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Standard Practice for Respiratory Protection[1]

This standard is issued under the fixed designation F3387; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice sets forth minimally accepted practices for occupational respirator use; provides information and guidance on the proper selection, use, and maintenance of respirators; and contains requirements for establishing, implementing, and evaluating respirator programs.

1.2 This practice covers the use of respirators to protect persons against the inhalation of harmful air contaminants and oxygen-deficient atmospheres in the workplace. The following are not covered by this practice:

1.2.1 Underwater breathing devices,

1.2.2 Aircraft oxygen systems,

1.2.3 Supplied-air suits,

1.2.4 Use of respirators under military combat conditions, and

1.2.5 Medical inhalators and resuscitators.

1.3 *Units*—The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ANSI Standards:*[2]

ANSI/ASSE Z117.1 Safety Requirements for Entering Confined Spaces

ANSI/ASSE Z88.2 Practices for Respiratory Protection

ANSI Z88.6 Respiratory Protection—Respirator Use—Physical Qualifications for Personnel

ANSI Z88.10 Respirator Fit Testing Methods

2.2 *CAN/CSA Standards:*[3]

CAN/CSA Z94.4 Selection, Use, and Care of Respirators

CAN/CSA Z180.1 Compressed Breathing Air and Systems

2.3 *CGA Standards:*[4]

CGA C-7 Guide to Classification and Labeling of Compressed Gases

CGA G-7.1 Commodity Specification for Air

2.4 *NFPA Standards:*[5]

NFPA 1851 Standard on Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting

NFPA 1981 Standard on Open-Circuit Self-Contained Breathing Apparatus (SCBA) for Emergency Services

2.5 *Federal Standards:*[6]

29 CFR Part 1910.134 Respiratory Protection

29 CFR Part 1910.146 Permit-Required Confined Spaces

42 CFR Part 84 Respiratory Protective Devices

49 CFR Part 180 Continuing Qualification and Maintenance of Packagings

3. Terminology

3.1 *Definitions:*

3.1.1 *abrasive blasting respirator, n*—airline respirator designed to protect the wearer from inhalation of, impact of, and abrasion by materials used or generated in abrasive blasting.

3.1.2 *aerodynamic diameter, n*—diameter of a unit density sphere having the same terminal settling velocity as the particle in question.

3.1.3 *aerosol, n*—particles, solid or liquid, suspended in air (for example, dust, fumes, mists, or fibers).

[1] This practice is under the jurisdiction of ASTM Committee F23 on Personal Protective Clothing and Equipment and is the direct responsibility of Subcommittee F23.65 on Respiratory.

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

[3] Available from Canadian Standards Association (CSA), 178 Rexdale Blvd., Toronto, ON M9W 1R3, Canada, http://www.csagroup.org.

[4] Available from Compressed Gas Association (CGA), 14501 George Carter Way, Suite 103, Chantilly, VA 20151, http://www.cganet.com.

[5] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[6] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

3.1.4 *airline respirator (supplied-air respirator, SAR), n*—atmosphere-supplying respirator in which the respirable air is supplied from a hose or breathing tube rather than being carried by the wearer.

3.1.5 *air-purifying respirator, n*—respirator in which ambient air is passed through an air-purifying element by either inhalation or by means of a blower.

3.1.6 *ambient air pump, n*—motorized blower used to supply air to a continuous-flow airline respirator.

3.1.7 *approved, v*—respirator for which a formal certificate was issued by the National Institute for Occupational Safety and Health (NIOSH) or by NIOSH and the Mine Safety and Health Administration (MSHA) in accordance with 42 CFR Part 84 and is maintained in full compliance with the certificate.

3.1.8 *assigned protection factor, APF, n*—minimum expected workplace level of respiratory protection that would be provided by a properly functioning and used respirator or a class of respirators to properly fitted and trained wearers when all elements of an effective respirator program are established and being implemented.

3.1.9 *atmosphere-supplying respirator, ASR*—class of respirators that supply a respirable atmosphere independent of the workplace atmosphere.

3.1.9.1 *Discussion*—This class includes airline respirators and self-contained breathing apparatus (SCBA).

3.1.10 *bioaerosol, n*—liquid droplet (generated, for example, by coughing, sneezing) or a solid particle (generated, for example, by sweeping, shoveling) suspended in the air that is living or originates from living organisms.

3.1.10.1 *Discussion*—Bioaerosols include living or dead microorganisms, fragments, toxins, and particulate waste products from all varieties of living things. They are capable of causing infection and an adverse or allergic response potentially leading to disease. Individual bioaerosols most often range in size from 0.4 to 3937 µin. (0.01 to 100 µm) in diameter.

3.1.11 *biomonitoring, v*—determination of the concentration of a substance in biological fluids or tissue and used for occupational exposure surveillance.

3.1.12 *canister (air purifying), n*—container with (*1*) gas- and vapor-removing sorbent or catalyst, or (*2*) gas- and vapor-removing sorbent or catalyst that removes gases and vapors and filter that removes particles from inspired air (or air drawn through the unit).

3.1.12.1 *Discussion*—Typically attached to a full-face piece, either mounted directly to the chin or connected to a breathing tube so the canister may be worn in the front or back of the person. Respirators with air-purifying canisters are approved by NIOSH as gas masks and contain an approval number TC-14G-xxxx.

3.1.13 *canister (carbon dioxide scrubbing), n*—container filled with a chemical used to remove carbon dioxide from exhaled air before that air is rebreathed in a closed-circuit SCBA.

3.1.14 *canister (oxygen generating), n*—container filled with a chemical that generates oxygen by chemical reaction used in closed-circuit SCBA.

3.1.15 *cartridge, n*—small container filled with sorbents or catalysts that remove gases and vapors from the inspired air.

3.1.15.1 *Discussion*—The cartridge may also have particulate filters that are an integral part or ones that are replaceable.

3.1.16 *ceiling limit, n*—maximum allowable concentration of an airborne contaminant that shall not be exceeded at any time.

3.1.17 *certified, v*—see *approved*.

3.1.18 *change schedule, n*—time interval after which a used filter, cartridge, or canister is replaced with a new one.

3.1.19 *confined space, n*—enclosed space not designed for human occupancy that has the following characteristics: restricted entry and exit, primary function is something other than human occupancy, and contains potential or known respiratory hazards.

3.1.19.1 *Discussion*—Examples of confined spaces include, but are not limited to: tanks, silos, vessels, pits, sewers, pipelines, tank cars, boilers, septic tanks, and utility vaults. See 29 CFR 1910.146 and ANSI/ASSE Z117.1 for more details on permit-required confined spaces.

3.1.20 *contaminant, n*—potentially harmful, irritating, or nuisance airborne material.

3.1.21 *continuous-flow respirator*—atmosphere-supplying respirator that provides a continuous flow of respirable air to the respiratory inlet covering.

3.1.22 *demand respirator, n*—atmosphere-supplying respirator that admits respirable air to the respiratory inlet covering only when a negative pressure is created inside the respiratory inlet covering by inhalation.

3.1.23 *dust, n*—aerosol consisting of mechanically produced solid particles derived from the breaking up of larger particles.

3.1.24 *end-of-service-life indicator, ESLI, n*—system or device that warns the wearer of the approach of the end of adequate respiratory protection.

3.1.25 *escape-only respirator, n*—respirator intended only for use during emergency egress from a hazardous atmosphere.

3.1.26 *filter, n*—material used in air-purifying respirators to remove solid or liquid aerosols from inspired air; some filters are encapsulated in a container and some are not.

3.1.26.1 *HE filter, n*—NIOSH classification for a 99.97 % efficiency filter used in a powered air-purifying respirator (PAPR) that is effective against all particulate aerosols.

3.1.26.2 *N-series particulate filter, n*—NIOSH classification for particulate filters effective against particulate aerosols free of oil; time-use restrictions may apply.

3.1.26.3 *P-series particulate filter, n*—NIOSH classification for particulate filter effective against all particulate aerosols.

3.1.26.4 *R-series particulate filter, n*—NIOSH classification for particulate filter effective against all particulate aerosols; time-use restrictions may apply.

3.1.26.5 *Discussion*—N-, R-, and P-series particulate filters

are tested at 99.97, 99, and 95 % efficiency levels, referred to as Classes 100, 99, and 95, respectively.

3.1.27 *filtering face piece, n*—negative-pressure respirator in which the filter is an integral part of the face piece or comprises the entire face piece.

3.1.28 *fit factor, n*—numeric expression of how well a tight-fitting respirator fits a wearer during a quantitative fit test, and it is the ratio of the measured challenge agent concentration outside the respirator (C_{out}) to its concentration inside the respirator (C_{in}).

$$\text{Fit factor} = C_{out} / C_{in} \quad (1)$$

3.1.28.1 *Discussion*—A fit factor resulting from a qualitative fit test has been validated to 100 (Annex A5).

3.1.29 *fit test, n*—use of a qualitative or quantitative protocol to evaluate sealing surface leakage of a specific tight-fitting respirator while worn by an individual.

3.1.30 *fume, n*—aerosols formed by condensation of a vaporized solid.

3.1.31 *gas, n*—fluid that has neither an independent shape nor volume and tends to expand indefinitely.

3.1.31.1 *Discussion*—In contrast, liquids have independent volume but not independent shape.

3.1.32 *hazard ratio, n*—number obtained by dividing the concentration of a contaminant by its occupational exposure limit.

3.1.33 *hazardous atmosphere, n*—atmosphere that contains a contaminant(s) in excess of the occupational exposure limit or is oxygen deficient.

3.1.34 *helmet, n*—hood that offers head protection to the wearer against impact and penetration.

3.1.35 *high-efficiency particulate air (HEPA) filter, n*—HEPA filters are considered N100, R100, P100, and HE.

3.1.35.1 *Discussion*—P100 and HE filters are identified with a magenta color.

3.1.36 *hood, n*—tight- or loose-fitting respiratory inlet covering that completely covers the head and neck and may cover portions of the shoulders.

3.1.37 *immediately dangerous to life or health, IDLH, n*—any atmosphere that poses an immediate hazard to life or immediate irreversible debilitating effects on health.

3.1.38 *loose-fitting face piece, n*—respiratory inlet covering that is designed to form a partial seal with the face, does not cover the neck and shoulders, and may or may not offer head protection against impact and penetration.

3.1.39 *mass median aerodynamic diameter, MMAD, n*—calculated aerodynamic diameter that divides the aerosol particles based on the weight of the particles.

3.1.39.1 *Discussion*—By weight, 50 % of the particles will be larger than the MMAD and 50 % of the particles will be smaller than the MMAD.

3.1.40 *maximum use concentration, MUC, n*—maximum atmospheric concentration of a hazardous substance from which a wearer can be expected to be protected when wearing a respirator and is frequently determined by the assigned protection factor of the respirator or class of respirators and the exposure limit of the hazardous substance.

3.1.40.1 *Discussion*—The MUC can frequently be determined mathematically by multiplying the assigned protection factor specified for a respirator by the required time-weighted average occupational exposure limit (OEL), short-term exposure limit, or ceiling limit. When no OEL is available for a hazardous substance, an employer shall determine a MUC on the basis of relevant available information and informed professional judgment.

3.1.41 *mist, n*—aerosol composed of liquid droplets produced either mechanically or by condensation of vaporized liquid.

3.1.42 *mouthpiece and nose clamp assembly, n*—respiratory inlet covering that is held in the wearer's mouth and shall always be used in conjunction with a nose clamp.

3.1.43 *negative-pressure respirator, n*—respirator in which the air pressure inside the respiratory inlet covering is negative during inhalation with respect to the ambient air pressure.

3.1.44 *occupational exposure limit, OEL, n*—maximum allowable concentration of a contaminant in the air to which an individual may be exposed over a period of time.

3.1.44.1 *Discussion*—Commonly used OELs include Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) and ACGIH® threshold limit values (TLVs®).[7] These may be time-weighted averages, short-term limits, or ceiling limits.

3.1.45 *physician or other licensed healthcare professional, PLHCP, n*—individual whose legally permitted scope of practice (that is, license, registration, or certification) allows them to independently provide, or be delegated the responsibility to provide, some or all of the healthcare services required by 29 CFR 1910.134(e).

3.1.46 *positive-pressure respirator, n*—respirator in which the pressure inside the respiratory inlet covering is normally positive with respect to ambient air pressure (Annex A6).

3.1.47 *powered air-purifying respirator, PAPR, n*—air-purifying respirator that uses a blower to move the ambient atmosphere through air-purifying elements into the respiratory inlet covering.

3.1.48 *pressure-demand respirator, n*—atmosphere-supplying respirator in which the pressure inside the respiratory inlet covering, in relation to the pressure surrounding the outside of the respiratory inlet covering, is positive during both inhalation and exhalation.

3.1.49 *qualitative fit test, QLFT, n*—pass/fail fit test that relies on the subject's sensory response to detect a challenge agent.

3.1.50 *quantitative fit test, QNFT, n*—fit test that uses an instrument to measure face seal leakage.

3.1.51 *required fit factor, RFF, n*—numeric value established as pass/fail point or acceptance criterion for a quantitative fit test.

[7] ACGIH® and TLVs® are registered trademarks of the American Conference of Governmental Industrial Hygienists.

3.1.52 *respirator, n*—personal protective equipment (PPE) designed to protect the wearer from inhalation of hazardous atmospheres.

3.1.53 *respirator manufacturer, n*—entity that designs or manufactures (or both) a respirator, or has a respirator designed or manufactured (or both) for them under their name or trademark.

3.1.54 *respirator user instructions, n*—instructions and information provided by the respirator manufacturer.

3.1.55 *respiratory inlet covering, n*—that portion of a respirator that connects the wearer's respiratory tract to an air- or atmosphere-supplying respirator.

3.1.55.1 *Discussion*—They may be either tight fitting or loose fitting in design. It may be a face piece, helmet, hood, or mouthpiece/nose clamp.

3.1.56 *self-contained breathing apparatus, SCBA, n*—atmosphere-supplying respirator in which the respirable gas source is designed to be carried by the wearer.

3.1.57 *service life, n*—period of time that a respirator provides adequate protection to the wearer.

3.1.58 *shall, v*—denoting a mandatory requirement.

3.1.59 *should, v*—denotes a recommendation.

3.1.60 *sorbent, n*—material that removes specific gases and vapors from the inhaled air.

3.1.61 *supplied-air respirator, n*—see *airline respirator*.

3.1.62 *tight-fitting respiratory inlet covering, n*—respirator component designed to form a complete seal with the face or neck.

3.1.62.1 *Discussion*—A half-face piece (includes quarter-masks, filtering face piece, and half-face piece with elastomeric face pieces) covers the nose and mouth; a full-face piece covers the nose, mouth, and eyes. Tight-fitting hoods seal at the neck.

3.1.63 *user, n*—person or organization who makes use of the respirator; for example, one involved in selecting, maintaining, or wearing the respirator.

3.1.64 *vapor, n*—gaseous phase of matter that normally exists in a liquid or solid state at room temperature and pressure.

3.1.65 *wearer, n*—person who wears the respirator.

3.1.66 *wearer seal check (namely, user seal check), n*—procedure conducted by the wearer to determine if a tight-fitting respirator is properly donned; see Section 11.

3.1.67 *written record, n*—documentation, either paper or electronic, of any record-keeping requirements and details of the respirator program.

4. Significance and Use

4.1 The purpose of this practice is to provide information and guidance on the proper selection, use, and maintenance of respirators, which will help safeguard the life and health of respirator wearers. This practice is written for all persons concerned with respiratory protection, but especially for those primarily responsible for establishing and administering an acceptable respirator program. This practice contains requirements recommended for enforcement authorities in establishing regulations or codes for respiratory protection use.

4.2 *Exceptions*—Users of this practice shall be aware that regulatory agencies may have requirements that are different from this practice.

5. Respirator Program Requirements

5.1 *Purpose*—This section establishes requirements for using respirators in the workplace. The following requirements are supplemented by recommended practices in subsequent sections of this practice.

5.2 *Permissible Practice*—In the control of those occupational diseases or injuries caused by breathing contaminated air or oxygen-deficient atmospheres, the primary objective shall be to minimize the workplace exposure. 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 implemented or evaluated, appropriate respirators shall be used according to the requirements of this practice.

5.3 *Employer Responsibility:*

5.3.1 The employer shall select approved respirators according to the airborne hazards likely to be encountered in the workplace and provide them at no cost to the employee. The selection process shall include workplace and user factors that are specific and unique to each workplace.

5.3.2 The employer shall be responsible for establishing and maintaining a respirator program that shall include the requirements outlined in 5.5.

5.3.3 The employer shall allow a respirator wearer to leave the hazardous atmosphere for any respirator-related cause. Reasons may include, but are not limited to:

5.3.3.1 Respirator fails to provide adequate protection;

5.3.3.2 Respirator malfunction;

5.3.3.3 Detecting air-contaminant leakage into the respirator;

5.3.3.4 Increased breathing resistance;

5.3.3.5 Unusual discomfort in wearing the respirator;

5.3.3.6 Illness of the respirator wearer, including sensation of dizziness, nausea, and weakness;

5.3.3.7 Breathing difficulty, coughing, sneezing, vomiting, fever, and chills;

5.3.3.8 To wash their face and the respirator face piece to minimize skin irritation;

5.3.3.9 To change the air-purifying elements or other components whenever needed; and

5.3.3.10 When the respirator reaches the limits of its service life.

5.3.4 The employer shall investigate malfunctions of respirators to determine the cause and ensure corrective measures are taken. Suspected manufacturing defects should be reported to the manufacturer and the certifying agency.

5.3.5 The employer shall use a respirator equipped with an end-of-service-life indicator or establish a change schedule for

filters, cartridges, and canisters. Guidance for determining a change schedule is contained in Annex A1.

5.3.6 The employer shall train the wearer in the proper and effective use of the provided respirators, including the proper egress from the hazardous environment before the end of service is reached and during failures of the respirator according to Section 9.

5.3.7 For all tight-fitting respirators, the employer shall ensure that employees perform a wearer seal check each time they put on the respirator using the procedures described in Section 11. Either the positive or negative pressure checks according to the respirator manufacturer's recommended wearer seal check method shall be used. Wearer seal checks are not substitutes for qualitative or quantitative fit tests.

5.4 *Wearer Responsibility:*

5.4.1 The wearer shall use the provided respirator in accordance with instructions and training received.

5.4.2 The wearer shall guard against damage to the respirator.

5.4.3 The wearer shall immediately leave the contaminated area according to established procedures if the wearer detects contaminant by odor, taste, or irritation; an ESLI indicates end of cartridge service life; or a respirator malfunction occurs. The wearer shall also immediately report the situation to the person designated by the employer in the written standard operating procedures (SOP).

5.4.4 The wearer shall report to the person designated by the employer in the written SOP any physical or medical condition that could impair the ability to wear a respirator properly.

5.4.5 The wearer who uses a tight-fitting respirator shall perform a wearer seal check to ensure that an adequate seal is achieved each time the respirator is worn.

5.5 *Minimal Acceptable Respirator Program Elements:*

5.5.1 *Program Administration*—Responsibility and authority for the respirator program shall be assigned to a single person (Section 6). That person shall be identified to all respirator wearers as the respirator program administrator in the written SOP.

5.5.2 *SOP*—Written SOP covering the complete respirator program shall be established and implemented (Section 7).

5.5.3 *Medical Evaluation*—A physician or other licensed healthcare professional (PLHCP) shall determine whether or not an employee has any medical conditions that would preclude the use of respirators, limitations on use, or other restrictions.

5.5.3.1 The program administrator shall advise the PLHCP of the following conditions to aid in determining the medical evaluation required:

(1) Type and weight of the respirator to be used by the employee;

(2) Duration and frequency of respirator use (including use for rescue and escape), typical work activities, and environmental conditions (for example, temperature and humidity extremes);

(3) Hazards for which the respirator will be worn, including potential exposure to reduced-oxygen environments; and

(4) Additional protective clothing and equipment to be worn.

5.5.3.2 Written records of medical evaluations shall be secured and maintained as medical records.

5.5.3.3 For additional information on medical evaluations, refer to ANSI Z88.6.

5.5.4 *Respirator Selection*—The selection of the proper type(s) of respirator(s) shall be based upon their capabilities, limitations, and respiratory hazards (Section 8).

5.5.5 *Training*—Each respirator wearer shall be given training and retraining according to Section 9.

5.5.6 *Fit Testing*—Each wearer shall be fit tested before being assigned a tight-fitting respirator (Section 10).

5.5.7 *Maintenance, Inspection, and Storage*—Maintenance shall be carried out by properly trained individuals according to the respirator user instructions and on a schedule that ensures that each respirator wearer is provided with a respirator that is clean, sanitary, and in good operating condition. Each respirator shall be inspected by the wearer before its use to ensure that it is in proper working condition. Respirators shall be stored in a convenient, clean, and sanitary location according to the respirator user's instructions (Section 12).

6. Program Administration

6.1 *Respirator Program Administrator*—An individual shall be assigned responsibility and authority for administering the respirator program. This individual shall have access and direct communication to the site manager for matters impacting worker safety and health. It is preferable that the administrator be in the company's industrial hygiene, environmental, health physics, or safety engineering department. A third-party entity meeting these requirements may provide this service.

6.2 *Respirator Program Administrator Qualifications*—Respirator program administrators shall be knowledgeable in respiratory protection and competent in the administration of their duties. Program administrators shall keep abreast of current issues, advances, and regulations.

6.3 *Responsibilities:*

6.3.1 *Respirator Program Administrator Responsibilities*—The administrator's responsibilities shall ensure that the following components of the respirator program are conducted:

6.3.1.1 Measurement, estimation, or review of information on the concentration of airborne contaminant(s) in the work area before respirator selection and periodically during respirator use;

6.3.1.2 Ensuring that medical evaluations, training, and fit testing are performed;

6.3.1.3 Selection of the appropriate type or class of respirator that will provide adequate protection for each contaminant, present or anticipated;

6.3.1.4 Maintenance of records and written procedures in a manner that documents the respirator program and allows for the evaluation of the program's effectiveness;

6.3.1.5 Evaluation of the respirator program's effectiveness; and

6.3.1.6 Revision of the program as necessary.

6.3.2 *Respirator Program Audit*—The most comprehensive respirator program is of little value if it is not maintained and implemented as designed and corrected when deficiencies are identified. Therefore, in addition to ongoing surveillance, the

program administrator shall annually audit the respirator program to ensure that the program procedures reflect the requirements of current applicable regulations and industry-accepted standards and the program as implemented reflects the written procedures.

6.3.2.1 To aid objectivity, an additional audit shall be conducted by a knowledgeable person not directly associated with the program, rather than the respirator program administrator. The frequency of this outside audit should be determined by the size and complexity of the respirator program and previous audit findings. An audit checklist, or equivalent, shall be prepared and updated as necessary.

6.3.2.2 The audit shall focus, as a minimum, on the following areas:

(1) Respirator program;
(2) Program administration;
(3) Training;
(4) Medical evaluation;
(5) Fit testing;
(6) Air sampling and classification of hazard(s);
(7) Selection and issuance;
(8) Use;
(9) Equipment cleaning, maintenance, and inspection;
(10) Breathing air quantity and quality;
(11) Storage;
(12) Emergency preparedness;
(13) Special problems; and
(14) Corrective action.

6.3.2.3 Action shall be taken to correct any defects or shortcomings found during the audit. Findings shall be documented, including plans to correct problem areas with target dates for completion and tracking mechanisms to ensure completion.

6.3.3 *Medical Surveillance*—When applicable, medical surveillance, which may include biomonitoring, shall be carried out periodically to determine if respirator wearers are adequately protected. An occupational health professional (for example, industrial hygienist, health physicist), in conjunction with a PLHCP, shall determine the medical surveillance program requirements.

7. Standard Operating Procedures (SOP)

7.1 Written SOP shall be established by the employer and shall cover a complete respirator program for routine and emergency situations. Copies of the procedures shall be available for all wearers to read. The procedures shall be reviewed in conjunction with the annual respirator program audit and revised by the program administrator as necessary.

7.2 *Operating Procedure Elements for Respirator Use*—Written SOP shall include information necessary, as appropriate, for the proper use of respirators, including:

7.2.1 Hazard assessment;
7.2.2 Respirator selection;
7.2.3 Medical evaluation;
7.2.4 Training;
7.2.5 Fit testing;
7.2.6 Issuance;
7.2.7 Maintenance, inspection, and storage;
7.2.8 Air-purifying element change schedule;
7.2.9 Breathing air quality;
7.2.10 Monitoring respirator use;
7.2.11 Hazard re-evaluation;
7.2.12 Employer policies; and
7.2.13 Program evaluation and auditing.

7.3 *Special Considerations for Respirators Used for Emergency Escape*—Written SOP shall be developed covering respirators used for emergency escape. Using guidance in Section 8, a hazard assessment shall be performed to determine if, during an emergency, the use of respirators for escape is required and, if so, the appropriate type of respirator for escape shall be selected. Consideration should be given to past emergencies and occurrences that required using respirators for escape, as well as conditions that may have necessitated their use, such as equipment or power failures, uncontrolled chemical reactions, fire, explosion, or human error.

7.3.1 An adequate number of escape respirators shall be provided and accessible where they may be needed.

7.3.2 *Personnel Assigned to Work Areas Where Escape Respirators Are Required*—Personnel assigned to areas where respirators may be required for escape shall be enrolled in the complete respirator program, including medical evaluation and training in the use and limitations of escape respirators.

7.3.3 *Visitors and Personnel Not Assigned to Work Areas Where Escape Respirators Are Required*—Medical approval is not required for visitors and personnel not assigned to work areas where hooded or mouthpiece escape-only respirators are provided for potential emergencies. However, they shall be trained in how to don and use the escape-only respirator according to the respirator user instructions.

7.3.3.1 For work areas where self-contained breathing apparatus having a tight-fitting respiratory inlet covering, gas masks, or other non-escape-only respirators are selected for emergency escape, visitors shall receive medical evaluation, respirator training, and fit testing.

7.3.4 *Operating Procedure Elements for Emergency Respirator*—Written SOP shall be developed for all emergency use and anticipated emergency use.

8. Respirator Selection

8.1 Respirator selection for routine and emergency use shall involve:

8.1.1 Hazard assessment;
8.1.2 Respirator selection of type or class of respirators that can offer adequate protection; and
8.1.3 Maintaining written records of hazard assessment and respirator selection (Section 14).

8.2 *Hazard Assessment*—Perform a hazard assessment including evaluation of potential respiratory hazards (oxygen deficiency or airborne contaminants) and any other hazardous conditions present such as eye and skin hazards, humidity and temperature extremes, and other environmental conditions to assist in the selection of an appropriate respirator

8.2.1 When the only hazard identified is a bioaerosol, the guidance in 8.3.3 shall be followed.

8.2.2 *Hazard Assessment Steps for the Inhalation Hazard:*

8.2.2.1 The nature of the inhalation hazard shall be established by determining:

(1) Which contaminant(s) may be present in the workplace;

(2) The physical state and chemical properties of all airborne contaminants;

(3) By measurement or estimation, the likely airborne concentration of the contaminant(s);

(4) If the potential for an oxygen-deficient environment exists;

(5) Whether there is an occupational exposure limit for each contaminant;

(6) If an IDLH atmosphere exists;

(7) If there is an applicable health regulation or OSHA substance-specific standard (for example, lead, asbestos) for the contaminant(s); and

(8) If the contaminant(s) can be absorbed through the eyes or skin, produce skin sensitization, or be irritating or corrosive to the eyes or skin.

8.2.2.2 Determine which contaminant(s) may be present in the workplace. The following factors concerning an operation or process shall be taken into consideration:

(1) Operation or process characteristics as they relate to the release of air contaminants through routine or non-routine procedures, malfunctioning of equipment, or processes or spills;

(2) Materials used, produced, or stored, including raw materials, end products, by-products, chemical reactivity, and wastes; and

(3) Emergency repair, shutdown procedures, escape, and rescue operations.

8.2.2.3 Determine the physical state and chemical properties of all airborne contaminants. The physical states for all airborne contaminants as they are likely to be encountered shall be identified as follows:

(1) Gas or vapor, or

(2) Particle.

8.2.2.4 If the contaminant is a particulate hazard, determine if it is an oil or if an oil aerosol is present along with the particulate contaminant.

NOTE 1—Knowledge of the presence of airborne oil is needed to select a particulate filter properly (8.3.2.11 and Annex A2).

NOTE 2—Examples of activities that are known to produce airborne oil include use of air compressor systems with oil lubricators and operation of motor vehicles.

8.2.2.5 Determine the likely airborne concentration of the contaminant(s). An estimate of the airborne concentrations of contaminants to which persons might be exposed shall be conducted as follows:

(1) Air sampling and analysis conducted in accordance with recognized occupational hygiene practices (**1**);[8]

(2) Mathematical modeling or estimating based on the workplace volume and physical properties (for example, vapor pressure); or

(3) Experience from similar circumstances and materials.

8.2.2.6 Anticipated exposures should account for variations in process operation, rate and direction of air movement, temperature (ambient or process), and seasonal variations. The workplace atmosphere shall be assessed on a regular basis for respiratory hazards to confirm that the proper type of respirator is being used.

8.2.2.7 Determine if the potential for an oxygen-deficient environment exists. Where the potential for an oxygen-deficient atmosphere exists, the oxygen concentration shall be measured. Where oxygen concentration is below 159 mmHg (21 kPa) (20.9 % oxygen at sea level), the cause of the deficiency shall be identified and understood or monitored if appropriate, or both. Where oxygen concentration is confirmed to be below 19.5 % (at sea level), the cause of the deficiency shall be determined and ongoing monitoring shall be performed (Annex A3) or the atmosphere shall be assumed to be IDLH until the cause of the deficiency is understood and controlled to greater than 122 mmHg (16.27 kPa) (16 % oxygen at sea level); see 8.2.2.10.

8.2.2.8 Oxygen deficiency is classified as either IDLH or non-IDLH by this practice.

(1) Oxygen-Deficiency IDLH—An oxygen partial pressure less than 122 mmHg (16.27 kPa) (16 % oxygen at sea level) shall be considered IDLH.

(2) Oxygen-Deficiency Non-IDLH—An oxygen partial pressure of ≥122 mmHg (16.27 kPa) (16 % oxygen at sea level) and less than 148 mmHg (19.73 kPa) (19.5 % oxygen at sea level) shall be considered an oxygen-deficient atmosphere that is not immediately dangerous to life.

8.2.2.9 Determine whether there is an occupational exposure limit for each contaminant. Occupational exposure limits shall be identified such as published threshold limit value, permissible exposure limit, derived air concentration (radiological protection limits), or any other available exposure limits or estimate of toxicity for the contaminant(s).

8.2.2.10 Determine if an IDLH atmosphere exists. A location shall be considered to be IDLH when:

(1) The identity or concentration of a contaminant is unknown (for example, interior structural fire-fighting) or it is an atmosphere known or suspected to have concentrations above the IDLH level for that contaminant (see Ref (**2**) for IDLH values for specific substances);

(2) It is a space that contains less than the normal 159 mmHg (21 kPa) (20.9 % oxygen at sea level) oxygen, unless the source of the oxygen reduction is understood and controlled or the oxygen concentration is unknown;

(3) Oxygen partial pressure is below 122 mmHg (16.27 kPa) (16 % oxygen at sea level);

(4) Total atmospheric pressure less than 584 mmHg (77.86 kPa) equivalent to 7000 ft (2134 m) altitude or any combination of reduced percentage of oxygen and reduced pressure that leads to an oxygen partial pressure less than 122 mmHg (16.27 kPa) (for example, areas other than sea level) (8.3.4 and Annex A3); or

(5) Any confined space containing less than 159 mmHg (21 kPa) (20.9 % oxygen at sea level) oxygen, unless the source of the oxygen reduction is understood and controlled (8.3.4 and 8.3.5). This restriction is imposed because any reduction in the percentage of oxygen present is proof, at a minimum, that the confined space is not adequately ventilated.

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

8.2.2.11 Determine if there is an applicable OSHA substance-specific standard for the contaminant(s). Determine if there is an applicable substance-specific standard by reviewing applicable standards, for example, OSHA, MSHA. If so, there may be specific respirators required that will influence the selection process.

8.2.2.12 *Determination of Other Hazards:*

(1) Determine whether the contaminant(s) can be absorbed through the eyes or skin, produce skin sensitization, or be irritating or corrosive to the eyes or skin.

(2) Determine the nature of other hazards and environmental conditions that may exist that would affect respirator selection, such as:

(a) Heat, cold, humidity;

(b) Head impact hazards;

(c) Welding arc;

(d) Splash; and

(e) Eye impact.

8.3 *Respirator Selection:*

8.3.1 *General Considerations:*

8.3.1.1 Proper respirator selection for any situation shall consider the following:

(1) The nature of the hazard;

(2) Worker activity and workplace factors;

(3) Respirator use duration;

(4) Respirator limitation; and

(5) Use of approved respirators.

8.3.1.2 *Nature of the Hazard*—Nature of the hazardous atmosphere shall be determined by the hazard assessment:

(1) IDLH;

(2) Non-IDLH;

(3) Oxygen deficient; or

(4) Bioaerosol.

8.3.1.3 *Worker Activity*—Worker activity and worker location in a hazardous area shall be considered in selecting the proper respirator. These considerations shall include:

(1) The period of time for which the respirator is to be used, whether the worker is in the hazardous area continuously or intermittently during the work shift;

(2) Physical demands made on the worker, whether the work rate is light, medium, or heavy;

(3) Work area layout;

(4) Work activities; and

(5) Temperature and humidity of the work environment (8.3.8.5) or concern for heat stress, or both, based on other personal protective equipment (PPE) selected.

8.3.1.4 Several of these considerations may apply. For example, extreme physical exertion can cause the wearer to deplete the air supply in a SCBA such that service life is significantly reduced.

8.3.1.5 *Respirator Use Duration*—The period of time that a respirator shall be worn is an important factor that shall be taken into account in selecting a respirator. Consideration shall be given to the type of use, such as routine, non-routine, emergency, or rescue. Respirator wearers shall be given breaks throughout the day. The work/rest period may be dependent on other factors such as heat stress, work rate, and intended service life of the respirator.

8.3.1.6 *Respirator Limitations*—Performance limitations of the various types of respirators shall be considered during the selection process. Types of respirators and considerations for their use are described in Annex A2. For example:

(1) Service Life—The expected service time of a cartridge or filter, or the amount of breathing air available;

(2) Worker Mobility—Limits for hoses may include length, entry, and exit points. Bulkiness may limit entry into tight spaces;

(3) Compatibility with Other Protective Equipment—Respirator fit when used with other equipment, for example, the need for safety glasses, face shield, or welding equipment;

(4) Durability—Physical limitations of a specific respirator;

(5) Comfort Factors—Respirator fit, weight, breathing resistance, and ease of use;

(6) Compatibility with the Environment—For example, if flammable, explosive, or corrosive substances are present; and

(7) Compatibility with Job and Workplace Performance—For example, use of a firearm with different types of face pieces.

8.3.1.7 *Approved Respirators*—Approved respirators shall be used. Under 42 CFR Part 84, respirators are approved by NIOSH except respirators used in mine rescue and other mine emergencies, which are required to be approved by both NIOSH and MSHA. Any change or modification, however minor, may adversely affect the performance of the respirator and the resulting respirator configuration will not be NIOSH approved. Respirators approved by NIOSH and NIOSH/MSHA under provisions of 42 CFR Part 84 are listed in the NIOSH Certified Equipment List, which is available on the NIOSH website at: http://www.cdc.gov/niosh/npptl/topics/respirators/cel/.

8.3.2 *Selection Steps*—The following shall be considered or known for the respirator selection:

8.3.2.1 If there is an oxygen-deficient atmosphere, the type of respirator selected depends on the partial pressure of oxygen and the concentration of other contaminant(s) that may be present; go to 8.3.2.2.

8.3.2.2 If the atmosphere is oxygen-deficient IDLH, go to 8.3.4 and 8.3.5; if not, go to 8.3.2.3.

8.3.2.3 If an OSHA substance-specific standard or regulation exists for the contaminant, those guidelines or requirements for respirator selection shall be followed.

8.3.2.4 If unable to determine what potentially hazardous contaminant(s) may be present, the atmosphere shall be considered IDLH; go to 8.3.5.

8.3.2.5 If no exposure limit is available or can be determined, the atmosphere shall be considered IDLH; go to 8.3.5.

8.3.2.6 If the contaminant concentration is unknown, the atmosphere shall be considered IDLH; go to 8.3.5.

8.3.2.7 If the measured or estimated concentration of the contaminant(s) is considered IDLH, go to 8.3.5.

8.3.2.8 *Determine the Hazard Ratio:*

(1) Hazardous Substance(s) with Independent Toxicological Effect—Divide the measured or estimated concentration (Co) by the occupational exposure limit or guideline (OEL) to

obtain a hazard ratio (HR) (HR = Co/OEL) of each contaminant. A respirator type and respiratory inlet covering with an assigned protection factor greater than the largest hazard ratio shall be selected (refer to OSHA assigned protection factors in 29 CFR 1910.134).

(2) Two or More Hazardous Substances with Similar Toxicological Effect—When two or more substances with similar toxicology are present, the combined effect of exposure shall be considered rather than considering each substance individually. Refer to ACGIH® threshold limit values (TLVs®) and biological exposure indicies (BEIs®) guides,[9] which address calculating threshold limit values for mixtures of components that additively affect the same target organ. If the calculated result for the mixture is greater than one, this indicates a respirator is required and this result is also the hazard ratio. A respirator type and respiratory inlet covering with an assigned protection factor greater than the hazard ratio shall be selected to ensure an appropriate level of protection (refer to OSHA assigned protection factors in 29 CFR 1910.134). If an air-purifying respirator is selected, continue with 8.3.2.9;

8.3.2.9 If the contaminant(s) is a gas or vapor only, go to 8.3.2.12. If an aerosol-only contaminant is present, go to 8.3.2.11.

8.3.2.10 If the contaminant is a bioaerosol, go to 8.3.3.

8.3.2.11 If a high-efficiency (HEPA) filter is required by a specific regulation or standard, then an HE, N100, R100, or P100 filter shall be used. If no such regulation or standard exists, an appropriate N-, R-, or P-series filter may be used. If an oil is present or its presence unknown, an R, P, or HE filter shall be selected. If no oil is present, an N, R, P, or HE filter can be selected (refer to Annex A2 for description of these filters). Refer to 8.3.6 for filter change schedule.

8.3.2.12 If the contaminant is a gas or vapor, an atmosphere-supplying respirator shall be used unless:

(1) The air-purifying respirator has an end-of-service-life indicator (ESLI) that will indicate to the wearer before contaminant breakthrough, or

(2) Chemical cartridge/canister change schedule is implemented. Some substance-specific regulations include specific chemical cartridge/canister change schedules. (See 8.3.7 and Annex A1 for guidance in establishing a change schedule.)

8.3.2.13 When aerosols and gases/vapors are both present, a filter in combination with a chemical cartridge/canister shall be selected. Substances from the TLV booklet with the inhalable fraction vapor (IFV) footnote should be considered to be present in both aerosol and vapor form unless determined otherwise.

8.3.2.14 If the material can be absorbed through the skin or is a skin or eye irritant, other appropriate PPE, which is compatible with the respirator, shall be used.

8.3.3 *Bioaerosols*—For respirator selection for bioaerosols, refer to CAN/CSA Z94.4. Respirator selection for bioaerosols without OELs cannot follow the procedures in this practice. Where regulations or guidelines exist that are specifically applicable to some bioaerosols, they shall be considered during the respirator selection process. These guidelines may come from agencies such as Centers for Disease Control and Prevention (CDC) or OSHA.

8.3.4 *Respirator Selection for Oxygen Deficiency*—Air-purifying respirators shall not be used in atmospheres with a partial pressure of oxygen (PO_2) less than 148 mmHg (19.73 kPa) (19.5 % oxygen at sea level). For atmospheres with a PO_2 equal to or greater than 122 mmHg (16.27 kPa) (16 % oxygen at sea level) and less than 148 mmHg (19.73 kPa) (19.5 % oxygen at sea level), an atmosphere-supplying respirator shall be selected. Under these conditions, an airline respirator is allowed if the source of the oxygen reduction is understood and controlled. For atmospheres with a PO_2 less than 122 mmHg (16.27 kPa) (16 % oxygen at sea level) or a confined space with an oxygen concentration less than 159 mmHg (21 kPa) (20.9 % oxygen at sea level) (unless the source of the oxygen reduction is understood and controlled), a full-face pressure-demand SCBA or combination multifunctional full-face pressure-demand airline respirator with self-contained air cylinder shall be selected. Table 1 summarizes the respiratory protection required for protection against reduced-oxygen atmospheres. Acclimatized workers can continue to perform their work without atmosphere-supplying respirators at altitudes up to 14 000 ft (4267.2 m), as long as the ambient oxygen content remains above 148 mmHg (19.73 kPa) (19.5 % oxygen at sea level) and the wearer has no medical condition that would require the use of supplemental oxygen.

8.3.5 *Respirators for Use Under IDLH Atmospheres:*

8.3.5.1 *Respirator Selection*—Respiratory protection for IDLH conditions caused by the presence of toxic materials or a reduced percentage of oxygen as described in conditions in 8.3.4 shall be a full-face-piece, pressure-demand SCBA or a full-face-piece, multifunctional, pressure-demand supplied-air respirator with self-contained air supply. Respirators that provide a minimum flow rate of 100 lpm shall be selected. Demand SCBA respirators shall not be used for entering IDLH atmospheres. The respirator shall be selected to ensure that the capacity of the auxiliary cylinder is sufficient for the anticipated egress from an IDLH atmosphere.

8.3.5.2 *Standby Personnel*—When respirators are worn under IDLH conditions, at least one standby person shall be present in a safe area. Standby personnel shall be trained and have the proper equipment available to assist the respirator wearer in case of difficulty. Communications (visual, voice, signal line, telephone, radio, or other suitable means) shall be maintained between the standby person and the wearer. While working in the IDLH atmosphere, the wearer shall be equipped with safety harness, safety lines, hoist, and so forth if necessary to permit removal to a safe area. Provisions for rescue other than safety harness and lines may be used, if equivalent.

8.3.5.3 *Interior Structural Fire-Fighting*—For respiratory protection in interior structural fire-fighting, a full-face-piece, positive-pressure SCBA that meets the requirements of NFPA 1981 should be used.

8.3.6 *Filter Change Schedules*—Filters shall be replaced if damaged for hygienic reasons or if any increase in breathing resistance is noted. For detailed information on use limitations

[9] ACGIH®, TLVs®, and BEIs® are registered trademarks of the American Conference of Governmental Industrial Hygienists.

TABLE 1 Respirator Selection for Combined Effect of Altitude and Reduced Percentage of Oxygen

NOTE 1—Oxygen partial pressures <122 mmHg dictate the need for an SCBA or a combination airline respirator with auxiliary air cylinder and assumes a normal, healthy, un-acclimatized worker. Also, see Annex A3 for other considerations in using respirators in reduced-oxygen atmospheres.

NOTE 2—For oxygen partial pressures between 159 and 148 mmHg, air-purifying respirators may be worn if the source of the oxygen reduction is understood and controlled and the type of other inhalation hazards and their concentrations are such that the protection provided by air-purifying respirators is adequate.

NOTE 3—For oxygen partial pressure ≥122 and <148 mmHg, airline respirators may be worn if the source of the oxygen reduction is understood and controlled.

NOTE 4—At 10 000 ft (3048 m) or higher, or in any space where the total ambient pressure is less than 523 mmHg, specially designed and approved SCBA supplying enriched oxygen or a closed-circuit SCBA shall be used. At least 23 % oxygen is required at 10 000 ft (3048 m) or a total ambient pressure of <523 mmHg and 27 % oxygen at 14 000 ft (4267 m) or a total ambient pressure of less than 450 mmHg.

Altitude/Total Pressure	20.9 % PO_2 [mmHg]	Percent O_2 <19.5 % PO_2 [mmHg]	<16 % and below (Table Note 1) PO_2 [mmHg]
Sea level 760 mmHg	159 to 148 (19.5 % O_2) Air-purifying respirator if needed for non-oxygen-deficient inhalation hazards (Table Note 2).	<148	<122
1000 ft 733 mmHg	153	143	117
2000 ft 707 mmHg	147.8	138 O_2 deficiency non-IDLH	113
3000 ft 681 mmHg	142	133 Airline respirator (Table Note 3)	109
4000 ft 656 mmHg	137	128	105
5000 ft 632 mmHg	132	123	101
6000 ft 609 mmHg	127	119	97
7000 ft 584 mmHg	122	114	93
8000 ft 565 mmHg	118[A]	110 O_2 deficiency IDLH	90
9000 ft 543 mmHg	113[A]	106 Pressure demand, full-face SCBA or combination airline/SCBA	87
10 000 ft (Table Note 4) 523 mmHg	109[A]	102	84
11 000 ft 503 mmHg	105[A]	98	80
12 000 ft 484 mmHg	101[A]	94	77
13 000 ft 465 mmHg	97[A]	91	74
14 000 ft 450 mmHg	94[A]	88	72

[A]Acclimatized workers can continue to perform their work without atmosphere-supplying respirators, at altitudes up to 14 000 ft, as long as the ambient oxygen content remains above 19.5 % and the wearer has no medical condition that would require the use of supplemental oxygen.

of filters, refer to the respirator user instructions or contact the manufacturer directly. See NIOSH for more details on filter efficiency degradation (**3**, **4**).

8.3.6.1 R-series filters shall be replaced after 8 h of use (continuous or intermittent) when oil is present. However, service time for the R-series filter can be extended using the same two methods described above for N-series filters (**3**, **4**).

8.3.7 *Chemical Cartridge/Canister Change Schedules*—For gas and vapor cartridges or canisters that do not have ESLI, a change schedule shall be established (Annex A1). The schedule

should be based on a determination of the service life from testing, modeling, or other means of estimating capacity.

8.3.7.1 Warning properties shall not be used as a method of determining end of service life.

8.3.7.2 For cartridges and canisters with an ESLI, the respirator user instructions shall be followed.

8.3.8 *Additional Considerations Affecting Respirator Selection:*

8.3.8.1 *Alternative Respirators for Problematic Fitting Characteristics*—A tight-fitting respirator shall not be selected if a situation is encountered whereby a worker cannot obtain a satisfactory fit with a tight-fitting respirator as described in 10.4. Recommended alternatives to provide adequate respiratory protection are:

(1) Providing the wearer with a loose-fitting respiratory inlet covering of sufficient assigned protection factor for the hazard, or

(2) Transferring the worker to a job or worksite where respiratory protection is not required.

8.3.8.2 *Communications*—Ambient noise and communication needs shall be considered when specific respirators are selected. A respirator with communication aids should be selected if communication is critical and the noise levels interfere with communication (Annex A4).

8.3.8.3 *Vision Correction:*

(1) Spectacles—When a half-face-piece respirator wearer uses eyewear, it 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. Spectacles with straps or temple bars that pass through the sealing surface of full-face-piece respirators shall not be used. If corrective lenses are required, the respirator manufacturer's spectacle kit shall be used.

(2) Contact Lenses—Contact lenses may be worn with respirators if permitted by the employer. The contact lens wearer shall practice wearing the respirator while wearing contact lenses.

8.3.8.4 *Headwear Worn with Respirators*—A head or face covering that passes between the sealing surface of a tight-fitting respirator face piece and the wearer's face shall not be used. Headwear or other equipment shall not be worn if it interferes with the respirator performance.

8.3.8.5 *Respirator Use in Temperature Extremes:*

(1) Respirator Use in Low-Temperature Environments—Low temperatures may cause detrimental effects on the performance of respirators and may add undue physiological stress. The effects of low temperatures shall be considered in the selection and maintenance of respirators and respirable gas supplies.

(2) Respirator Use in High-Temperature Environments—High temperatures may affect the performance of the respirator and may add undue physiological stress. The effects of high temperatures shall be considered in respirator selection.

8.3.8.6 *Negative- or Positive-Pressure Atmospheres*—When working in negative-pressure (that is, hypobaric) atmospheres, the partial pressure of oxygen shall be considered and, if below 122 mmHg, a closed-circuit respirator having enriched oxygen source shall be used.

(1) When used in positive-pressure (that is, hyperbaric) atmospheres, breathing with a closed-circuit SCBA gradually increases inspired carbon dioxide concentrations. The resulting arterial carbon dioxide tension ($PaCO_2$) may become unacceptable. Respirator program administrators shall consider workplace factors before use in positive-pressure atmospheres to ensure arterial carbon dioxide levels ($PaCO_2$) are maintained within acceptable levels.

8.3.9 *Specific Applications Involving the Use of a Respirator:*

8.3.9.1 *Abrasive Blasting*—Respirators specifically approved for abrasive blasting shall be selected when there is a potential for abrasive rebound.

8.3.9.2 *Welding and Cutting*—Respirators specifically designed for welding and cutting shall be used. These respirators have a variety of respirator accessories for use during welding operations including, but not limited to:

(1) Welding shields to protect the filters against sparks and spatter;

(2) Spark-resistant filters;

(3) Filters that can be worn on the back; and

(4) Shaded lenses for flame cutting and grinding.

8.3.9.3 *Welding in Confined Spaces*—Welding in a confined space can present an atmospheric hazard because of the generation of contaminants and displacement of oxygen. A pressure-demand SCBA or a multifunctional pressure-demand supplied-air respirator with self-contained air supply shall be used during welding in confined spaces when welding can reduce the ambient oxygen level and supplemental ventilation and atmospheric monitoring are not provided according to 29 CFR 1910.146 and ANSI/ASSE Z117.1. For more information on respirator types, refer to Annex A2.

9. Training

9.1 All users shall be trained in their area of responsibility by a qualified person(s) to ensure the proper use of respirators.

9.2 *Qualifications of the Respirator Trainer*—Anyone providing respirator training shall:

9.2.1 Be knowledgeable in the application and use of the respirator(s);

9.2.2 Have practical knowledge in the selection and use of respirator(s) and work practices at the site;

9.2.3 Have an understanding of the site's respirator program; and

9.2.4 Be knowledgeable of applicable regulations.

9.3 *Training for Employees*—The workplace supervisor, person issuing and maintaining respirators, respirator wearers, and emergency or rescue teams shall be given initial and annual training described in this section by a respirator trainer(s).

9.3.1 *Workplace Supervisor*—A workplace supervisor, who has the responsibility of overseeing the work activities of one or more persons who are assigned to a work area where respirator use is required, shall be trained to perform their responsibilities effectively. Training shall include the following subjects, as applicable:

9.3.1.1 Basic respiratory protection practices;

9.3.1.2 Nature and extent of respiratory hazards encountered by persons under their supervision;

9.3.1.3 Recognition and resolution of respirator use problems;

9.3.1.4 Principles and criteria for selecting respirators used by persons under their supervision;

9.3.1.5 Training respirator wearers;

9.3.1.6 Fit testing and issuing respirators;

9.3.1.7 Respirator inspection;

9.3.1.8 Proper respirator use, including monitoring respirator use;

9.3.1.9 Specific air-purifying element change schedule;

9.3.1.10 Supplied breathing air quality requirements;

9.3.1.11 Respirator maintenance and storage; and

9.3.1.12 Regulations concerning respirator use.

9.3.2 *Person Issuing Respirators*—A person assigned the task of issuing respirators shall be given adequate training to ensure that the respirator is in an approved configuration and that the correct respirator is issued for each application in accordance with the written SOP.

9.3.3 *Respirator Wearer(s)*—To ensure the proper and safe use of a respirator, the minimum training of each respirator wearer shall include an explanation of the following elements:

9.3.3.1 Wearer responsibilities (5.4);

9.3.3.2 Need for respiratory protection;

9.3.3.3 Nature, extent, and effects of respiratory hazards in the workplace and why a particular type of respirator has been selected for a specific respiratory hazard;

9.3.3.4 Need to inform their workplace supervisor of any respirator problems experienced by them or their coworkers;

9.3.3.5 Need to inform their workplace supervisor and PLHCP of changes that may impair their ability to wear a respirator;

9.3.3.6 Why engineering controls are not being applied or are not adequate and what effort is being made to reduce or eliminate the need for respirators;

9.3.3.7 Operation, capabilities, and limitations of the respirator selected;

9.3.3.8 Instructions for inspecting, donning, and doffing the respirator, including a requirement for tight-fitting respirators that a wearer seal check shall be conducted each time the respirator is donned or adjusted (Section 11).

9.3.3.9 Importance of proper respirator fit and use;

9.3.3.10 Specific air-purifying element change schedule;

9.3.3.11 The significance of odor, taste, or irritation properties of the gas or vapor, and these shall not be relied upon to determine the end of service;

9.3.3.12 How to maintain and store the respirator;

9.3.3.13 Instructions in emergency respirator use and procedures;

9.3.3.14 Regulations concerning respirator use;

9.3.3.15 Requirements specified in 5.4.3 that permit the wearer to leave the hazardous area for any respirator-related cause; and

9.3.3.16 Hazards from accidently using inert gas instead of breathing air to atmosphere-supplied respirator wearers (A2.3).

9.3.4 *Emergency and Rescue Teams*—Teams that are established by employers for the purpose of responding to emergencies or rescues or both, such as industrial fire brigades, shall be properly trained in the use of respirators and be aware of the inherent risks. A suitable training program shall be established that includes periodic emergency drills to ensure team members develop the proficiency and familiarity with the respirators to perform such emergency or rescue operations or both effectively.

9.3.5 *Training for Personnel Maintaining and Servicing Breathing Air Systems*—All personnel who service and maintain breathing air systems shall be trained by the system manufacturer and receive appropriate certifications as may be required so as to understand the hazards associated with nitrogen or other inert gases and procedures to avoid their introduction.

9.4 *Training Frequency*—Each respirator wearer shall be trained before initial use and retrained at least once every twelve months. Workplace supervisors and persons issuing respirators shall be retrained as determined by the program administrator to perform their responsibilities effectively.

9.5 *Records*—For each wearer, records shall be maintained that give the date and type of training received (for example, lesson plan), performance results (as appropriate), and the instructor's name.

10. Respirator Fit Tests

10.1 A qualitative or quantitative respirator fit test shall be used to determine the ability of the individual respirator wearer to obtain a satisfactory fit with a tight-fitting respirator. Personnel with facial hair or facial jewelry between the face and face seal area of the respirator shall not be fit tested. If a fit factor greater than 100 is required, a quantitative fit test (QNFT) method shall be used. The results of fit tests, among other criteria, shall be used to select specific models, sizes, and styles of respirators for use by individual respirator wearers.

10.2 Refer to ANSI Z88.10 for guidance on how to conduct fit testing of tight-fitting respirators and appropriate methods to be used.

10.3 *Fit Test Pass/Fail Criteria:*

10.3.1 *Negative-Pressure Respirator Fit Tests*—If a quantitative fit test is used, a fit factor that is at least ten times greater than the assigned protection factor (APF) of the negative-pressure respirator shall be obtained before that make and model of respirator is assigned to an individual (APFs are given in 29 CFR 1910.134).

10.3.1.1 The fit factors of both quantitatively and qualitatively fit-tested negative-pressure respirators include a safety factor of ten. Negative-pressure air-purifying respirators that are quantitatively fit tested shall pass the fit test with a fit factor that is at least ten times greater than the APF of the respirator. Therefore, half-face-piece and full-face negative-pressure air-purifying respirators that are quantitatively fit tested shall have a minimum fit factor of 100 and 500 to be allowed to be worn in atmospheres up to their assigned protection factors of 10 and 50, respectively. The fit factor obtained during qualitative fit testing of negative-pressure air-purifying respirators is limited to 100. Half-face-piece and full-face-piece negative-pressure respirators qualitatively fit tested with validated methods

(ANSI Z88.10) shall not be worn in concentrations greater than ten times the exposure limit (Annex A5).

10.3.2 *Positive-Pressure Respirator Fit Tests*—Positive-pressure, tight-fitting respirators shall be fit tested in a negative-pressure mode. Face-seal leakage in positive-pressure respirators, including powered air-purifying respirators (PAPRs), is primarily outward from the face piece into the surrounding atmosphere (Annex A6). Fit testing a positive-pressure respirator is to ensure there is no gross leakage in the face piece seal resulting in lower protection. Gross leakage through a SCBA face seal will result in loss of supplied breathing air and operational time. Qualitative fit testing adequately detects gross leakage in the face piece seal. When a quantitative fit test is used, a fit factor of at least 100 for half-face piece and 500 for full-face-piece respirators shall be obtained.

10.3.2.1 Tight-fitting positive-pressure respirators shall be fit tested only in the negative-pressure mode, regardless of the mode of operation used for respiratory protection. This is accomplished by either:

(1) Following the respirator user instructions for temporarily converting the wearer's individually assigned respirator into a negative-pressure respirator with appropriate filter, cartridges, adapters, or combinations thereof, or,

(2) Using a surrogate negative-pressure respirator face piece with sealing surfaces and materials that are the same as the respirator to be assigned to the wearer. For example, a negative-pressure air-purifying face piece may be used as a surrogate face piece for a powered air-purifying or SCBA face piece made by the same manufacturer if the sealing surfaces and materials are identical.

10.3.3 *Fit Testing Tight-Fitting Hoods*—When fit testing tight-fitting hoods, the required fit factor for full-face-piece respirators shall be used.

10.3.4 *Testing Frequency*—A respirator fit test shall be carried out for each wearer of a tight-fitting respirator before initial use. Refer to ANSI Z88.10 for guidance regarding fit test frequency (currently at least once every twelve months or repeated when a wearer expresses concern about respirator fit or comfort or has a condition that may interfere with face piece sealing, such as a significant change in weight or other characteristics that may affect the fit of the face piece seal).

10.4 *Respirator Fitting Problems*—Paragraph 8.3.8.1 recommends alternatives to provide adequate respiratory protection when a worker cannot obtain a satisfactory fit with a tight-fitting respirator.

10.4.1 *Worker Conditions That May Adversely Affect Fit*—Not every individual may be able to obtain a satisfactory fit. Refer to ANSI Z88.10 for specific examples that include, but are not limited to: unique facial features, facial hair, absence of teeth or dentures, injury to the face, use of cosmetics, facial jewelry, and certain hairstyles.

10.4.2 *PPE and Other Items That May Interfere with Fit*—When any PPE or respirator accessory or both has the potential to interfere with the seal, it shall be worn during the fit test to ascertain compatibility with the respirator. Refer to ANSI Z88.10 for examples such as eyeglasses, goggles, face shields, head protection, skull caps, hearing protection, welding helmets, or other protective devices that can potentially interfere with the seal of the respirator.

10.5 *Cleaning Fit Test Respirators*—Respirators used for fit testing shall be cleaned and sanitized in accordance with 12.2. Wipes (for example, sanitization, cleaning, respirator) shall only be used for respirators assigned to a specific individual and are not a substitute for more comprehensive cleaning procedures described in Annex A8.

10.6 *Fit Test Considerations:*

10.6.1 *Number of Respirators*—No one size or model of respirator will fit all types of faces. To accommodate different facial types, a variety of sizes, models, and styles from which to choose shall be provided for the wearer.

10.6.2 *Wearer Acceptance*—Comfort is an important factor in wearer acceptance of the respirator. Other factors that influence wearer acceptance include respirator breathing resistance, vision, communications, and weight. Annex A7 demonstrates the dramatic loss of protection (and increase in exposure) when respirators are not worn in a contaminated environment. Respirators with greater wearer acceptance are more likely to be worn properly and thus provide more protection. Wearer acceptance of a particular respirator model shall be considered in selecting a respirator, since this may determine whether or not the respirator is worn properly. If the results of the respirator fit test show that the person can obtain an acceptable fit with two or more models of appropriate respirators, then the person shall be permitted to use the preferred respirator model.

10.6.3 *Respirator Configuration*—Fit testing of tight-fitting respirators shall be done in accordance with ANSI Z88.10.

10.7 *Fit Test Records*—Fit test records shall be kept in a manner consistent with current legal requirements and company policies.

10.7.1 *Record Contents*—Respirator fit test records shall follow the guidance in ANSI Z88.10.

11. Wearer Seal Checks

11.1 A wearer seal check shall be conducted each time a tight-fitting respirator is donned or adjusted to determine if the respirator is properly seated to the face by following the procedures recommended by the manufacturer or by using appropriate wearer seal checks described in 11.4 and 11.5.

11.2 The procedures described in 11.4 and 11.5 are generic in nature and may be difficult to carry out on some respirators. For more exact guidance related to the respirator in use, refer to the respirator user instructions.

11.3 If the respirator cannot be donned without air leakage, do not enter the contaminated area. See your supervisor.

NOTE 3—Wearer seal checks are not substitutes for qualitative or quantitative fit tests.

11.4 *Filtering Face Piece Respirator Wearer Seal Check*—For wearer seal check instructions for a specific filtering face piece respirator, refer to the respirator user instructions provided with the respirator.

11.5 *Elastomeric Face Piece Respirator Wearer Seal Check*—Wearer seal checks for elastomeric face piece respirators are conducted by attempting to create pressure in the face piece and holding for a brief period.

11.5.1 *Negative-Pressure Wearer Seal Check*—A negative-pressure respirator wearer seal check is performed by blocking the inlet opening of the respirator's face piece so air cannot flow into it. Typically, this is done by closing off the canister(s), cartridge(s), or filter(s) by covering with the palm of the hand(s), replacing the inlet seal on a canister(s), or squeezing a breathing tube or blocking its inlet so that it will not allow the passage of air. Because of the variety of respirator designs, other methods for closing off the inlet may be used and the respirator user instructions should be checked. Then, the wearer inhales gently and holds their breath for a brief period (about 5 s). The donning is considered to be satisfactory if a slight negative pressure can be created inside the face piece without the detection of any inward leakage of air between the sealing surface of the face piece and the respirator wearer's face. If a sensation of air leakage is felt at the sealing surface, reposition the face piece or straps or both and conduct the check again. Failure to maintain a negative pressure can also indicate a leak. Repeat as necessary until the face piece is correctly donned.

11.5.2 *Positive-Pressure Wearer Seal Check*—A positive-pressure wearer seal check can be used on respirators equipped with both inhalation and exhalation valves. The exhalation valve cover, valve, or breathing tube is closed off and then the wearer exhales gently. The donning of the respirator is considered to be satisfactory if a slight positive pressure can be built up inside the face piece without the detection of any outward leakage of air between the sealing surface of the face piece and the respirator wearer's face. For some respirators, this check method requires that the respirator wearer first remove an exhalation cover from the respirator and then replace it without disturbing the fit after completion of the check.

12. Maintenance, Inspection, Storage, and Disposal

12.1 Written procedures shall be developed that incorporate the respirator user instructions and applicable regulations.

12.2 *Decontaminating, Cleaning, and Sanitizing*—Respirators issued to an individual shall be decontaminated as necessary and cleaned and sanitized regularly per respirator user instructions. Each respirator shall be cleaned and sanitized before being worn by different individuals. Respirators intended for emergency use shall be cleaned and sanitized after being used. Annex A8 provides additional information for decontaminating, cleaning, and sanitizing.

12.3 *Inspection:*

12.3.1 The wearer shall inspect the respirator immediately before each use to ensure that it is in proper working condition. The respirator user instructions shall be referred to for applicable expiration dates or end of service life for components.

12.3.2 After cleaning and sanitizing, each respirator shall be reassembled and inspected to determine that it is in proper working condition.

12.3.2.1 Respirator inspection shall include a check:

(1) That the respirator assembly includes all components as required by the approval;

(2) For tightness of connections;

(3) For the condition of the respiratory inlet covering, head harness, valves, connecting tubes, harness assemblies, lenses or visors, hoses, filters, cartridges, canisters, end-of-service-life indicator, electrical components, and shelf-life date(s); and

(4) For the proper function of regulators, alarms, and other warning systems.

12.3.2.2 Each rubber or other elastomeric part shall be inspected for pliability and signs of deterioration.

12.3.2.3 Each breathing air and oxygen cylinder shall be inspected to ensure that it is fully charged according to respirator user instructions and that any applicable hydrostatic test dates are current.

12.3.3 Each respirator stored for emergency or rescue use shall be inspected at least monthly.

12.3.4 Respirators that do not meet applicable inspection criteria shall not be used and shall be repaired or replaced (12.4).

12.3.5 A record of inspection dates shall be kept for each respirator maintained for emergency or rescue use.

12.4 *Parts Replacement and Repair*—Repairs, including replacement of parts, shall only be done by persons trained in proper respirator maintenance and assembly. Replacement parts shall only be those designated for the specific respirator being repaired. After replacement of parts or repairs, the respirator should be inspected or tested in accordance with 12.3. Reducing or admission valves, regulators, and alarms shall be adjusted or repaired by the respirator manufacturer or a technician certified by the manufacturer. Instrumentation for valve, regulator, and alarm adjustments and tests shall be calibrated according to respirator user instructions.

12.5 *Storage*—Respirators shall be stored according to the respirator user's instructions in a manner that will protect them against physical hazards, biological and chemical agents, vibration, shock, sunlight, heat, extreme cold, excessive moisture, and insects. Respirators shall be stored to prevent distortion of rubber or other elastomeric parts. Emergency and rescue-use respirators that are placed in work areas shall be quickly accessible at all times, and the location where they are stored shall be clearly marked.

12.6 *Disposal*—If applicable, respirator components shall be disposed of in accordance with appropriate federal, state, and local regulations.

13. Breathing Gas

13.1 *Breathing Gas Quality*—Only high-purity compressed gaseous air, reconstituted synthetic air (blended 21 % oxygen and 79 % nitrogen), compressed gaseous oxygen, liquid air, or liquid oxygen shall be used for respiration. Compressed air or liquid air shall, as a minimum, meet the requirements for Grade D air as specified in CGA G-7.1. Compressed gaseous or liquid oxygen shall meet the requirements of United States Pharmacopoeia (**5**) for medical or breathing oxygen.

13.2 *Water Content:*

13.2.1 *Airline Respirators*—Compressed gaseous air used with airline respirators shall have a maximum dew point 10 °F (5 °C) lower than the lowest ambient temperature to which any regulator or control valve on the respirator or air supply system may be exposed (refer to Table A9.1). Table A9.2 shall be used to determine the maximum water content for the pressure of the airline respirator system for the lowest temperature in which the airline respirator will be used.

13.2.2 *SCBA*—Compressed gaseous air used in self-contained breathing apparatus shall have a maximum water content based on its cylinder pressure and the lowest anticipated storage or use temperature. Table A9.3 shall be used to determine the maximum water content for the pressure of the SCBA air cylinder for the lowest use temperature in which the SCBA will be used.

13.3 *Breathing Air Systems*—Breathing air systems that use an oil-lubricated compressor or air compressors powered by internal combustion engines shall have a continuous carbon monoxide monitor with alarm detectable by the wearers. If the monitor alarms, the compressor shall be shut down immediately until the source of contamination is abated.

13.3.1 The intake of compressors and ambient air pumps shall be located and monitored to prevent entry of contaminated air into the system.

13.3.2 See Annex A10 for a description of breathing air equipment and systems.

13.3.3 *Air Quality Sampling*—To ensure a continued high-quality air supply that complies with the requirements in 13.1 and account for any distribution system contaminant input, a representative sample shall be taken at air supply points of attachment where the respirator wearer connects to the system. Air quality sampling frequency shall be:

13.3.3.1 Before initial use;

13.3.3.2 Performed periodically (for example, quarterly), as directed by the program administrator;

13.3.3.3 Following major overhaul, modifications, or extensive repairs of any part of the breathing air system;

13.3.3.4 Before reuse, if the compressor has been idle for a long period as defined by the program administrator; and

13.3.3.5 Whenever inadequate air quality is suspected.

13.3.3.6 There are no routine air sampling requirements for ambient air pumps.

13.3.3.7 Purchased breathing air shall be tested as specified in Table 2.

13.3.3.8 Compressed breathing air shall be tested as specified in Table 3.

TABLE 2 Minimum Periodic Air Sampling for Purchased Breathing Air

Method of Preparation	Analysis
Compression—supplier does not fill cylinders with any other gases	Check 10 % of cylinders from each lot for CO concentration and odor.
Compression—supplier fills cylinders with gases other than air	Analyze all cylinders for percent oxygen. Check 10 % of cylinders from each lot for CO concentration and odor.
Reconstitution	Analyze all cylinders for percent oxygen. Check 10 % of cylinders from each lot for CO concentration and odor.

TABLE 3 Air Sampling for Compressed Breathing Air

Type/Sample	Compressor Type		
	Oil Lubricated	Non-Oil Lubricated	Combustion Engine Powered
Water Vapor	X	X	X
CO	X	. . .	X
Condensed hydrocarbon	X	. . .	X
CO_2	. . .	. . .	X
Odor	X	X	X

13.3.4 *Special Considerations for Oxygen Systems*—If high-pressure oxygen passes through an oil- or grease-coated orifice, an explosion or fire may occur. Compressed gaseous oxygen shall not be used in airline respirators or self-contained breathing apparatus that have previously used compressed air. Compressed gaseous air may contain low concentrations of oil introduced from equipment during processing or normal operation. Oxygen concentrations greater than 23.5 % shall be used only in equipment designed for oxygen service or distribution.

13.3.5 *Maintenance and Inspection of Breathing Air Systems*—The breathing air system components shall be inspected and maintained in accordance with the manufacturer's recommendations. Inspectors of breathing air systems shall be trained in accordance with the system component manufacturer's recommendations and frequency. Records of inspection and maintenance shall be kept. Carbon monoxide monitors, if used, shall be calibrated and maintained according to the manufacturer's recommendations.

13.4 *Compressed Gas Cylinders*—Cylinders shall be hydrostatically tested and maintained in accordance with applicable Department of Transportation specifications for shipping containers (49 CFR Part 180). Only the compressed air cylinder assembly or compressed oxygen cylinder assembly listed on the NIOSH approval label for the SCBA shall be used.

13.4.1 Breathing gas cylinders shall be marked according to CGA C-7. Further details on sources of compressed air and its safe use are found in CGA G-7.1.

14. Recordkeeping

14.1 The employer shall establish a records retention program. The following applicable records shall include:

14.1.1 Respirator program;

14.1.2 Medical evaluation;

14.1.3 Hazard assessment;

14.1.4 Respirator selection;

14.1.5 Emergency respirator inspection;

14.1.6 Breathing-air system inspection and maintenance;

14.1.7 Training;

14.1.8 Fit testing; and

14.1.9 Program evaluation.

14.2 All records shall be kept in a manner consistent with current regulatory requirements and company policies.

15. Keywords

15.1 occupational respirator use; respirator; respirator protection use

ANNEXES

(Mandatory Information)

A1. GUIDANCE ON ESTABLISHING CARTRIDGE AND CANISTER CHANGE SCHEDULES

A1.1 Chemical cartridges and canisters have a finite service life. The service life can be, and most often is, different for each chemical and chemical mixture. When chemical cartridge or canister respirators are selected, their effectiveness against the workplace chemicals shall be determined. For safe use of respirators using cartridges and canisters, it is imperative to replace them before breakthrough occurs. Breakthrough is when the cartridge or canister no longer adsorbs all of the chemical. The time required for a stated concentration of a chemical to be detected on the downstream side of a cartridge is the breakthrough time. When the stated concentration is the OEL or based on the OEL, the breakthrough time is the service time.

A1.1.1 Various methods exist for getting a service-life estimate. Using the same methods for establishing the service life can also indicate whether the respirator is a practical choice or whether an SAR should be selected for the application.

A1.1.2 This is accomplished by establishing a change schedule based on the expected service life of the cartridge or canister for each respirator application for cartridges and canisters that do not have an end-of-service-life indicator.

A1.1.3 To establish a change schedule, you should:

A1.1.3.1 Gather workplace data for the respirator application;

A1.1.3.2 Obtain a service-life estimate;

A1.1.3.3 Adjust the service-life estimate to your work environment; and

A1.1.3.4 Establish a change schedule.

A1.2 **Gather Workplace Data for the Respirator Application**—There are several pieces of information that should be obtained from the workplace to be able to establish a change schedule. The most common type of information is:

A1.2.1 *Workplace Concentration of All Gaseous and Vaporous Contaminants, Especially Those for Which Respiratory Protection is Required*—The estimates needed shall be able to be compared to the appropriate OEL to determine the respirator use, for example, full-shift or short-term use;

A1.2.2 Workplace temperature;

A1.2.3 Workplace relative humidity;

A1.2.4 *Work Rate (Breathing Rate While Doing the Task)*—This determines the amount of contaminated air flowing through the respirator;

A1.2.5 Work periods and their duration; and

A1.2.6 Cartridge or canister (type and manufacturer) being considered.

A1.2.7 Contaminant concentration, workplace temperature, relative humidity, and work rate (flow rate through the cartridge or canister) have an effect on the cartridge or canister service life. A higher concentration of the same chemical shortens the service life. The service-life reduction is not inversely proportional to the contaminant concentration. Thus, it is not an easy calculation to determine the service life if the cartridge has not been tested at the exact workplace conditions.

A1.3 **Obtain a Service-Life Estimate**—The service-life estimate can be obtained from the following sources:

A1.3.1 Cartridge/canister testing in the laboratory (previously published or individually done);

A1.3.2 Cartridge/canister testing in the workplace;

A1.3.3 Cartridge/canister service life software from respirator manufacturers, NIOSH, or OSHA; or

A1.3.4 Cartridge/canister service life rules of thumb, which are to be used in conjunction with empirical data.

A1.3.5 The best service-life estimate is based on the same conditions, or as close as possible, as the workplace conditions. This reduces extrapolation from the actual results to the workplace conditions. Laboratory testing is often limited to the conditions it can test. For example, the laboratory may not be able to generate the exact workplace concentrations or it may not be able to make mixtures in the same proportions as found in the workplace. Most published service-life test results are for single compounds at a high concentration compared to what may be found in the workplace. These results may have to be adjusted for differences between workplace and testing conditions for such things as concentration, flow rate, and relative humidity. These shortcomings can be overcome by testing in the workplace.

A1.3.6 Workplace testing has the advantage of not having to generate the atmosphere because it already exists in the workplace. It does offer its own set of challenges, including getting the equipment into the workplace and solving challenges such as electricity, intrinsic safety, and close proximity to where workers are to obtain representative samples.

A1.3.7 The most popular method to obtain a service-life estimate is to use software that calculates the service life based on several inputs. These inputs include workplace concentration, work rate estimate, temperature and humidity estimates, and chemical cartridge or canister variables, to name a few. Most respirator manufacturers have developed software tools for making these estimates with their cartridges and canisters. The important thing is to use the information from the manufacturer for the respirator being used and following the respirator manufacturer's warnings for limitations of the

service-life software. This solves the issue of gathering the cartridge or canister data because the manufacturer typically builds this into the software or has tested its own cartridges. There is also software available from NIOSH and OSHA. The most recent NIOSH version will calculate a service-life estimate for use in an atmosphere of a mixture of up to five organic vapors and various relative humidities. This software only works for organic vapor cartridges. If exposures are to acid gases or bases, other methods will need to be used. Oftentimes, the manufacturer will include data for chemicals other than organic vapors.

A1.3.8 It is also possible that the chemical of interest is not included in the software. Various reasons can cause this, such as no OEL, the chemical is a mixture such as gasoline or naphtha, or the chemical is a solid at normal temperatures. If there is no OEL, the software developer may not know what breakthrough concentration to use. In the case of a mixture, the chemical properties needed to calculate the breakthrough time will not exist. Properties like boiling point and molecular weight usually only exist for components of the mixture, not the mixture itself. Because many of the software tools require the liquid index of refraction, materials that are solid at the workplace temperature cannot be included.

A1.3.9 Some software may allow the wearer to enter their own chemicals if they can collect the chemical properties and values needed. In other instances, one may need to select a chemical surrogate that would have similar properties to the mixture or the solid chemical. In the case of gasoline, one might choose octane as the surrogate to use for the service-life estimate.

A1.3.10 The rules of thumb for estimating organic vapor cartridge/canister service life are available at the following OSHA website: http://www.osha.gov/SLTC/etools/respiratory/change_schedule_ruleofthumb.html and should only be used along with one of the other methods of predicting service life for specific contaminants. These rules of thumb include:

A1.3.10.1 If the chemical's boiling point is >158 °F (>70 °C) and the concentration is <200 ppm, you can expect a service life of 8 h at a normal work rate;

A1.3.10.2 Service life is inversely proportional to work rate; and

A1.3.10.3 Reducing concentration by a factor of ten will increase service life by a factor of five.

A1.3.11 Humidity above 85 % will reduce service life by 50 %. (**Warning—**The humidity rule of thumb only applies to very limited situations, such as high concentrations (≈>500 ppm) of low-volatility (high boiling point) substances. At lower concentrations, the effect of humidity can be much greater for high-volatility substances.)

A1.4 **Adjust the Service-Life Estimate for Your Workplace**—Depending on how close the chemicals and values are to the workplace conditions, confidence in the concentration value and the accuracy (uncertainty) of the software, safety factors, or adjustments to the service-life estimate may be needed. These should then be applied to the service-life estimate before establishing the change schedule.

A1.5 **Establish a Change Schedule**—The change schedule is the time interval after which a used cartridge or canister is replaced with a new one. An appropriate change schedule ensures the cartridge or canister will be changed before the downstream concentration (what is coming out of the cartridge) reaches an unacceptable level. The service-life estimate should be reduced by consideration of the uncertainties used to obtain it. This would include uncertainty about the exact workplace concentration, estimate of the work rate, presence of other gases and vapors, single contaminant or mixture, and type of OEL (ceiling versus time-weighted average).

A1.5.1 Cartridge and canister reuse is another consideration for the change schedule. The service-life estimate may indicate the cartridge will last much longer than the duration of the task. In this case, a cartridge's reuse on a subsequent day may be an option. Before allowing the respirator to be reused, migration of collected vapors during storage shall be considered. If migration is likely, then reuse after storage should not be allowed. The change schedule should state that a new cartridge is to be used each day the task is performed. The more volatile the chemical, the more likely migration will occur during periods of non-use. Organic chemicals with a boiling point less than 149 °F (65 °C) are referred to as low-boiling chemicals. These chemicals are more likely to migrate. The usual recommendation for a low-boiling chemical is to never reuse the cartridge the next day or later. This means that, even though the service-life estimate is longer than one day's use, the change schedule would be set to discard the cartridge or canister after that day's use. Note that 149 °F (65 °C) is not a fine line between migration and no migration. In addition, the chemical structure can have an effect. Another alternative for determining the effect from migration is to calculate values of immediate breakthrough concentrations upon reuse (IBURs). The calculation of the IBUR value is explained in Ref (**6**). As stated by the authors in this article, "Of course, professional judgment is essential in applying such guidance." Migration is typically not a concern for cartridges and canisters that work by chemisorptions.

A1.5.2 Catalytic reaction is another removal mechanism in which the sorbent acts as a catalyst (for example, hopcalite for converting CO to CO_2) that decomposes and detoxifies the contaminant by formation of relatively innocuous substances. The catalyst is generally effective unless it becomes deactivated, thus preventing its operation. Catalysts in cartridges or canisters may be consumed or decomposed over time as a result of the reaction. The change schedule for these cartridges needs to be based on the life of the catalyst or prevention of poisoning of the catalyst.

A1.5.3 Finally, the change schedule should be convenient and easy to track and enforce, for example, at breaks or shift changes.

A1.6 **Change Schedule Verification**—The change schedule should be verified as being appropriate for the workplace.

A2. RESPIRATOR CLASSIFICATION BY MODE OF OPERATION AND CONSIDERATIONS FOR SELECTION AND USE OF RESPIRATORS

A2.1 **General**—The operational characteristics, capabilities, and performance limitations of the various types of respirators should be considered in respirator selection. All respirators that have an assigned protection factor (APF) are limited by the maximum use concentration. They shall never be used above their maximum use concentrations (MUC). Immediately dangerous to life or health (IDLH) concentrations or regulations take precedence over calculated maximum use concentrations (that is, negative-pressure air-purifying respirators can never be used for entry into IDLH conditions even if the MUC calculation would indicate). Escape-only respirators do not have APFs.

A2.2 **Respirator Classification**—Respirators are classified as follows:

A2.2.1 *Atmosphere-Supplying Respirators:*
A2.2.1.1 SCBA:
(1) Closed circuit
(a) Demand and
(b) Pressure demand.
(2) Open circuit
(a) Demand and
(b) Pressure demand.
A2.2.1.2 SAR:

NOTE A2.1—SAR and combination SAR/APR can also be approved as "Type CE" abrasive blasting respirators.

(1) Type A supplied-air (hose mask with blower) respirator—no longer used.

(2) Type B supplied-air (hose mask) respirator—no longer used.

(3) Type C supplied-air (airline) respirator:

(a) Continuous flow,
(b) Demand, and
(c) Pressure demand.

A2.2.1.3 Multifunctional (combination of A2.2.1.1 and A2.2.1.2).

A2.2.2 *Air-Purifying Respirators:*
A2.2.2.1 Non-powered (APR):
(1) Gas and vapor removing,
(2) Particulate removing, and
(3) Combination of (*1*) and (*2*) above.
A2.2.2.2 Powered (PAPR):
(1) Gas and vapor removing,
(2) Particulate removing, and
(3) Combination of (*1*) and (*2*) above.
A2.2.2.3 Multifunctional (combination of APR and PAPR):
(1) Gas and vapor removing,
(2) Particulate removing, and
(3) Combination of (*1*) and (*2*) above.

A2.2.3 Combined atmosphere-supplying and air-purifying respirator.

A2.3 **Atmosphere-Supplying Respirators**—This is a class of respirators that supplies a respirable atmosphere (for example, air or oxygen) independent of the workplace air. This class includes Type C supplied-air (airline) respirators and SCBA. If nitrogen or any inert gas (argon, helium, neon, and so forth) is accidentally supplied to an atmosphere-supplying respirator, the results can be fatal. Although normally considered harmless, these gases can result in the asphyxiation of a respirator wearer. To understand the nature of this hazard, it is necessary to understand that the sensation of breathlessness is not triggered by a lack of oxygen but by a buildup of carbon dioxide in the arterial blood. If an atmosphere-supplying respirator is connected to a source of inert gas (including nitrogen), the wearer breathes the inert gas with no oxygen, the inert gas flushes out carbon dioxide from the body and prevents its buildup, and the wearer senses no problem. If uncorrected, this will lead to unconsciousness and death.

A2.3.1 *SCBA:*

A2.3.1.1 *Description*—SCBA are respirators in which the source of the supplied atmosphere is carried by the wearer. The breathing atmosphere is air, oxygen, or oxygen-enriched air stored in a cylinder or an oxygen-generating chemical contained in a canister. SCBA are commonly equipped with full-face pieces, although half-face pieces, mouthpieces, and hoods are available.

A2.3.1.1.1 SCBA are designed as closed-circuit or open-circuit SCBA. SCBA may be approved for entry and escape or escape only from hazardous atmospheres including IDLH atmospheres, however, OSHA standards and this practice allow only the pressure-demand SCBA to be used in IDLH environments. SCBA of rated duration of less than 15 min are approved for escape only.

A2.3.1.2 *SCBA Limitations/Use*—The period during which the SCBA will provide protection is limited by the amount of air or oxygen in the apparatus, the ambient atmospheric pressure (service life of open-circuit SCBA is cut in half by a doubling of the atmospheric pressure), and the type of work being performed. Important considerations in selecting SCBA are their weight, bulk, service life, and the training required for their maintenance and safe use.

A2.3.1.2.1 Self-contained breathing apparatus equipped with a full-face piece are approved for use at various low temperatures depending on the manufacturer's specifications.

A2.3.1.2.2 See Annex A9 for compressed air moisture content requirements and respirator user instructions for other considerations that wearers should be aware of when using SCBA in a low-temperature environment.

A2.3.1.3 *Closed-Circuit SCBA:*

A2.3.1.3.1 *Description*—In closed-circuit breathing apparatus, the exhaled gas is cleaned and rebreathed. Oxygen may be supplied from cylinders or chemically generated from canisters. Exhaled breath is scrubbed of carbon dioxide by a chemical bed such as sodium hydroxide before being rebreathed. All types are equipped with either a tight-fitting face piece or, for escape only, a mouthpiece with nose clip and goggles. Units are available in which the pressure in the face

piece is negative during inhalation (demand SCBA). Other units are available in which the pressure is positive during inhalation (pressure-demand SCBA).

A2.3.1.3.2 *Limitations/Use*—All closed-circuit SCBA have the advantage of lower weight for the same use duration as open-circuit apparatus. These SCBA are available in rated durations from 15 min to 4 h. Disadvantages include increased complexity and cost. With the exception of the liquefied gas systems, closed-circuit SCBA tend to generate more heat, making the inspired air hotter than the open-circuit SCBA.

A2.3.1.4 *Open-Circuit SCBA:*

A2.3.1.4.1 *Description*—A supply of compressed breathing air is carried by the wearer. In this type, breathing air is exhaled to the surrounding environment after use rather than recirculated. Open-circuit SCBA are equipped with a full-face piece or tight-fitting hood. They are available in both negative-pressure (demand) and positive-pressure (pressure-demand) configurations.

A2.3.1.4.2 *Limitations*—The equipment is simpler and cheaper than the closed-circuit apparatus. Open-circuit SCBA are available in various rated durations. Breathing gas is usually compressed air, but systems that use compressed oxygen or cryogenic air have been developed. The actual service time is usually less than the NIOSH-rated service time. NIOSH approval can only be maintained if the SCBA compressed air cylinder is fully charged to the rated cylinder air pressure with compressed breathing air before use. The compressed breathing air shall meet or exceed the requirements of CGA G-7.1 Grade D breathing air and, if used at low temperatures, shall comply with the maximum water content requirements to prevent freezing (Annex A9).

A2.3.2 *Type C SAR:*

A2.3.2.1 *Description*—A Type C SAR is an atmosphere-supplying respirator for which the source of the breathing air is not designed to be carried by the wearer. This SAR is also known as an airline respirator. Respirable air is supplied to the airline respirator through a 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. The airline respirator may operate in the continuous-flow, demand, or pressure-demand mode. A regulator, flow-control valve, or orifice is provided to govern the rate of airflow to the wearer. Exhaled air passes to the ambient atmosphere through a valve(s) or opening(s) in the respiratory inlet covering. Up to 300 ft (91 m) of hose length is permissible, depending upon the certification. The NIOSH-approved airline respirator includes the air supply hoses and male/female quick disconnect fittings; therefore, substitution of other hose or other respirator manufacturers' air supply hoses or fittings voids the approval, and the respirator is no longer considered acceptable. Airline quick disconnect fittings shall be incompatible with other fittings used in the workplace to prevent inadvertent supply with non-breathing air or other gas. Abrasive blasting versions of this respirator (known as Type CE) are equipped with additional devices to protect the wearer from impact and abrasion of rebounding abrasive material.

A2.3.2.1.1 *Continuous Flow*—Equipped with a loose-fitting or tight-fitting respiratory inlet covering. At least 4 ft^3 (115 L) of air per minute for tight-fitting face pieces and hoods and 6 ft^3 (170 L) of air per minute for loose-fitting face pieces, helmets, and hoods is required to flow continuously into the respirator. A positive pressure is normally maintained in the face piece. Continuous-flow types require a greater supply volume of breathing air than demand or pressure demand because the air is essentially flowing at a constant rate independent of breathing rate. Some continuous-flow airline respirators are approved with vortex tubes, which can either heat or cool the air entering the face piece for use in cold or hot environments, respectively.

A2.3.2.1.2 *Demand*—Equipped with a tight-fitting respiratory inlet covering only. The demand valve permits flow of air only during inhalation. The demand SAR does not maintain positive pressure in the respiratory inlet covering during inhalation.

A2.3.2.1.3 *Pressure Demand*—Equipped with a tight-fitting respiratory inlet covering only. A positive pressure is normally maintained in the respiratory inlet covering during use.

A2.3.2.2 *Limitations/Use*—Airline respirators shall not be used in IDLH environments. Their use is limited to situations from which the wearer can escape unharmed without the aid of the respirator (that is, non-IDLH atmospheres) because the air supply could be interrupted. The wearer is restricted in movement by the hose and the hose is subject to being severed, pinched off, or disconnected. However, SARs can be used in IDLH atmospheres when combined with a self-contained air supply (refer to A2.3.2.3).

A2.3.2.2.1 Care shall be taken not to allow contamination of SAR hoses with materials used in the workplace, because some chemicals can permeate through the wall of the hoses. This condition could allow the permeated chemical to evaporate inside the SAR hose and then be inhaled by the respirator wearer. Hose supplied by the manufacturer and recommended operating pressures and hose lengths shall be used. The compressed breathing air quality shall meet or exceed the requirements of Grade D breathing air.

A2.3.2.2.2 For high work rates, the air supply pressure should be set at the higher end of the pressure range for the hose length being used, as listed in the respirator user instructions.

A2.3.2.2.3 Some airline respirators are approved with bulkhead fittings so that they can be used inside of encapsulating suits.

A2.3.2.3 *Multifunctional-Type Airline Respirators with Self-Contained Air Supply:*

A2.3.2.3.1 *Description*—These types of respirators combine the capabilities and functions of the airline respirator and SCBA into a single respirator. The self-contained air supply on this type of respirator allows the wearer to enter and work in an IDLH atmosphere with this respirator. Such multifunctional respirators are certified by NIOSH in accordance with the requirements for self-contained breathing apparatus and may be used for:

(1) Situations requiring extended work periods in which the self-contained air supply alone does not provide sufficient time. In this situation, the wearer may connect the airline to an air source to afford additional service time; and

(2) Situations requiring the use of a SCBA.

A2.3.2.3.2 *Limitations*—These multifunctional respirators are generally divided into the following two groups:

(1) Multifunctional-type, supplied-air respirators equipped with a self-contained (auxiliary) escape air supply having a rated service life of less than 15 min. These may be used to enter an IDLH atmosphere only if connected to a supplied air source. The self-contained air supply in this case is only to be used for egress purposes.

(2) Multifunctional-type, supplied-air respirators equipped with a self-contained air supply having a rated service life of 15 min or more. These may be used to enter an IDLH atmosphere breathing from the self-contained air supply, provided that not more than 20 % of the rated self-contained air supply is used during entry.

A2.3.2.3.3 To escape from an IDLH atmosphere in the event that the primary air supply (that is, airline function) fails to operate, the wearer switches to the self-contained air supply and disconnects the air supply hose. Wearers should carefully read and understand the requirements and limitations detailed on the NIOSH approval label.

A2.4 Air-Purifying Respirators

A2.4.1 *Description*—Ambient air before being inhaled is passed through an air-purifying element, which removes aerosols, vapors, gases, or a combination of these contaminants. They are available in two modes of operation:

A2.4.1.1 Non-powered or APR (negative-pressure) type, in which the wearer's breathing draws air through the air-purifying element. The non-powered (negative-pressure) APR is equipped with a tight-fitting respiratory inlet covering. Those APR equipped with a mouthpiece and nose clamp are for escape only.

A2.4.1.2 Powered APR or PAPR type contains a blower, stationary or carried by the wearer, that passes ambient air through an air-purifying element and then supplies purified air to the respiratory inlet covering. The respiratory inlet covering may be tight fitting or loose fitting.

A2.4.2 *Limitations/Use*—Air-purifying respirators shall not be used in IDLH atmospheres. Air-purifying respirators do not protect against oxygen-deficient atmospheres.

A2.4.2.1 The appropriate type of canister, cartridge, or filter shall be selected for the particular atmosphere and conditions. The time period over which protection is provided is dependent on the canister, cartridge, or filter type; the concentration of the contaminant; humidity levels in the ambient atmosphere; and the wearer's respiratory rate. A canister, cartridge, or filter change schedule shall be established unless the respirator is equipped with an end-of-service-life indicator (8.3.6 and 8.3.7).

A2.4.2.2 The non-powered air-purifying respirators may cause discomfort because of a noticeable resistance to inhalation or increase in dead space or both, but have the advantage of being small, light, and simple in operation. Powered respirators are limited by battery life, weight, and complexity but have lower breathing resistance. In addition, the PAPR canister, cartridge, or filter life and airflow shall be checked before each use.

A2.4.3 *Vapor- and Gas-Removing Respirators:*

A2.4.3.1 *Description*—These APR and PAPR use chemical-removing cartridges or canisters that are containers filled with sorbent or catalysts to remove contaminants. The term "gas mask" is often used to refer to a full-face-piece APR that incorporates a canister. The canister may be mounted to the wearer's face piece, chest, or back.

A2.4.3.1.1 Cartridges and canisters have a limited service life that varies with different contaminants, airborne concentrations, and many other factors. Water vapor in air (usually) accelerates this decrease. Cartridges and canisters are not effective for every chemical.

A2.4.3.2 *Limitations/Use*—Vapor- and gas-removing respirators provide no protection against aerosol contaminants. Chemical cartridges and canisters are specific for the gas/vapor they are designed for and can only be selected for those chemicals they are effective against. The proper type of canister or cartridge should be selected for the particular contaminants and operational conditions. The time period over which protection is provided is dependent on the canister or cartridge type, the concentration of contaminant, the temperature and humidity levels in the ambient atmosphere, the wearer's respiratory rate, and so forth. Cartridges and canisters shall be changed before the end of their service life by using an ESLI or establishing a change schedule (Annex A1). While these respirators are not approved for entry into IDLH atmospheres, respirators with canisters, that is, gas masks, are approved for escape only from IDLH atmospheres.

A2.4.4 *Aerosol-Removing Respirators:*

A2.4.4.1 *Description*—Aerosol-removing respirators use particulate filters for removing dusts, mists, metal fumes, fibers, bioaerosols, and other particles from the air. For non-powered APR, NIOSH (refer to 42 CFR 84) certifies three levels of filter efficiency: 95, 99, and 99.97 % (that is, 100) and three filter series: N—not resistant to oil, R—resistant to oil, and P—oil proof. PAPR designed to remove particles use high-efficiency filters. The high-efficiency filter shall be at least 99.97 % efficient per the NIOSH tests to be approved.

A2.4.4.2 *Limitations*—Aerosol-removing respirators provide protection against aerosols only and do not provide protection against gases and vapors. All particulate-removing filters are single use, meaning the filter material cannot be cleaned and reused.

A2.4.4.2.1 The N-series filter should not be used where oil is present. In extremely dusty conditions, the filters should be changed at the end of the shift. Any R or P series is appropriate for use in workplaces where oil is present. Manufacturers provide guidance on when P-series filters should be replaced and shall be followed. The PAPR high-efficiency filter should be replaced whenever the PAPR minimum airflow identified by the airflow indicator cannot be maintained.

A2.4.4.2.2 In addition, any class filter should be changed whenever the filter is damaged, unacceptable breathing resistance is noticed, as required by the program administrator, or for hygiene reasons.

A2.4.5 *Combination Aerosol-, Vapor-, and Gas-Removing Respirators*—These respirators are equipped with cartridge(s) or canister(s) and filters to remove vapors, gases, and aerosol

from air. The filter may be a permanent or a replaceable part of the cartridge. The advantages and disadvantages of the component sections of the combination respirator are described above.

A2.5 Multifunctional Air-Purifying Respirators

A2.5.1 *Description*—A multifunctional air-purifying respirator is a PAPR that is also approved to operate as a non-powered respirator for use in the event that the motor fails or there is a need for clandestine operation.

A2.5.2 *Limitations/Use*—All of the limitations of A2.4.2 shall apply except the limitations associated with battery life.

A2.6 **Combined Atmosphere-Supplying and Air-Purifying Respirators**—These respirators can be used in either an atmosphere-supplying or air-purifying mode. The air-purifying element provides protection while the air supply is not used. When using a combination respirator (for example, airline respirators with an air-purifying filter), employers shall ensure that the assigned protection factor is appropriate to the mode of operation in which the respirator is being used.

A3. OXYGEN DEFICIENCY

A3.1 **Introduction**—Oxygen is a normal component of our atmospheric environment, which is necessary to sustain life. Earth's atmosphere is made up of the following gases, excluding water vapor, in the proportions noted in Table A3.1.

NOTE A3.1—Small amounts of other gases, such as carbon dioxide, neon, krypton, and helium are also present, as is water vapor. Partial pressure equals the fractional concentration of the gas in question times the total atmospheric pressure.

A3.1.1 The percent by volume of these gases does not vary with altitude; however, the partial pressures decrease with increasing altitude because the total pressure decreases.

A3.1.2 A reduction in the partial pressure of oxygen (PO_2) may result from:

A3.1.2.1 *Reduction of the Percent by Volume of Oxygen*—This situation can result from the oxygen being displaced or otherwise removed. It is the most common form of oxygen-deficiency hazard warranting extreme care when entering confined spaces.

A3.1.2.2 *Reduced Atmospheric Pressure*—This situation occurs when the total atmospheric pressure is reduced. The oxygen percent by volume may remain at 20.9 %, but the PO_2 will be lower than normal.

A3.1.3 The effect of oxygen deficiency on the body is the same in either case. It is the partial pressure of oxygen available that is of utmost importance and not the percent by volume or atmospheric pressure.

A3.1.4 As shown in Table A3.2, the greater the altitude, the lower the PO_2. People live and work at high altitudes. They do so with little or no physiological effect because they are acclimatized. The human body can adapt to the reduced PO_2 levels by making compensating changes to its respiratory, cardiovascular, and hematopoietic systems. Complete acclimatization requires about four week's residence at the ambient PO_2. Acclimatized individuals entering a confined space at high altitude should not be required to wear SCBA for protection against oxygen deficiency if the partial pressure of oxygen inside the confined space is the same as the PO_2 outside the confined space.

TABLE A3.1 Gases Making Up Earth's Atmosphere, Excluding Water Vapor

Gas	Volume (%)	Partial Pressure at Sea Level (mmHg)
Nitrogen	78.1	593
Oxygen	20.9	159
Argon	0.9	7.1

A3.1.5 When people who are not acclimatized work in areas of reduced PO_2, they will experience a feeling of fatigue. The same work rate in an environment with normal PO_2 compared to an environment of reduced PO_2 produces a higher breathing rate, a greater heart rate, and possibly other symptoms of fatigue that, under normal conditions, would not be customary at this workload.

A3.2 **Considerations for Reduced Oxygen Levels**—When someone breathes in normal air at 21 % oxygen, part of the oxygen is absorbed to be used by the body. However, on exhalation, the breath will at first consist of this same inspired air, since there is little oxygen/carbon dioxide exchange in the airways (trachea and bronchi) of the lung. As a person continues to exhale, the last portion of the breath is from the alveoli (where exchange of oxygen and carbon dioxide occur) and may contain 5 % carbon dioxide and 16 % oxygen.

A3.2.1 When a worker wears a respirator, a portion of the worker's exhaled breath remains in the respirator. This exhaled air has a lowered oxygen percentage because of the oxygen removed by the lungs, and the similar amount of carbon dioxide added. Thus, on inhalation, the percentage of oxygen inhaled is reduced by including this re-breathed air. When respirators are used in oxygen-deficient environments, the effect of re-breathing the exhaled air in the face piece can be significant since it will lead to further reductions in oxygen content.

A3.2.2 When used in reduced-oxygen atmospheres, the volume inside the face piece of air-purifying or atmosphere-supplying respirators can affect the oxygen content breathed by the wearer. This is particularly a problem with full-face-piece

TABLE A3.2 Oxygen-Deficient Conditions and Probable Effects

Percent O_2 at Sea Level	Equivalent Atmospheric Pressure (mmHg)	Ambient Atmospheric PO_2 (mmHg)	Equivalent Altitude, ft (m)	Probable Effects
20.9	760	159	Sea level	None in healthy adults.
19	694	145	2500 (762)	
16.6	603	126	6000 (1829)	
16	584	122	7000 (2134)	Increased pulmonary ventilation and cardiac output, incoordination, impaired attention, and thinking.
15.4	559	117	8000 (2438)	Rapid exposure to altitudes over 8000 ft (2438 m) may cause high-altitude sickness (respiratory alkalosis, headache, nausea, and vomiting) in unacclimatized individuals. Rapid ascent increases the risk of high-altitude pulmonary edema and cerebral edema.
14.2	523	109	10 000 (3048)	
13.7	498	104	11 000 (3353)	Abnormal fatigue on exertion, faulty coordination, impaired judgment, emotional upset.
12.8	461	97	13 000 (3962)	
12.2	450	94	14 000 (4267)	Impaired respiration, very poor judgment and coordination, tunnel vision.
<10.4	<380	<79	>18 000 (5486)	Excessive rate and depth of breathing at rest. Severe limitations on activity—high work rate results in collapse and unconsciousness.

respirators. For negative-pressure air-purifying respirators, reducing the volume of the face piece by using a respirator designed with a small mask volume or using a nose cup will lessen this effect. For atmosphere-supplying respirators, the effect is significant only with demand- and pressure-demand-type respirators (not continuous flow). Using a nose cup, which reduces the effective face piece volume, or using continuous-flow respirators may lessen this effect. At high altitudes, increasing the oxygen content of the air supplied to the respirator, as shown in Table 1, is necessary to provide sufficient oxygen.

A4. VERBAL COMMUNICATIONS

A4.1 Verbal communications, especially when wearing a respirator in a noisy industrial environment, can be difficult. It is important to ensure that respirator wearers can comfortably communicate when necessary, because a worker who is speaking very loudly or yelling may cause a face piece seal leak, and the worker may be tempted to dislodge the respirator temporarily to communicate. Both situations are undesirable.

A4.1.1 There are several options that may be used to aid communications when wearing respirators:

A4.1.1.1 Materials;
A4.1.1.2 Speaking diaphragms;
A4.1.1.3 Built-in microphones;
A4.1.1.4 Hand or coded signals;
A4.1.1.5 Cranial, throat, or ear microphones; and
A4.1.1.6 Use of telephone handsets.

A4.2 **Materials**—Some respirators are designed (or built) of materials to minimize adverse effects on voice transmission.

A4.3 **Speaking Diaphragms**—A speaking diaphragm consists of a resonating surface and cavity that vibrates during speech, thereby amplifying the wearer's voice outside of the respirator.

A4.3.1 Several points shall be considered when using speaking diaphragms:

A4.3.1.1 They are key components in maintaining the airtight integrity of the face piece, requiring care when installing and handling;

A4.3.1.2 Using a respirator with a speaking diaphragm during welding, cutting, burning, or grinding operations is of special concern, as flying sparks may burn a hole in the diaphragm, thereby creating a leak. Some respirator manufacturers have compensated for these applications by providing shrouds to cover the diaphragm or by using metal diaphragms; and

A4.3.1.3 Not all face piece respirators are available with speaking diaphragms. Check with the respirator manufacturer for the availability of respirator models with speaking diaphragms.

A4.4 **Built-In Microphones**—Some respirator manufacturers make available small microphones that are mounted inside, or connected to, the respiratory inlet covering. The microphone may be connected to a radio, telephone, loudspeaker, or other means of electronic transmittal. Two considerations are:

A4.4.1 Any component that is attached to or through the respiratory inlet covering may affect its function and, in cases in which components are provided by the manufacturer, strict adherence to the installation instructions and leak test procedures is necessary to ensure that the airtight integrity is maintained; and

A4.4.2 Voice-actuated-type communication systems may cause continuous sound transmission of the blower noise when used with powered air-purifying respirators or air flow noise when used with airline respirators.

A4.5 **Hand or Coded Signals**—A predetermined set of signals may be useful in communicating.

A4.6 **Cranial, Throat, or Ear Microphones**—Cranial and throat microphones are held in place with a harness against the wearer's head or larynx, respectively. Ear microphones are worn in the same manner as a wireless earphone and function as both a microphone and speaker. Use of these devices that do not require making penetrations or attachments to the respirator should not impact the NIOSH approval status. They may be used with radios, telephones, loudspeakers, or other means of electronic transmittal, similar to face piece microphones.

A4.6.1 Considerations when using these devices are:

A4.6.1.1 Cranial microphones should not be placed under the head harness of face piece respirators unless the respirator wearer has been fit tested in that manner, since their dislodgement may loosen the respirator straps; and

A4.6.1.2 When connecting wires are passed underneath the bibs or neck seals of supplied-air hoods or helmets, they should be attached to the wearer's body to avoid disturbing the bib positioning.

A4.7 **Use of Telephone Handsets**—Since a person exhales while speaking, the exhalation valve in a face piece respirator is partially open. This is a perfect location to place a handset or handheld microphone to obtain the clearest voice transmission. An alternative is to hold the handset or microphone to the wearer's throat while speaking.

A4.8 **Safety Considerations**—Electronic devices should be selected and used with caution in explosive atmospheres. Ensure that all such devices comply with requirements for permissibility and intrinsic safety. The effect of radio frequency emissions should be considered when using such devices in the vicinity of sensitive electronic equipment.

A5. REQUIRED FIT FACTOR

A5.1 When conducting quantitative fit testing, a numeric expression of how well a tight-fitting respirator fits a wearer is obtained under the conditions of the test procedure. This numeric expression is called a fit factor and is the ratio of the measured challenge (test) agent concentration outside the respirator (C_{out}) to its concentration inside the respirator (C_{in}), that is, fit factor = C_{out} / C_{in}. The respirator program administer shall determine what passing criterion to use for judging the respirator fit to be adequate. In other words, what is the minimum numeric value for the fit factor for determining whether the fit is satisfactory or not. This value is called the required fit factor (RFF). The RFF is the acceptance criterion for a successful quantitative fit test. Program administrators can select pass/fail criteria recommended by ANSI, NIOSH, or others that are more conservative than the OSHA requirements. The goal is to choose an RFF that program administrators believe will help ensure the wearer receives the assigned protection level of the selected respirator in their workplace.

A5.2 An assigned protection factor (APF) is a number given or assigned to a class of respirators that represents the level of protection expected to be provided to a respirator wearer based on workplace or simulated workplace respirator performance studies. It represents the minimum ratio of C_{out} to C_{in} as a result of respirator use when the respirator is properly selected and used in a continuing effective respiratory protection program as specified by 29 CFR 1910.134 or this Practice F3387.

A5.3 Fit factors, while numerically similar, are not the same as protection factors (**7-11**). Fit factors are obtained from a qualitative or quantitative fit test that is typically conducted away from the work area. For quantitative fit testing, this is done by attaching a probe or sampling adapter to the face piece, which is then connected to the QNFT equipment through sampling hoses. The wearer performs a variety of head, body, or breathing exercises, or combinations thereof, to challenge the face piece seal. Fit factors can vary with each donning with the same wearer on the same respirator. The length of time the respirator is worn during fit testing is almost always much shorter in duration than wear time in the workplace. For these and other reasons, the fit factor may not represent the performance of the respirator in the workplace. To account for the differences or uncertainties between the fit test and workplace conditions (for example, work rate and work activity, aerosol particle size, and environmental conditions), the RFF is selected as a multiple of the APF. The most common approach to help ensure the wearer receives the protection assigned to the respirator is achieved by applying an uncertainty or safety factor to the APF. For example, OSHA applies a safety factor of 10. This means that, when fit testing a respirator with an APF of 10, the RFF would be 100 (10 × 10). Alternative approaches include multiple donning, increasing fit test frequency, or a combination of these approaches. With respect to selecting a RFF, if too low the respirator fit may not provide an acceptable level of protection in the workplace. Too high of an RFF may result in rejecting adequate fitting respirators and

increase the time needed for fit testing. It may also result in selecting more uncomfortably fitting respirators, resulting in reduced wear (Annex A7). In addition, fit test methods have limitations as to how high of a fit factor they can accurately measure.

A5.4 Qualitative fit test methods recognized by ANSI Z88.10 and OSHA are designed to be equivalent to quantitative fit factors of 100. Qualitative fit tests should not be used where higher fit factors are required. Studies conducted by NIOSH have shown a safety factor of 10 ensured that wearers received the APF level of protection when worn during simulated workplace protection factor studies **(12-14)**. In general, workplace protection factor (WPF) studies suggest using a safety factor of 10 for tight-fitting, negative-pressure respirators. Other studies suggest different safety factors may be acceptable **(15-17)**.

A5.5 In summary, for negative-pressure respirators, OSHA applies a single safety factor of 10 for all workplace applications and use conditions. When program administrators feel the need to increase the confidence that wearers are obtaining acceptable fit of their face piece, a variety of fit-testing approaches can be implemented. These include increasing the safety factor, increasing the frequency of fit testing, or a combination of these approaches. Respirator program administrators can also use a number of other approaches to ensure workers are obtaining acceptable respiratory protection. These approaches may include medical surveillance, program audits, wearer feedback, evaluating respirator use in the workplace, and so forth. OSHA requires, and this subcommittee recommends, an RFF of ten times the APF for negative-pressure respirators. The respirator program administrator may decide to use a higher safety factor or other combination of approaches described in this annex.

A6. POSITIVE-PRESSURE DESIGNATION

A6.1 In the past, PAPR, continuous-flow SAR, and pressure-demand atmosphere-supplying respirators have been referred to as positive-pressure respirators. However, positive pressure has never been defined for PAPR and continuous-flow SAR. No pressure value or time duration that the positive pressure shall be maintained has ever been established. These respirators are susceptible to being over breathed when the wearer's breathing rate exceeds the supplied-air flow rate of the respirator. Brief negative pressures have been measured in these respirators, but these negative pressure spikes have never been correlated to lower protection. Workplace protection factor and simulated workplace protection factor studies have shown these respirators to provide higher protection factors compared to negative-pressure respirators.

A6.2 On the other hand, pressure-demand atmosphere-supplying respirators are tested to maintain a positive pressure when tested against an airflow of 40 lpm minute volume. Under higher work conditions, these respirators could possibly be over breathed as well. However, based on all of the testing done on pressure-demand atmosphere-supplying respirators, they have been assigned the highest APF. Although 40 lpm minute volume is the flow rate required by NIOSH for pressure-demand certification testing, many atmosphere-supplying respirators operate with a flow of 100 lpm minute volume or greater.

A6.3 NIOSH has used the term "other positive-pressure respirators" in many of its publications **(18)**. In this case, this term refers to continuous-flow SAR that meets the pressure-demand positive-pressure requirement. This term has come about because NIOSH does not refer to all continuous-flow SAR as positive-pressure respirators. Continuous-flow SAR approved as pressure demand could then be used where pressure-demand SAR are required.

A7. EFFECTIVE PROTECTION FACTOR (EPF)

A7.1 The term "protection factor" describes how much a respirator will reduce contaminant exposure expressed as the ratio of contaminant outside the respirator (C_o) to the concentration inside the respirator (C_i). The protection a respirator [$(C_o) / (C_i)$] can provide is affected by the circumstances under which the respirator is selected, used, and maintained. Thus, a number of terms related to protection factors have been defined by the American Industrial Hygiene Association Respiratory Protection Committee to accommodate these circumstances.

A7.2 This annex focuses on effective protection factors as they include an assessment and illustration of the adverse effect on protection of non-wear time of a respirator when it is actually needed to reduce worker exposure below occupational exposure levels. The definition of an effective protection factor (EPF) was defined by the AIHA Respiratory Protection Committee **(19)**. The definition of EPF is a measure of the protection provided by a properly selected, fit-tested, and functioning respirator when it is worn for only some fraction of

the total exposure in the workplace. It is the ratio of the contaminant concentration outside the respirator to that in the air actually inhaled [EPF = C_o / $C_{inhaled}$]. It is determined by sampling outside the respirator and in the breathing zone during the total exposure period, regardless of whether the respirator is being worn. While the respirator is worn, breathing zone sampling is done from within the respirator. When the respirator is not worn, sampling is ambient. The EPF is strongly influenced by non-wear time, regardless of the respirator's APF.

A7.3 An APF is the level of respiratory protection that a properly functioning respirator or class of respirators would be expected to provide to properly fitted and trained users in the workplace. The APF takes into account all expected sources of face piece penetration (for example, face seal penetration, filter penetration, and valve leakage). It is not intended to take into account factors that degrade performance such as poor maintenance, failure to follow manufacturer's instructions, and failure to wear the respirator during the entire exposure period. The EPF may be determined by correcting the assigned protection factor for the time that the respirator is not worn during the exposure period. It is valid only if the air contaminant concentration is relatively constant over the exposure period using:

$$EPF = \frac{T_t}{\frac{T_w}{APF} + T_{nw}} \quad \text{(A7.1)}$$

where:

EPF = effective protection factor,
T_t = total time in contaminated workplace,
T_w = time respirator worn in contaminated workplace,
T_{nw} = time respirator not worn in contaminated workplace, and
APF = assigned protection factor.

A7.4 A few key points to note with regard to the 2002 EPF definition:

A7.4.1 The respirator is properly selected.

A7.4.2 The respirator is properly fit tested to the specific wearer.

A7.4.3 The respirator is properly functioning.

A7.4.4 The EPF is strongly influenced by the non-wear time, regardless of the respirator's APF.

A7.5 The AIHA/RPC 2002 EPF definition has its roots in a proposed definition by Alan Hack, Chuck Fairchild, and Barbara J. Skaggs of the Los Alamos National Laboratory (**20**). That proposal does not refer to the protection as an EPF; it more correctly refers to it as a worker use factor (WUF), quite simply indicating that it represents the ratio of the concentration of contaminant in the workplace air to the amount actually inhaled [WUF = C_o / $C_{inhaled}$]. The authors state that, "because of the potential for workers to frequently remove their respirator during the day, even while in the working environment, the WUF is not a measure of the performance of the respirator. In fact, the amount of time that the respirator is not worn during the period of exposure is more important in determining the WUF than is the protection provided while the respirator is worn."

A7.6 Table A7.1 and Fig. A7.1 illustrate how the percentage of time a respirator is not worn impacts respiratory protection. Respirator manufacturers may provide similar information (**21**).

A7.7 As indicated in Table A7.1, not wearing the respirator for 10 % of the time reduces the potential maximum APF of 100 to 9.2, an APF of 20 to 6.9, and an APF of 10 to 5.3. The same respirator worn for only 50 % of the exposure time reduced the potential maximum APF of 100 to 2.0, an APF of 20 to 1.9, and an APF of 10 to 1.8. This reduction has nothing to do with the respirator and everything to do with the wearer's use practices and exposure times. Fig. A7.1 provides a graphical illustration of Table A7.1 calculations.

A7.8 When describing an EPF in a *JISRP* article, the authors state the EPF reflects bad practice which cannot be related to the respirator performance (**22**). This type of study will be greatly influenced by the non-wear time and will generate a highly pessimistic protection factor.

A7.9 EPFs should be used with extreme caution and not used to determine the effectiveness of a respirator. Not wearing a respirator when one is needed for even short periods of time substantially reduces the amount of protection that a respirator can provide.

TABLE A7.1 EPF Values for a Percentage of Non-Wear Time for Maximum APF Values

Time Worn, T_w	Time Not Worn, T_{nw}	Percentage of Time Not Worn	Effective Protection Factor (EPF)		
			Max APF of 100	Max APF of 20	Max APF of 10
480	0	0	100	20	10
456	24	5	16.8	10.3	6.9
432	48	10	9.2	6.9	5.3
408	72	15	6.3	5.2	4.3
384	96	20	4.8	4.2	3.6
360	120	25	3.9	3.5	3.1
240	240	50	2.0	1.9	1.8

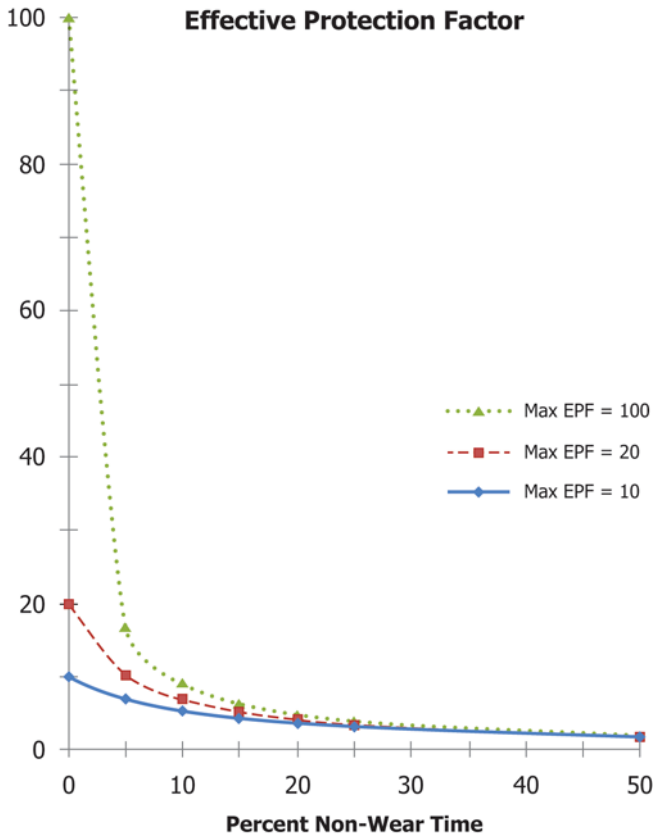

FIG. A7.1 EPF Values for a Percentage of Non-Wear Time for Maximum APF Values

A8. DECONTAMINATING, CLEANING, AND SANITIZING RESPIRATORS

A8.1 **Decontaminating**—Respirators may become contaminated with toxic materials or bioaerosols. Decontamination is removing or neutralizing these toxic materials or bioaerosols.

A8.1.1 Decontamination is important to avoid cross contamination, allow for the potential reuse of respirators, prevent a health hazard to a wearer or respirator handler (or person assigned to decontaminate the respirator, or both), and for the proper disposal of contaminated respirators.

A8.1.2 Separate decontamination steps may be required before cleaning. In some cases, initial decontamination may need to be done before doffing the respirator and, in other cases, immediately upon removal of the respirator.

A8.1.3 All decontamination should be done according to standard operating procedures. Verification of decontamination procedures may be necessary.

A8.2 **Cleaning and Sanitizing**—The following is an example of a procedure for cleaning and sanitizing respirators, including inspection and assembly. In all cases, the respirator user instructions should be followed. Respirator user instructions may differ from those outlined in the following:

A8.2.1 Remove, when necessary, the following components of respiratory inlet covering assemblies before cleaning and sanitizing:

A8.2.1.1 Filters, cartridges, and canisters;

A8.2.1.2 Speaking diaphragms;

A8.2.1.3 Valve assemblies; and

A8.2.1.4 Any components recommended by the respirator manufacturers.

A8.2.2 Wash respiratory inlet covering assemblies in warm (follow respirator user instructions) cleaner or sanitizer solution, or both. A soft brush may be used to facilitate removal of dirt or other foreign material.

A8.2.3 Rinse respiratory inlet covering assemblies in clean, warm water (follow respirator user instructions).

A8.2.4 Clean and sanitize all parts removed from the respiratory inlet covering as recommended by the respirator user instructions.

A8.2.5 Dry parts, if necessary, to remove foreign material and hand wipe respiratory inlet covering assemblies, all parts, and all gasket- and valve-sealing surfaces with a damp, lint-free cloth.

A8.2.6 Inspect parts and replace any that are defective.

A8.2.7 Reassemble parts on respiratory inlet covering assemblies.

A8.2.8 Visually inspect and, where possible, test parts and respirator assemblies for proper function.

A8.2.9 Place the respiratory inlet covering in an appropriate container for storage or attach filters, cartridges, and canisters, as appropriate.

A8.2.10 Place assembled respirators in appropriate containers for storage.

A8.2.11 Machines may be used to expedite the cleaning, sanitizing, rinsing, and drying of large numbers of respirators. Extreme care should be taken to ensure against tumbling, agitation, or exposure to temperatures above those recommended by the manufacturer, 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.

A8.2.12 Cleaners and 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 cleaners, sanitizing agents, and many solvents can damage rubber or elastomeric parts and should be used with caution.

A8.2.13 Respirators may be washed in a detergent solution as a separate operation and then sanitized by immersion in a sanitizing solution. Some sanitizing solutions that have proven effective are:

A8.2.13.1 Bleach solution (made from mixing 2 teaspoons 5.25 % bleach per gallon of tap water (2 mL 5.25 % bleach per liter of tap water), 2-min immersion;

A8.2.13.2 Iodine solution made by mixing one tablespoon (15 mL) of 1.75 % aqueous iodine solution in 1.5 gal (5.7 L) of tap water; 2-min immersion; or

A8.2.13.3 Quaternary ammonium compounds in water; 2-min immersion.

A8.2.14 Follow respirator user instructions.

A8.2.15 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 wearer (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 with time; 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 should be thoroughly rinsed from the respirator parts.

A9. DEW POINT

A9.1 The dew point temperature of compressed breathing air shall be lower than the temperature of the atmosphere in which atmosphere-supplying respirators are worn. If the ambient temperature falls below the dew point of compressed breathing air, any moisture present can condense and form liquid water. If the ambient temperature is freezing, then regulator or control valves can freeze. Adiabatic cooling further contributes to the problem of freezing. Adiabatic cooling occurs in atmosphere-supplying respirators as high-pressure compressed air loses heat as its pressure is reduced.

A9.2 **Determining Atmospheric Dew Point Temperature for CGA G7.1 Compliance**—The CGA G-7.1 Grade D air quality dew point criterion is ≤–50 °F (–45.6 °C) (67 ppm v/v) or the dew point shall be 10 °F (5 °C) lower than the coldest temperature where the respirator is worn. Atmospheric water vapor content can be measured by various methods, such as colorimetric detector tubes to determine moisture compliance with CGA G-7.1. These measurements can be compared to Table A9.1, which lists dew point temperatures and their corresponding moisture contents for dew point temperatures

TABLE A9.1 Dew Point Temperatures and Corresponding Moisture Content

°F	°C	ppm (v/v)	mg/m^3	°F	°C	ppm (v/v)	mg/m^3
–110	–78.9	0.6	0.4	–30	–34.4	235	173
–105	–76.1	1	0.7	–25	–31.7	316	233
–100	–73.3	1.6	1.2	–20	–28.9	422	311
–95	–70.6	2	1.5	–15	–26.1	560	412
–90	–67.8	4	3	–10	–23.3	738	543
–85	–65.0	5	4	–5	–20.6	968	713
–80	–62.2	8	6	0	–17.8	1262	929
–75	–59.4	12	9	5	–15.0	1636	1204
–70	–56.7	17	13	10	–12.2	2109	1553
–65	–53.9	24	18	15	–9.4	2704	1991
–60	–51.1	34	25	20	–6.7	3450	2540
–55	–48.3	48	35	25	–3.9	4381	3225
–50	–45.6	67	49	30	–1.1	5537	4076
–45	–42.8	92	68	35	1.7	6850	5043
–40	–40.0	127	94	40	4.4	8353	6150
–35	–37.2	173	127	45	7.2	10 144	7468

ranging from –110 °F (–78.9 °C) to 45 °F (7.2 °C) at one atmosphere of pressure.

A9.3 **Maximum Allowable Moisture Content Using Pressure Dew Point Temperature**—In Table A9.1, atmospheric dew point temperatures and their corresponding moisture contents are listed. However, the pressure dew point temperature of compressed breathing air becomes a critical factor in evaluating air quality of breathing air use in extremely cold temperatures, such as those that occur in some geographic locations in North America. The increased pressure of breathing air for atmosphere-supplying respirator results in the pressure dew point temperature of the compressed air being considerably lower than the dew point of ambient air (at one atmosphere of pressure) with the same temperature.

A9.3.1 *Maximum Allowable Moisture Content for Airline Respirator Low-Pressure Compressed Air Considering Pressure Dew Point Temperature*—Table A9.2, adapted from CAN/CSA Z180.1, takes into account pressure dew point temperatures at typical operating pressures of airline respirators and is used for determining the allowable moisture content to protect against valve freezing. To use Table A9.2, locate the operating pressure for the airline respirator and find the lowest temperature in which the respirator will be used, then read the maximum water content from the left column.

A9.3.2 *Maximum Allowable Moisture Content for SCBA High-Pressure Compressed Air Considering Pressure Dew Point Temperature*—Table A9.3, adapted from CAN/CSA Z180.1, takes into account pressure dew point temperatures at typical operating pressures of SCBA and is used for determining the allowable moisture content to protect against valve freezing. To use Table A9.3, locate the operating pressure of the SCBA and find the lowest temperature in which the respirator will be used, then read the maximum water content from the left column.

TABLE A9.2 Compressed Air Moisture Content Airline Respirators

Maximum Water Content Measured at Atmospheric Dew Point and Temperature	Lowest Use Temperature							
	50 psig (344.8 kPa)		75 psig (517.1 kPa)		100 psig (689.5 kPa)		125 psig (861.9kPa)	
ppm (mL/m^3)	°C	°F	°C	°F	°C	°F	°C	°F
844	–1	31	. . .	. . .	. . .	. . .	. . .	. . .
693	–3	27	0	34	. . .	. . .	. . .	. . .
567	–6	22	–2	30	. . .	. . .	. . .	. . .
463	–8	19	–4	25	–1	31	. . .	. . .
377	–10	15	–7	21	–4	26	–2	30
305	–12	11	–9	17	–6	22	–4	26
247	–15	7	–11	13	–9	18	–7	22
199	–17	3	–13	9	–11	13	–9	17
159	–19	–1	–16	5	–13	9	–11	13
127	–21	–5	–18	0	–16	5	–14	9
101	–23	–9	–20	–4	–18	1	–16	4
80	–26	–13	–23	–8	–20	–4	–18	0
63	–28	–17	–25	–12	–22	–8	–21	–4
50	–30	–21	–27	–16	–25	–12	–23	–9
39	–33	–26	–30	–20	–27	–16	–26	–13
30	–35	–29	–32	–24	–30	–20	–28	–17

TABLE A9.3 Moisture Content High-Pressure Compressed Air Cylinders

Maximum Water Content Measured at Atmospheric Dew Point and Temperature	Lowest Use Temperature 2216 psig (15.3 MPa)		3000 psig (20.7 MPa)		4500 psig (31.0 MPa)	
ppm (mL/m^3)	°C	°F	°C	°F	°C	°F
27	–7	20	–6	23	–5	23
24	–8	19	–7	20	–7	20
21	–10	16	–9	18	–9	17
18	–11	13	–10	15	–10	15
15	–13	11	–12	12	–12	12
14	–14	8	–13	9	–14	9
12	–16	5	–15	6	–15	6
11	–18	2	–16	4	–17	3
9	–19	0	–18	1	–18	0
8	–20	–3	–19	–2	–20	–3
7	–22	–6	–21	–4	–22	–6
6	–23	–8	–22	–7	–23	–9
5	–24	–11	–24	–10	–25	–12
5	–26	–14	–25	–13	–26	–15
4	–27	–16	–27	–15	–28	–17
4	–29	–19	–29	–18	–30	–20
3	–30	–22	–30	–21	–31	–23
3	–32	–24	–32	–24	–33	–26
2	–33	–27	–33	–26	–34	–29

A10. BREATHING AIR EQUIPMENT AND SYSTEMS

A10.1 **Breathing Air Equipment Descriptions**—Breathing air may be supplied from ambient air pumps, breathing air compressors or systems, or air cylinders. Breathing air shall meet the Grade D quality specified in CGA G-7.1.

A10.1.1 *Ambient Air Pump*—A motorized apparatus that takes air from the ambient atmosphere and, without purifying it, supplies the air in a continuous flow to a respirator. Ambient air pumps are generally limited to a few respirators depending on the size of the pump and the air flow requirements of the respirators. A disadvantage of air pumps is the heat that is usually imparted to the supplied air.

A10.1.2 *Breathing Air Compressor*—An air compression device shall meet the following criteria:

A10.1.2.1 Does not intentionally introduce oil or other contaminants into the air discharged from the compressor;

A10.1.2.2 Is inspected and maintained by personnel trained in accordance with the manufacturers' recommendations and frequency;

A10.1.2.3 Capable of providing the volume of air at a discharge pressure appropriate for the selected respirator; and

A10.1.2.4 Has the air intake for the compressor located in a clean area, where the air is most likely free from contamination.

A10.1.3 Precautions should be taken to ensure that the engine exhaust is prevented from entering the air intake.

A10.1.4 *Types of Air Compressors*—An oil-lubricated compressor is considered one in which there is a potential for an interface between the lubricating oil and the air being compressed. This would apply to units in which crankcase oils are used to lubricate compression surfaces, such as cylinder walls. Oil-lubricated compressors, and air compressors powered by internal combustion engines, should have a continuous carbon monoxide monitor with alarm. If the monitor alarms, the compressor should be shut down immediately until the source of contamination is abated.

A10.1.4.1 Compressors that use oil to lubricate parts of the machine which do not have the potential to come in contact with the compressed air are not considered as oil lubricated. These compressors, referred to sometimes by the misleading name "oil-free compressor," actually have oil in the crankcase but are sealed such that oil cannot contaminate the compression chamber unless the seals wear or break.

A10.1.4.2 Oil-less compressors have no oil in the crankcase and, therefore, cannot discharge oil or oil decomposition products to the respirator wearer.

A10.2 **Breathing Air Systems**—Breathing air systems process ambient air and distribute Grade D quality breathing air.

A10.2.1 *System Criteria*—Breathing air systems shall meet the following criteria:

A10.2.1.1 Dedicated as a breathing air system after purification;

A10.2.1.2 Adequately sized for the application (for example, generates sufficient airflow to the respirator(s));

A10.2.1.3 Air pressure shall be controlled and monitored (for example, regulator and gauge) where the respirator wearer connects to the system;

A10.2.1.4 Piping shall be made of corrosion-resistant materials such as stainless steel, carbon steel, black iron, or copper, which is suitable for the environment where installed;

A10.2.1.5 Internal surfaces shall be free of grease, oil, and applied coatings;

A10.2.1.6 Care shall be taken to prevent contamination when handling or assembling components; and

A10.2.1.7 Designed to prevent cross contamination or backflow from non-breathing air or other gas systems by use of check valves, cross connectors, and so forth.

A10.2.2 Breathing air couplings at the point of attachment where the respirator wearer connects to the system should be:

A10.2.2.1 Incompatible with outlets for non-respirable plant air or other systems to prevent inadvertent servicing of airline respirators with non-respirable gas,

A10.2.2.2 Equipped with suitable non-corrosive fittings, and

A10.2.2.3 Labeled to avoid inadvertently disconnecting service lines.

A10.2.3 *System Components*—A processing and distribution system for breathing air generally consists of the following components to provide, at a minimum, Grade D quality air:

A10.2.3.1 Compressor;

A10.2.3.2 Mechanical separator to remove liquid and particulate contaminants;

A10.2.3.3 Sorbent bed(s);

A10.2.3.4 Dryer/catalytic converters;

A10.2.3.5 Receiver/storage container;

A10.2.3.6 Pressure regulator(s);

A10.2.3.7 Safety devices;

A10.2.3.8 Carbon monoxide monitors, if an oil-lubricated compressor is used;

A10.2.3.9 Manifolds/piping;

A10.2.3.10 Connecting piping;

A10.2.3.11 Isolation valves;

A10.2.3.12 Cylinders/vessels;

A10.2.3.13 Receiver; and

A10.2.3.14 Blowdown devices.

NOTE A10.1—Air purification systems are recommended as part of breathing air systems to ensure the highest quality of breathing air practical. However, they are not specifically required if Grade D breathing air can be provided without a purification system.

APPENDIX

(Nonmandatory Information)

X1. OVERVIEW OF THE HISTORY OF THE ANSI Z88.2 STANDARD FOR RESPIRATORY PROTECTION

X1.1 This practice for respiratory protection is the revised version of ANSI/ASSE Z88.2-2015. In July of 2017, the responsibility for managing the Z88 Secretariat was transferred from ASSE to ASTM International. As part of this process, existing ANSI/ASSE Z88 standards being updated were reformatted and balloted within ASTM Subcommittee F23.65 and Committee F23 as new standards. When this process is complete, a new ASTM/ANSI F23.65 Standard Practice for Respiratory Protection will be issued. Other existing Z88 standards will follow this process. A summary of the history of the ANSI/ASSE Z88.2 standard is provided in the following.

X1.2 Because of the withdrawal of the 1992 version of this standard by ANSI in 2002, this standard was viewed as a new standard rather than the fourth version. The American National Standard for Respiratory Protection, Z88.2-2015, was substantially delayed because of professional disagreements over appropriate assigned protection factors (APFs) for air-purifying half-face-piece respirators and the associated drawn-out appeals processes. On December 10, 2010, the ANSI Board of Standards Review Panel denied the final appeal and recommended the review process be started with a new subcommittee. The Z88 committee established a new Z88.2 subcommittee and directed it to start with the existing draft Z88.2 standard. During the production of this standard, the Occupational Safety and Health Administration (OSHA) revised its respiratory protection standard to add definitions and requirements for APFs and maximum use concentrations (MUCs). (See 63 FR 1152; 29 CFR 1910.134; 71 FR 50122, August 24, 2006.) OSHA established APFs after thoroughly reviewing available literature, including workplace protection factor studies, comments submitted to the record, and hearing testimony. APFs provide employers with critical information to use when selecting respirators for employees exposed to atmospheric contaminants found in industry. Proper respirator selection is an important component of an effective respiratory protection program. Accordingly, the OSHA APFs are necessary to protect employees who shall use respirators to protect them from airborne contaminants. (See OSHA Guide, Assigned Protection Factors for the Revised Respiratory Protection Standard, Occupational Safety and Health Administration, U.S. Department of Labor, OSHA 3352-02, 2009.)

X1.3 In addition to OSHA rule making on APFs, OSHA also updated Appendix A to §1910.134: Fit Testing Procedures (Mandatory) (63 FR 20098, April 23, 1998; 69 FR 46993, August 4, 2004), and ANSI published the American National Standard, ANSI/AIHA Z88.10-2010 Respirator Fit Testing Methods, approved on December 3, 2010. These rules and standards thoroughly address the topics of APFs and fit testing. Thus, this Z88.2-2015 standard did not contain details on these topics but did provide reference to the appropriate OSHA regulations and ANSI/AIHA Z88.10-2010.

X1.4 The ANSI/ASSE Z88.2-2015 standard has updated sections on oxygen deficiency (including an easy-to-use table indicating what types of respirators are required to work safely in increasingly dangerous oxygen-deficient environments), respirator selection, use of emergency respirators, and respirator audits. Also included were new annexes on classification of and considerations for selection and use of respirators, establishing cartridge/canister change schedules, required fit factor value for respirator fit testing, calculating effective protection factors, compliance with compressed air dew point

requirements, compressed breathing air equipment, and systems and designations of positive-pressure respirators.

X1.5 The first version of ANSI Z88.2 was approved August 11, 1969 and was a revision of the respiratory protection portion of American National Standard safety code for head, eye, and respiratory protection, ASA Z2.1-1959. The second revision of this standard, ANSI Z88.2-1980, entitled American National Standard Practices for Respiratory Protection was approved on May 22, 1980. The third version of this standard, American National Standard for Respiratory Protection, ANSI Z88.2-1992, was approved August 6, 1992.

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