

CHAPTER 9
REV: JAN2003
RESPIRATORY PROTECTION

1. **GENERAL.**

a. Navy occupational safety and health (NAVOSH) standards place primary emphasis on engineering, administrative and work practice controls. Respirators are worn in those instances where these controls are not feasible and/or are ineffective in reducing personnel exposures below permissible exposure limits. Respiratory protection can also be provided as an interim measure while controls are being sought or installed.

b. For the purposes of this chapter, the terms “exposure” and “overexposure” refer to concentrations of air contaminants in the breathing zone of the employee and outside of the respirator. That is, the exposure of the employee regardless of the use of a respirator.

c. Surgical masks worn by operating room personnel, dentists and dental technicians are not considered respirators. They are for medical/dental use only and worn for the protection of the patient - not for the protection of the health care provider.

d. Details of the Occupational Safety and Health Administration (OSHA) and the NAVOSH respiratory protection program policy are in references 9-1 through 9-3. Additional respirator information is available on the Navy Environmental Health Center Respirator Homepage (http://www-nehc.med.navy.mil/ih/Respirator/Resp_index.htm).

2. **WRITTEN STANDARD OPERATING PROCEDURES.** Each activity where respirators are used must have a written respiratory protection program addressing all of the program elements specified in References 9-1 through 9-3. A comprehensive written program will include specific provisions and procedures for respirator selection, use, fit testing, storage, maintenance and care, training, and medical qualifications of those personnel required to wear respirators. Worksite standard operating procedures (SOPs) are required in all areas where respirators are used. Each worksite SOP will be worksite specific, telling the wearer which respirator to wear and under what conditions it should be worn. SOPs will also include emergency and rescue guidance where appropriate. A more in depth discussion of respirator SOPs is provided at the following website: <http://www-nehc.med.navy.mil/ih/Respirator/SOP.htm>. In addition, the following website includes a generic, fill-in-the-blank, Navy respirator instruction and standard operating procedures for all elements of the respirator program: <http://www-nehc.med.navy.mil/downloads/IH/GENERIC SOP.doc>.

In contrast to the detailed SOPs required for a complete respirator program, paragraph 1503.g. of reference 9-2 has greatly relaxed shore-based NAVOSH program requirements for voluntary use respirators. Paragraph 1503.g. and page 21 of the Glossary in reference 9-2 allows the Respiratory Protection Program Manager (RPPM) to issue personnel, choosing to wear them, NIOSH (National Institute for Occupational Safety and Health) approved filtering facepiece respirators for voluntary use (when respirators are not required to control exposures or required

by the activity) without fit testing and medical examination. Issue of these respirators must be under the control of the RPPM. Voluntary respirator users must be trained annually on the limitations stated on the respirator approval label and the information contained in Appendix D of 29 CFR 1910.134 (reference 9-1). The RPPM must ensure these respirators are not dirty or contaminated and that they do not interfere with working safely. All other respirator usage requires enrollment in the complete respirator program.

3. **RESPIRATOR SELECTION GUIDELINES.** Use only respirators approved by NIOSH or NIOSH/Mine Safety and Health Administration (MSHA). In selecting the correct respirator for a given circumstance, consider the following issues:

a. Nature of the Hazard.

(1) Oxygen deficiency. Definitions of oxygen-deficient atmospheres vary between agencies and organizations. According to Paragraph 1507 of reference 9-2, and paragraph 84.2(y) of 42 CFR 84 (reference 9-4), both the Navy and NIOSH consider atmospheres containing less than 19.5% oxygen to be oxygen deficient. Furthermore, NIOSH approval for air-purifying respirators is valid only for atmospheres containing 19.5% oxygen or greater at sea level. In contrast, American National Standard Institute (ANSI) Z88.2 (reference 9-5) defines oxygen-deficient IDLH atmospheres as follows:

“Oxygen deficiency immediately dangerous to life or health [IDLH] is defined as an oxygen content below 12.5% at sea level (95 mmHg ppO₂) or an atmospheric pressure less than 450 mmHg (8.7 psi) equivalent to 14,000 ft (4270 m) altitude.”

Both OSHA (paragraph (d)(2)(iii) of reference 9-1) and NAVOSH policy (paragraph 1507 of reference 9-2) state that all oxygen-deficient atmospheres (less than 19.5% O₂ by volume) shall be considered IDLH and that personnel entering these atmospheres must wear either self-contained breathing apparatus (SCBA) or combination airline/SCBA. However, OSHA allows an exception when the employer can demonstrate that, under all foreseeable conditions, the oxygen concentration can be maintained within the ranges at the altitudes specified in Table II of the OSHA Respirator Standard (reproduced below), then any atmosphere-supplying respirator may be used.

Table II 29 CFR 1910.134	
Altitude (feet)	Oxygen-deficient Atmospheres (% O ₂) for which the employer may rely on any atmosphere-supplying respirator
Less than 3,001	16.0-19.5
3,001-4,000	16.4-19.5
4,001-5,000	17.1-19.5
5,001-6,000	17.8-19.5
6,001-7,000	18.5-19.5
7,001-8,000	19.3-19.5

At high altitudes, OSHA (reference 9-1) and ANSI Z88.2-1992 (reference 9-5), require oxygen-enriched breathing air for atmosphere-supplying respirators. Open-circuit atmosphere-supplying respirators will not provide adequate oxygen at high altitudes because the partial pressure of oxygen in the compressed breathing air will have a lower partial pressure upon delivery to the facepiece. This is analogous to the partial pressure of atmospheric oxygen being lower at high altitudes. The equation for calculating ambient atmospheric partial pressure of oxygen (ppO₂) is shown below:

$$ppO_2 = (\text{fractional concentration of } O_2) \times (\text{total atmospheric pressure})$$

At 14,000 feet, air delivered to the facepiece from an SCBA air cylinder containing 21% oxygen would have a partial pressure of 94.5 mmHg (0.21 X 450 mmHg = 94.5 mmHg), which would be below the 95 mmHg ANSI Z88.2 criteria for oxygen-deficient IDLH atmospheres defined above. This is why ANSI Z88.2 (reference 9-5) requires respirators that are specially designed to provide enriched oxygen at high altitudes. NIOSH does not approve the use of enriched oxygen in open-circuit SCBA, therefore, closed-circuit SCBA must be used to maintain atmospheres above the oxygen-deficient IDLH level. Closed-circuit SCBA supply enriched oxygen. For example: the Navy's oxygen breathing apparatus (OBA) supplies nearly 100% oxygen after a few minutes of operation.

(2) Physical properties. Physical properties of the hazard include physical state, particle size, molecular weight, boiling point, and vapor pressure.

(3) Chemical properties. Chemical properties of the hazard include solubility in water and other liquids; reactivity with other chemicals; reactivity with sorbent materials in respirator cartridges/canisters; and hazardous decomposition products. For particulates, it is important to know whether the aerosol does or does not contain oil. This is because the particulate filter approval classification under 42 CFR 84 (reference 9-4) classifies filters based on whether the aerosols being filtered contain oil. Oil aerosols tend to degrade filter efficiency.

(4) Physiological effects. Physiological effects on the body include skin absorption; eye and mucus membrane irritation; simple or chemical asphyxiation; anesthesia; sensitization; carcinogenic; and reproductive hazards.

(5) Concentration. The actual concentration of a toxic compound must be known to determine the degree of protection necessary. Use the Navy Occupational Exposure Limits (OELs) (8 hour time-weighted average or ceiling value) in selecting the proper respirator. Navy OELs are listed in Appendix A Table Z-1-A and Table Z-2 and Appendix B Table 1 of this manual. If the contaminant concentration cannot be determined then consider the atmosphere to be IDLH. Reference 9-5 (ANSI Z88.2-1992) defines IDLH atmospheres as "Any atmosphere that poses an immediate hazard to life or poses immediate irreversible debilitating effects on health." According to paragraph 1507 of reference 9-2, only full face pressure demand SCBA or full face pressure demand combination airline/SCBA can be worn into oxygen-deficient or IDLH atmospheres.

NOTE: The online NIOSH Pocket Guide to Chemical Hazards contains IDLH atmosphere concentrations, along with exposure limits, chemical and physical properties, health hazards, analytical sampling methods, and much more. This document is available at <http://www.cdc.gov/niosh/npg/npg.html>. The Pocket Guide is linked to the NIOSH Documentation for IDLH Concentrations at the following website: <http://www.cdc.gov/niosh/idlh/intridl4.html>.

(6) Warning properties. Warning properties include odor, taste, or irritant effects. If the odor or irritation threshold of a substance occurs at concentrations greater than the Navy OEL or the substance causes olfactory fatigue, it should be considered to have poor warning properties. Chemical cartridge air-purifying respirators are appropriate for protection against isocyanates and other substances without good warning properties up to their maximum use concentration if a cartridge change out schedule is developed and implemented. Alternatively, atmosphere supplying respirators or air-purifying respirators equipped with approved end-of-service-life (ESLI) indicators can be used.

b. Nature of the operation. Consider operation or process characteristics; work area characteristics; materials used or produced during the process; workers' duties and actions; and abnormal situations (e.g., emergencies which may necessitate a different respirator selection).

c. Location of the hazardous area. Location of the hazardous area may limit the types of respirators that can be safely used. For example, if entry into the hazardous area requires using ladders or crossing railroad tracks, then airline respirators should not be selected because of the possibility of tangling or severing the supplied air hoses. Also, when using SCBA or combination airline/SCBA, the distance from the hazardous area to the nearest staging area containing a breathable atmosphere must be known to ensure that the SCBA selected will have an adequate supply of breathing air or that the service life of the auxiliary escape cylinder of the combination airline/SCBA is adequate for emergency escape.

d. Time respiratory protection is required. The length of time a respirator will have to be worn is a factor that must be considered. This is most evident when using an SCBA, where, by definition, the air supply is finite. However, time is also a factor during routine use of air-purifying respirators when worker acceptance and comfort are essential to ensure proper use of the device and cartridge change out schedules must be established and implemented.

e. Employee's health. Effective use of a respirator is dependent on an individual's ability to wear a respirator. Most respirators increase physical stress on the body, especially the heart and lungs. Individuals shall not wear a respirator on the job or be fit tested unless they have been medically qualified.

f. Respirator characteristics, capabilities, and limitations. References 9-5 and 9-6 provide excellent descriptions of the various classes of respiratory protection. Also see paragraph 12 of this chapter.

g. Assigned Protection Factors (APFs). The protection afforded by respirators is dependent upon the seal of the facepiece to the face; leakage around valves; and leakage through

or around cartridges or canisters. By considering and measuring the effect of these variables, the degree of protection may be estimated and combined with a safety factor to assign a protection factor. Protection factors are assigned by OSHA, NIOSH, and ANSI. At the time of this writing, there was an extensive controversy within the respirator community concerning APFs. ANSI, in reference 9-5, and NIOSH, in reference 9-7, list conflicting information on assigned protection factors. Some OSHA substance specific standards are in conflict with both ANSI and NIOSH APFs. Navy personnel shall use the protection factors listed in Table 9-1. However, for protection against contaminants that are regulated by individual OSHA standards (e.g., formaldehyde, benzene, vinyl chloride), refer to the specific OSHA standard. Refer to Navy policy for the chemicals covered by OSHA substance specific standards, such as lead and asbestos in references 9-2 and 9-3. Protection factors are only applicable if all elements of an effective respiratory protection program are in place and being enforced.

h. Fit Factor. Not to be confused with assigned protection factor, a fit factor is a ratio of the challenge agent concentration outside the respirator to the challenge agent inside the respirator facepiece on a particular individual measured during quantitative fit testing. In general, the higher the fit factor, the better the respirator seals to the individual's face. Passing a qualitative fit test is equivalent to passing a quantitative fit test with a fit factor equivalent to 100 (See paragraph 5.).

i. Maximum Use Concentration. The maximum use concentration (MUC) for a class of respirators determines the maximum level of protection that a class of respirators can provide against a contaminant. The MUC is calculated by multiplying the APF by the OEL. However, if the IDLH concentration is lower than the MUC, then the IDLH concentration takes precedence over the calculated MUC.

j. Hazard Ratio. Another useful calculation in respirator selection is the hazard ratio, which indicates the minimum APF required. Hazard ratio is calculated by dividing the exposure concentration by the OEL.

k. Effective Protection Factor. Protection factors are voided when employees remove their respiratory protection while in the contaminated atmosphere or when respirators are worn improperly such as with facial hair between the face and facepiece seal. If the respirator is not worn 100 percent of the time while the individual is exposed, then an effective protection factor (EPF) based on a realistic estimate of the time that the respirator was worn, can be calculated. The EPF must be greater than the calculated hazard ratio. The EPF equation is shown below:

$$EPF = APF / [1 + T_{not}(APF - 1)]$$

Where:

T_{not} = Percentage of time respirator was not worn.

APF = Assigned protection factor

Example: A half mask respirator (APF = 10) was not worn during 20 percent of the employee's exposure. The effective protection factor is calculated below:

$$EPF = 10 / [1 + 0.2(10 - 1)] = 3.6$$

As shown above, not wearing the respirator during exposure greatly lowers the protection afforded by the respirator. In this case, not wearing the respirator during 20 percent of the exposure lowered the half mask EPF from 10 to 3.6.

4. **TRAINING.**

a. **Requirements.** Respirator users must be trained in the proper selection, use, maintenance, and limitations of respirators. Instruction must include demonstrations on how the respirator should be worn, how to adjust it, and how to determine if it fits properly. Personnel who issue respirators and supervisors of personnel required to wear respirators must also be trained in respiratory protection. The purpose of the training for issuers and supervisors is to further assure the proper selection, use, and maintenance of respirators.

b. **Training Topics.** Activities shall ensure that training is conducted in a manner that is understandable to the employee and that each employee can demonstrate knowledge of at least the following aspects of respiratory protection:

(1) How to wear the respirator as it was originally intended, which includes the following information:

(a) The respirator and all functional parts must be in place and worn in the appropriate positions;

(b) All straps must be secure and properly adjusted;

(c) There must be no modification to the respirator or straps; and

(d) Facelet or knitted coverings that interfere with the facepiece seal will void the approval of the respirator, and therefore will not be worn. Clothing, such as caps or hoods, will not be worn between the respirator and the skin of the face.

(2) The respirator's capabilities and limitations including:

(a) Why the respirator is necessary, including identification of contaminants or contaminant types against which the respirator is designed to afford protection;

(b) How improper fit, usage, or maintenance can compromise the protection of the respirator;

(c) Limitations on the service life and change out schedule of the cartridge, canister, or filter that is used;

(d) Warning properties of the contaminant(s); and

(e) How to use the respirator in emergency situations, including situations in which the respirator malfunctions.

(3) How to properly inspect, maintain, and store the respirator;

(4) How to perform positive/negative user seal checks (See paragraph 6);

(5) How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators; and

(6) The general requirements of references 9-2 or 9-3, as applicable.

c. Frequency of training. Respirator wearers, issuers, and their supervisors are to receive initial training and annual refresher training. Retraining is also required when it is apparent that the employee has not retained the information presented in respirator training or when other situations arise in which retraining appears necessary for the employee to safely use the respirator.

5. **FIT TESTING.**

a. Requirements. All tight fitting negative and positive pressure respirators must be fit tested to ensure proper facepiece to face seal. Respirators shall not be worn when conditions prevent a good facepiece to face seal. Examples include:

(1) Sideburns, beards, and/or skull caps that project under the facepiece;

(a) Neither negative pressure nor positive pressure respirators with a tight-fitting facepiece will be fit tested on or worn by persons with beards.

(b) Airline hoods/helmets and PAPR hoods/helmets (i.e., no facepiece to face seal nor partial sealing surface) may be worn by personnel with beards, when such respirators will provide adequate protection.

(2) Temple bars on glasses when wearing full-face respirators;

(3) The absence of one or both dentures;

(4) Facial deformities; and

(5) Facial jewelry.

b. Fit test frequency. Personnel required to wear tight fitting respirators shall be qualitatively or quantitatively fit tested both initially before wearing the respirator and annually.

c. Quantitative fit test. Quantitative fit testing determines the amount of leakage occurring between the wearer's face and the sealing surface of the respirator. As mentioned in paragraph 3.h., a fit factor is the ratio of the challenge agent concentration outside the respirator to the challenge agent concentration inside the respirator facepiece on a particular individual measured during quantitative fit testing. There are two basic quantitative fit testing technologies:

(1) Controlled negative pressure method (i.e., DYNATECH Nevada Fit Tester 3000) - measures the rate of pressure decay as a function of the rate of controlled leakage into an otherwise sealed respirator. Test exercises are performed prior to face seal leakage measurements.

(2) Aerosol challenge method measures and compares the concentration of a challenge test agent inside and outside of the respirator during a series of test exercises. There are two aerosol fit testing methods, which include forward light scattering photometry (e.g., Air Techniques International, TDA-99M) and condensation nuclei counting (i.e., TSI, Portacount[®]). Probed respirators with High-Efficiency Particulate Air (HEPA), N100, R100, or P100 filters are required for aerosol challenge quantitative fit testing. As an alternative to probed respirators, fit test adapters made by the same manufacturer can be used to sample inside an individual's own respirator.

(3) Use the quantitative fit test protocols in Appendix A of reference 9-1, which includes each of the quantitative fit test technologies referred to in the previous two subparagraphs.

d. Qualitative fit test. Qualitative fit tests involve a test subject's response (either voluntary or involuntary) to a challenge chemical. These tests are fast, easily performed, and use inexpensive equipment. Because they are based on the respirator wearer's subjective response, accuracy may vary. Qualitative fit tests include the irritant smoke test, the odorous vapor test, and two taste tests. Procedures for these test methods are detailed in Appendix A of reference 9-1. Each qualitative fit test requires a screening test to ensure that the individuals being fit tested can detect the fit test agent. If they cannot detect the challenge agent then they cannot be fit tested by that method. Passing a qualitative fit test is equivalent to achieving a fit factor of 100 during quantitative fit testing.

(1) Irritant smoke test.

(a) The irritant smoke test is performed by directing irritant smoke from a ventilation smoke tube towards the respirator while the test subject performs a series of exercises. Only use ventilation smoke tubes, in which the active ingredient is hydrogen chloride. If the wearer cannot detect the irritant smoke, then they pass the fit test and are assumed to have a fit factor of 100.

(b) The respirator wearer will react involuntarily, usually by coughing or sneezing, in response to leakage around or through the respirator. Since this is a qualitative test,

the fit test operator is interested in any response to the smoke; the degree of response is not important. A screening test must first be performed using a weak concentration of irritant smoke to ensure that the test subject can detect it. If the test subject has no response to the irritant smoke during the screening test, then they cannot be fit tested by this method.

NOTE: The test substances are irritants to the eyes, skin, and mucous membranes. Therefore, individuals being fit tested with half mask respirators must keep their eyes closed or wear goggles during testing. It is imperative that this fit test be performed without an enclosure, in a well ventilated area and in strict accordance with the published test protocol in Appendix A of reference 9-1.

(c) The respirator must be equipped with N100, R100, P100, or HEPA (for PAPRs) filters.

(2) Odorous vapor test.

(a) The odorous vapor test relies on the respirator wearer's ability to detect isoamyl acetate (i.e., banana oil) inside the respirator. The test is performed by suspending a paper towel wetted with 0.75 ml isoamyl acetate inside a test chamber (e.g., inverted 55 gallon drum liner over a suspended frame). Allow two minutes for the concentration to equilibrate. If the wearer cannot detect the banana oil, then they pass the fit test and are assumed to have a fit factor of 100.

(b) The respirator must be equipped with organic vapor cartridges or canister.

(c) Limitations of this method include wide variation in individual odor thresholds, olfactory fatigue, and dependence on the wearer's honest response, since there is no involuntary response. This method also requires a screening test to ensure that the test subject can smell banana oil.

(3) Taste tests.

(a) The taste tests rely on the respirator wearer's ability to detect the sweet taste of sodium saccharin or the bitter taste of Bitrex™ (i.e., denatonium benzoate) inside the respirator. The tests are performed by placing an enclosure (i.e., hood) over the respirator wearer's head and shoulders and spraying the test agent into the enclosure with a nebulizer while the test subject performs a series of exercises while breathing through their mouth. If the wearer is unable to taste the sodium saccharin or the Bitrex™, then they pass the fit test and are assumed to have a fit factor of 100.

(b) Respirators must be equipped with a particulate filter.

(c) Limitations of this method include variation in individual taste thresholds and dependence on the wearer's honest indication of taste since there is no involuntary response. A screening test is needed to ensure that the test subject can taste sodium

saccharin or Bitrex™. The wearer must not eat, drink (except plain water), or chew gum for 15 minutes before the test to avoid masking the taste of saccharin or Bitrex™.

e. Negative pressure respirators. The fit factors of both quantitatively and qualitatively fit tested negative pressure respirators include a safety factor of ten. According to paragraph 9.1.1 of ANSI Z88.2-1992 (reference 9-5), negative-pressure respirators that are quantitatively fit tested must pass the fit test with a fit factor that is at least 10 times greater than the assigned protection factor of the respirator. Therefore, half mask and full face negative pressure, air-purifying respirators that are quantitatively fit tested must pass with 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 times the OEL, respectively. According to page 1225 of the preamble to the OSHA Respirator Standard (reference 9-1), the fit factor achieved during qualitative fit testing of negative pressure air-purifying respirators is limited to 100. The preamble's explanation is reproduced below:

“This limitation is based on the fact that the existing evidence only validates the use of qualitative fit testing to identify users who pass the QLFT [qualitative fit test] with a respirator that achieves a minimum fit factor of 100. Dividing the fit factor of 100 by a standard safety factor of 10 means that a negative pressure air purifying respirator fit tested by QLFT cannot be relied upon to reduce exposures by more than a protection factor of 10. The safety factor of 10 is used because protection factors in the workplace tend to be much lower than the fit factors achieved during fit testing; the use of a safety factor is a standard practice supported by most experts to offset this limitation.”

Therefore, qualitatively fit tested half mask and full face negative pressure, air-purifying respirators cannot be worn at concentrations greater than 10 times the OELs.

f. Positive pressure respirators. Tight-fitting, positive pressure respirators, including powered air purifying respirators (PAPRs) must be fit tested in the negative pressure mode (fit tested as negative pressure air-purifying respirators). This can be accomplished by either temporarily converting the facepiece, per manufacturer's instructions, into a negative pressure air-purifying respirator or by using a “surrogate” negative-pressure facepiece with sealing surfaces and materials that are identical to the wearer's positive pressure facepiece. In other words, if the facepiece sealing surfaces and materials are indistinguishable from the positive pressure respirator facepiece, then the negative pressure, air-purifying respirator can be worn as a surrogate during fit testing. OSHA allows positive pressure respirators to be either qualitatively or quantitatively fit tested. Fit testing positive pressure respirators is to ensure there is no gross leakage in the facepiece seal. Positive pressure half mask and full face respirators that are quantitatively fit tested must pass with a minimum fit factor of 100 and 500, respectively. Individuals may wear positive pressure respirators up to the assigned protection factor of the respirator (see Table 9-1) after passing either qualitative or quantitative fit testing.

g. Fit Test Operator Qualifications. Clause 5 of reference 9-8 provides excellent guidance for training fit test operators. Annex A1 of reference 9-8 is an evaluation form for RPPMs to use as a check-off list for their fit test operators' demonstration of knowledge and proper performance of conducting fit tests.

6. **USER SEAL CHECKS.** The user shall check the seal of the respirator by using positive and negative pressure user seal checks every time a respirator is donned. These pressure checks are NOT substitutes for quantitative or qualitative fit tests. It is essential to adequately train respirator users to perform these checks. User seal checks should be done according to the manufacturer's recommendations, or by using the following procedures:

(1) Negative pressure user seal check.

(a) The inlet opening of the respirator's canister(s), cartridge(s), or filter(s) is closed off by covering with the palm of the hand(s) or by squeezing a breathing tube or blocking its inlet so that it will not allow the passage of air.

(b) The respirator wearers are instructed to inhale gently and hold their breath for at least 10 seconds.

(c) If the facepiece collapses slightly and no inward leakage of air is detected, then the respirator has been properly donned and the facepiece is not leaking.

(2) Positive pressure user seal check.

(a) The exhalation valve or breathing tube, or both, is closed off and the wearer is instructed to exhale gently.

(b) If a slight positive pressure can be built up inside the facepiece (e.g., facepiece bulges slightly outward) without detecting any outward leakage of air between the sealing surface of the facepiece and the wearer's face, then the respirator has been properly donned.

(c) For some respirators, this test method requires that the respirator wearer first remove the exhalation valve cover from the respirator and then replace it after completion of the test. These tasks are often difficult to carry out without disturbing the fit of the respirator. Both OSHA in the preamble to reference 9-1 (page 1239), and paragraph 1513.c. of reference 9-2 state that there are respirators that user seal checks cannot be performed on and that these respirators cannot be used to control exposure.

7. **CLEANING.**

a. Requirements. Clean and disinfect respirators regularly using the following schedules:

(1) Respirators issued for the exclusive use of one worker will be cleaned and disinfected as often as necessary to be maintained in a sanitary condition.

(2) Respirators used by more than one worker will be thoroughly cleaned and disinfected before use by another worker.

(3) Respirators for emergency use will be cleaned and sanitized after each use.

(4) Respirators used in fit testing and training will be cleaned and disinfected after each use.

b. Methods. Provided below are examples of respirator cleaning and disinfecting procedures. These procedures and the maximum cleaning and rinsing temperature may differ from respirator manufacturer's instructions and the OSHA methods listed in Appendix B-2 of reference 9-1. OSHA's Appendix B-2 is mandatory and states that manufacturer's instructions may be followed if they are equivalent (i.e., if they meet OSHA's objective of successfully cleaning and disinfecting respirators without damage to them and if they do not harm the respirator users). Although the methods listed below will properly clean and sanitize respirators, the respirator manufacturer's instructions take precedence.

(1) Manual cleaning.

(a) Remove canisters, filters, valves, straps, and speaking diaphragm from the facepiece.

(b) Wash facepiece and accessories in warm soapy water. Gently scrub with a soft brush. Cleaner temperatures should not exceed 110° F (43° C).

(c) Rinse parts thoroughly in clean water no hotter than 110° F (43° C) to remove all traces of detergent. This is very important to prevent dermatitis.

(d) Air dry in a clean place or wipe dry with a lintless cloth.

(e) Reassemble.

NOTE: When using a commercially available cleaner, follow the manufacturer's instructions.

(2) Machine cleaning. Machines may be used to expedite the cleaning, sanitizing, rinsing, and drying of large numbers of respirators.

(a) Extreme care must be taken to ensure against excessive tumbling and agitation, or exposure to temperatures above those recommended by the manufacturer, as these conditions are likely to result in damage to the respirators.

(b) Ultrasonic cleaners, clothes-washing machines, dishwashers, and clothes dryers have been specially adapted and successfully used for cleaning and drying respirators.

(3) Disinfection. Disinfection procedures include:

(a) Immerse the respirator body in a bleach solution (made from mixing either 2 ml 5.25 percent bleach per liter of tap water or 2 teaspoons 5.25 percent bleach per gallon of tap water) for two minutes. Rinse thoroughly in clean water no hotter than 110° F (43° C) to remove all traces of disinfectant and dry.

(b) Immerse the respirator body for two minutes in a quaternary ammonium solution (200 ppm of quaternary ammonium compounds in water with less than 500 ppm total hardness). Depending on water hardness, different concentrations of quaternary ammonium salts are required to achieve sanitizing strength. Rinse thoroughly in clean water no hotter than 110° F (43° C) to remove all traces of disinfectant and dry.

(c) Immerse the respirator body for two minutes in a ~ 50 ppm iodine solution made by mixing one tablespoon or 15 ml of (1.75 percent aqueous iodine solution) in 1.5 gallons of tap water. Rinse thoroughly in clean water no hotter than 110° F (43° C) to remove all traces of disinfectant and dry.

(d) Immersion times shall be limited to minimize damage to the respirator. These solutions can age rubber and rust metal parts. Caution must be taken to thoroughly rinse the respirator after cleaning and disinfection to prevent dermatitis.

NOTE: When using a commercially prepared solution for disinfection/decontamination, follow the manufacturer's directions.

8. **STORAGE**.

a. Requirements. Respirators must be stored in a convenient, clean, and sanitary location.

(1) Ensure that respirators are stored in such a manner as to protect against dust, harmful chemicals, sunlight, excessive heat or cold, and excessive moisture. Storage measures that can be used to protect respirators against dusts, chemicals, and moisture include plastic bags capable of being sealed and plastic containers with tight-fitting lids, such as freezer containers.

(2) Pack or store the respirator so that the facepiece and exhalation valves will rest in a normal position. Do not hang the respirator by its straps. These precautions will help avoid distortion of the respirator parts or stretching of its straps.

b. Emergency use respirators. Respirators placed at stations and work areas for emergency use should be accessible at all times. They should be stored in clearly marked compartments that are dedicated to emergency equipment storage.

9. **INSPECTION AND MAINTENANCE**.

a. Disposable air-purifying respirators.

(1) Check for holes in the filter or damage to sorbent, such as loose charcoal granules.

(2) Check straps for elasticity and deterioration.

(3) Check metal nose clip for rust or deterioration.

(4) If present, check integrity of sealing surface.

b. Reusable air-purifying respirators.

(1) Check rubber facepiece for dirt, pliability of rubber, deterioration, cracks, tears, or holes.

(2) Check straps for breaks, tears, loss of elasticity, broken attachment snaps and proper tightness.

(3) Check valves (exhalation and inhalation) for holes, warpage, cracks, and dirt.

(4) Check filters, cartridges and canisters for dents, corrosion and expiration dates. Check protection afforded by canister and its limitations. Cartridge and canisters are to be changed according to the cartridge change out schedule or immediately if any odors, eye irritation (in the case of full-face masks) or respiratory irritation are detected or increased breathing resistance is noted.

c. Atmosphere-supplying respirators.

(1) Check appropriate items listed under air-purifying respirators.

(2) Check hood, helmet, blouse or suit for cracks, tears, torn seams, and abrasions; check integrity of headgear suspension.

(3) Check face shields for cracks, breaks, abrasions or distortions that would interfere with vision.

(4) Check abrasive blasting protective screen for integrity and condition.

(5) Check air supply system for air quality, breaks or kinks in supply hoses and detachable coupling attachments, tightness of connectors, and manufacturer's recommendations concerning the proper setting of regulators and valves. Ensure the coupling is incompatible with other non-breathing air couplings used at the activity. Check that hose lengths and pressure settings are as specified in the NIOSH approval label. Ensure hoses are approved for use with the respirator assembly.

(6) When an air compressor is used to provide breathable air, check air-purifying elements, carbon monoxide and/or high temperature alarm and location of compressor air inlet.

d. Self-contained breathing apparatus.

(1) Check the facepiece and breathing hose for integrity as described above for atmosphere-supplying respirators.

(2) Check the integrity of and air pressure in the cylinder. Ensure that cylinders have current hydrostatic test approval stamps/stickers. As shown below, the required test frequency varies based on the cylinder composition. Also check the integrity of the regulator, harness assembly, and all straps and buckles.

HYDROSTATIC TEST FREQUENCY FOR SCBA CYLINDERS	
CYLINDER CONSTRUCTION	HYDROSTATIC TEST FREQUENCY
Steel	5 years
Aluminum	5 years
Composite	3 years

(3) Ensure the regulator and warning devices (end-of-service alarm) function properly.

(4) Emergency use respirators will be inspected on a monthly basis in addition to before and after each use. Inspection records must be maintained. The preamble to the OSHA Respirator Standard (reference 9-1) states that examining emergency respirator performance before each use is not intended to be as extensive and thorough a process as the monthly inspection, but includes a basic examination conducted prior to each use to assure the wearer that the respirator which they are about to don in an emergency situation will work properly (e.g., that the cylinders on the SCBA are charged, that air is available and flowing). Ensure air cylinders are fully charged (i.e., regulator gauge must read between 90% to 100% of the rated cylinder pressure).

10. **WORK AREA SURVEILLANCE.** Respirators are selected on the basis of the hazards to which the employees are exposed, as determined by the BUMED industrial hygiene surveys. BUMED industrial hygiene surveys should include identification of the contaminant, nature of the hazard, concentration in the breathing zone, recommended respiratory protection and personal protective equipment, and if appropriate, biological monitoring. In addition, the local industrial hygienist will carefully and fully document any apparent deficiencies in a respirator program and bring them to the attention of the RPPM (see paragraph 16 of this chapter).

11. **EMPLOYEE ACCEPTANCE.** Many factors affect the employee's acceptance of respirators, including comfort, ability to breathe without objectionable effort, adequate visibility under all conditions, provisions for wearing prescription glasses (if necessary), ability to

communicate, ability to perform all tasks without undue interference, and confidence in the facepiece fit. Failure to consider these factors is likely to reduce cooperation of the users in promoting a satisfactory program. The local BUMED industrial hygienist should assist the command in the detection and resolution of these problems (see paragraph 16 of this chapter).

12. **MEDICAL EVALUATION.** According to paragraph 1513.b.1 of reference 9-2, medical evaluations are performed according to the Medical Surveillance Procedures Manual and Medical Matrix (reference 9-9) to ensure that employees who are required to wear respirators are physically able to perform their assigned tasks while using the equipment. Appendix 15-A of reference 9-2 (see paragraph 1513.a.(5)) is used to inform the cognizant credentialed BUMED occupational medicine provider with information needed to understand the respirator and the environment in which it will be worn. Appendix 15-A is also used by the health care professional to furnish their medical evaluation of the individual's physical ability to perform their duties while wearing that respirator and indicate when the respirator user shall return for their next medical evaluation. The health care professional provides completed copies of Appendix 15-A to the RPPM and to the worker.

13. **APPROVED RESPIRATORS.**

a. Approval transition.

(1) Previously, respirators were jointly approved by NIOSH and the Mine Safety and Health Administration (MSHA) under 30 CFR Part 11. On 8 June 1995, NIOSH updated the respirator certification procedures and reissued them under 42 CFR 84 (reference 9-4).

(2) NIOSH is now the sole certification agency. MSHA only certifies jointly with NIOSH if the respirator is being tested specifically for mine rescue. Both NIOSH approved and NIOSH/MSHA certified respirators are approved for use.

NOTE: NIOSH identifies approved respirators in the NIOSH Certified Equipment List. The last hard copy of the NIOSH Certified Equipment List was published on 30 September 1993. Since then NIOSH has certified thousands of respirators. NIOSH provides the NIOSH Certified Equipment List electronically at the following website: <http://www.cdc.gov/niosh/celintro.html>.

(3) The 1995 certification changes, the first in a series of planned changes, affected only non-powered particulate air-purifying respirators. Manufacturers could continue to sell particulate filters approved under 30 CFR 11 procedures until 10 July 1998. Distributors and users can sell and wear 30 CFR 11 approved particulate respirators until their supply is depleted or until the expiration date for combination chemical cartridge/particulate cartridges. The old approval number sequence under 30 CFR 11 for particulate filters was TC-21C. Particulate respirators approved under 42 CFR 84 have the approval number sequence of TC-84A. Chemical cartridge and airline respirators that include particulate filter elements will also have labels indicating the new particulate filter classification, TC-84A.

(4) The Bureau of Mines was the first agency to test and certify respirators. The approval schedules for Bureau of Mines respirators have expired and are not considered valid except in the following two cases:

(a) Gas masks approved by the U.S. Bureau of Mines (Schedule 14F) are approved until further notice.

(b) SCBA approved under Schedule 13E which have a low air warning device and which were purchased before June 30, 1975 are still valid.

b. Classes of particulate respirators.

(1) There are nine classifications of non-powered particulate air-purifying respirators certified under three filter classes: N, R and P. Each class has three levels of filter efficiency: 95%, 99% and 99.97% (designated 100 in this system). N, R, and P 100 filters are equivalent to 30 CFR 11 HEPA filters. However, according to Navy policy for shore-based commands (Chapters 17 and 21 of reference 9-2), only P100 filters can be used on air purifying respirators worn for protection against asbestos and lead because they are the only HEPA filters approved for negative pressure, air-purifying respirators that are magenta (purple) in color. All nine classes can be used as protection against tuberculosis in health care facilities per paragraph f. of reference 9-10. Similarly, all nine classes can be used as protection against anthrax. NIOSH tests filters under worst case conditions of the most penetrating particle sizes and at very high flow rates simulating strenuous work that could not be sustained for more than brief periods of time. Large particles are filtered by the filtration mechanisms of sedimentation, impaction and interception, while very small particles are filtered by the diffusion filtration mechanism. Particles 0.1 to 0.4 microns in size are the most filter penetrating size because these median sized particles are too small to be filtered by large particle removal mechanisms and are too large for effective removal by the diffusion filtering mechanism. Tuberculosis bacilli are 1 - 4 microns long and 0.3 - 0.6 microns in diameter. Anthrax bacilli are 1 - 8 microns long and 1 - 1.5 microns in diameter, while the spores are 1 micron in diameter. At the breathing rates found in the workplace, 95% efficient filters filter out more than 99.5% anthrax sized bacilli and spores.

(2) Oil aerosols tend to degrade filter efficiency. Oils are hydrocarbon liquids with high boiling points, high molecular weights, and low vapor pressure. Oil aerosols can consist of mineral, vegetable, animal and synthetic substances that are slippery, combustible, and soluble in organic solvents such as ether but not soluble in water. A partial list of filter degrading oils includes mist from the following oils: alboline; white mineral oil; bayol F; blandlube; drakeol; paraffin oil; liquid petrolatum; water-insoluble petroleum-based cutting oils; heat-treating oil; hydraulic oil; lubricating oil; drawing oil; crystal 325; cable oil; drawing oil; engine oil; heat-treating oils; dioctyl phthalate; corn oil; and transformer oil.

(a) N-series (i.e., NO oil) filters cannot be used in an atmosphere containing oil aerosols. They generally should be used and reused subject only to considerations of hygiene, damage, and increased breathing resistance. However, for dirty workplaces that could result in high filter loading, service time for N-series filters should only be extended

beyond 8 hours of use (continuous or intermittent) by performing an evaluation in specific workplace settings that demonstrates that:

1. Extended use will not degrade the filter efficiency below the efficiency level specified in 42 CFR 84, or

2. that the total mass particulate loading of the filter(s) is less than 200 mg per respirator (i.e., summed over all filters in a respirator).

NOTE: These determinations would need to be repeated whenever conditions change or modifications are made to processes that could change the type of particulate generated in the user's facility.

(b) R-series (i.e., oil-RESISTANT) filters should be used only for a single shift (or for 8 hours of continuous or intermittent use) when airborne oil mist is present. However, service life for the R-series filter can be extended using the same two methods described above for N-series filters. As above, these determinations would need to be repeated whenever conditions change or modifications are made to processes that could change the type of particulate generated in the user's facility.

(c) P-series (i.e., oil-PROOF) filters should be used and reused according to the manufacturer's time-use limitation recommendations when oil aerosols are present. P-series filters should be used and reused subject only to considerations of hygiene, damage, and increased breathing resistance if oil aerosols are not present.

NOTE: NIOSH guidance concerning these new particulate respirators is provided in reference 9-10, which may be downloaded from <http://www.cdc.gov/niosh/userguid.html>. Additional guidance on the new particulate respirators is available in reference 9-11 which may be downloaded from <http://www.cdc.gov/niosh/pseries.html>. Other NIOSH documents can be ordered from the NIOSH publication web site at <http://www.cdc.gov/niosh/pubs.html> or at the following address:

Publications Dissemination, DSDTT
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, Ohio 45226-1998
Phone number (800) 356-4674

(3) OSHA does not require establishing change out schedules for particulate respirators. However, since N and R filters must be replaced before 200 mg loading is reached, then change out schedules can be calculated if we know the workplace concentration and the daily breathing volume. NIOSH estimates that a typical worker inhales 10 m³ air per day. This equates to a 20 lpm breathing or work rate. This information can be used to determine when N and R filters will become loaded with 200 mg. For example: What is the estimated filter change out schedule for an operation in which the Upper Tolerance Limit (UTL_{95%, 95%}), was 8 mg/m³ for total dust (Particulates not otherwise regulated)? The UTL_{95%, 95%} is the concentration below

which we are 95 percent confident that 95 percent of exposures lie (see Chapters 3 and 4). Since no oil is present, a half mask respirator equipped with N95 filters was selected for protection.

Calculate daily filter loading by multiplying 8 mg/m^3 exposure by the 10 m^3 air/day breathing volume. This equals 80 mg/day. Next calculate how many days it takes to load 200 mg on the filters by dividing 200 mg by 80 mg/day. This equals 2.5 days, therefore, change filters every 2 ½ days or earlier if breathing starts to be difficult or filters become damaged or unsanitary. This same logic can be applied to R filters to estimate service life and establish filter change out schedules. If P filters are used, replace them according to respirator manufacture's recommendations.

c. Powered Air Purifying Respirators (PAPRs) use a motor and blower to pull air through the filter to provide a continuous flow of clean air to the user. This also provides a cooling effect in warm temperatures. PAPRs are manufactured with tight-fitting facepieces (half-face and full-face), hoods, helmets, and loose fitting facepieces. Tight-fitting facepiece PAPRs must supply a minimum of 4 cubic feet per minute (CFM) of air to the user. PAPRs with hoods, helmets, and loose-fitting facepieces must supply a minimum of 6 CFM. Until recently, air flow to all PAPRs had been continuous flow, however, the NIOSH User Notice of 7 April 2000 (<http://www.cdc.gov/niosh/00-8371.html>) allows tight-fitting PAPRs to be certified as "Breath Responsive PAPRs," designed to deliver filtered air to the users upon demand to match their respiratory requirements. Certification tests for breathing air flow rate will be the same as for pressure demand respirators under paragraph 84.157 of 42 CFR 84 (reference 9-4). PAPRs with hoods and helmets may be worn by individuals when conditions like facial hair prevent a good facepiece to face seal. However, the NIOSH User Notice of 31 January 1991 prohibits wearing facial hair with PAPRs having loose fitting facepieces. PAPRs with loose fitting facepieces have partial sealing surfaces at the temple, cheek, or chin that help maintain positive pressure inside the facepiece. Any facial hair contacting these sealing surfaces affect proper functioning of the respirator. Per paragraph 84.1100(d) of 42 CFR 84, powered air purifying respirators must be equipped with filters meeting the 30 CFR 11 criteria for HEPA filters but the filters must have a 42 CFR 84 approval label. Like the P100 filters for negative pressure, air-purifying respirators, PAPR HEPA filters are magenta or purple in color.

d. Gas and vapor removing air-purifying respirators

(1) Gas and vapor removing air-purifying respirators, remove specific individual contaminants or a combination of contaminants by catalytic reaction or sorption.

(a) A catalyst is a substance that affects the rate of a chemical reaction but is not itself permanently changed in the reaction. Catalysts usually increase the rate of reaction. Catalytic reactions in respirator filter media are used to capture or inactivate the contaminant. For example, hopcalite (a mixture of copper and manganese oxides) removes carbon monoxide by converting it to carbon dioxide in the presence of oxygen in ambient air. Moisture and organic vapors render hopcalite ineffective as a catalyst in this reaction. Therefore, canisters made with the hopcalite are "sandwiched" between layers of drying agent. The Type N canister with hopcalite has an end-of-service life indicator, which turns from dark blue to light blue to indicate when the sorbent is no longer protecting against carbon monoxide.

(b) Sorption means to “to take up and hold.” The sorbent in respirator cartridges or canisters (e.g., activated charcoal) is the material doing the sorption. The sorbate is the contaminant being captured. Types of sorption include adsorption and absorption.

(1) In adsorption, the contaminant adheres to the surface of the sorbent. Therefore, it is very important to have a large sorbent surface area. Sorbent materials are ground and packed so that there is about 5.6-14 acres of surface area per ounce. The primary sorbent used is activated charcoal (one teaspoon of activated charcoal has a surface area approximately equal to the surface area of a football field). Silica gel, molecular sieve and alumina are also used as sorbents. Activated charcoal is made from coconut shells, coal, petroleum or other carbon containing raw materials. It is “activated” by heat treating at 800-900°C, which helps create the necessary porosity, giving the charcoal an internal honeycomb structure (like a bath sponge). Heating also leaves the carbon “pure” by driving out contaminants from the raw material, making it capable of adsorbing the maximum amount of gas or vapor contaminant. There are two types of adsorption, physisorption and chemisorption.

(a) Physisorption is a surface attraction, resulting from physical force interactions between sorbent and sorbate. The bonding is by weak Van der Waals - type forces and it is easy to separate the sorbent and sorbate. For example, heating will drive the gas or vapor off the sorbent. Another mechanism is preferential physisorption that occurs when vapor “B” displaces vapor “A” on the sorbent if the sorbent has a higher affinity for vapor B. Water vapor can drive off a sorbate and decrease the ability of a sorbent to adsorb a vapor or gas. That is why the service life of chemical cartridges is shorter in humid environments.

(b) Chemisorption is similar to physisorption, but results from chemical bonding between the sorbent and the sorbate. The bonds can be either ionic or covalent. The sorbent surface is chemically treated to make it more specific for the target gas or vapor. For example, charcoal is treated with nickel chloride to remove ammonia. Another example is treating activated charcoal with iodine to remove mercury. Original mercury vapor cartridges had an end-of-service life indicator (ESLI) that changed color as the sorbent became saturated. Since the ESLI was located on the front of the cartridges, the cartridges had to be worn in a plenum mounted on the belt so that the user could observe the ESLI. Recently however, ESLIs have been located on the upper edges of cartridges so that they are visible to the respirator wearer while cartridges are worn on the facepiece.

(2) In absorption, the absorbed substance is held in the bulk of the solid rather than on its surface. The contaminant actually penetrates into the sorbent where it is held there chemically. Absorption is a slower removal mechanism than adsorption because it involves a chemical reaction between the sorbent and the sorbate. Absorption used to be the method of choice for acid gas removal (using sodium hydroxide or potassium hydroxide with lime), but has been superseded by chemisorptive removal. Many acid gas cartridges used to contain Whetlerite[®]. Whetlerite[®] contained chromates that could leach out of the sorbent. On 1 September 1990, NIOSH rescinded the approval of chromium-impregnated cartridges.

(2) The sorbent material of chemical cartridge respirators is available in a variety of sizes, including face mounted cartridges, chin mounted canisters, and front or back mounted industrial canisters. Although these sorbent containers vary considerably in the amount of sorbent material that they hold, the maximum use concentration of all chemical cartridge respirators is calculated by multiplying the APF of the respirator times the OEL of the contaminant. As mentioned in paragraph 3.i., the IDLH concentration always takes precedence over the calculated MUC.

(3) Combination particulate/gas and vapor removing respirators combine the respirator characteristics of both particulate and gas/vapor removing air-purifying respirators. Unlike 30 CFR 11, there are no pesticide or spray painting cartridge respirators approved under 42 CFR 84 (reference 9-4). Instead, either an organic vapor cartridge with a prefilter or a combination organic vapor cartridge/particulate filter must be used.

(4) Approval schedules are being developed for testing and certifying air purifying respirators as protection against chemical, biological, and radiological (CBR) warfare agents. The following website provides information concerning the progress being made in this endeavor: <http://www-nehc.med.navy.mil/ih/Respirator/NIOSHSBCCOM.htm>.

(5) Reliance on odor thresholds and other warning properties is no longer permitted as the sole basis for determining that an air-purifying respirator will afford adequate protection against exposure to gas and vapor contaminants. Reference 9-1 requires establishing a change out schedule for chemical canisters and cartridges based on objective information that will ensure that they are changed before the end of their service life. This data along with the logic for relying on this change out schedule must be described in the written respirator program. The basis for cartridge change out schedules ideally should be based on the results of cartridge/canister breakthrough studies that are conducted under worst-case conditions of contaminant concentration, humidity, temperature, and air flow rate through the filter element. Such information may be based on reliable use recommendations from the activity's respirator and/or chemical suppliers. Alternatively, either atmosphere-supplying respirators, or, where they are available and appropriate for the workplace, air-purifying respirators equipped with ESLs can be worn as protection against gases and vapors.

(a) Methods for testing cartridge service life and determining change out schedules include laboratory testing, field testing, respirator carbon tubes, and mathematical modeling service life software.

1. Laboratory measurement of breakthrough time requires challenging the chemical cartridges at the highest contaminant concentration expected in the workplace in an environment that duplicates the worst case temperature, humidity, and work rate. Set the cartridge change out schedule at 90% of the measured breakthrough time.

2. Field testing actually measures cartridge breakthrough time in the workplace. A high flow pump connected to the cartridge simulates the work rate (~20 l/min is the average work rate, ~30 l/min is moderately heavy work rate that cannot be sustained for long periods of time, and ~80 l/min is a very heavy work rate). Samples are collected

downstream to determine breakthrough time. Set the cartridge change out schedule at 90% of the measured breakthrough time.

3. Respirator carbon tubes are small glass tubes filled with sorbent material from the chemical cartridges. Typical industrial hygiene sampling pumps can be used to draw workplace air through the respirator carbon tubes. There is a linear relationship between breakthrough time and bed residence time of the respirator carbon tube (i.e., the time required for a molecule of air to pass through a packed adsorbent bed). Both the bed residence time of the respirator carbon tube and the respirator cartridge can be calculated – then the breakthrough time of the carbon tube is used to predict the cartridge breakthrough time. Set the cartridge change out schedule at 90% of the calculated breakthrough time.

4. Most chemical cartridge respirator manufacturers offer free respirator cartridge service life software, based on Wood's mathematical model (reference 9-12), to estimate respirator cartridge change out schedules. The software requires characterization of workplace chemical concentrations and workplace environmental data. Each manufacturer's software is specific for their own cartridges. OSHA provides their "Advisor Genius" service life software in which breakthrough times can be calculated for any manufacturers' cartridges if pertinent information is known about the manufacturers' sorbent material such as the: (1) weight of sorbent in the cartridge in grams; (2) bulk density of the packed sorbent bed in g/cm³; (3) carbon micropore volume in cm³/g; and (4) diameter of the cartridge bed in centimeters. A list of manufacturers' software websites and the OSHA Advisor Genius website are provided in Appendix A of the *CHEMICAL CARTRIDGE CHANGE OUT SCHEDULE PROTOCOL* discussed in the paragraph below. Most service life software is based on the exposure from a single contaminant and is strongly influenced by high humidities. In contrast, exposures in most workplaces are from mixtures of contaminants and high humidity is a common problem.

(b) A method for establishing and implementing respirator cartridge change out schedules for mixtures of chemicals that incorporates those factors, which are problematic to mathematical modeling (i.e., humidity, temperature, atmospheric pressure, breathing rate, and varying concentrations of multiple contaminants) is provided on the NAVENVIRHLTHCEN Home Page <http://www-nehc.med.navy.mil/ih/Respirator/ChangeSchedule.htm>.

e. Supplied-air respirators provide breathing air independent of the environment. Such respirators are to be used in place of chemical cartridge, air-purifying respirators when: (1) a cartridge change out schedule has not been established and implemented, (2) there are no appropriate end-of-service-life indicator respirators, or (3) the contaminant is of such high concentration or toxicity that an air-purifying respirator is inadequate. Supplied-air respirators, also called air-line respirators, are classified into the following subgroups: Type A and AE, Type B and BE, Type C and CE.

(1) Type A has a tight fitting facepiece with a large diameter hose (7/8" ID), and a blower that can be operated either electrically or by hand. The blower takes fresh air from a source outside the contaminated atmosphere and blows it into the users facepiece. The hose length is limited to 300 feet and is ONLY approved for non-IDLH atmospheres. Per reference 9-13, the Type A respirator lost approval for entry into IDLH atmospheres in 1977.

(2) Type AE is the same as Type A, but also has abrasive blasting approval.

(3) Type B respirators also have large diameter hoses, but no blower. The wearer uses “lung power” to draw air through the hose and into the facepiece. The hose length is limited to 75 feet. Type B respirators must have a tight fitting facepiece to create negative pressure for drawing air through the air hose.

(4) Type BE is the same as Type B, but also has abrasive blasting approval.

NOTE: The NAVENVIRHLTHCEN has written a letter to NIOSH requesting that they revoke the hose mask and hose mask with blower certifications since, based on their antiquated technology, their mode of operation provides inadequate protection.

(5) Type C respirators are supplied with breathing air from a compressor or a large cylinder that provides air at a maximum of 125 psi using a maximum of 300 feet of hose. The operating pressure and hose lengths must be specified by the manufacturer. Type C respirators operate either in continuous flow, demand, or pressure-demand modes.

(a) In continuous flow Type C respirators, air flows into the facepiece at a continuous rate. For tight-fitting facepieces, the minimum air flow into the facepiece is 4 CFM and maximum is 15 CFM. For hoods, helmets, and loose-fitting facepieces, minimum flow rate is 6 CFM and the maximum flow rate is 15 CFM.

(b) In demand Type C respirators, air flows through the regulator only during inhalation, which causes air pressure inside the respirator facepiece to be **negative** relative to the surrounding atmosphere. Leakage into the facepiece may occur if there is a poor seal between the respirator and the user's face. Demand regulators consist of the regulator housing, diaphragm, inlet port, outlet port to the facepiece, needle valve, and lever arms. Inhalation creates a negative pressure on the outlet side of the regulator going to the facepiece. This negative pressure causes the diaphragm to be pulled in, raising the lever arms up against the needle valve. As the needle valve is pushed up, air flows from the air source through the regulator to the facepiece. Flow stops when the user stops inhaling or when the user exhales. When the user exhales, positive pressure builds up in the regulator. This causes the diaphragm and the lever arms to fall down, relieving pressure on the needle valve. The needle valve closes and cuts off air flow to the facepiece. The cycle repeats when the user inhales again. **Along with hose masks and hose masks with blowers, demand respirators should not be worn.**

(c) Pressure-demand Type C respirator regulators maintain **positive pressure** inside the facepiece at all times. The regulators are the same as demand regulators, except there is a spring located on the outside of the diaphragm. The spring exerts 1½ inches water gauge (w.g.) of pressure on the diaphragm, which causes the lever arms to push up against the needle valve. The needle valve opens, allowing air to flow through the regulator into the facepiece. Pressure builds up in the facepiece, causing the diaphragm to push down against the spring, and the needle valve closes. When the wearer exhales, air is forced out of the exhalation

valve, causing pressure in the regulator to drop to less than 1½ inches w.g. The pressure drop forces the spring against the diaphragm and lever arms, which open the needle valve. There is also a spring located in the exhalation valve to release any excess pressure built-up in the facepiece.

f. Self-Contained Breathing Apparatus (SCBA) provides the wearer with a large independent supply of breathable air that is not connected to an outside air source. Pressure-demand SCBA are approved for IDLH atmospheres. NIOSH recently established approval standards for certifying self-contained breathing apparatus to protect fire fighters and other first responders against CBR agents after terrorist attacks. Please refer to the following website for more information: <http://www.cdc.gov/niosh/npptl/scbasite.html>. SCBA are classified as closed-circuit or open-circuit.

(1) Closed-circuit SCBA are referred to as rebreather devices because they recirculate the user's exhaled breath within the respirator after CO₂ is removed and O₂ is replaced. Closed-circuit SCBA are smaller and lighter than open-circuit SCBA and can be designed to function for longer service times (one to four hours) but still stay within the required weight limitation (i.e., 35 lbs). Closed-circuit SCBA are typically thought of as negative pressure respirators. However, there are six closed-circuit respirators that NIOSH has approved as pressure-demand SCBA (i.e., positive pressure respirators). Re-oxygenation is accomplished by either a tank of compressed oxygen or by chemical reaction.

(a) With compressed oxygen, the breathing air is supplied from an inflatable bag. Exhaled air passes through a scrubber where CO₂ is removed using either sodium hydroxide or potassium hydroxide sorbent media. Removal of the CO₂ reduces the air flow going back to the breathing bag causing it to collapse against the admission valve, which opens the valve to admit oxygen until the bag is reinflated. The re-oxygenated air is sent back to the facepiece. Only the oxygen is replenished. Other air constituents, except CO₂, are recirculated.

(b) With chemically generated oxygen, CO₂ is not removed, but is used to chemically react with potassium superoxide and water vapor (in the exhaled air) to make oxygen. Oxygen is not released until the exhaled breath reaches the potassium superoxide canister, which creates a short delay before oxygen generation. The time delay can be overcome in some closed-circuit SCBA by striking a chlorate candle, which is designed to provide oxygen until the potassium superoxide reaction starts. The Navy's OBA works this way.

NOTE: OBA are used only for damage control and fire fighting aboard ships and for training fire fighters. It is a military-unique item, and is not approved by NIOSH/MSHA for industrial use. OBA are being replaced by NIOSH/MSHA approved open-circuit SCBA.

(2) In open-circuit SCBA, exhaled air is expelled to the outside atmosphere. The advantage over closed-circuit SCBA is that any contaminant(s) in the facepiece will be purged instead of being recirculated. Open-circuit SCBA are heavier because of the large tank of atmospheric air that must be carried on the back. Due to the weight restriction, the maximum service time is one hour. Regulators work the same way as in airline respirators, but they are

two-stage regulators instead of single-stage. Open-circuit SCBA also operate as demand or pressure-demand devices. Per reference 9-7, pressure-demand SCBA have an assigned protection factor of 10,000. In contrast, demand SCBA have protection factors no greater than 50. According to paragraph 1507 of reference 9-2, respirators used for firefighting must be NIOSH approved, full facepiece, pressure demand SCBA equipped with air cylinders rated for at least 30 minutes and meeting National Fire Protection Association requirements.

(3) Escape only SCBA are available as both open- and closed-circuit. Closed-circuit escape-only respirators operate in the demand mode. Open-circuit escape-only respirators can be demand, pressure demand or continuous flow. They can be full face, hooded, or mouthpiece. NIOSH approval requires mouthpiece respirators to be equipped with noise clips to prevent inhalation of hazardous atmospheres. The emergency escape breathing device (EEBD) is a closed-circuit, oxygen generating SCBA especially developed for the Navy. This respirator is to be used only aboard ship for escape from a hazardous atmosphere. **It must never be used for entry into a hazardous atmosphere.** The EEBD is being replaced by the NIOSH/MSHA approved OCENCO M-20 Self Contained Self Rescuer, which is a 10 minute closed-circuit mouthpiece respirator using compressed oxygen for oxygen replenishment.

g. Combination Type C/Self-Contained Breathing Apparatus are Type C supplied-air respirators, either demand or pressure-demand, in combination with an SCBA cylinder as an auxiliary air supply. Continuous flow supplied-air respirators are not compatible for use with an auxiliary SCBA. If the SCBA breathing air were delivered to the facepiece in the continuous flow mode, then the auxiliary air supply would be depleted too quickly for escape. Pressure demand combination Type C/SCBA are approved for IDLH atmospheres. Auxiliary SCBA have service use times of 3 to 60 minutes. If the auxiliary air supply is rated for 3, 5, or 10 minutes, then the airline mode of operation must be used upon entry into IDLH atmospheres. If the auxiliary air supply is rated for 15 minutes or longer, entry can be made into the IDLH atmosphere on the SCBA, provided that no more than 20% of the rated capacity of the SCBA is used for entry.

h. Combination Type C/air-purifying respirators are approved as air-purifying cartridge respirators. They can be particulate filter, chemical cartridge, or canister. They cannot be worn into oxygen-deficient atmospheres or IDLH atmospheres. The supplied air can be continuous flow or pressure-demand. Depending on the respirator, the air-purifying component can be used for:

- (1) Escape-only following loss of air supply,
- (2) Entry and exit to and from air supply, including movement between air supplies, or
- (3) No restrictions

i. Nullification of approval. A respirator's approval is nullified when:

- (1) Components between different types or makes of respirators are mixed.

(2) Unapproved components are used.

(3) A respirator is used in atmospheric concentrations for which it is not approved. That is, airborne concentrations exceed the maximum use concentration calculated from the assigned protection factor of the respirator.

(4) An approved respirator is used in atmospheres for which it is not approved. For example, an organic vapor cartridge respirator cannot be used for protection against mercury vapor. Similarly, a dust respirator is not approved protection for organic vapor exposures.

14. **BREATHING AIR FOR SUPPLIED-AIR RESPIRATORS.**

a. Grade D breathing air. All compressed breathing air will meet the quality specification for grade D breathing air as described in reference 9-14. A detailed discussion on breathing air is provided at the following website:

<http://www-nehc.med.navy.mil/ih/Respirator/BreathingAirQuality.htm>.

b. Breathing air must be sampled and analyzed quarterly for all shore-based and shipboard breathing air compressors (both oil-lubricated and non-oil-lubricated). According to paragraph 1506 of reference 15-2, newly purchased compressors must be equipped with continuous carbon monoxide monitor and alarm systems. Existing compressors must have continuous carbon monoxide monitor and alarm systems installed when they are upgraded during major maintenance. Calibrate monitor and alarm systems on compressors used for supplying breathing air according to the manufacturer's instructions.

NOTE: Ambient Air Breathing Apparatus (AABA) are exempt from this requirement. The following website further expounds upon the logic for AABA exemption: <http://www-nehc.med.navy.mil/ih/Respirator/AABAairQuality.pdf>. AABA are defined as portable electrically- or pneumatically-powered, oil-less air pumps, which supply breathing air to low pressure continuous flow respirators. Although AABA do not generate oil mist, oil vapor, or carbon monoxide, they also do not produce Grade D breathing air. The ambient air that is drawn through the inlet particulate filter is delivered to the respirator(s) without significant change to the air quality. Therefore, air inlets must be placed in a contaminant-free environment.

c. Collect and analyze breathing air using the procedures specified in reference 9-14. In addition, there are commercially available breathing air test kits that meet the CGA 7.1 analytical requirements (<http://www-nehc.med.navy.mil/ih/Respirator/BATestKits.htm>). A generic SOP for analyzing breathing air is provided at the following website:

<http://www-nehc.med.navy.mil/ih/Respirator/QuarterlyAirQualityTesting.pdf>. Ensure the following minimum specifications for Grade D (reference 9-14) breathing air are met:

CGA G-7.1-1997 GRADE D COMPRESSED AIR PURITY REQUIREMENTS	
Characteristic	CGA G-7.1-1997 Requirements

Oxygen content (v/v)	19.5%-23.5%
Oil (Condensed)	$\leq 5 \text{ mg/m}^3$
Carbon monoxide	$\leq 10 \text{ ppm}$
Carbon dioxide	$\leq 1,000 \text{ ppm}$
Water content	A dew point $\leq -65^\circ\text{F}$ (24 ppm v/v) or the dew point must be 10° F lower than the coldest temperature where the respirator is worn.
Odor	No pronounced odor

15. **COLOR CODING.**

a. ANSI Z88.7-2001 (reference 9-15) replaces ANSI K13.1-1973 as the color coding standard for air-purifying respirator canisters, cartridges, and filters. Each color on the filtering element must be visible from one meter. P100 filters and high efficiency particulate air (HE) filters (for powered air purifying respirators) are purple (NIOSH, in 42 CFR 84, refers to this color as magenta). The HE abbreviation replaces the HEPA abbreviation. Orange was selected for P95, P99, R95, R99, and R100 filters. Orange was the previous color coding for dust/fume/mist filters. Teal was selected for N95, N99 and N100 filters. Combination chemical cartridges with particulate filters have stripes indicating the type of particulate filter. An abbreviated version of the color coding table in ANSI Z88.7 is provided below. Although the color coding scheme of ANSI Z88.7 provides a rapid means of respirator cartridge identification, make the final decision on respirator cartridge selection by consulting the approval information provided on the NIOSH certification labels.

ANSI Z88.7-2001 RESPIRATOR FILTER COLOR CODING	
CONTAMINANT(s)	COLOR CODE
Acid gases	White
Organic vapors	Black
Ammonia gas	Green
Ammonia and methyl amine gas	Green
Carbon monoxide gas	Blue
Acid gases and organic vapors	Yellow
Acid gases, ammonia, and organic vapors	Brown
Organic vapors, chlorine, chlorine dioxide, hydrogen chloride, hydrogen fluoride, sulfur dioxide, formaldehyde, hydrogen sulfide (escape only) ammonia, and methyl amine	Pale Brown (Tan)
Acid gases, ammonia, organic vapors, and carbon monoxide	Red
Other vapors and gases or combinations not listed above	Olive
HE (HEPA) for PAPRs	Purple
P100	Purple
P95, P99, R95, R99, R100	Orange
N95, N99, N100	Teal

16. **RESPIRATOR PROGRAM AUDIT.**

a. Per references 9-2 and 9-3, the activity's respiratory protection program must be evaluated annually. This may be accomplished in conjunction with the annual industrial hygiene survey.

b. Also, per reference 9-2, the RPPM must audit the program annually. The RPPM must ensure that each discrepancy is corrected and revise respirator standard operating procedures, if required.

17. **REFERENCES.**

9-1 Code of Federal Regulations, Title 29, Part 1910.134. Respiratory Protection.

9-2 OPNAVINST 5100.23 Series, Chapter 15, Respiratory Protection.

9-3 OPNAVINST 5100.19 Series, Chapter B6, Respiratory Protection Program.

9-4 Code of Federal Regulations, Title 42, Part 84. Respiratory Protective Devices.

9-5 American National Standard for Respiratory Protection (ANSI). Z88.2-1992. ANSI, New York, NY. 1992.

- 9-6 National Institute for Occupational Safety and Health (NIOSH). Guide to Industrial Respiratory Protection. DHHS (NIOSH) Pub. No. 87-116. NIOSH, Cincinnati, OH. 1987.
- 9-7 National Institute for Occupational Safety and Health (NIOSH). Respirator Decision Logic. DHHS (NIOSH) Pub. No. 87-108. NIOSH, Cincinnati, OH. 1987.
- 9-8 American National Standard for Respiratory Protection (ANSI). Z88.10-2001, Respirator Fit Testing Methods. ANSI, New York, NY. 2001.
- 9-9 NAVENVIRHLTHCEN Technical Manual, Medical Surveillance Procedures Manual and Medical Matrix, latest revision
- 9-10 National Institute for Occupational Safety and Health (NIOSH). Guide to the Selection and Use of Particulate Respirators Certified under 42 CFR Part 84. DHHS(NIOSH) Pub. 96-101. NIOSH, Cincinnati, OH. 1996.
- 9-11 National Institute for Occupational Safety and Health (NIOSH). Respirator User Notice May 2, 1997. NIOSH, Cincinnati, OH. 1997.
- 9-12 Wood, Gerry O.: Estimating Service Lives of Organic Vapor Cartridges. Am. Ind. Hyg. Assoc. J. 55(1): 11-15 (1994).
- 9-13 Federal Register 42:250 of 30 December 1977. Pages 65167-65168.
- 9-14 Compressed Gas Association (CGA). CGA G-7.1-1997, Commodity Specification For Air.. CGA, Arlington, VA. 1997.
- 9-15 American National Standard Institute (ANSI). Z88.7-2001, Color Coding of Air-Purifying Respirator Canisters, Cartridges, and Filters. ANSI, New York, NY. 2001.

**Table 9-1
Assigned Protection Factors^{1 & 2}**

Assigned Protection Factor (APF)	Class of Respirator	Source of APF³
5	Filtering facepieces ⁴	NIOSH
	Quarter mask respirator	NIOSH
10	Elastomeric ⁵ half mask respirators equipped with particulate filters and/or chemical cartridges, or combination particulate/chemical cartridge filters.	ANSI/NIOSH
	Supplied-air half mask respirators operated in the demand mode	ANSI/NIOSH
25	Powered air-purifying respirators equipped with a hood or helmet	NIOSH
	Supplied-air respirators equipped with a hood or helmet operated in a continuous flow mode	NIOSH
	Powered air-purifying respirators equipped with a loose fitting facepiece ⁶	ANSI
50	Air-purifying full face respirator equipped with particulate filters, chemical cartridges or combination particulate/chemical cartridges	NIOSH
	Powered air-purifying full face or half mask respirator equipped with HEPA filters, chemical cartridges, or combination HEPA/chemical cartridges	NIOSH
	Gas mask equipped with chemical canister or combination particulate/chemical canister	NIOSH
	Powered air-purifying gas mask equipped with chemical canister or combination HEPA/chemical canister	NIOSH
	Supplied-air half mask respirator operated in continuous flow mode	ANSI/NIOSH
	Half mask pressure demand supplied-air respirator	ANSI
	Supplied-air full face respirators operated in demand or continuous flow mode	NIOSH
	Full face demand SCBA	NIOSH
2,000	Full face pressure demand supplied-air respirator	NIOSH
>2,000 or IDLH Atmosphere	Full face pressure demand SCBA or combination full face pressure demand supplied-air respirator with auxiliary SCBA	NIOSH
Firefighting	Full face pressure demand SCBA ⁷	NIOSH

¹ Assigned Protection factors are only applicable if all elements of an effective respiratory protection program are established and being enforced.

² For protection against contaminants that are regulated by OSHA substance specific standards (e.g., formaldehyde, benzene, vinyl chloride, asbestos, lead), refer to the specific standard to obtain the correct APFs. Refer to Navy policy for the chemicals covered by OSHA substance specific standards, such as lead and asbestos in references 9-2 and 9-3.

³ NIOSH reference is NIOSH Respirator Decision Logic. ANSI reference is ANSI Z88.2-1992.

⁴ Filtering facepiece respirators are air-purifying respirators in which the facepiece is an integral part of the filter media. Tight fitting respirators on which user seal checks cannot be performed may not be worn.

⁵ Elastomeric facepieces are made of rubber-like synthetic polymer, such as silicone rubber.

⁶ Loose-fitting PAPRs form a partial seal with the face and do not cover the neck and shoulders.

⁷ Firefighting SCBA must meet NFPA 1981 requirements.

