

CHAPTER 9

RESPIRATORY PROTECTION

I. GENERAL.

A. Navy safety and occupational and health (SOH) 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 medical care providers 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. In some instances (e.g., Pandemic Influenza) patients may be required to wear surgical masks as an infection control measure.

D. Details of the Occupational Safety and Health Administration (OSHA) and the Navy SOH industrial respiratory protection program policy are in reference 1, Chapter 15 of reference 2, and Chapter B6 of reference 3. Activities must follow both Navy and OSHA policy unless they are in conflict; then Navy respirator policy takes precedence. Medical evaluation of respirator users is an example of policy conflict. Since Navy respirator medical policy differs from OSHA policy; Navy policy takes precedence over OSHA policy. Issues not specifically addressed in Navy policy do not constitute conflicts with OSHA policy.

E. The Navy SOH chemical, biological, radiological, nuclear (CBRN) respirator program is set forth in Chapter 26 of reference 2. Additional requirements of the CBRN Respirator Program are addressed under appropriate sections of this Chapter.

II. WRITTEN STANDARD OPERATING PROCEDURES.

A. Each activity where respirators are used must have a written respiratory protection program addressing all program elements specified in References 1 through 3. Developing a written program requires consideration of unique characteristics of the workplace and the requirements necessary for a successful program. 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. When possible, anticipate emergencies and develop a hazard assessment and a contingency plan prior to the actual event. For a more in depth discussion see the website article entitled *Writing Respirator SOPs* under the Navy and Marine Corps Public Health Center (NAVMCPUBHLTHCEN) [Industrial Hygiene](#) homepage. Also see the article entitled *Generic Respirator SOPs* under the NAVMCPUBHLTHCEN

[Industrial Hygiene](#) homepage, which includes a generic, fill-in-the-blank, command instruction and standard operating procedures for all elements of the respirator program.

B. In contrast to the detailed SOPs required for a complete respirator program, paragraph 1503.g. of reference 2 has greatly relaxed shore-based SOH program requirements for voluntary use respirators. Paragraph 1503.g. and page 21 of the Glossary in reference 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 1).

1. The RPPM must ensure that voluntary use filtering facepieces: (1) are issued only when the contaminant of concern to the employee is a particulate; (2) are not dirty or contaminated; and (3) do not interfere with working safely.
2. When the contaminant of concern to the employee is a gas or vapor, NIOSH approved elastomeric respirators equipped with appropriate chemical cartridges may be issued for voluntary respirator use and elements of the respiratory protection program must be met, including medical screening and fit-testing. Hooded respirators are also permitted for voluntary use and all elements of the respiratory protection program shall be met.

III. RESPIRATOR SELECTION GUIDELINES.

A. 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:

B. Nature of the Hazard.

1. Oxygen deficiency. Definitions of oxygen-deficient atmospheres vary between agencies and organizations. According to paragraph 1507 of reference 2, and paragraph 84.2(y) of 42 CFR 84 (reference 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 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.”

- a. Both OSHA (paragraph (d)(2)(iii) of reference 1) and Navy SOH policy (paragraph 1507 of reference 2) consider all oxygen-deficient atmospheres (less than 19.5% O₂ by volume) to be 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.

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

b. At high altitudes, OSHA (reference 1) and ANSI Z88.2-1992 (reference 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 because the partial pressure of atmospheric oxygen is lower at high altitudes. The equation for calculating ambient atmospheric partial pressure of oxygen (ppO₂) is shown below:

$$\text{ppO}_2 = (\text{fractional concentration of O}_2) \times (\text{total atmospheric pressure})$$

c. At 14,000 feet, atmospheric pressure is 450 mmHg. At this altitude, air delivered to the facepiece from an SCBA air cylinder containing 21% oxygen will have a partial pressure of 94.5 mmHg (0.21 X 450 mmHg = 94.5 mmHg), which is below the 95 mmHg ANSI Z88.2 criteria for oxygen-deficient IDLH atmospheres defined above in paragraph III.B.1. This is why, at high altitudes, ANSI Z88.2 (reference 5) requires use of respirators that are specially designed to provide enriched oxygen. NIOSH does not approve the use of enriched oxygen in open-circuit SCBA; therefore, closed-circuit SCBA must be used to maintain high altitude atmospheres above the oxygen-deficient IDLH level because 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.

d. The best way to determine oxygen concentration is by direct measurement. However, if the contaminant concentration is known, then the oxygen concentration can be estimated. The % contaminant is simply subtracted from normal 20.9 % oxygen concentration. The following equation calculates the %

contaminant concentration from the contaminant concentration in parts per million (ppm):

$$\% \text{ Contaminant} = \text{ppm contaminant} / 10^6 \times 100$$

Example: What is the oxygen concentration in a toluene concentration of 2,500 ppm?

Answer: $\% \text{ Contaminant} = 2,500 \text{ ppm toluene} / 10^6 \times 100 = 0.25 \%$ toluene

Therefore, Oxygen concentration = 20.9% oxygen - 0.25 % toluene = 20.65% oxygen. Although this atmosphere is not oxygen deficient, the IDLH concentration for toluene is 2,000 ppm.

2. Contaminant characteristics. Determine all of the materials used in the operation. Through interviews with supervisory personnel, work process flow charts, standard operating procedures, and material safety data sheets identify the raw materials, impurities, intermediate products, end products, by-products, and waste-products. Identify the physical and chemical properties, physiological effects, warning properties, concentration, and occupational exposure limits.
 - a. Physical properties. Physical properties of the hazard include particle size, molecular weight, boiling point, lower explosive limit, and vapor pressure. Is the physical state solid, vapor, or gas? Is the contaminant present in more than one physical state (e.g., does it exist as both a particulate and a vapor)? Please refer to reference 6 for a detailed discussion concerning how certain contaminants may exist as a vapor at one concentration; but at another concentration they may exist as both vapor and particulate.
 - b. 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. Is the substance corrosive? Some substances (e.g., NO_2 and SO_2) react with water vapor to form acids. This is particularly important when temperatures drop below the dew point because these acids condense into liquid aerosols. Particulate filters approved under 42 CFR 84 (reference 4) are classified by their ability to filter oil; therefore, it is important to know whether the aerosol contains oil. Oil aerosols tend to degrade filter efficiency.
 - c. 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.
 - d. 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 occupational exposure limit (OEL) or the substance causes olfactory fatigue, it should be considered to have poor warning properties. Some substances (e.g., hydrogen sulfide) upon brief exposure desensitize individuals, making them unable to detect the substance through

sense of smell. Olfactory fatigue is a more gradual loss of sense of smell caused by exposure to certain substances. Chemical cartridge air-purifying respirators are appropriate for protection against gases and vapors, including 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.

e. Concentration. The actual concentration of a toxic compound must be known to determine the degree of protection necessary. If the contaminant concentration cannot be determined then consider the atmosphere to be IDLH. Reference 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 2, only full face pressure demand SCBA or full face pressure demand combination airline/SCBA can be worn into oxygen-deficient or IDLH atmospheres.

i. 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. The Pocket Guide is linked to the [NIOSH Documentation for IDLH Concentrations](#).

ii. Use the Navy adopted OELs. Paragraph 1602 of reference 2 states that the Navy will follow the hierarchy of exposure standards listed below:

(i) 1989 OSHA permissible exposure limits (PELs).

1. The Navy uses 1989 PELs, which are lower than current, original PELs. The original PELs were published in 1974 and came mostly from the 1968 American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs). In 1989, using primarily the 1987 ACGIH TLVs, OSHA updated the PELs, changing about 400 PELs. However, in July of 1992, the Eleventh Circuit Court of Appeals vacated the new PELs and restored the original 1974 PELs to the status of current PELs. So the current OSHA PELs are basically the 1968 ACGIH TLVs. As a result of the Court action, the current PELs are over 40 years old. Over the past 40 years much information has come to light making it clear that many of the original PELs do not provide a sufficient level of protection.

(ii) Substance specific regulations issued by OSHA under section 6(b) of the Occupational Safety and Health Act of 1970 [such as Asbestos and Lead standards].

(iii) Navy developed standards. When there is no OSHA PEL or Navy developed standard, the ACGIH TLV shall be used as the Navy OEL. When the OEL is based on a limit derived from the OSHA Z-1, Z-2, or

Z-3 Tables, reports of data shall include the ACGIH TLV as additional guidance.

1. Navy adopted OELs are listed in [Appendix A Table Z-1-A and Table Z-2](#) of this manual.

C. Nature of the operation. Initially perform a hazard assessment for each work process. Reassess operations when work conditions change and after installation or modification of ventilation systems. 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).

D. 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.

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

F. 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. (See Section XII.)

G. Respirator characteristics, capabilities, and limitations. References 5 and 7 provide excellent descriptions of the various classes of respiratory protection. Also see paragraph XIII of this chapter. The NIOSH Respirator Decision Logic, included in reference 7 has been updated in reference 8.

H. Need for eye protection. For some operations, full face respirators may be required for eye and face protection even when contaminant concentrations are below 10 times the OELs. Per paragraph 84.76 of 42 CFR 84, full facepiece lenses must meet impact and penetration requirements of GGG-M-125d of 11 Oct 1965, as amended on 1 July 1969, which is the federal specification for airline and air-filtering respirators. This outdated federal standard was based on the 1960's versions of ANSI Z87.1, which tested safety glasses and industrial eye protection made from glass (most modern lenses are made from polycarbonate). There is a 2003 version of "ANSI Z87.1, Occupational and Educational Personal Eye and Face Protective Devices (reference 9)" and the 2003 version is the first version of ANSI Z87.1 to include respirator lens testing.

1. Although OSHA has not formally adopted this standard and it is not required by NIOSH, respirator manufacturer voluntary compliance with ANSI Z87.1-2003 requires tight-fitting full face respirators, helmets, and loose fitting respirators to meet the high impact level, optical, and markings requirements of this standard. ANSI Z87.1-2003 requires compliant respirators to be marked “Z87+” on the lens and “Z87” on the lens frame. According to NIOSH, respirator certification standards will eventually require compliance with ANSI Z87.1-2003; but it may take NIOSH a long time to incorporate this requirement into all their pertinent respirator certification standards. According to respirator manufacturers, most respirator lenses meet the high impact requirements; but only a few meet both impact and optical requirements of ANSI Z87.1-2003. As an example, the MSA Millennium, worn by Navy CBRN first responders, meets the high impact requirements but not the optical requirements.

2. During the interim period, purchase of ANSI Z87.1-2003 compliant respirators will ensure use of respirators that have undergone and passed ANSI Z87.1-2003 testing guaranteeing that they provide proper eye and face protection. Since marking “Z87+” on the lenses and “Z87” on the lens frames is a currently a voluntary requirement of ANSI Z87.1-2003, not all ANSI Z87.1-2003 compliant respirators are receiving these markings. Also, respirators must pass both the high impact testing and optical testing to receive the Z87.1+ marking. Therefore, check with the respirator manufacturer to ensure respirators at a minimum meet high impact compliance testing per ANSI Z87.1-2003.

I. Fit Factor. Fit factor is a type of protection factor. Specifically, fit factor is a ratio of the challenge agent concentration outside the respirator ($C_{(out)}$) to the challenge agent inside the respirator facepiece ($C_{(in)}$) on a particular individual measured during quantitative fit testing. Therefore, $FF = (C_{(out)}) / (C_{(in)})$. Another way to express fit factor is $(FF = 100 / \% \text{ leakage})$. For example: a full face air-purifying respirator has an assigned protection factor of 50, which is based on inward leakage of 2%. In this case, $FF = 100 / 2\% = 50$. 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 V). Other protection factors include: (1) Assigned Protection Factor (APF), which is the protection afforded by a certain class of respirators (see paragraph III.I.); (2) Workplace Protection Factor (WPF), which is a measure of respiratory protection afforded in the workplace; and (3) Simulated Workplace Protection Factor (SWPF), similar to (WPF) but measured in a simulated laboratory environment.

J. 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 during WPF studies and SWPF studies the degree of protection may be estimated and combined with a safety factor to assign a protection factor. APFs only apply when respirators are used within the context of a comprehensive respirator program. Therefore, APFs are defined as the workplace levels of respiratory protection that would be provided by properly functioning and properly used respirators or class of

respirators when all elements of an effective respiratory protection program are established and are being enforced.

1. OSHA promulgated their APF final ruling (reference 10) on 24 August, 2006. The APF final rule applies to OSHA regulated substances including OSHA substance-specific standards. This standard eliminates separate APF tables in most OSHA substance-specific standards and resolves inconsistencies between OSHA, NIOSH, and ANSI APF values. Standardizing the APFs will reduce confusion and help clarify the respirator selection process. OPNAVINST 5100.19E (reference 3) adopted the OSHA APFs (see Table 9-1) with the exception of filtering facepiece respirators, for which the Navy retains its current APF of five. Please note that there is a typographical error in the APF Table in OPNAVINST 5100.19E. The APF of five for filtering facepiece respirators should have been under half mask column, not the quarter mask column. There are no quarter mask filtering facepiece respirators.
2. There are a few exceptions that do not follow the APF table such as the respirator selection provisions of the 1,3-Butadiene (BD) Standard, which retains its APF table because of the short service life of air-purifying cartridges above 50 ppm BD. Other respirator selection requirements retained to provide protection against hazardous conditions that are unique to OSHA substance specific substances are discussed in Section VIII of reference 10.
3. Footnote 3 of Table 9-1 concerns the APF of airline respirators and powered air purifying respirators (PAPRs) designed with hoods or helmets. This footnote emphasizes that employers are responsible for ensuring that these types of respirators provide a protection level of 1,000 or greater. The footnote states that respirator manufacturers must provide employees with proof based on WPF or SWPF studies demonstrating that their respirators perform at an APF of 1,000; otherwise these hood/ helmet respirators will receive an APF of 25, which is the same APF granted to loose-fitting PAPRs and airline respirators. In their APF Final Rule (reference 10), OSHA did not identify specific test conditions, performance criteria, and testing protocols that are acceptable to OSHA and that must be followed by the manufacturer to determine protection level testing. However, in their preamble, OSHA cited the Organizational Resource Counselors Worldwide (ORC) Study, performed at Lawrence Livermore National Laboratory as an acceptable SWPF testing protocol, and stated that PAPRs and SARs passing this testing protocol will provide the required level of protection for employees who use these respirators. Cohen, et, al. published the findings of this ORC study in a journal article (reference 11).
4. Per reference 12, OSHA will post a website indicating how hooded airlines and PAPRs must be tested to be granted an APF of 1,000. A third party must perform this testing. Currently, only Edgewood Chemical Biological Center is doing this type of testing. OSHA will post a list on their website of all hooded airlines and PAPRs that pass the required testing, thus demonstrating that they perform with an APF of 1,000. OSHA also said that previous interpretations of studies where OSHA granted an APF of 1,000 for specific operations (e.g., pharmaceutical and lead construction) will be extended to all applications. The Navy only accepts the higher APF for hood/ helmet PAPRs and airline respirators that OSHA indicates as

providing an APF of 1,000. OSHA further stated in reference 12 that NIOSH will eventually include certification testing in their approval process to verify that performance of every approved respirator model is consistent with the established APF for its class of respirator.

K. 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.

(MUC = APF X OEL). However, if the IDLH concentration is lower than the MUC, then the IDLH concentration takes precedence over the calculated MUC.

For multi-component mixtures the MUC can be calculated by:

$MUC_{(Mixture)} = [Exposure_1/MUC_1 + Exposure_2/MUC_2 + \dots + Exposure_n/MUC_n]$
Should be < 1.

If 1 is exceeded for half mask $MUC_{(Mixture)}$, then calculate $MUC_{(Mixture)}$ for full face. Remember IDLH takes precedence over calculated MUC.

L. 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. Determine the hazard ratio for each air contaminant. Then compare each hazard ratio with the APFs in Table 9-1. Select a respirator with an APF greater than the largest calculated hazard ratio. Appendix E of reference 13 addresses calculation of hazard ratios for mixtures of components that additively or synergistically affect the same target organ.

M. 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.

IV. 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. 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 properly wear the respirator, 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.
 - e. Wearing contact lenses in contaminated atmospheres with respiratory protection is permitted as long as eye and face protection is worn as appropriate for workers exposed to eye injury hazards.
2. The respirator's capabilities and limitations including:
 - a. How their respirator was selected based on the nature and degree of workplace specific inhalation hazards.
 - b. Why the respirator is necessary, including identification of contaminants or contaminant types against which the respirator is designed to afford protection;
 - c. How improper fit, usage, or maintenance can compromise the protection of the respirator;
 - d. Limitations on the service life and change out schedule of the cartridge, canister, or filter which is used;
 - e. Warning properties of the contaminant(s); and
3. How to use the respirator in emergency situations, including situations in which the respirator malfunctions.

4. How to properly inspect, maintain, and store the respirator;
5. How to perform positive/negative user seal checks (See paragraph VI);
6. How to recognize medical signs and symptoms that may limit or prevent the effective use of respirators; and
7. The general requirements of references 2 or 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.

V. **FIT TESTING.**

A. Requirements. All tight fitting negative and positive pressure respirators must be fit tested to ensure proper facepiece to face seal. Respirators, including voluntary use 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;
2. Neither negative pressure nor positive pressure respirators with a tight-fitting facepiece will be fit tested on or worn by persons with beards.
3. Temple bars on glasses when wearing full-face respirators;
4. The absence of one or both dentures. If dentures are worn during respirator use, then dentures must be worn during fit testing;
5. Facial deformities; and
6. Cosmetics and facial jewelry.
 - a. Airline hoods/helmets and PAPR hoods/helmets that have no facepiece to face seal or partial sealing surface may be worn by personnel with beards, when such respirators will provide adequate protection. On 2 October 2006, NIOSH issued a letter to respirator manufacturers entitled [NIOSH Policy for Respirator Sealing Surfaces and Facial Hair](#). The letter stated that areas of the skin, which contact the face or neck seal and nose cup seal, must be free of any hair. Also any respirator manufacturer making false claims, such as advertising that a tight fitting, full facepiece, or hooded respirator that is configured with a nose cup, is designed for users with facial hair, may be subject to rescission of NIOSH approval.

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 III.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:

Controlled negative pressure method (i.e., Fit Tester 3000 by Occupational Health Dynamics (OHD)) - measures the rate of pressure decay as a function of the rate of controlled leakage into an otherwise sealed respirator. OHD has a new version of the Fit Tester 3000 called the [Quantifit](#). When using the Controlled Negative Pressure (CNP) method, the air-purifying filter is replaced with the CNP leak-tight test adapter to seal the normal air pathways into the respirator (therefore filtering facepiece respirators cannot be fit tested with the CNP method). Test exercises are performed prior to face seal leakage measurements. OSHA accepted an abbreviated CNP exercise protocol which includes only five test exercises instead of the eight test exercises required by the originally approved CNP protocol. OSHA addresses this procedure at the following [website](#).

1. Aerosol challenge method measures and compares the concentration of a generated challenge test agent (e.g., 0.6 micron corn oil aerosol) inside and outside of the respirator during a series of test exercises. The *Generated Aerosol Quantitative Fit Testing Protocol* in Appendix A of reference 1 is actually based on the original quantitative fit test apparatus developed by Burgess in 1961 (which used a dioctyl phthalate challenge aerosol); although the first practical system was developed by Hyatt in 1972. This type of fit testing was considered the “Gold Standard” to which all other quantitative fit test methods were measured. This type apparatus is probably now only found in laboratory situations. Some of the language in this protocol is antiquated because OSHA is describing the original forward light scattering photometric based apparatus, which contained strip cart recorders and other antiquated technology.

a. The OSHA *Generated Aerosol Quantitative Fit Testing Protocol* also includes technology on which the [TDA-99M](#) is based. The TDA-99M is a newer, more compact forward light scattering fit testing apparatus developed by Air Techniques International. The TDA-99M can also be used to test facepiece serviceability by checking for leaks on a portable test stand. The Armed Services jointly developed the TDA-99M technology into the Joint Services Mask Leakage Tester ([JSMLT](#)), which is being used for mask serviceability testing and for quantitative fit testing of military gas masks worn during military unique operations.

2. Condensation nuclei counting (i.e., [TSI](#), Portacount[®] Plus) is an aerosol fit testing method that measures ambient room air particles as the test atmosphere. This quantitative fit testing method requires probed respirators with High-Efficiency Particulate Air (HEPA), N100, R100, or P100 filters. As an alternative to probed respirators, fit test adapters made by TSI or the respirator manufacturer can be used to sample inside an individual's own respirator. The TSI N95-Companion™ Model 8095 can be combined with the Portacount[®] Plus to quantitatively fit test N95 filtering facepiece respirators. TSI has a new apparatus called the PortaCount[®] Pro+ (Model 8038), which has a built in TSI N95-Companion.

3. Use the quantitative fit test protocols in Appendix A of reference 1 in conjunction with fit test apparatus instruction manuals.

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 described in Appendix A of reference 1. Each qualitative fit test requires a sensitivity 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 stannic chloride, which on exposure to the moisture in the air, produces hydrogen chloride gas and hydrochloric acid. Some smoke tubes contain titanium tetrachloride, which are not as irritating as the stannic chloride tubes. Therefore, Titanium tetrachloride tubes are not recommended. If during the test, the wearer does not 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 sensitivity 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.

i. 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. Attach a short length of tubing to the end of the smoke tube (to ensure the person being fit tested is not injured by the jagged end of the tube). 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 1. A low flow air sampling pump set to deliver 200 ml/minute is the method of choice to ensure consistent delivery of smoke.

c. Appendix A of the OSHA Respirator Standard requires equipping respirators with HEPA filters (N,R,P 100 filters). However, ANSI Z88.10 (reference 14) states that the respirator must be equipped with chemical cartridges approved for hydrogen chloride in combination with N, R, or P 100 particulate filters [or HEPA filters for PAPRs].

d. The next revision of reference 14 will not include the irritant smoke protocol because it does not pass the ANSI Z88.10 Sensitivity Test for validating fit test methods. The Sensitivity Test is the most important ANSI fit test validation criteria because it determines the probability that the new test method will correctly identify an inadequately fitting respirator. ANSI Z88.10 requires that fit test methods must correctly detect at least 95% respirators with unacceptable fits.

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 sensitivity 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 BitrexTM (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 BitrexTM, then they pass the fit test and are assumed to have a fit factor of 100.

b. Respirators must be equipped with any 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 BitrexTM. 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 BitrexTM.

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 5), negative pressure, air-purifying 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 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.”

1. 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 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. For industrial use, including firefighting, 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 14 provides excellent guidance for training fit test operators. Annex A1 of reference 14 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. The crux of this ANSI standard information for training fit test operators is in Enclosure (8-3) of the *Generic Respiratory Protection Program SOP*, which can be found under the NAVMCPUBHLTHCEN [Industrial Hygiene](#) homepage. Enclosure (8-4) is the *Fit Test Operator Evaluation Form*, modified from Annex A of ANSI Z88.10, for RPPMs to evaluate and verify fit test operators' qualifications.

H. Special Considerations for Fit Testing CBRN Respirators. According to paragraph 2605.c.(5) of reference 2, all negative and positive pressure tight-fitting CBRN respirators must be quantitatively fit tested by any of the quantitative fit testing methods in Appendix A of reference 1, which include forward light scattering photometry (Joint

Services Mask Leakage Tester (JSMLT)), condensation nuclei counting (Portacount™), and controlled negative pressure ((CNP)(Fit Tester 3000 or Quantifit)). This is in contrast to fit testing positive pressure respirators for industrial use, which may be either qualitatively or quantitatively fit tested.

1. There has been confusion in the CBRN respirator community concerning the required fit factor. The passing fit factor for full face tight fitting respirators, including CBRN respirators is 500 (see paragraph 2605.c.(5) of 2). However, Appendix A of reference 1, the NIOSH *Statement of Standard for Chemical, Biological, Radiological, and Nuclear (CBRN) Full Facepiece Air Purifying Respirator (APR)* (reference (15), and some CBRN respirator manufactures' instruction manuals have been a source of confusion over the fit factor for CBRN respirators.

a. The following quote from Appendix A of 29 CFR 1910.134 for *Generated Aerosol Quantitative Fit Testing Protocol*, has been misinterpreted. This quote states that "*The sampling instrument shall be selected so that a computer record or strip chart record may be made of the test showing the rise and fall of the test agent concentration with each inspiration and expiration at fit factors of at least 2,000.*" This quote only requires that the fit test apparatus be sensitive enough to record fit factors of 2,000, which is not the same as setting the passing fit factor to 2,000.

b. The laboratory protection level test (LRPL) required in reference 15 is another source of confusion. The LRPL is a fit testing certification requirement that must be passed with a minimum fit factor of 2,000 by 95% of the fit test panel required for NIOSH CBRN approval. However, the purpose of the LRPL is for certifying CBRN respirators - not for requiring the respirator user to pass with a fit factor of 2,000.

c. Certain CBRN respirator manufacturers' instruction manuals require passing fit factors higher than 500. However, according to OSHA (reference 16) it is not the respirator manufacturers' position to prescribe passing fit factors - OSHA is the only legal authority to declare a passing fit factor, which is 500 for full face air-purifying respirators.

d. It is important to reiterate that the CBRN Respirator Program requires quantitative fit testing with a passing fit factor of 500 for all tight-fitting respirators worn during first response to a CBRN incident. Although the minimum passing fit factor is 500, RPPMs are encouraged to fit test using a higher fit factor if they wish. If an individual is fit tested with more than one sized respirator, issue them the respirator for which they passed with the highest fit factor.

i. Fit factors obtained by the CNP method are at least four times lower than aerosol quantitative fit test methods. CNP probably would not pass many fit tests if the required passing fit factor was 2,000.

2. When fit testing CBRN approved Millennium gas masks with the TSI, Portacount™ Plus, use the *MSA Speaking Diagram Fit Test Adapter Kit* for

Millennium (MSA # 10006227), priced at \$20.00 to sample inside the respirator. Also equip the Millennium with a CBRN canister instead of just a HEPA filter. The CBRN canister is much heavier than the HEPA filter and will make a difference as to how the respirator seals to the wearer's face (CBRN canisters can weigh up to 500 grams (17.64 oz.)). Also, the wearer needs to become aware of how the large CBRN canister feels on the mask. The *MSA Speaking Diagram Fit Test Adapter Kit* for Millennium gives more accurate readings than the TSI Military Drink Tube Adapter, which restricts the flow to the Portacount™ Plus to a degree. Also, fit testing via the drink tube puts stress on the drink tube, which is one of the most vulnerable parts of the mask to leak. Please note that TSI has a version of the speaking diagram adapter kit (TSI PN 8025-29), but is priced at \$125.00 for the kit. TSI's kit is sold with P100 filters for Advantage and Millennium masks. The MSA kit only contains the probed disc that replaces the speaker diaphragm and filters are ordered separately. The TSI instructions for using the *Speaking Diaphragm Fit Test Adapter Kit* are provided at the following [website link](#). Also see the MSA website on the [fit test adaptor](#). Please note that this website refers to MSA part number 10006227 as the *QuickCheck Adapter for Advantage 1000*. **Again, fit test with a CBRN canister (which includes a P100) - not with only a light-weight P100 filter.**

3. When using the Controlled Negative Pressure (CNP) method, the heavy CBRN canister is replaced with the CNP leak-tight test adapter to seal the normal air pathways into the respirator. Occupational Health Dynamics (OHD), the manufacturer of the Fit Tester 3000 and the Quantifit makes a CBRN leak-tight test adapter that approximates the weight and the size of CBRN canisters. Ensure the CBRN leak-tight test adapter is worn when fit testing CBRN gas masks with the CNP method. The OHD part number for the CBRN leak-tight test adapter is 9513-0207 (Kit number 24).

VI. USER SEAL CHECKS.

A. 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 1 (page 1239), and paragraph 1513.c. of reference 2 state that there are respirators that user seal checks cannot be performed on and that these respirators cannot be used to control exposure.

VII. 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.
 - a. Paragraph I.1. of CPL 2-0.120 (reference 17) states that the use of individually-wrapped cleaning towelettes may be used between employees being tested, however these respirators must be thoroughly cleaned at the end of each day. However, to most of the respirator community use of towelettes is not considered a proper respirator cleaning method and is not recommended.

B. Methods. Provided below are examples of respirator cleaning and disinfecting procedures. These procedures, including the maximum cleaning and rinsing temperature may differ from respirator manufacturer's instructions and the OSHA methods listed in Appendix B-2 of reference 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.
 - i. 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.
- C. Disinfection. Types of disinfection procedures include:
- 1. 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. This makes a 72 ppm free available chlorine solution. Rinse thoroughly in clean water no hotter than 110° F (43° C) to remove all traces of disinfectant and dry.
 - 2. 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.
 - 3. 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.
 - a. Immersion times must 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.
 - b. When using a commercially prepared solution for disinfection/ decontamination, follow the manufacturer's directions.

VIII. 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 which 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.

- a. Aboard ship, check with the foreign material exclusion policy for bilge protection. Aboard some ships, clear plastic bags are not allowed because they cannot be seen in the bilge water and can potentially clog the bilge pumps. However, tinted bags, which are visible are allowed.

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.

IX. INSPECTION AND MAINTENANCE.

Although the methods listed below will ensure proper respirator inspection, the respirator manufacturer's instructions take precedence.

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. Supplied-Air 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. Also check the integrity of the regulator, harness assembly, and all straps and buckles. Check the air cylinder integrity and air pressure. Ensure the regulator and warning devices (end-of-service alarm) function properly.
2. Ensure that cylinders have current hydrostatic test approval stamps/stickers. Typically, the SCBA maintenance including management of DOT hydrostatic test dates and other related cylinder maintenance programs are controlled by the issuing fire department qualified technicians. The National Fire Protection Association (NFPA), specific NFPA codes such as NFPA 1404 (reference 18) and NFPA 1500 (reference 19) require regular maintenance checks of the hydrostatic test dates. As shown below, the required test frequency varies based on the cylinder composition.

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

- a. NFPA 1852 (reference 20) sets forth generic SCBA maintenance testing requirements and each SCBA manufacturer has its own specific maintenance testing parameters. The PosiChek3, made by Biosystems is the only SCBA test equipment that performs all of the maintenance testing required by NFPA 1852 and the SCBA manufacturers. Mention of this product does not constitute an endorsement by the Navy and Marine Corps Public Health Center or by the Department of the Navy.

i. Originally, in the mid-1980s there were only a few testing apparatus that could perform the NFPA 1981 SCBA flow rate testing. This original equipment was expensive and cumbersome and no fire department was capable of performing the required manufacturer's required maintenance in-house.

ii. Although the PosiChek3 is the only SCBA testing equipment currently available, software from each SCBA manufacturer must be used with the PosiChek3 for the specific SCBA in use. Plus, the user must be trained and certified by the SCBA manufacturer.

iii. SCBA can still be sent back to the manufacturer or sent to a manufacturer's authorized repair center. However, if a fire department has 15 - 20 SCBA to maintain it is more cost effective to purchase the PosiCheck3, purchase the SCBA manufacturer's software, and have their repair technicians trained and certified by the SCBA manufacturer.

E. Emergency use respirators.

1. 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 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).

2. CBRN Respirator Inspection. According to Section 2606.c.(3) of reference 2, since CBRN respirators are worn for emergency use, they will be inspected monthly according to manufacturer's instructions and a written inspection record will be maintained for the life of the respirator. Also, employees shall inspect their respirators for serviceability prior to donning them.

X. 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, medical surveillance. In addition, the local industrial hygienist will carefully and fully document any apparent deficiencies in a respirator program during the industrial hygiene survey and bring them to the attention of the RPPM (see paragraph XVI of this chapter).

XI. 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 XVI of this chapter).

XII. MEDICAL EVALUATION.

A. Civilian Respirator Medical Evaluation

1. According to Section 1508 of OPNAVINST 5100.23G, civilians will be medically evaluated according to the [Medical Surveillance Procedures Manual/Medical Matrix](#). Medical evaluation is age dependent, according to the following schedule:

(under 35)	(35-45)	(over 45)
5 yrs	2 yrs	1 yr

2. Appendix 15-A of reference 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 and signed copies of Appendix 15-A to the RPPM and to the worker.

3. Paragraph 1503.c. states that activities shall fit test, issue, and train personnel to wear respirators and ensure personnel are medically qualified. The exception is for escape-only respirators.

i. The intent of paragraph 1503.c. is to allow exclusion of medical evaluation only for visitors and other personnel not assigned to work areas where escape only respirators are worn - not for exclusion of personnel assigned to these areas. Escape only respirators are defined as devices that are designed and approved for use only during escape from hazardous atmospheres. Most of these escape only respirators are either mouthpiece respirators or hooded devices, which are lightweight and do not lend themselves to be fit tested. However, some work areas require full face pressure demand open-circuit SCBA or tight-fitting gas masks for escape purposes and personnel may have to walk for two miles or climb a ladder to escape from the complex while wearing respirators. All personnel who may need to escape while wearing tight-fitting respirators, such as these must be found medically able to do so. Also, these respirators come in different sized facepieces and fit testing is critical not only to ensure that facepieces do not leak for prevention of inhalation exposure; but also in the case of SCBA to prevent excess leakage that causes loss of air supply during escape.

b. Navy does not require medical approval for visitors and personnel not assigned to the work areas where activities provide escape-only respirators for potential emergencies. But they must be briefed in the use of the escape

respirator, and escorted at all times by personnel who are trained in the use of the respirator, and who can guide and assist them in emergencies.

c. Please note that personnel assigned to work in areas where escape-only respirators are provided for potential emergencies must be medically evaluated to determine if they can wear the escape-only respirator - the exception is for visitors to these areas.

4. Navy voluntary respirator use policy does not require medical evaluation for personnel choosing to wear filtering facepiece respirators when there is no exposure.

B. Shore-based Military Respirator Medical Evaluation.

1. Per Sections 1508 and 2602 of OPNAVINST 5100.23G, military personnel, who have been confirmed as “Fit for Full Duty” and having a current annual Periodic Health Assessment (PHA), are deemed medically qualified for use of all types of respirators. The phrase “Fit for Full Duty” is interpreted as having no deployment-limiting conditions. This is consistent with a “fully or partially medically ready status” of the Individual Medical Readiness (IMR) classification described in BUMED Notice 6110, Tracking and Reporting Individual Medical Readiness Data.

2. PHA screening, IMR, and deployment readiness tracking for activity military personnel is accomplished and verified by the IMR point of contact for the command or at the local MTF. Questionable cases will be referred to the MTF for a Respirator User Certification exam (Medical Matrix Program 716).

C. Shipboard Military Respirator Medical Evaluation.

1. Paragraph B060.d(1) of OPNAVINST 5100.19 Series states that medical department representative (MDR) shall: “Confirm that personnel, who are issued respirators have no deployment limiting medical conditions, and have a current annual Preventive Health Assessment per OPNAVINST 6120.3 (see paragraph B0613).”

2. Paragraph B0613 states that: “Military personnel, who have been confirmed by the MDR as having no deployment limiting medical conditions, and with a current annual Preventive Health Assessment per OPNAVINST 6120.3 are considered qualified to wear any type of respiratory protection. Shipboard personnel undergoing shore firefighting training are not required to obtain medical qualification or respirator fit testing for self-contained breathing apparatuses (SCBA), including the oxygen breathing apparatus (OBA), prior to reporting for training. Special evaluations shall be performed after prolonged absences from work for medical reasons or whenever a potential respirator-related medical problem has been identified.”

XIII. APPROVED RESPIRATORS.

A. Approval transition.

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

see the article entitled *History of Negative Pressure Particulate Respirator Certification* under the NAVMCPUBHLTHCEN [Industrial Hygiene](#) homepage.

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. 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 now provides the [NIOSH Certified Equipment List](#) electronically. 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. In most cases, the respirators in use can continue in service because most filters certified under 42 CFR 84 will be “drop-in” replacement products for old filters certified under 30 CFR 11.

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 (although it is doubtful that any of these respirators are still in use):

- 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.

5. A historical summary of respirator approval schedules is provided below.

APPROVAL SCHEDULES					
	Gas Mask	Airline	SCBA	Particulate	Chemical Cartridge
Original BM	BM-14	BM-19	BM-13	BM-21	BM-23
30 CFR 11	TC-14G	TC-19C	TC-13F	TC-21C	TC-23C
42CFR 84	TC-14G	TC-19C	TC-13F	TC-84A	TC-23C ^A

^A Combination chemical cartridge and airline respirators that include particulate filter elements will also have labels indicating the new particulate filter classification, TC-84A.

B. Classes of particulate respirator filters.

1. There are nine classifications of non-powered particulate air-purifying respirator filters certified under three 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 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 21. Filters are very efficient at filtering very large particles by sedimentation, impaction, and interception and very small particles by diffusion. These removal mechanisms are illustrated in figure 9-1 and are discussed below.

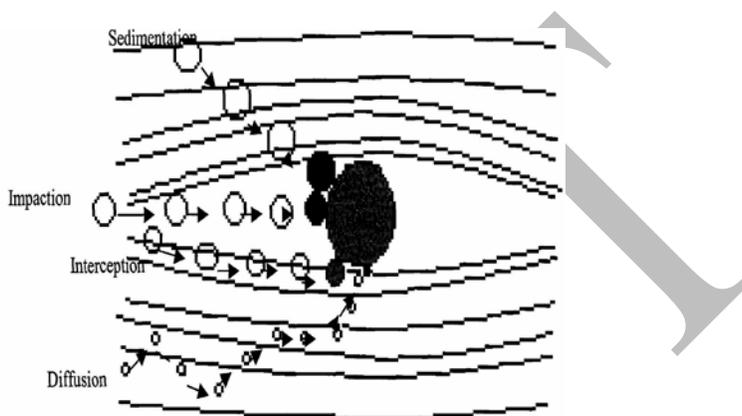


Figure 9- 1

- a. **Impaction** - Particles cannot bend with the airstreams as air goes around the fiber, so the particles impact onto the fiber. Impaction is primarily a function of the particles' momentum or inertia and usually occurs when the velocity of airstreams is high; the particles are large (greater than 1 micron diameter) and heavy; and since particles with high mass and velocity have more momentum, it is unlikely that they can turn with the airstreams around the fiber.
- b. **Interception** - Particles stay in the airstreams but are pulled onto the fiber by van der Waal's and electrostatic forces. Interception affects particles between one half and one micron in diameter (lighter in weight than affected by impaction). Generally, particles passing the fiber within a distance of half of the particle diameter will be captured. Filtration efficiency is enhanced by high relative humidity because the moisture forms a liquid meniscus between the particles and fibers, which assures adhesion.
- c. **Sedimentation** - Only large particles (2 microns and above) are affected by sedimentation. Sedimentation works only at low air flow rates. As particles fall through the airstreams by the force of gravity they are captured by the fiber.
- d. **Diffusion** - Smaller particles (less than 0.2 microns diameter) with slower velocities are captured by diffusion. Small particles are subject to Brownian movement - the random movement or bouncing motion of small molecules, almost like vibration, which increases the probability that the particle will contact another object. Slower velocity means the particle remains near the filter for a longer time, which increases the probability that the particle will

contact the fiber and be captured. This is the main mechanism in high-efficiency particulate air filters.

e. Electrostatic Attraction - Charged particles in the airstreams are attracted by oppositely charged fibers. Electrostatic attraction is often used to increase filter efficiency. There are two basic methods of establishing electrostatic attraction in filters. The original method consisted of impregnating a blend of wool and synthetic fibers with wood resin, which is then dried and energized by a mechanical needling process. This creates a positive charge on the fibers and a negative charge on the resin. Unfortunately, this mechanism is not effective for oil mist or atmospheres with high humidity, which dissipate the electrostatic charge.

i. In the newer method, electret fibers have permanent, strong electrostatic charges embedded inside plastic fibers during processing. Fibers maintain a positive charge on one side and an equally negative charge on the other side. Besides attracting oppositely charged particles to them, electret fibers polarize neutral particles by attracting the oppositely charged dipole to the fiber. They are less affected by high humidity, heat, and oily particles. Also, see paragraph XIII.B.6. concerning nanoparticles.

f. Figure 9-2, illustrates filter efficiency of 95% filters. According to the “single fiber filtration theory” and demonstrated by results of empirical testing, the most penetrating particle size is in the range of 0.1 to 0.4 microns with 0.3 micron particles producing the worst filter efficiency. In this size range, none of the filtration mechanisms dominate particle capture. However, for particles of this size the filters are still 95% efficient. Particles larger and smaller than 0.3 microns are very efficiently filtered by N95 filter media. The filters are more than 99% efficient on either side of the 0.3 micron dip in efficiency.

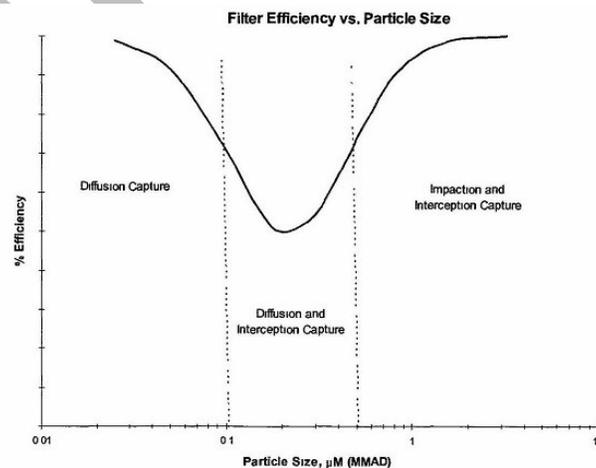


Figure 9- 2

2. Guidance for selecting between a 95% filter versus a 100% filter: The following guidance is for **0.1 to 0.4 micron sized particles**, which are the most filter

penetrating sized particles. As mentioned in the discussion about fit factors under paragraph III.H., the protection factor (PF) equals 100 divided by % respirator leakage (PF = 100/ % leakage). Per Table 9-1, half mask and full face, negative pressure air-purifying respirators have an assigned protection factor (APF) of 10 and 50, respectively. These APFs equate to 10% leakage for half masks and 2% leakage for full face respirators, assuming that there is 0% filter leakage. To determine filter efficiency needed:

a. First calculate the hazard ratio (HR) to determine what APF is required and therefore what class of respirator is needed (HR = [Exposure]/ OEL);

b. Next rearrange PF equation and calculate leakage for the class of respirator:

$$\begin{aligned} (\% \text{ leakage} = 100/ \text{APF}) \\ (\% \text{ leakage}_{(\text{half mask})} = 100/ 10 = 10\%) \qquad (\% \text{ leakage}_{(\text{full face})} = 100/ 50 = 2\%) \end{aligned}$$

c. Then calculate total leakage by adding filter leakage and respirator class leakage. Example:

95% filters have 5% leakage, so $(\% \text{ leakage}_{(\text{total})} = 100/ \% \text{ leakage}_{(\text{respirator class})} + 5\%_{(\text{filter leakage})})$

d. Finally, calculate protection factor using the total % leakage (PF = 100/ % leakage_(total))

If PF > HR then a 95% filter is sufficient;

If PF < HR then a 100% filter is required;

Examples For Selection of 95% Versus 100% Filter	
100% Filter Required	95% Filter is Sufficient
Exposure = 250 ppm, OEL = 15 ppm	Exposure = 50 ppm, OEL = 20 ppm
HR = 250 ppm /15 ppm = 16.7	HR = 50 ppm /20 ppm = 2.5
Must use full face: APF = 50; Leakage = 2%	Can use half mask: APF = 10; Leakage = 10%
% leakage = 100/ APF	% leakage = 100/ APF
% leakage = 100/ 50 = 2%	% leakage = 100/ 10 = 10%
Total leakage %	Total leakage
% leakage _(total) = 100/ % leakage _(respirator class) + 5% _(filter leakage)	% leakage _(total) = 100/ % leakage _(respirator class) + 5% _(filter leakage)
% leakage _(total) = 2% + 5% = 7%	% leakage _(total) = 10% + 5% = 15%
Recalculate PF (PF = 100/ % leakage _(total))	Recalculate PF (PF = 100/ % leakage _(total))
PF = 100/ 7% = 14.3	PF = 100/ 15% = 6.7
Since PF (14.3) < HR (16.7) use a 100% filter.	Since PF (6.7) > HR (2.5) use a 95% filter.

3. 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:
 - i. Extended use will not degrade the filter efficiency below the efficiency level specified in 42 CFR 84, or
 - ii. 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).
 - (i) 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.

NIOSH guidance concerning 42 CFR 84 particulate respirators is provided in reference 21, which may be downloaded from the following [website link](#). Additional guidance on these particulate respirators is available in reference 22 which may be downloaded from [NIOSH Respirator User Notice of 2 May 1997](#). Other NIOSH documents can be ordered from the [NIOSH publication web site](#).

4. 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 m^3 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 ($\text{UTL}_{95\%, 95\%}$), was 8 mg/m^3 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.

a. Example: 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 2.5 days or earlier if breathing starts to be difficult or filters become damaged or unsanitary. This same logic can also 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.

5. Respiratory Protection Against Pandemic Influenza: All nine classes of NIOSH approved particulate respirator filters can be used as protection against microorganisms (e.g., anthrax, tuberculosis, and avian influenza H5N1 viruses). At the breathing rates found in the workplace, 95% efficient filters filter out more than 99.5% of these microorganisms. Figure 9-3 shows the efficiency of N95 filters at removing microorganisms of various size ranges.

N95 FILTER EFFICIENCY VERSUS SIZE DISTRIBUTIONS OF MICROORGANISMS & RESPIRATORY GENERATED DROPLETS

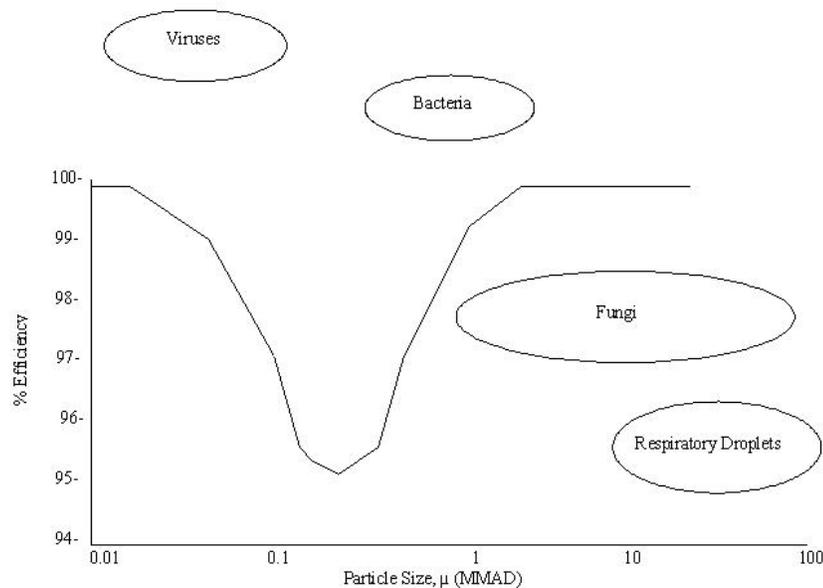


Figure 9-3

a. N95 filter media is the minimal protective filter recommended for protection against pandemic influenza. N95 filter media will effectively filter out 10 to 100 micron sized virus laden droplets produced by the respiratory tract

and also viruses, which are much smaller in size (0.08 to 0.12 microns). According to reference 23, a sneeze generates nearly 2 million droplets, which can be expelled at nearly 200 miles per hour and a cough produces approximately 100,000 droplets. N95 filter media is available both as replaceable filters for elastomeric respirators and is also the integral portion of filtering facepiece respirators.

b. Although N95 filtering media is an effective filter, protection against inhalation of influenza aerosols is also dependent on how well the respirator seals to the face to prevent leakage. Lawrence, et. al., (reference 24) compared the performance of surgical masks, N95 filtering facepiece respirators, and elastomeric half mask respirators equipped with N95 filtering media. They determined that surgical masks both as a class and individually provided very little protection and that filtering facepiece respirators do not perform as well as elastomeric half masks. They also determined that passing fit-testing resulted in a higher level of protection when compared with no fit testing for both filtering facepiece and elastomeric respirators.

c. Lawrence, et. al., stated that differences in design features could be the reason elastomeric half-facepiece respirators as a whole provided a higher level of protection than the filtering-facepiece respirators. They explained that all of the elastomeric respirators were equipped with adjustable head straps, whereas some of the filtering-facepiece respirators had only elastic, nonadjustable straps.

d. The minimum respiratory protection required for protection against Pandemic Influenza is a properly fitting N95 filtering facepiece respirator. There is a wide spectrum of filtering facepiece designs. Many are poorly designed and do not fit the wearer very well. In some cases the whole facepiece consists of filter media. However, many are very well designed and some even include a sealing surface to ensure a tight seal with the face. Also, if filtering facepiece respirators are selected for use, select cup shaped filtering facepieces with good sealing surfaces that can pass fit testing and meaningful user seal checks. The NAVMCPUBHLTHCEN developed the *NAVY POCKET GUIDE FOR HEALTH CARE PROVIDERS - PANDEMIC INFLUENZA PROTECTION PROCEDURES* based on the best practices prescribed in the plethora of information on pandemic influenza and control of tuberculosis and other infectious diseases and is available under the NAVMCPUBHLTHCEN [Industrial Hygiene](#) homepage.

e. An adequate amount of sizes and numbers of respirators must be stored to ensure that when needed, there will be sufficient quantities on hand for personnel required to wear them and that they will correctly fit the users. As with all respirators, stockpiles of stored respirators must be maintained in pristine condition.

6. Nanoparticles. Nanoparticles are very small with diameters less than 100 nm in at least one dimension. Because of their small size, air sampling results indicating low mass concentrations may actually contain very large surface areas of nanoparticles. Nanoparticles may be more biologically reactive than larger particles of similar chemical composition because of their increased surface area and their

smaller, more lung penetrating size. Currently, there are no specific exposure limits for nanoparticles although occupational exposure limits exist for larger particles of similar chemical composition.

a. In “[Approaches to Safe Nanotechnology](#),” NIOSH provides interim guidance on control technologies, work practices, and personal protective equipment demonstrated to be protective against fine and ultrafine particles. According to single fiber filtration theory, particles larger than 0.3 microns are collected most efficiently by impaction, interception, and gravitational settling, while particles smaller than 0.3 microns (300 nm) are collected most efficiently by diffusion or electrostatic attraction. Penetration of 0.3 micron particles represents the worst case because these particles are considered to be in the range of the most penetrating particle size. However, the most penetrating particle size range for a given respirator can vary based on the type of filter media employed and the condition of the respirator. For example, the most penetrating particle size for electrostatically charged filter media can range from 50–100 nm (0.05 - 0.1 micron). Reference 25 summarizes evidence indicating that the most penetrating size for electret filters may be much less than 100 nm. This article also questions if NIOSH filter certification testing is effective at determining filtration efficiency against aerosols less than 100 nm because the forward light scattering photometry detection method is not capable of adequately measuring the light scatter of such small particles.

b. As stated in “[Approaches to Safe Nanotechnology](#),” filter filtration efficiency increases as particle size decreases below the most penetrating particle size (300 nm) to the point when particles are so small that they behave like vapor molecules and may literally bounce through a filter by what is described by the “thermal rebound theory.” In NIOSH’s ongoing respirator filter media research of particles in the 3–100 nm range, they observed that penetration of nanoparticles through filter media decreased down to 3 nm as expected by traditional filtration theory and no evidence for thermal rebound of nanoparticles in the size ranges was found. Therefore, NIOSH stated that, based on these preliminary findings, NIOSH certified respirators should provide the expected levels of protection if properly selected and fit tested as part of a complete respiratory protection program.

c. Nanoparticle filtration research is ongoing and NIOSH has dedicated the following [website](#) to post findings of this research as results become available.

C. 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 is the process in which one substance takes up or holds another. In respirator chemical cartridges, sorption occurs by vapors being incorporated into a sorbent material or adhering to the sorbent surface. The sorbent in respirator cartridges or canisters (e.g., activated charcoal) is the material doing the sorption. The sorbate is the vapor contaminant being captured. Types of sorption include adsorption and absorption.

i. 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.

(i) Physisorption is a reversible 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 especially for organic compounds with low boiling points. For example, heating will drive the gas or vapor off the sorbent. Another mechanism is preferential physisorption which 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. Physisorption is the main mechanism for capturing organic vapors on pure activated charcoal.

(ii) Chemisorption is similar to physisorption and is used to capture volatile inorganic substances (e.g., acid gases and ammonia) 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 end-of-

service life indicators (ESLIs) that changed color as the sorbent became saturated. Since ESLIs were 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 ESLIs. 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.

ii. In absorption, the absorbed vapor 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.

c. 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 III.J., the IDLH concentration always takes precedence over the calculated MUC.

2. 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 4). Instead, either an organic vapor cartridge with a prefilter or a combination organic vapor cartridge/particulate filter must be used.

3. Respirator Cartridge Change Out Schedules. 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 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 for each operation. 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 ESLIs 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.
- i. 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.
 - ii. 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.
 - iii. 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.
 - iv. Most chemical cartridge respirator manufacturers offer free respirator cartridge service life software, based on Wood’s mathematical model (reference 26), 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 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.
- b. The article entitled *Chemical Cartridge Change Out Schedules* includes 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) and is provided under the NAVMCPUBHLTHCEN [Industrial Hygiene](#) homepage. This article also contains a list of websites for respirator

manufacturers' cartridge service life calculator software. The [Industrial Hygiene](#) homepage also has an article entitled *Calculating Chemical Cartridge Change Out Schedules For Mixtures*, which contains a spreadsheet for calculating change out schedules for mixtures of chemicals.

i. *NIOSH MultiVapor Beta Version 2.1.3* is available at the [following website](#). This program can be used to estimate breakthrough time(s) of one or a mixture of organic vapors through organic vapor air-purifying respirator cartridges at any humidity. It requires: 1) parameters of the cartridge and the carbon it contains, 2) physical characteristics of the vapor(s) present, and 3) environmental and use conditions.

4. CBRN Respirator Cartridge Change Out Schedules. Section 2606.c.(7) of OPNAVINST 5100.23G states that in the absence of industrial hygiene air sampling data that:

a. Respirator cartridges used by security guards must be changed after every 8-hour shift.

b. Cartridges used by personnel assigned to secondary decontamination stations at medical treatment facilities and by security guards stationed at the decontamination corridor must be changed every 2.5 hours.

c. The logic behind establishing these change out schedules is discussed in the following sections. Currently, all NIOSH CBRN agent approved gas masks achieved CAP 1 approval, in which their service life must last for 15 minutes against the representative test agents at concentrations exceeding IDLH concentrations. Since these CAP 1 respirators are not allowed to be worn in IDLH atmospheres, their service life will be considerably longer than 15 minutes in atmospheres less than IDLH.

d. OSHA has a rule of thumb related to increased service life resulting from decreased concentration. This rule of thumb states that "*Reducing workplace concentration by a factor of 10 will, in general, increase service life by a factor of five.*"

i. For example: NIOSH CBRN certification testing empirically determines that CBRN approved canisters last 15 minutes at 2600 ppm cyclohexane. Therefore, according to the OSHA rule of thumb, this canister should last 75 minutes at 260 ppm, 375 minutes at 26 ppm, and 1875 minutes at 2.6 ppm.

e. OSHA also has a rule of thumb for humidity, which states that "Humidity above 65% can reduce service life by 50%." However, this rule of thumb probably does not apply to CBRN agent approved canisters since NIOSH CBRN agent certification testing is performed at both 25 ± 5 percent relative humidity; and 80 ± 5 percent relative humidity.

f. Another OSHA rule of thumb is "Every 10° C (50° F) increase can reduce service life up to 10%," which may need to be considered in very hot environments. NIOSH CBRN agent certification testing is performed at $77 \pm 5^{\circ}$ F.

g. To receive NIOSH CBRN certification, the complete respirator assemblage (including canister) must also have a minimum service life of at least eight hours against initial concentrations of 210 mg/m³ Sarin (GB) vapor challenge and 50 mg/m³ Distilled Sulfur Mustard (HD) vapor and must have at least a two hour service life against 0.860 milliliters liquid HD.

h. The USACHPPM Summary of Chemical Agent Air Exposure Values of 8/03/04 indicates that the IDLH concentrations of HD and GB are 2 and 0.1 mg/m³, respectively. Doing the math for the OSHA rule of thumb “*Reducing workplace concentration by a factor of 10 will, in general, increase service life by a factor of five,*” for Sarin and Mustard vapor shows that the service life against these chemical warfare agents below the IDLH concentration greatly exceeds 8 hours. However, being conservative, canisters will be changed after eight hours, two hours if liquid agent is present.

i. If air sampling data is available, more detailed information on respirator cartridge change out schedules, including a method for validating estimated change out schedules, is provided under the NAVMCPUBHLTHCEN [Industrial Hygiene](#) homepage.

5. NIOSH CBRN approved full face air-purifying respirators are listed on the following [website](#). The MSA CBRN agent approved Millennium respirator (TC-14G-0270) has been the preferred make and model respirator because of its similarity to the Navy’s military gas masks (MCU-2A/P). Although the Millennium has been the first choice, equivalent masks are also authorized for purchase if they are specified as the respirator component of NFPA CBRN certified protective ensembles purchased for Navy first responders.

D. 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 either tight-fitting or loose fitting respiratory inlet coverings. Tight fitting PAPRs include facepieces (half-face and full-face) or tight fitting hoods that seal tightly at the neck. Loose fitting PAPRs include hoods and helmets that do not seal tightly at the neck, along with loose fitting facepieces, which form a partial seal with the face and do not cover the neck and shoulders. Tight-fitting PAPRs must supply a minimum of 4 cubic feet per minute (CFM) [equal to 115 liter per minute] of air to the user. Loose fitting PAPRs must supply a minimum of 6 CFM [equal to 170 liter per minute]. NIOSH is in the process of developing new certification testing criteria for approval of industrial use PAPRs. Details can be found at the following [website](#). PAPRs with loose fitting 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.

1. Currently, paragraph 84.1100(d) of 42 CFR 84 requires that PAPRs 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. Magenta colored approval labels are associated with high-efficiency filters used for protection against oil aerosols.

2. CBRN PAPRs. Paragraph 2606.c.1.(d) of reference 2 states that until NIOSH CBRN approved powered air purifying respirators (PAPRs) are available, personnel assigned to secondary decontamination stations at MTFs and military security personnel stationed at the decontamination corridor will wear full-face rubber PAPRs equipped with combination organic vapor, acid gas, and HEPA filters. Full face PAPRs were chosen because at that time, the *Draft OSHA APF Standard* granted full face PAPRs an APF of 1,000. Paragraph 2606.c.1.(d) further states that once NIOSH CBRN approved PAPRs are available, they will be the only air-purifying respirators permitted for use during these operations. MSA now has a full face NIOSH CBRN approved PAPR called the MSA Responder CBRN PAPR. This PAPR is approved with both the MSA Millennium and the MSA Ultra Elite tight-fitting facepieces. Because of its similarity to the Navy military gas mask (MCU-2/P), the Navy issues the MSA Millennium as the respirator component of Level C first responder protective ensembles. Personnel who are already fit tested with MSA Millennium gas masks or the MSA Ultra Elite facepiece will not have to be fit tested for the MSA Responder CBRN PAPR equipped with the same facepiece. Please see the following website for more information on the [MSA Responder CBRN PAPR](#). Also see the following website for a list of [NIOSH CBRN approved PAPRs](#). The following discussion describes why “full face” CBRN PAPRs are the respirators of choice for MTF secondary decontamination stations and decontamination corridor security personnel.

- i. The [NIOSH CBRN PAPR approval standard](#) sets forth CBRN approval criteria for both tight-fitting PAPRs and loose-fitting PAPRs. NIOSH classifies both full face CBRN PAPRs and tight neck-sealing hooded CBRN PAPRs as tight-fitting PAPRs. The NIOSH CBRN PAPR approval standard has provisions for granting CBRN approval to loose-fitting PAPRs, which must not to be confused with loose-fitting facepiece PAPRs listed in Table 9-1. Under the CBRN PAPR approval standard, loose-fitting PAPRS can be hooded devices. Tight sealing hooded CBRN PAPRs seal tightly around the neck; but loose-fitting CBRN PAPRS, including loose-fitting hooded units do not have any tight sealing surface.
- ii. Loose fitting CBRN PAPRs are not tested as stringently as tight-fitting CBRN PAPRs. Loose-fitting PAPRs are not subjected to liquid mustard agent permeation testing as is required for the tight fitting CBRN PAPRs. Also, the canisters of tight fitting CBRN PAPRs are tested at twice the challenge concentrations as are the loose-fitting CBRN PAPRs. Another distinction is that the Laboratory Respiratory Protection Level (LRPL) [NIOSH quantitative fit testing certification criteria]. The tight fitting CBRN PAPRs are tested both with the blower running and then again with the blower off. In contrast, the loose-fitting CBRN PAPRs are only tested with the blower running. If power is lost to loose-fitting PAPRs the wearer

cannot pull contaminated air through the filters; but if power is lost to tight fitting full face PAPRs the wearers' negative pressure during their inhalation will still pull contaminated air through the air-purifying filters.

iii. Also, hooded PAPRs only have an APF of 25 unless proven by testing and interpreted by OSHA as having a higher APF. Every tight-fitting full face PAPR that has received NIOSH CBRN approval is awarded an APF of 1,000 - in other words, it can be worn into atmospheres up to 1,000 times the OEL.

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 a cartridge change out schedule has not been established and implemented or there are no appropriate end-of-service-life indicator respirators. 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 user's facepiece. The hose length is limited to 300 feet and is Only approved for non-IDLH atmospheres. Per reference 27, the Type A respirator lost approval for entry into IDLH atmospheres in 1977.

a. Type AE is the same as Type A, but also has abrasive blasting approval.

2. 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 hose.

a. Type BE is the same as Type B, but also has abrasive blasting approval.

i. The NAVMCPUBHLHCEN 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.

3. 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. Care must be taken not to allow contamination of airline hoses with materials used in the workplace because these chemicals can permeate through the wall of airline hoses. This condition could allow the permeated chemical to evaporate inside the airline hose and then be inhaled by the respirator wearer. 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. The pressure demand Type C regulator maintains positive pressure inside the facepiece at all times. The pressure demand regulator housing consists of a diaphragm, air inlet port from the air supply, air outlet port to the facepiece, admission valve, and lever arms. There is usually a spring located between the diaphragm and the outside case of the regulator. This spring holds the admission valve slightly open, allowing for the capability of continual air flow into the facepiece. When this positive pressure is reduced by inhalation, breathing air is admitted to the facepiece at higher pressure. Air would continually flow into the facepiece except that all pressure demand respirators have a spring located in the special facepiece exhalation valve that maintains approximately 1.5 to 3 inches WG positive pressure in the facepiece at all times. This spring releases any excess pressure in the facepiece through the exhalation valve instead of allowing the excess pressure to escape through the facepiece sealing surface.

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. 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, NIOSH has approved several closed-circuit respirators 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 re-inflated. 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, potassium superoxide reacts with water vapor in the exhaled breath to generate oxygen ($4 \text{ KO}_2 + 2 \text{ H}_2\text{O} \rightarrow 4 \text{ KOH} + 3 \text{ O}_2$). CO₂ is removed through reaction with potassium hydroxide ($2 \text{ KOH} + \text{CO}_2 \rightarrow \text{K}_2\text{CO}_3 + \text{H}_2\text{O}$) and with potassium carbonate ($\text{K}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O} \rightarrow 2 \text{ KHCO}_3$). 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.

i. 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 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 10, pressure-demand SCBA have an assigned protection factor of 10,000. In contrast, demand SCBA have a protection factor of only 50. According to paragraph 1507 of reference 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 NFPA 1981 compliance (see XIII.F.2.b.i.)

a. There is a demand hooded SCBA and a pressure demand hooded SCBA on the market, both of which have tight-fitting neck seals. Neither can be worn into IDLH atmospheres and both require fit testing by converting them into air-purifying respirator mode. Even though they are hooded devices, neither can be worn with facial hair that interferes with the nose cup or tight-fitting neck seal. Please see the following website for [NIOSH policy](#) on this issue.

b. The following website link lists [NIOSH CBRN approved SCBA](#). NIOSH CBRN approved SCBA service life must be rated for 60 minutes.

i. NIOSH CBRN SCBA certification requires NFPA 1981 compliance as a component of NIOSH CBRN SCBA approval. Likewise, changes to the NFPA 1981-2007 edition (Standard on Open-Circuit SCBA for Emergency Services) require NIOSH CBRN SCBA approval as a component of NFPA 1981 compliance. The combined effect of these two standards is that NFPA 1981 compliance and NIOSH CBRN approval must be issued jointly. Now,

both NFPA 1981 compliant SCBA and NIOSH CBRN approved SCBA must pass a three tiered approval, which includes initial NIOSH 42 CFR Part 84 approval, followed by joint issuance of NFPA 1981 compliance certification, and NIOSH CBRN approval. One solution is for NIOSH CBRN SCBA approval applications and NFPA 1981 SCBA compliance certification applications to be accepted at the same time as 42 CFR Part 84 approvals. Please see the following website for more information on [NFPA 1981 compliance certification and NIOSH CBRN SCBA approval](#).

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 Scott emergency escape breathing device (EEBD) is a closed-circuit, oxygen generating SCBA especially developed for the Navy. This respirator was designed 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 has been phased out and replaced by the NIOSH approved (TC-13F-386) [OCENCO M-20.2 Self Contained Self Rescuer](#), which is a 10 minute closed-circuit mouthpiece respirator using compressed oxygen for oxygen replenishment.

a. NIOSH CBRN Escape Only Respirators. Currently, all NIOSH CBRN approved escape respirators are air-purifying devices and do not provide oxygen and therefore will not provide protection against oxygen deficient atmospheres. Hooded CBRN approved escape only respirators are not fit tested. See the following website for a list of [NIOSH CBRN approved escape respirators](#).

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 rapidly for escape. Pressure demand combination Type C/SCBA are approved for entry into 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,

3. No restrictions

I. Nullification of approval. NIOSH approval is issued only to specific and complete respirator assemblages after NIOSH tests the respirator assemblage and it is found to comply with the requirements under 42 CFR 84 and after the manufacturer's quality plan is determined to be satisfactory (Please see following [NIOSH website link](#)). A respirator's approval is nullified when:

1. Unapproved components are used (e.g., components between different types or makes of respirators are mixed).
2. Non-NIOSH authorized additions or changes to the respirator void the approval.
 - a. Further clarification on this important issue is found in the [Respirator User Notice of May 4, 2007](#), which states:

“...users of NIOSH approved respirators are cautioned against interchanging subassemblies or making unapproved modifications to their respirators. Respirators which have been modified by the interchanging of subassemblies or other deviations using parts not produced and distributed under the respirator manufacturer's controlled system, no longer meet the definition of being approved as a NIOSH certified respirator and the use of the NIOSH approval label is not authorized for that unit.”

3. A respirator is used in atmospheric concentrations for which it is not approved. That is, airborne concentrations exceed the maximum use concentration calculated using 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.

XIV. BREATHING AIR FOR SUPPLIED-AIR RESPIRATORS.

Grade D breathing air. All compressed breathing air must meet the quality specification for grade D breathing air as described in reference 28. A detailed discussion on breathing air is provided under the NAVMCPUBHLTHCEN [Industrial Hygiene](#) homepage.

A. 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 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.

1. OSHA in paragraph (i)(5) of reference 1 states that the employer shall ensure that compressors used to supply breathing air to respirators are constructed and situated so as to prevent entry of contaminated air into the air supply system.

Therefore, locate air intakes in fresh outdoor atmospheres, such as above roof level and away from ventilation exhausts.

B. According to B0611 of reference 3:

“Ships shall equip compressor systems with either high-temperature or carbon monoxide monitor and alarm systems or both, to control carbon monoxide levels. High-temperature cut-off switches on fixed compressors, which shut down the compressor at a temperature below which the lubricating oil breaks down (i.e., thermal degradation point), meet the requirement for high-temperature alarms, provided that quarterly monitoring meets the requirements for Grade-D breathing air. Ships shall equip all new and/or upgraded FIXED breathing air compressor systems with high-temperature cut-off switches. New and/or upgraded PORTABLE breathing air compressor systems will be equipped or operated with carbon monoxide monitor and alarm systems during SCBA air cylinder charging operations. Calibrate monitor and alarm systems on compressors used for supplying breathing air according to the manufacturer’s instructions.”

1. Per paragraph c. of the cover letter to reference 3, the requirement to equip all new and/or upgraded fixed breathing air compressor systems with high temperature cut-off switches commences in fiscal year 2008 and starting in fiscal year 2009, new and/or upgraded portable breathing air compressor systems will be equipped or operated with carbon monoxide monitor and alarm systems during SCBA air cylinder charging operations. This is due to limitations on ship design and construction.

C. Ambient Air Breathing Apparatus (AABA) are exempt from this requirement. 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.

D. Collect and analyze breathing air using the procedures specified in reference 28. The article entitled "[Compressed Breathing Air](#)" under the NAVMCPUBHLTHCEN [Industrial Hygiene](#) homepage provides a list of commercially available breathing air test kits which meet the CGA 7.1 analytical requirements. This article also contains a generic SOP for analyzing breathing air. Ensure the following minimum specifications for Grade D (reference 28) breathing air are met:

CGA G-7.1-2004 GRADE D COMPRESSED AIR PURITY REQUIREMENTS	
Characteristic	CGA G-7.1-2004 Requirements
Oxygen content (v/v)	19.5%-23.5%
Oil (Condensed)	≤ 5 mg/m ³
Carbon monoxide	≤ 10 ppm
Carbon dioxide	≤ 1,000 ppm
Water content	A dew point ≤ -65°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

XV. COLOR CODING.

A. ANSI Z88.7-2001 (reference 29) replaced 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 replaced 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

XVI. RESPIRATOR PROGRAM AUDIT.

A. Per references 2 and 3, the respirator program must be audited annually by the RPPM (or shipboard RPM [Respirator Program Manager]) and periodically reviewed and evaluated by the cognizant industrial hygiene office during performance of baseline or periodic industrial hygiene surveys. Checklists like the ones in Appendix B6-A of reference 3 are very useful when performing program audits and reviews. A checklist for shore-based Navy industrial respirator programs and for Navy CBRN respirator programs is provided under the NAVMCPUBHLTHCEN [Industrial Hygiene](#) homepage. Although this checklist can be used for both the annual RPPM audit and the periodic BUMED

program review; the two types of program evaluation differ with the thoroughness of workplace inspection and records evaluation. More specifically, the RPPM performs a complete workplace inspection and records audit, while BUMED performs a representative workplace inspection and record review as described below. Sections XVI.B. and XVI.C. discuss the shore-based RPPM annual audit and industrial hygiene periodic evaluation; however, this information is also applicable to shipboard respirator program reviews.

B. RPPM Annual Audit - In addition to the checklist, the RPPM audit includes examination of respirators in the workplace. The RPPM performs a complete inspection of all workplaces where respirators are worn to ensure proper respirator use. Besides the annual audit, the RPPM needs to perform frequent, random inspections to assure that respirators are properly selected, used, cleaned, and maintained. The RPPM should keep records of these ongoing surveillance findings. In addition to workplace inspections, the RPPM performs an annual audit of all records associated with the respirator program including respirator training; medical evaluation; fit testing; cartridge change out schedules; monthly inspection of emergency respirators; and compressor inspection and maintenance, including testing for Graded D air quality. Included in this audit is a review of the periodic BUMED Industrial Hygiene Surveys, which contains the written records documenting hazard assessment and the logic on which respirator selection is based. All problems identified during the RPPM audits and the periodic BUMED program evaluations must be corrected as soon as possible.

C. BUMED PERIODIC REVIEW - In addition to the checklist, the local BUMED industrial hygiene office (BUMED IH) should accomplish a workplace inspection of personnel wearing respirators. The BUMED IH periodic review of the respirator program is not intended to be a complete audit of the respirator program like the RPPM annual audit. BUMED IH is not expected to inspect each individual respirator wearer at the command. The BUMED IH respirator program review is scheduled to occur at the time of the periodic industrial hygiene survey. Therefore, BUMED IH will evaluate respirator use throughout the command's workplaces during the normal course of their periodic survey. In the workplace, BUMED IH should inspect respirators, have the respirator wearers perform positive and negative pressure user seal checks, see how respirators are cleaned and stored, and ask the workplace supervisor for the worksite SOP. If SOP respirator instructions are not clear to the BUMED IH reviewer, they are probably not clear to the respirator wearer. BUMED IH should record the names of individuals they encounter in their workplace inspection and take this list of personnel to the RPPM and check to see if they are included on the RPPM's roster - if they're not on this list, find out why! Check the list of respirator user names in the RPPM's records to ensure that fit testing, medical evaluation, and training are up-to-date. The RPPM will have a signed Appendix 15-A for each medically qualified civilian respirator wearer and the RPPM can confirm from command records or from local medical treatment facility Individual Medical Readiness point of contact that military personnel in the respirator program are fit for full duty and therefore medically qualified to wear all types of respiratory protection. Check the RPPM's other record keeping requirements, including records for Grade D breathing air quality testing, supplied air compressor inspection and maintenance, monthly emergency use respirator inspections, RPPM training, cartridge change out schedules, and the annual RPPM program audit. Again, the BUMED IH

periodic review is not intended to be as thorough as the RPPM annual audit. However, the BUMED evaluation of respirator use in the workplace and the program record evaluation must be complete enough for BUMED IH to determine the effectiveness of the respirator program. The BUMED respirator program review/ evaluation can either be a separate document or an annex to the periodic BUMED Industrial Hygiene Survey Report. BUMED IH will verify, during their next periodic review, that all identified problems were corrected.

D. For readers interested in information on private industry respirator program evaluation requirements, a discussion entitled *Comparison of Navy, OSHA, and ANSI Respirator Program Audits* is provided under the NAVMCPUBHLHCEN [Industrial Hygiene](#) homepage.

DRAFT

TABLE 9-1.-Assigned Protection Factors ^D					
Type of respirator ^{A, B}	Quarter mask	Half mask	Full facepiece	Helmet/Hood	Loose-fitting facepiece
1. Air-Purifying Respirator.....	5	10	50	.....	.....
Filtering Facepiece Respirators5	.....	.....	.....
2. Powered Air-Purifying Respirator (PAPR).....	50	1000	25/1000 ^C	25
3. Supplied-Air Respirator (SAR) [Airline Respirator] ^E
Demand mode.....	10	50	.....	.....
Continuous flow mode.....	50	1000	25/1000 ^C	25
Pressure-demand or other positive-pressure mode	50	1000 ^F	.....	.....
4. Self-Contained Breathing Apparatus (SCBA)
Demand mode.....	10	50	50	.....
Pressure-demand or other positive-pressure mode
(e.g., open/ closed circuit).....	10,000	10,000	.....

^A Employers may select respirators with greater protection factors than what is required by the hazard.

^B APFs are only applicable if all elements of an effective respirator program are established and enforced in accordance with this chapter.

^C The employer must have evidence that testing of these respirators demonstrates performance at a level of protection of 1,000 or greater to receive an APF of 1,000. According to OSHA, they will post acceptable protection factor testing protocols and maintain a list of hooded respirators demonstrated to achieve an APF of 1,000. In the absence of such testing, all other PAPRs and SARs with helmets/hoods are to be treated as loose-fitting facepiece respirators, and receive an APF of 25. For further guidance see paragraph III.I.3. of this document.

^D These APFs do not apply to respirators used solely for escape. For escape respirators used in association with contaminants that are regulated by OSHA substance specific standards (e.g., acrylonitrile, formaldehyde, benzene) refer to the appropriate substance-specific standards. Paragraph (d)(2)(ii) of 29 CFR 1910.134 states that “Respirators provided only for escape from IDLH atmospheres shall be NIOSH certified for escape from the atmosphere in which they will be used.”

^E When using a combination respirator ensure that the APF is appropriate to the mode of operation in which the respirator is being used. For example, a combination full facepiece pressure-demand SAR with an air-purifying canister would have an APF of 1,000 in the pressure-demand mode; but would have an APF of 50 in the negative pressure air-purifying mode.

^F The protection provided by combination, full facepiece pressure-demand SARs with auxiliary SCBA is equivalent to the protection provided by full facepiece pressure-demand SCBA; therefore, the APF of 10,000 for pressure-demand SCBA applies.

XVII. REFERENCES.

¹ Occupational Safety and Health Administration (OSHA): 29 CFR Parts 1910 and 1926 Respiratory Protection: Final Rule. Federal Register 63(5):1278–1279. Washington, D.C.: U.S. Government Printing Office, Office of the Federal Register, January 8, 1998.

http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=12716

² OPNAVINST 5100.23 Series.

<http://doni.daps.dla.mil/OPNAV.aspx?RootFolder=%2fDirectives%2f05000%20General%20Management%20Security%20and%20Safety%20Services%2f05%2d100%20Safety%20and%20Occupational%20Health%20Services&View=%7bDEF0EB11%2d3785%2d4F67%2dB5A1%2dAE9F8EB752BC%7d>

³ OPNAVINST 5100.19 Series.

<http://doni.daps.dla.mil/OPNAV.aspx?RootFolder=%2fDirectives%2f05000%20General%20Management%20Security%20and%20Safety%20Services%2f05%2d100%20Safety%20and%20Occupational%20Health%20Services&View=%7bDEF0EB11%2d3785%2d4F67%2dB5A1%2dAE9F8EB752BC%7d>

-
- ⁴ National Institute for Occupational Safety and Health (NIOSH): 42 CFR Part 84: Respiratory Protective Devices; Final Rules and Notice. Federal Register 60(110):30336–30398. Washington, D.C.: U.S. Government Printing Office, Office of the Federal Register, June 8, 1995.
http://www.access.gpo.gov/nara/cfr/waisidx_04/42cfr84_04.html
- ⁵ American National Standards Institute (ANSI): American National Standard for Respiratory Protection (ANSI Z88.2). New York: ANSI, 1992.
- ⁶ Perez, C. and Soderholm S. C.: Some Chemicals Requiring Special Consideration when Deciding Whether to Sample the Particle, Vapor, or Both Phases of an Atmosphere. Appl. Occup. Environ. Hyg. 6(10):859-864 (1991).
- ⁷ National Institute for Occupational Safety and Health (NIOSH): NIOSH Guide to Industrial Respiratory Protection. DHHS (NIOSH) Publication No. 87-116. Cincinnati, Ohio: NIOSH, 1987.
<http://www.cdc.gov/niosh/docs/87-116/>
- ⁸ National Institute for Occupational Safety and Health (NIOSH): Respirator Selection Logic. DHHS (NIOSH) Publication No. 2005-100. Cincinnati, OH: NIOSH, 2004. <http://www.cdc.gov/niosh/docs/2005-100/>
- ⁹ American National Standards Institute (ANSI): American National Standard Practice for Occupational and Educational Personal Eye and Face Protective Devices (ANSI Z87.1). New York: ANSI, 2003.
- ¹⁰ Federal Register Vol 71 # 164, PP 50122 - 50192. 29 CFR Parts 1910, 1915, and 1926 Assigned Protection Factors; Final Rule of 24 Aug 2006.
http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FEDERAL_REGISTER&p_id=18846
- ¹¹ Cohen, et. al.: Simulated Workplace Protection Factor Study of Powered Air-Purifying and Supplied Air Respirators. Am. Ind. Hyg. Assoc. J. 62:595–604 (2001).
- ¹² PHONCON OSHA Mr. J. Steelnack/NAVMCPUBHLTHCEN Mr. D. Spelce of 1 Aug 07
- ¹³ ACGIH®: TLVs and BEIs® Based on the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices. Cincinnati, Ohio: ACGIH, 2008.
- ¹⁴ American National Standards Institute (ANSI) ANSI/American Industrial Hygiene Association (AIHA): American National Standard for Respirator Fit Testing Methods (ANSI/AIHA-Z88.10). Fairfax, Va.: AIHA, 2001.
- ¹⁵ NIOSH Statement of Standard for Chemical, Biological, Radiological, and Nuclear (CBRN) Full Facepiece Air Purifying Respirator (APR) updated 30 Jan 2004. <http://www.cdc.gov/niosh/npptl/standardsdev/cbrn/apr/>
- ¹⁶ PHONCON OSHA Mr. J. Steelnack/NAVMCPUBHLTHCEN Mr. D. Spelce of 24 May 07
- ¹⁷ Occupational Safety and Health Administration (OSHA): Inspection Procedures for the Respiratory Protection Standard. OSHA Directive CPL 2-0.120, 1998. http://www.osha.gov/Publications/SECG_RPS/CPL_2-0_120.pdf
- ¹⁸ National Fire Protection Association (NFPA): NFPA 1404, Standard for Fire Service Respiratory Protection Training, 2006 Edition
- ¹⁹ National Fire Protection Association (NFPA): NFPA 1500, Standard on Fire Department Occupational Safety and Health Program, 2007 Edition
- ²⁰ National Fire Protection Association (NFPA): NFPA 1852, Standard on Selection, Care, and Maintenance of Open-Circuit Self-Contained Breathing Apparatus (SCBA), 2002 Edition
- ²¹ National Institute for Occupational Safety and Health (NIOSH): NIOSH Guide to the Selection and Use of Particulate Respirators Certified Under 42 CFR 84. DHHS (NIOSH) Pub. No. 96-101. Cincinnati, Ohio: NIOSH, 1996. <http://www.cdc.gov/niosh/userguid.html>
- ²² National Institute for Occupational Safety and Health (NIOSH). Respirator User Notice May 2, 1997. Cincinnati, Ohio: NIOSH, 1997. <http://www.cdc.gov/niosh/npptl/usernotices/run-050297.html>
- ²³ University of Cincinnati: Respiratory Protection Newsletter from Dr. McKay. January 2008 edition.
- ²⁴ Lawrence, et. al.: Comparison of Performance of Three Different Types of Respiratory Protection Devices. J. Occup. Environ. Hyg. 3:465-474 (2006).
- ²⁵ Eninger, et. al.: What Does Respirator Certification Tell Us About Filtration of Ultrafine Particles?. J. Occup. Environ. Hyg. 5:286-295 (2008).
- ²⁶ Wood, Gerry O.: Estimating Service Lives of Organic Vapor Cartridges operations. Am. Ind. Hyg. Assoc. J. 55(1):11-15 (1994).
- ²⁷ Federal Register Vol 42 # 250 PP 65167-65168. 30 CFR Part 11 Respiratory Protective Devices; Tests for Permissibility; Fees, Final Rule of 30 December 1977.
- ²⁸ Compressed Gas Association (CGA). CGA G-7.1-2004, Commodity Specification For Air.. CGA, Arlington, VA. 2004.
- ²⁹ American National Standard Institute (ANSI)/American Industrial Hygiene Association (AIHA). Color Coding of Air-Purifying Respirator Canisters, Cartridges, and Filters (ANSI/AIHA Z88.7-2001), Fairfax, Va.: AIHA, 2001.