when training occurred.

7.2.1 **Training of Supervisor.** A supervisor – that is, a person who has the responsibility of overseeing the work activities of one or more persons who must wear respirators – shall be given adequate training to ensure the proper use of respirators. Supervisor training shall include but shall not necessarily be limited to the following subjects:

(1) The basic respiratory-protection practices (see Section 3)

(2) The nature and extent of respiratory hazards to which persons under his supervision may be exposed (see Section 4 and 6.4 and 7.8)

(3) The principles and criteria of selecting respirators (see Sections 5 and 6)

(4) The training of respirator wearers (see 7.2.3)

(5) The issuance of respirators (see 7.2.2 and 7.5)

(6) The inspection of respirators (see 7.6 and 8.3)

(7) The use of respirators, including monitoring of use (see 7.3, 7.4, 7.7, 7.8, 7.9, and 9.)

(8) The maintenance and storage of respirators (see Section 8)

(9) The regulations concerning respirator use

7.2.2 **Training of Person Issuing Respirators.** A person assigned the task of issuing respirators to persons who must wear respirators for protection against harmful atmospheres shall be given adequate training to ensure that the correct respirator is issued for each application in accordance with written standard operating procedures. (See 7.5.)

7.2.3 **Training of Respirator Wearer.** To ensure the proper and safe use of a respirator, the minimum training of each respirator wearer shall include the following elements:

(1) The reasons for the need of respiratory protection (see 3.2)

(2) The nature, extent, and effects of respiratory hazards to which the person may be exposed (see Section 4 and 6.3)

(3) An explanation of why engineering controls are not being applied or are not adequate and of what effort is being made to reduce or eliminate the need for respirators (see 3.2)

(4) An explanation of why a particular type of respirator has been selected for a specific respiratory hazard (see Section 6)

(5) An explanation of the operation, and the capabilities and limitations, of the respirator selected (see Section 5 and 6.5 and 6.6)

(6) Instruction in inspecting, donning, checking the fit of, and wearing the respirator (see 7.2.3.1(1) and (2) and 7.4 and 7.6)

(7) An opportunity for each respirator wearer to handle the respirator, learn how to don and wear it properly, check its seals, wear it in a safe atmosphere, and wear it in a test atmosphere (see 7.2.3.1(3) and (4) and 7.4 and 7.6)

(8) An explanation of how maintenance and storage of the respirator is carried out (see Section 8)

(9) Instructions in how to recognize and cope with emergency situations (see 7.1.1)

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(10) Instructions as needed for special respirator use (see Section 9)

(11) Regulations concerning respirator use

7.2.3.1 **Wearing Instructions and Training.** Wearing instructions and training, including practice demonstrations, shall be given to each respirator wearer and shall cover:

(1) Donning, wearing, and removing the respirator

(2) Adjusting the respirator so that its respiratory-inlet covering is properly fitted on the wearer and so that the respirator causes a minimum of discomfort to the wearer

(3) Allowing the respirator wearer to wear the respirator in a safe atmosphere for an adequate period of time to ensure that the wearer is familiar with the operational characteristics of the respirator

(4) Providing the respirator wearer an opportunity to wear the respirator in a test atmosphere to demonstrate that the respirator provides protection to the wearer. A test atmosphere is any atmosphere in which the wearer can carry out activities simulating work movements and respirator leakage or respirator malfunction can be detected by the wearer.

7.2.3.2 **Retraining.** Each respirator wearer shall be retrained at least annually.

7.3 **Respirator Sealing Problems.** Respirators shall not be worn when conditions prevent a seal of the respirator to the wearer.

7.3.1 A person who has hair (stubble, moustache, sideburns, beard, low hairline, bangs) which passes between the face and the sealing surface of the facepiece of the respirator shall not be permitted to wear such a respirator.

7.3.2 A person who has hair (moustache, beard) which interferes with the function of a respirator valve(s) shall not be permitted to wear the respirator.

7.3.3 A spectacle which has temple bars or straps which pass between the sealing surface of a respirator full facepiece and the wearer's face shall not be used.

7.3.4 A head covering which passes between the sealing surface of a respirator facepiece and the wearer's face shall not be used.

7.3.5 The wearing of a spectacle, a goggle, a face shield, a welding helmet, or other eye and face protective device which interferes with the seal of a respirator to the wearer shall not be allowed.

7.3.6 If scars, hollow temples, excessively protruding cheekbones, deep creases in facial skin, the absence of teeth or dentures, or unusual facial configurations prevent a seal of a respirator facepiece to a wearer's face, the person shall not be permitted to wear the respirator.

7.3.7 If missing teeth or dentures prevent a seal of a respirator mouthpiece in a person's mouth, the person shall not be allowed to wear a respirator equipped with a mouthpiece.

7.3.8 If a person has a nose of a shape or size which prevents the closing of the nose by the nose clamp of a mouthpiece/nose-clamp type of respirator, the person shall not be permitted to wear this type of respirator.

7.4 **Respirator Sealing Tests.** To ensure proper protection, the wearer of a respirator equipped with a facepiece shall check the seal of the facepiece prior to each entry into a hazardous atmosphere. This may be done using procedures recommended by respirator manufacturers or by any of the field tests described in Appendix A7.

7.5 **Issuance of Respirators.** The proper respirator shall be specified for each application and shall be listed in the written standard operating procedures. If a respirator is marked for the worker to whom it is assigned or for other identification purposes, the markings shall not affect the respirator performance in any way.

7.6 **Respirator Inspection Prior to Use.** Each person issued a respirator for routine, nonroutine, emergency, or rescue use shall inspect the respirator prior to its use to ensure that it is in good operating condition.

7.7 **Monitoring Respirator Use.** The use of respirators on a routine or nonroutine basis shall be monitored to ensure that the correct respirators are being used, that the respirators are being worn properly and that the respirators being used are in good working condition.

7.8 **Monitoring Respiratory Hazard During Use.** The level of the respiratory hazard in the workplace to which a person wearing a respirator is exposed shall be monitored periodically. The time-weighted average concentration of the respiratory hazard shall be determined to ensure that the proper type of respirator is being utilized (see Appendix A8).

7.9 **Leaving a Hazardous Area.** A respirator wearer shall be permitted to leave the hazardous area for any respirator-related cause. Reasons which may cause a respirator wearer to leave a hazardous area include, but are not limited to, the following:

(1) Failure of the respirator to provide adequate protection

(2) Malfunction of the respirator

(3) Detection of leakage of air contaminant into the respirator

(4) Increase in resistance of respirator to breathing

(5) Severe discomfort in wearing the respirator

(6) Illness of respirator wearer, including: sensation of dizziness, nausea, weakness, breathing difficulty, coughing, sneezing, vomiting, fever, and chills

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8. Maintenance of Respirators

8.1 **General.** A program for the maintenance of respirators shall include the following:

(1) Cleaning and sanitizing
(2) Inspection for defects
(3) Repair
(4) Storage

Each respirator shall be properly maintained to retain its original shape and effectiveness.

8.2 **Cleaning and Sanitizing.** Each respirator shall be cleaned and sanitized to ensure that the respirator wearer is provided with a clean and sanitized respirator at all times. A respirator issued for other than continuous personal use by a particular worker, such as with routine, nonroutine, emergency, or rescue use, shall be cleaned and sanitized after each use.

8.3 **Inspection.** Each respirator shall be inspected routinely before and after use. A respirator shall be inspected by the user immediately prior to each use to ensure that it is in proper working condition.

After cleaning and sanitizing, each respirator shall be inspected to determine if it is in proper working condition, if it needs replacement of parts or repairs, or if it should be discarded. Each respirator stored for emergency or rescue use shall be inspected at least monthly. Respirator inspection shall include a check for tightness of connections; for the condition of the respiratory-inlet covering, head harness, valves, connecting tubes, harness assemblies, filters, cartridges, canisters, end-of-service-life indicator, and shelf life date(s); and for the proper function of regulators, alarms, and other warning systems.

Each rubber or other elastomeric part shall be inspected for pliability and signs of deterioration. Each air and oxygen cylinder shall be inspected to ensure that it is fully charged according to the manufacturer's instructions.

A record of inspection dates, findings, and remedial actions shall be kept for each respirator maintained for emergency or rescue use.

8.4 **Part Replacement and Repair.** Replacement of parts or repairs shall be done only by persons trained in proper respirator assembly and correction of possible respirator malfunctions and defects. Replacement parts shall be only those designed for the specific respirator being repaired. Reducing or admission valves, regulators, and alarms shall be returned to the manufacturer or to a trained technician for repair or adjustment. Instrumentation for valve, regulator, and alarm adjustments and tests must be approved by the valve, regulator, or alarm manufacturer.

8.5 **Storage.** Respirators shall be stored in a manner that will protect them against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals. Respirators shall be stored to prevent distortion of rubber or other elastomeric parts. Respirators shall not be stored in such places as lockers and tool boxes unless they are protected from contamination, distortion, and damage. Emergency and rescue-use respirators that are placed in work areas shall be quickly accessible at all times, and the storage cabinet or container in which they are stored shall be clearly marked.

9. Special Problems

9.1 **Vision.** When a respirator user must wear corrective lenses, a protective spectacle or goggle, a face shield, a welding helmet, or other eye and face protective device, the item shall be fitted to provide good vision and shall be worn in such a manner as not to interfere with the seal of the respirator to the wearer.

Temple bars or straps of a corrective spectacle which pass between the sealing surface of a respirator full facepiece and the respirator wearer's face may prevent a good seal of the facepiece to the face and therefore such a spectacle shall not be used when a respirator equipped with a full facepiece must be worn. As a temporary measure, a corrective spectacle with short temple bars that do not protrude between the sealing surface of a full facepiece and the respirator wearer's face may be taped to the respirator wearer's head. Special corrective lenses which are made to be mounted inside a full facepiece are available and should be used by a person who needs corrective lenses.

The wearing of contact lenses by persons who must wear a respirator equipped with a full facepiece, helmet, hood, or suit shall not be permitted.

9.2 **Communications.** Speech transmission while wearing a respirator is often necessary to perform specific tasks. Although a respirator facepiece distorts the human voice to some extent, the respirator's exhalation valve usually provides a pathway for some speech transmission over short distances in relatively quiet areas. However, talking while wearing a respirator equipped with a facepiece may adversely affect the seal of the facepiece, especially a quarter-mask or half-mask facepiece, to the wearer's face.

A mechanical speech-transmission device, called a speaking diaphragm, is an integral part of the facepiece in some respirators. It usually consists of a resonant cavity and diaphragm which transmit sound. The diaphragm also acts as a barrier to the ambient atmos-

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phere and thus should be handled carefully to prevent possible puncture which would permit leakage of an air contaminant into the respirator. Various methods of electronically transmitting and amplifying speech through the respirator are available. These utilize a microphone connected to a speaker, telephone, or radio transmitter. Usually, the microphone is mounted inside the respiratory-inlet covering, while the amplifier, power pack, and speaker or transmitter are attached to the exterior of the respiratory-inlet covering, carried on the body, or remotely located. Respirators with electronic speech-transmission devices having a battery power supply should be used with caution in explosive atmospheres. When an electronic speech-transmission device is used in underground mining, it shall be certified as complying with the Mine Safety and Health Administration's requirements for permissibility and intrinsic safety which are set forth in a document entitled Electric Motor-Driven Mine Equipment and Accessories, *Code of Federal Regulations*, Part 18, Chapter I, Subchapter D, Title 30 (formerly Bureau of Mines Schedule 2G). Sealed power sources shall be checked for integrity of the seals. Connecting cables from microphones inside the respiratory-inlet covering shall have gas-tight seals where they pass through the covering. When the speaker diaphragm is part of the barrier between the respirator wearer and the ambient atmosphere, it shall be frequently inspected for leakage and should be adequately protected from puncture or rupture. A microphone mounted on the respirator wearer's throat or head or a microphone/speaker worn in the respirator wearer's ear does not require penetration of a respirator facepiece by a cable.

9.3 Use of Respirators for Entry into Atmospheres Immediately Dangerous to Life or Health. When respirators are required for entry into atmospheres immediately dangerous to life or health, at least one standby person shall be present in a safe area. The standby person shall have the proper equipment available to assist the respirator wearers in case of emergency. Communications (visual, voice, signal-line, telephone, radio, or other suitable means) shall be maintained between the standby person and the respirator wearers. Respirator wearers in atmospheres immediately dangerous to life or health shall be equipped with safety harnesses and safety lines to permit them to be removed from the dangerous atmospheres to safe areas, if necessary; otherwise, equivalent provisions for the rescue of the respirator wearers from the dangerous atmospheres shall be used.

9.4 Respirator Use in Confined Spaces. All confined spaces shall be considered to be immediately dangerous to life or health unless proven otherwise. Before a person is allowed to enter a confined space, tests shall be carried out to determine the concentration of any known or expected flammable or toxic contaminant present and to determine the concentration of oxygen. A person shall not be allowed to enter a confined space without wearing the proper type of respirator. Even if the concentrations of air contaminants in a confined space are found to be below the established limits and sufficient oxygen is present (see "Oxygen Deficiency" in Table 1), the safest procedure is to continuously ventilate the enclosed space and to continuously monitor the concentration of air contaminants and of oxygen if persons are to work in the confined space.

An air-purifying respirator may be worn by a person in a confined space only if tests show that the atmosphere is not legally oxygen deficient (see Table 1 for minimum legal oxygen requirement) and only if tests show that the concentrations of air contaminants are not immediately dangerous to life or health. While a person is wearing an air-purifying respirator in a confined space, the level of respiratory hazards in the atmosphere of the confined space shall be monitored.

An air-line-type or hose-mask-type supplied-air respirator may be worn by a person in a confined space only if tests show that the atmosphere is not deficient in oxygen to a degree that would be immediately dangerous to life or health (see definitions in Section 2 for "oxygen deficiency – immediately dangerous to life or health" and "oxygen deficiency – not immediately dangerous to life or health") and only if tests show that concentrations of air contaminants are not immediately dangerous to life or health. While a person is wearing an air-line-type or hose-mask-type supplied-air respirator in a confined space, the level of respiratory hazards in the atmosphere of the confined space shall be monitored.

When the results of monitoring the atmosphere in a confined space, prior to entry of a person into the space, shows that the atmosphere is immediately dangerous to life or health [oxygen deficient or excessive concentration(s) of a contaminant(s) including concentration(s) of a substance(s) above the lower flammable limits], then a person who is required to enter the confined space shall wear either a positive-pressure self-contained breathing apparatus or a combination positive-pressure-air-line respirator with an auxiliary self-contained air supply. An oxygen-type open-circuit self-contained breathing apparatus shall not be worn in a confined space where the possibility of fire or explosion hazard is increased.

When respirators are used in a confined space, the provisions for a standby person given in 9.3 shall be carried out.

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9.5 Respirator Use in Low-Temperature Environments. A low-temperature environment may cause fogging of the lens in a respiratory-inlet covering and freezing or improper sealing, or both, of the exhalation valve. Coating the inside surface of the lens may prevent fogging at low atmospheric temperatures approaching 0°C (32°F), but severe fogging of the lens may occur at temperatures below −18°C (0°F). Full facepieces are available with nose cups that direct the warm and moist exhaled air through the exhalation valve without contacting the lens, and these facepieces should provide satisfactory vision at temperatures as low as −32°C (−25°F). At very low atmospheric temperatures, the exhalation valve of a respirator may freeze open or closed due to the presence of moisture. Dry respirable air should be used with an air-line respirator and with the type of self-contained breathing apparatus that employs a cylinder of air when these devices are used in a low-temperature atmosphere. The dew point of this breathing air should be appropriate to the temperature of the atmospheric air. High-pressure connections on self-contained breathing apparatus may leak because of metal contraction at low atmospheric temperature. These connections should not be overtightened, since they may break when the apparatus is returned to an atmosphere at normal room temperature. Some air-line-type supplied-air respirators may be equipped with a device called a vortex tube to warm the air supplied to the respirator-inlet covering of the respirator. Emergency-use respirators that are stored in low-temperature environments may require special elastomeric components that will retain their elasticity at low temperatures (regulator diaphragms, gaskets, and breathing tubes). Facepieces stored in low-temperature environments can become stiff and distorted to a degree that may prevent an adequate seal of the face to the facepiece. Special care shall be used to prevent distortion of facepieces stored at low temperatures. Some self-contained-breathing-apparatus models have cold-temperature accessories that may be utilized to help overcome these problems. The manufacturer's instructions shall be followed when utilizing these cold-temperature accessories.

9.6 Respirator Use in High-Temperature Environments. A person working in an atmosphere having a high temperature is under stress. Wearing a respirator in such an environment applies additional stress on the person. The additional stress due to the wearing of a respirator in a high-temperature environment should be minimized by using a respirator having a low weight and offering a low resistance to breathing. The air-line-type supplied-air respirator is recommended for use in a high-temperature environment. Air-line-type supplied-air respirators equipped with a vortex tube to cool the air supplied to the respiratory-inlet covering will substantially reduce the temperature of the air supplied to the respirator. Elastomeric components of respirators stored in high-temperature environments may deteriorate at an accelerated rate and the facepiece may become permanently distorted. Special care shall be used to prevent facepiece distortion. All such respirators shall be inspected and maintained at a frequency rate that will prevent the use of respirators with deteriorated elastomeric components.

10. Evaluation of Respirator Program Effectiveness

10.1 General. Periodic evaluation of the effectiveness of the respirator program is essential to ensure that persons are being provided with adequate respiratory protection. Improvement of the program and elimination of any deficiencies in the program cannot be carried out unless the program is appraised for effectiveness at periodic intervals. The effectiveness of the respirator program shall be evaluated at least annually and corrective action shall be taken to correct defects found in the program.

10.2 Wearer Acceptance. Wearer acceptance of respirators is an important matter to consider in evaluating the effectiveness of the respirator program. Respirator wearers shall be consulted periodically about their acceptance of wearing respirators. Numerous factors affect the acceptance of respirators. These factors include: comfort, resistance to breathing, fatigue, interference with vision, interference with communications, restriction of movement, interference with job performance, and confidence in the effectiveness of the respirator to provide adequate protection.

10.3 Inspection of Respirator Program Operation. Frequent inspection of the operation of the respirator program shall be conducted to ensure that proper types of respirators are selected, that respirator wearers are trained properly, that the correct respirators are issued and used, that respirators are worn properly, that respirators being used are in good operating condition, that respirators are inspected and maintained properly, that respirator storage is satisfactory, that respiratory hazards are monitored, and that medical and, when necessary, bioassay surveillance of respirator wearers is carried out.

10.4 Appraisal of Protection Afforded. Medical and, when necessary, bioassay surveillance of respirator wearers shall be conducted periodically to determine

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if respirator wearers are being provided with adequate respiratory protection. These data, when considered with the results of monitoring respiratory hazards, can serve as an indication of the degree of protection provided by the respirators and the effectiveness of the respirator program.

10.5 Evaluation. The results of investigating wearer acceptance of respirators, inspecting respirator program operation, and appraising protection provided by respirators shall be utilized to evaluate the effectiveness of the respirator program. Evidence of excessive exposure of respirator wearers to respiratory hazards shall be followed up by investigation to determine why inadequate respiratory protection was provided. Action shall be taken to correct any defects found in the respirator program. The findings of the respirator-program evaluation shall be documented, and this documentation shall list plans to correct faults in the program and target dates for the implementation of the plans.

11. References to Other Standards, Regulations, and Manuals

11.1 American National Standards Institute. When any of the following American National Standards is superseded by a revision approved by the American National Standards Institute, Inc, the revision shall apply.

(1) American National Standard Identification of Air-Purifying Respirator Canisters and Cartridges, ANSI K13.1-1973

(2) American National Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained, ANSI/CGA C-4-1954 (R1971)

(3) American National Standard Commodity Specification for Air, ANSI/CGA G-7.1-1973

(4) American National Standard Practice for Occupational and Educational Eye and Face Protection, ANSI Z87.1-1979

11.2 American Industrial Hygiene Association and American Conference of Governmental Industrial Hygienists

Respiratory Protective Devices Manual, 1963.

11.3 Compressed Gas Association

(1) Compressed Air for Human Respiration, Pamphlet G-7, 1976.

(2) Commodity Specification for Air, G-7.1, 1973.

11.4 National Fire Protection Association

(1) *Respiratory Protective Equipment for Fire Fighters,* NFPA 19B, 1971.

(2) *Breathing Apparatus for the Fire Service, A Fire Officer's Guide,* FSP-29B, 1975.

11.5 University of California, Los Alamos Scientific Laboratory

(1) Energy Research and Development Administration, Division of Safety, Standards and Compliance, Respirator Manual, LA-6370-M, August 1976.

(2) A Guide to Industrial Respiratory Protection, LA-6671-M, March 1977.

11.6 U.S. Department of the Interior, Bureau of Mines

(1) Schedule 13E, Self-Contained Breathing Apparatus, *Code of Federal Regulations,* Part 11, Chapter 1, Subchapter B, Title 30.

(2) Schedule 14F, Gas Masks, *Code of Federal Regulations,* Part 13, Chapter 1, Subchapter B, Title 30.

(3) Schedule 19B, Supplied-Air Respirator, *Code of Federal Regulations,* Part 14, Chapter 1, Subchapter B, Title 30.

(4) Schedule 21B, Filter-Type Dust, Fume and Mist Respirators, *Code of Federal Regulations,* Part 14, Chapter 1, Subchapter B, Title 30.

(5) Schedule 23B, Non-emergency Gas Respirators (Chemical Cartridge Respirators), *Code of Federal Regulations,* Part 14a, Chapter 1, Subchapter B, Title 30.

(6) Respiratory Protective Devices; Tests for Permissibility; Fees, *Code of Federal Regulations,* Part 11, Chapter 1, Subchapter B, Title 30.

(7) Information Circular 8559, Respirators Approved by the Bureau of Mines as of May 24, 1972.

11.7 U.S. Department of Health, Education, and Welfare, National Institute for Occupational Safety and Health

NIOSH Certified Personal Protective Equipment (February 1974 and supplements published periodically).

11.8 U.S. Department of Labor, Mine Safety and Health Administration

Electric Motor-Driven Mine Equipment and Accessories, *Code of Federal Regulations,* Part 18, Chapter 1, Subchapter D, Title 30 (formerly Bureau of Mines Schedule 2G).

11.9 U.S. Department of Labor, Occupational Safety and Health Administration

General Industry Safety and Health Standards, Part 1910, Title 29, *Code of Federal Regulations,* Subpart Z – Toxic and Hazardous Substances.

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11.10 U.S. Department of Transportation, Interstate Commerce Commission

Code of Federal Regulations, Title 49, Part 173, General Requirements for Shipments and Packagings, and Part 178, Shipping Container Specifications.

11.11 U.S. Nuclear Regulatory Commission, Office of Standards Development

Manual of Respiratory Protection Against Airborne Radioactive Materials, NUREG-0041, October 1976.

11.12 General Services Administration

(1) Federal Specification BB-A-1034a (June 21, 1968), Air, Compressed for Breathing Purposes.

(2) Interim Federal Specification GG-B-675d (September 23, 1976), Breathing Apparatus, Self-Contained.

11.13 U.S. Department of Defense

(1) Military Specification MIL-E-83252 (February 20, 1970), Emergency Oxygen Supply, Chlorate Candle, Aircraft CRU-74/P.

(2) Military Specification MIL-O-1563c (September 25, 1964), Oxides, Oxygen Producing.

11.14 Reference Books

(1) *Patty's Industrial Hygiene and Toxicology.* Volume I, Third Revised Edition. G. D. Clayton and F. E. Clayton (Editors), John Wiley and Sons, Incorporated, 1978.

(2) *Physiology of Respiration.* J. H. Comroe, Yearbook Medical Publishers Incorporated, 1965.

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Appendix

(This Appendix is not part of American National Standard Practices for Respiratory Protection, ANSI Z88.2-1980, but is included for information purposes only.)

A1. Approval Agencies

A1.1 Bureau of Mines (BM). The Bureau of Mines (BM), U.S. Department of Interior, tested and approved respirators from 1919 until 1972. Approvals were issued under the provisions of various schedules until May 25, 1972, the effective date of Title 30, *Code of Federal Regulations* (CFR), Part 11, "Respiratory Protective Devices; Tests for Permissibility; Fees." Title 30, CFR, Part 11 superseded and revoked the previous respirator approval schedules.

A1.2 National Institute for Occupational Safety and Health (NIOSH). Title 30, CFR, Part 11 gave jurisdiction for joint approval of respirators to the National Institute for Occupational Safety and Health (NIOSH), U.S. Department of Health, Education, and Welfare, and to the Bureau of Mines (BM), U.S. Department of the Interior.

A1.3 Mining Enforcement and Safety Administration (MESA). In 1974, a reorganization of the U.S. Department of the Interior resulted in the formation of the Mining Enforcement and Safety Administration (MESA), which assumed the health and safety activities of the Bureau of Mines (BM), including the respirator testing and approving functions. Subsequent respirator approvals were issued jointly by the National Institute for Occupational Safety and Health (NIOSH) and the Mining Enforcement and Safety Administration (MESA).

A1.4 Mine Safety and Health Administration (MSHA). The Federal Mine Safety and Health Amendments Act of 1977 transferred in March 1978 the authority for enforcement of mining safety and health from the U.S. Department of Interior to the U.S. Department of Labor. The act created in the U.S. Department of Labor the Mine Safety and Health Administration (MSHA) which replaced the Mining Enforcement and Safety Administration (MESA) of the U.S. Department of Interior. The Mine Safety and Health Administration (MSHA) has assumed the respirator testing and approving functions of the Mining Enforcement and Safety Administration (MESA). Respirator approvals are now issued jointly by the National Institute for Occupational Safety and Health (NIOSH) and the Mine Safety and Health Administration (MSHA).

A2. Status of Approved Respirators

The status of respirators approved under the provision of BM Schedules is different from the status of respirators approved under provisions of Title 30, CFR, Part 11. Amendments to Title 30, CFR, Part 11 published in the *Federal Register* on November 22, 1974 provide that:

(1) After June 30, 1975, respirators are approved for purchase and use if they have been approved jointly by MSHA (formerly BM and MESA) and NIOSH under provisions of Title 30, CFR, Part 11. However, gas masks which have been approved by the BM under provisions of BM Schedule 14F continue to be approved for purchase and use until further notice.

(2) Respirators, other than gas masks, which have been approved by the BM under provisions of certain BM Schedules, if purchased on or before June 30, 1975, and which are maintained in approved condition, shall be approved for use until the following dates; March 31, 1979 for self-contained breathing apparatus approved under provisions of BM schedules 13-13E; March 31, 1980 for supplied-air respirators approved under provisions of BM schedule 19B; March 31, 1976, for particulate-removing respirators approved under provisions of BM schedule 21B; March 31, 1976, for chemical-cartridge-type vapor- and gas-removing respirators approved under provisions of BM schedule 23B.

A3. Lists of Approved Respirators

Respirators approved by the BM under provisions of BM schedules were listed periodically through the years in BM information circulars. The last BM information circular listing approved respirators is IC-8559, "Respirators Approved by the Bureau of Mines as of May 24, 1972." Respirators approved jointly by NIOSH and MSHA under provisions of Title 30, CFR,

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Part 11 are listed in "NIOSH Certified Personal Protective Equipment." Supplements are issued periodically. Copies are available from:

Publications Dissemination, DTS
National Institute for Occupational Safety and Health
U.S. Department of Health, Education, and Welfare
4676 Columbia Parkway
Cincinnati, Ohio 45226

A4. Physiological and Psychological Limitations for Respirator Wearers

It is recommended that a physician determine if a person should or should not wear a respirator if the person has any of the following:

(1) Emphysema
(2) Chronic obstructive pulmonary disease
(3) Bronchial asthma
(4) X-ray evidence of pneumoconiosis
(5) Evidence of reduced pulmonary function
(6) Coronary artery disease or cerebral blood vessel disease
(7) Severe or progressive hypertension
(8) Epilepsy, grand mal or petit mal
(9) Anemia, pernicious
(10) Diabetes, insipidus or mellitus
(11) Punctured eardrum
(12) Pneumomediastinum gap
(13) Communication of sinus through upper jaw to oral cavity
(14) Breathing difficulty when wearing a respirator
(15) Claustrophobia or anxiety when wearing a respirator

A5. Suggested Procedures for Carrying Out Qualitative Respirator-Fitting Tests

A5.1 Irritant Smoke Test. The irritant smoke test can be used for both air-purifying respirators and atmosphere-supplying respirators. When an air-purifying respirator is tested, it should be equipped with a high-efficiency filter. The irritant smoke is produced by air flowing through a commercially available smoke tube normally used to check the performance of ventilation systems. Ventilation should be provided when carrying out a test to prevent contaminating the room where the test is carried out with smoke. The respirator wearer should keep his eyes closed during the test, even if the respirator offers eye protection. If the respirator wearer detects the penetration of the smoke into the respirator during the test, the wearer should be permitted to readjust the seal of the respirator. The test operator operates the smoke tube to direct smoke over the respirator, keeping the smoke tube about two feet from the respirator, and watches the reactions of the respirator wearer. If the respirator wearer does not detect penetration of smoke into the respirator, the test operator moves the smoke tube closer to the respirator and observes the reactions of the respirator wearer. When the smoke tube has been moved to within six inches of the respirator and the respirator wearer still has not detected penetration of smoke into the respirator, the smoke may be directed at potential points of leakage in the seal of the respirator to the wearer. If the respirator wearer still does not detect penetration of the smoke into the respirator, the wearer should carry out a series of exercises such as deep breathing, turning head from side to side, nodding head up and down, and talking while smoke is directed at the respirator. If the respirator wearer is unable to detect the penetration of smoke into the respirator, the wearer has achieved a satisfactory fit with the respirator.

A5.2 Odorous Vapor Test. The odorous vapor test can be used for both air-purifying respirators and atmosphere-supplying respirators. When an air-purifying respirator is tested, it should be equipped with a cartridge or canister which removes the test vapor from the air. An odorous material commonly used in the test is isoamyl acetate. If isoamyl acetate is employed as the test agent, an air-purifying respirator should be equipped with an organic vapor cartridge or canister. The simplest means of carrying out the test is to saturate a piece of fabric or sponge with liquid isoamyl acetate or to fill a stencil brush with liquid isoamyl acetate and then move the fabric, sponge, or stencil brush around the respirator worn by a person. The fabric, sponge, or stencil brush should be passed close to the potential points of leakage in the seal of the respirator while the wearer carries out exercises such as normal breathing, deep breathing, turning head from side to side, nodding head up and down, and talking. If the respirator wearer detects the odor of isoamyl acetate vapor during the test, the wearer should be permitted to readjust the seal of the respirator. If the respirator wearer is unable to detect the odor of isoamyl acetate vapor, the wearer has achieved a satisfactory fit with the respirator.

An improved qualitative respirator-fitting test using isoamyl acetate vapor as the test agent may be carried out using a hood, chamber, or room containing a known concentration of isoamyl acetate in the air. The

concentration of isoamyl acetate vapor in air commonly used is 100 parts per million by volume. The respirator wearer enters the enclosure containing the test atmosphere and carries out a series of exercises such as normal breathing, deep breathing, turning head from side to side, nodding head up and down, and talking. If the respirator wearer detects the odor of isoamyl acetate vapor during the test, the wearer should be permitted to readjust the seal of the respirator. If the respirator wearer is unable to detect the odor of isoamyl acetate vapor, the wearer has achieved a satisfactory fit with the respirator.

The use of isoamyl acetate vapor as a test agent has the following two major drawbacks: the odor threshold varies widely among persons, although most persons can detect by odor a concentration of isoamyl acetate vapor in air as low as 0.1 parts per million by volume; and olfactory fatigue may cause a person to fail to detect the odor of a low concentration of isoamyl acetate vapor in air. Before performing this test, all persons should be tested to determine their ability to sense the odor of isoamyl acetate vapor in air. Since the odorous vapor test is subjective, the validity of the test result depends on honest indication by the respirator wearer as to whether or not an odor was detected during the test.

A5.3 Other Qualitative Respirator-Fitting Tests. A stream of coal dust or talcum powder may be directed at the interface of a respirator facepiece with the wearer's face while the wearer carries out a series of exercises such as normal breathing, deep breathing, turning head from side to side, nodding head up and down, and talking. After removing the respirator facepiece from the wearer's face, any observation of coal dust or talcum powder on areas of the wearer's face which had been covered by the facepiece will indicate that the wearer did not obtain a satisfactory fit with the facepiece. A spray of fluorescein liquid particles may be directed at the interface of a respirator facepiece with the wearer's face while the wearer carries out a series of exercises such as normal breathing, deep breathing, turning head from side to side, nodding head up and down, and talking. After removing the respirator facepiece from the wearer's face, and with the wearer's eyes closed, ultraviolet light is directed at the wearer's face; any observation of fluorescein on areas of the wearer's face which had been covered by the facepiece will indicate that the wearer did not obtain a satisfactory fit with the facepiece. Negative-pressure and positive-pressure respirator sealing tests are not considered to be qualitative-type respirator-fitting tests, and these sealing tests should not be used for selecting specific makes and models of respirators for use by respirator wearers.

A6. Suggested Procedures for Carrying Out Quantitative Respirator-Fitting Tests

All quantitative respirator-fitting tests involve exposing the respirator wearer to a test atmosphere containing an easily detectable, relatively nontoxic aerosol, vapor, or gas as the test agent and then measuring the penetration of the test agent into the respirator. While wearing the respirator in the test atmosphere, the respirator wearer carries out a series of exercises simulating work movements. The respirator is equipped with a sampling probe which is connected by means of flexible tubing to an instrument which measures the penetration of the test agent into the respirator. Quantitative respirator-fitting tests can be used for both air-purifying respirators and atmosphere-supplying respirators. When carrying out a quantitative respirator-fitting test which uses an aerosol as the test agent, it is an acceptable procedure to equip an air-purifying respirator with a high-efficiency filter. When carrying out a quantitative respirator-fitting test which uses a vapor or gas as the test agent, it is an acceptable procedure to equip an air-purifying respirator with an appropriate cartridge or canister which removes the vapor or gas from the air.

A6.1 Exercises Carried Out by Respirator Wearers. A respirator wearer should carry out a series of exercises which stimulate work movements. The kinds of exercises carried out depend on the type of respirators. Each exercise should be carried out for at least two minutes.

The series of exercises for testing a respirator equipped with a facepiece should include but not be limited to the following:

(1) Normal breathing
(2) Deep breathing
(3) Turning head from side to side
(4) Nodding head up and down
(5) Talking
(6) Normal breathing

The series of exercises for testing a respirator equipped with a helmet, hood, or suit should include but not be limited to the following:

(1) Standing still, arms hanging downward along sides of body, normal breathing
(2) Bending forward and touching toes
(3) Raising arms above head and looking upward
(4) Bending knees and squatting
(5) Standing while holding a tubular rod about 76 centimeters in length with hands approximately 30 centimeters apart, twisting torso from side to side in an 180° arc, and slowly raising the arms from a downward direction to an upward direction having an angle of 45° with the horizontal plane

Table A1
Test Agents Suitable for
Carrying Out Quantitative Respirator-Fitting Tests

Test Agent	Concentration of Test Agent in Test Atmosphere	Particle Size if Test Agent is an Aerosol
Polydisperse sodium chloride aerosol	10–20 milligrams particulate matter per cubic meter of air	Mass median aerodynamic diameter of 0.5 to 0.7 micrometer with standard deviation of 2.0 to 2.4
Polydisperse DOP (dioctyl phthalate) aerosol	20–30 milligrams particulate matter per cubic meter of air	Mass median aerodynamic diameter of 0.5 to 0.7 micrometer with standard deviation of 2.0 to 2.4
Dichlorodi-fluoromethane (Freon 12) gas	250–1000 parts per million by volume	Not applicable

(6) Running in place

(7) Standing still, arms hanging downward along sides of body, normal breathing

A6.2 Test Atmospheres. Test atmospheres containing the test agents specified in Table A1 are suitable for carrying out quantitative respirator-fitting tests.

A6.3 Test Chambers. It is recommended that test chambers used to carry out quantitative respirator-fitting tests have the following characteristics:

(1) The design of the chamber and equipment used to generate the test atmosphere should ensure that the concentration of the test agent in the test atmosphere inside the chamber does not vary more than ±5% during a test.

(2) The design of the chamber and equipment used to disperse the test atmosphere in the chamber should ensure that the test agent is uniformly distributed in the test atmosphere throughout the chamber.

(3) The size of the chamber must permit a respirator wearer to carry out all of the designated exercises.

(4) The chamber should contain provisions to permit the test operator to visually observe the respirator wearer inside the chamber.

A6.4 Protection Factor Determination. The instrument which measures the penetration of the test agent into the respirator worn by a person in the test atmosphere should be connected to a fast-response recorder which records the penetration values. The average of the peaks of the penetration of the test agent into the respirator for each type of exercise carried out by the respirator wearer should be determined. The protection factor for a given make and model of respirator worn by a person in a test should be calculated by using the following equation:

$$\text{Protection factor} = \frac{100}{S/N}$$

where

S = The sum of average peak penetrations for all exercises (in percent)

N = The number of exercises

A7. Recommended Procedures for Field Testing the Seal of the Respirator to the Wearer

The seal of a respirator to a wearer can be tested in the field by procedures recommended by respirator manufacturers or by any of the following tests:

A7.1 Irritant or Odorous Test Agent. The person wearing a respirator is exposed to an irritant smoke, odorous isoamyl acetate vapor, or other suitable test agent easily detectable by irritation, odor, or taste (an air-purifying respirator must be equipped with the appropriate air-purifying element). If the respirator wearer is unable to detect the penetration of the test agent into the respirator, it can be reasonably assured that the seal of the respirator to the wearer is satisfactory.

A7.2 Negative-Pressure Sealing Test. A negative-air-pressure respirator sealing test can be used on air-purifying respirators equipped with tight-fitting respiratory-inlet coverings and on atmosphere-supplying respirators equipped with tight-fitting respiratory-inlet coverings and breathing tubes which can be squeezed

or blocked at the inlet to prevent the passage of air. This test may be difficult or impossible to carry out on valveless respirators. The inlet opening of the respirator's canister(s), cartridge(s), or filter(s) is closed off by covering with the palm of the hand(s), by replacing the inlet seal on a canister(s), or by squeezing a breathing tube or blocking its inlet so that it will not allow the passage of air. Then the wearer inhales gently and holds his breath for at least 10 seconds. If a facepiece collapses slightly and no inward leakage of air into the facepiece is detected, it can be reasonably assured that the fit of the respirator to the wearer is satisfactory. For a respirator equipped with a mouthpiece and nose clamp, if leakage of air into the nose or the mouth cannot be detected, then it can be reasonably assured that the fit of the respirator to the wearer is satisfactory.

A7.3 **Positive-Pressure Sealing Test.** A positive-air-pressure test can be used on respirators equipped with tight-fitting respiratory-inlet coverings which contain both inhalation and exhalation valves. This test may be difficult or impossible to carry out on valveless respirators. The exhalation valve or breathing tube, or both, is closed off and then the wearer exhales gently. The fit of a respirator equipped with a facepiece is considered to be satisfactory if a slight positive pressure can be built up inside the facepiece without the detection of any outward leakage of air between the sealing surface of the facepiece and the respirator wearer's face. The fit of a respirator equipped with a mouthpiece and nose-clamp is considered satisfactory if the respirator wearer senses a buildup of positive pressure and is unable to detect any outward leakage of air through the nose and in the area between the mouth and the mouthpiece. For some respirators, this test method requires that the respirator wearer first remove an exhalation cover from the respirator and then replace it after completion of the test. These tasks often are difficult to carry out without disturbing the fit of the respirator to the wearer.

A7.4 **Warning Concerning Negative-Pressure and Positive-Pressure Sealing Tests.** Care must be taken in carrying out a negative-pressure or positive-pressure sealing test; otherwise, the results of the sealing test may be unreliable. Thorough training in carrying out these tests should be given to respirator wearers.

A8. Monitoring of Respiratory Hazards

The intensity of potential exposures and actual exposure of respirator wearers to respiratory hazards is determined by using instruments to measure the concentrations of air contaminants or oxygen in the breathing zone of the respirator wearers. Adequate air sampling and analysis or appropriate calculations should be carried out to determine both the time-weighted average concentration and the peak concentration of the respiratory hazard to which a respirator wearer may be potentially exposed or is actually exposed. Concentrations of a substance causing a respiratory hazard should be determined during the work shift in order to accurately define both the time-weighted average concentration and the peak concentration of the substance. The concentrations of a substance in air may be affected by changes in process operation, changes in rate and direction of air movement, changes in temperature from day to night operation, and changes in seasons; these factors should be taken into account in carrying out a program of monitoring respiratory hazards.

It is essential that the volume of air sampled during a sampling test contain a sufficient quantity of the hazardous substance for accurate determination of the concentration of the substance in the workplace atmosphere. The volume of air to be sampled or the duration of the air-sampling period depends upon the following factors:

(1) Estimated concentration of the substance in air

(2) Sensitivity of the sampling instrument and sampling procedures

(3) Established permitted time-weighted average concentration and established permitted peak concentration for the substance in air

Although it is recognized that the concentration of a hazardous substance which occurs during an emergency cannot always be measured or calculated, every reasonable effort should be made to estimate what this concentration would be.

Consideration should be given to the use of a continuously operating air monitor and alarm to alert respirator wearers when a high concentration of a hazardous substance suddenly occurs.

A9. Recommended Procedures for Cleaning and Sanitizing Respirators

Recommended procedures for cleaning and sanitizing respirators are as follows:

(1) Remove, when necessary, the following components of respiratory-inlet covering assemblies before cleaning and sanitizing:

(a) Filters, cartridges, canisters

(b) Speaking diaphragms

(c) Demand and pressure-demand valve assemblies

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(d) Any components recommended by the respirator manufacturers

(2) Wash respiratory-inlet covering assemblies in warm (49°C or 120°F maximum temperature) cleaner-sanitizer solution. A stiff bristle (not wire) brush may be used to facilitate removal of dirt or other foreign material.

(3) Rinse respiratory-inlet covering assemblies in clean, warm (49°C or 120°F maximum temperature) water.

(4) Drain all water and air-dry the respiratory-inlet covering assemblies.

(5) Clean and sanitize all parts removed from respiratory-inlet covering as recommended by the manufacturers.

(6) Hand wipe respiratory-inlet covering assemblies, all parts, and all gasket and valve sealing surfaces with damp, lint-free cloth as needed to remove water residues and all foreign materials.

(7) Inspect parts and replace any which are defective.

(8) Reassemble parts on respiratory-inlet covering assemblies.

(9) Attach new filters, cartridges, and canisters to respiratory-inlet coverings.

(10) Visually inspect and, where possible, test parts and respirator assemblies for proper function.

(11) Place assembled respirators in appropriate containers for storage.

Machines may be used to expedite the cleaning, sanitizing, rinsing, and drying of large numbers of respirators. Extreme care must be taken to ensure against tumbling, agitation, or exposure to temperatures above those recommended by the manufacturer (normally 49°C or 120°F maximum), as these conditions are likely to result in damage to the respirators. Ultrasonic cleaners, clothes-washing machines, dishwashers, and clothes dryers have been specially adapted and successfully used for cleaning and drying respirators.

Cleaner-sanitizers that effectively clean the respirator and contain a bactericidal agent are commercially available. The bactericidal agent frequently used is a quaternary ammonium compound.

Strong cleaning and sanitizing agents and many solvents can damage rubber or elastomeric respirator parts. These materials must be used with caution.

Alternatively, respirators may be washed in a detergent solution and then sanitized by immersion in a sanitizing solution. Some sanitizing solutions which have proven effective are: (1) a hypochlorite solution (50 parts per million chlorine), 2-minute immersion; (2) an aqueous iodine solution (50 parts per million of iodine), 2-minute immersion; or (3) a quaternary ammonium solution (200 parts per million of quaternary ammonium compounds in water with less than 500 parts per million total hardness), 2-minute immersion.

Different concentrations of quaternary ammonium salts are required to achieve a sanitizing solution with waters of varying hardness. Inflammation of the skin of the respirator user (dermatitis) may occur if the quaternary ammonium compounds are not completely rinsed from the respirator. The hypochlorite and iodine solutions are unstable and break down as time progresses; they may cause deterioration of rubber or other elastomeric parts and may be corrosive to metallic parts. Immersion times should not be extended beyond the mentioned time periods, and the sanitizers must be thoroughly rinsed from the respirator parts.

Respirators may become contaminated with toxic materials. If the contamination is light, normal cleaning procedures should provide satisfactory decontamination; otherwise separate decontamination steps may be required before cleaning.

A10. Oxygen Deficiency – Immediately Dangerous to Life or Health

An atmosphere which causes an oxygen partial pressure of 100 millimeters of mercury column or less in the freshly inspired air in the upper portion of the lungs which is saturated with water vapor is classified as "oxygen deficiency – immediately dangerous to life or health." The rationale for this classification is that an oxygen partial pressure of 100 millimeters of mercury column in the freshly inspired air in the upper portion of the lungs, which is saturated with water vapor, corresponds to an oxygen partial pressure of 60 millimeters of mercury column in the alveoli of the lungs with a carbon dioxide partial pressure of 40 millimeters of mercury column is present in the alveoli of the lungs, and at these alveolar conditions the hemoglobin of the alveolar blood is 90% saturated with oxygen. When the oxygen content of the hemoglobin of the alveolar blood drops below 90% saturation, oxygen-deficiency symptoms become noticeable. Further details concerning oxygen deficiency will be found on pages 16 to 18 of "A Guide to Industrial Respiratory Protection," LA-6677-M, published by the Los Alamos Scientific Laboratory; on pages 140-148 of Volume I of "Patty's Industrial Hygiene and Toxicology," published by John Wiley and Sons, Incorporated, 1978; and in "Physiology of Respiration," published by Yearbook Medical Publishers Incorporated, 1965.

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The oxygen partial pressure in the freshly inspired air in the upper portion of the lungs which is saturated with water vapor is calculated using the following equation:

Partial pressure of oxygen in freshly inspired air in upper portion of lungs in units of millimeters of mercury column =

$$\left(\begin{array}{l}\text{Atmospheric air pressure in units of millimeters of mercury column}\end{array} - \begin{array}{l}\text{47.0 millimeters of mercury column}\end{array}\right) \times \begin{array}{l}\text{Decimal fraction by volume of oxygen in atmospheric air in workplace}\end{array}$$

NOTE: 47.0 millimeters of mercury column is the partial pressure of water vapor in the air in the upper portion of the lungs which is saturated with water vapor. The concentration of oxygen in normal atmospheric air is 20.95% by volume.

Examples of calculations:

(1) Determine the partial pressure of oxygen in the upper portion of the lungs of a person in a workplace at sea level when the atmospheric air in the workplace has a normal oxygen concentration.

The atmospheric air pressure at sea level is 760.0 millimeters of mercury column.

The concentration of oxygen in normal atmospheric air is 20.95% by volume.

Partial pressure of oxygen in freshly inspired air in upper portion of lungs =

$(760.0 - 47.0) \times 0.2095 =$ 149.37 millimeters of mercury column

(2) Determine the partial pressure of oxygen in the upper portion of the lungs of a person in a workplace at an altitude of 5000 feet above sea level when the atmospheric air has a normal oxygen concentration.

The atmospheric air pressure at an altitude of 5000 feet above sea level is 632.7 millimeters of mercury column.

The concentration of oxygen in normal atmospheric air is 20.95% by volume.

Partial pressure of oxygen in freshly inspired air in upper portion of lungs =

$(632.7 - 47.0) \times 0.2095 =$ 122.7 millimeters of mercury column

(3) Determine the partial pressure of oxygen in the upper portion of the lungs of a person in a workplace at an altitude of 10 000 feet above sea level when the atmospheric air has a normal oxygen concentration.

The atmospheric air pressure at an altitude of 10 000 feet above sea level is 522.7 millimeters of mercury column.

The concentration of oxygen in normal atmospheric air is 20.95% by volume.

Partial pressure of oxygen in freshly inspired air in upper portion of lungs =

$(522.7 - 47.0) \times 0.2095 =$ 99.66 millimeters of mercury column

(4) Determine the partial pressure of oxygen in the upper portion of the lungs of a person in a workplace at sea level when the concentration of oxygen in the atmospheric air in the workplace is 14.0% by volume.

The atmospheric air pressure at sea level is 760.0 millimeters of mercury column.

The concentration of oxygen in the atmospheric air in the workplace is 14.0% by volume.

Partial pressure of oxygen in freshly inspired air in upper portion of lungs =

$(760.0 - 47.0) \times 0.14 =$ 99.82 millimeters of mercury column

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