

RESPIRATOR SPECIAL PROBLEMS

I. GENERAL INFORMATION

Administration of respirator programs for the most part is rather straightforward. For example, there are correct procedures for respirator fit testing, cleaning, inspection and storage, and respirator selection. However, there are also problematic areas in respirator program administration, such as, facial hair, vision, communication, respirators worn in temperature extremes, and respirators worn for protection during welding and abrasive blasting. There are other issues such as patrons using respirators in hobby shops. Each of these problem areas along with others are addressed in this article.

Some areas of respiratory protection that may be considered as special problems (or at least special respirator program concerns) deserve their own articles, which can be found at the following website links: [CBRN respirators](#)¹, [compressed breathing air for atmosphere supplying respirators](#), [change schedules for respirator chemical cartridges](#), and [respiratory protection for nanoparticles](#).

II. FACIAL HAIR

Tight-fitting respirators are not allowed to be worn by individuals with facial hair that interferes with respirator facepiece-to-face seal or valve function. This is the policy set forth by the Occupational Safety and Health Administration (OSHA) in reference 1, by the Navy in references 2 and 3, and ANSI² Z88.10 (reference 4). The reason for the facial hair prohibition policy is because it causes leakage of contaminated workplace air into the respirator where it is then inhaled by the wearer. OSHA and Navy policies on facial hair are identical and are reproduced below.

A. OSHA in paragraph (g)(1) of 29 CFR 1910.134 and paragraph 1503.e of OPNAVINST 5100.23series both state:

1. *“The employer shall not permit respirators with tight fitting facepieces to be worn by employees who have:*

a. Facial hair that comes between the sealing surface of the facepiece and the face or that interferes with valve function; or

b. Any condition that interferes with the face to facepiece seal or valve function.”

B. In the preamble to reference 1, OSHA stated that they could not possibly specify every condition under which respirator use may be affected by an employee's facial hair. Instead, OSHA has written the standard in performance-oriented terms, stressing the importance of the face to facepiece seal and conditions that might interfere with that seal. OSHA further stated that the thrust of their entire standard is on ensuring that respirator fit and performance are not compromised by requiring employers to ensure their workers' respirators fit properly and properly perform.

¹ CBRN is the acronym for *chemical, biological, radiological, nuclear*.

² ANSI is the acronym for the American National Standards Institute, which is the private non-profit organization that develops American national consensus standards including the ANSI respirator standards.

C. The OSHA inspector instruction (reference 5) provides more details concerning facial hair. Paragraph H.1.a. of reference 5 states,

1. “The CSHO³ should be alert for the presence of facial hair (more than one day’s growth) that comes between the sealing surface of the respirator and the face as well as other conditions that could result in facepiece seal leakage or interfere with valve function of tight-fitting respirators, such as the presence of facial scars, the wearing of jewelry, or the use of headgear that projects under the facepiece seal.”

2. Note that OSHA instructs their inspectors to be alert for facial hair that is “more than one day’s growth” because it causes respirator leakage.

D. Hyatt, et al. (reference 6) investigated the effect of facial hair on the performance of half mask and full face respirators by performing quantitative fit testing on volunteers with varying amounts of facial hair, including stubble, sideburns, and beards. Their test results showed that persons with facial hair such as facial stubble, beards, and wide sideburns that interfere with the respirator seal, cannot expect to obtain as high a degree of respirator performance as clean-shaven individuals. The exact degree to which a particular beard or sideburns affects a specific person/ respirator combination depends on many factors such as the length, texture, and density of hair as well as the extent of the interference with the sealing surface of the respirator. They included an interesting discussion about tough bristles of one day’s facial hair growth may actually hold the respirator away from the face like prongs. This is graphically illustrated by their table in Figure 1 showing the effect of facial hair stubble on respirator facepiece leakage.

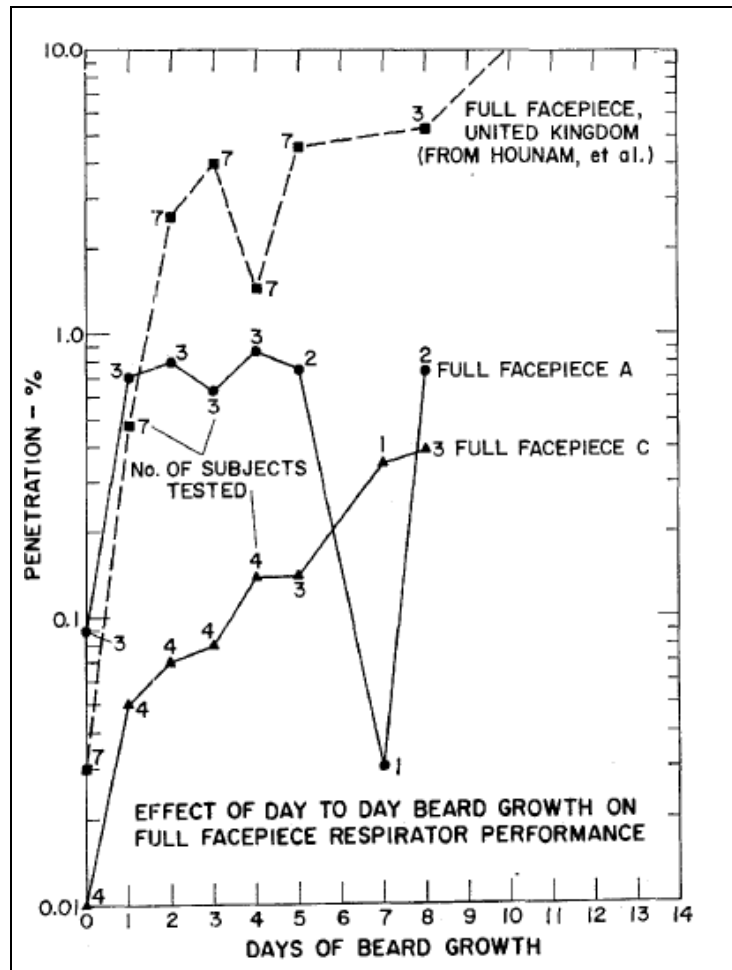
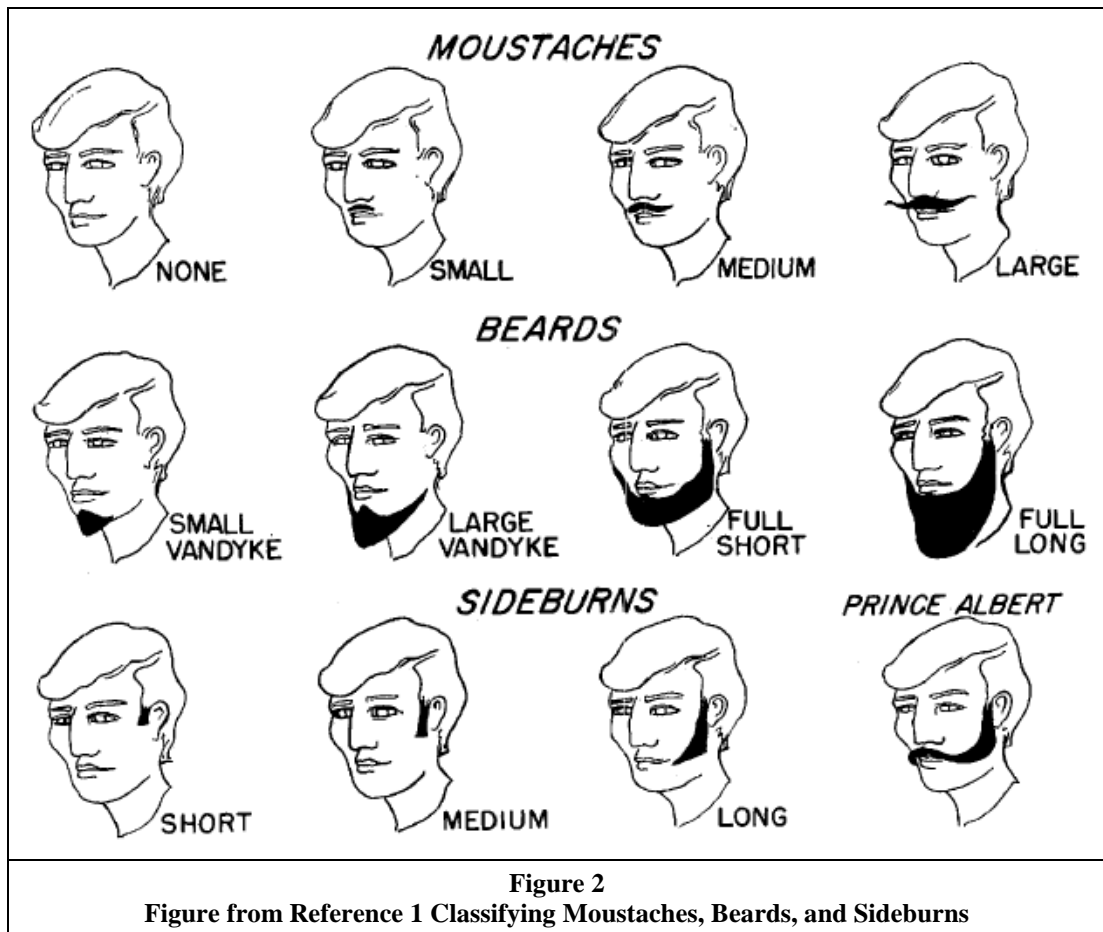


Figure 1
Table from Reference 6 Showing Facial Hair Stubble Effect on Respirator Leakage

³ CSHO stands for *Compliance Safety and Health Officer*, which is the title for OSHA inspectors who assure compliance with OSHA occupational safety and health regulations and standards.

1. Hyatt et al. included the following interesting anecdote in reference 6 concerning occupational hazards of facial hair:

“Although this paper is concerned only with the effect of facial hair on respirator performance, the problem of the beard as an occupational hazard is not new. For example, Alexander the Great prohibited his Grecian soldiers from wearing beards because they were too convenient a hand-hold in battle. The present day consequences of wearing beards are not likely to be as severe as in Alexander's time, but nevertheless a man wearing a respirator can unknowingly be placed in a hazardous situation if his facial hair interferes with the sealing of the respirator on his face.”



2. In addition to investigating the effect facial hair stubble has on respirator leakage, Hyatt et.al. attempted to establish a common language for describing different beard, moustache, and sideburn types, and established the classification system shown in Figure 2. Hyatt et al. admitted that this system falls short of describing the large variety of facial hairstyles, but it does cover the major categories. Hyatt, et al. found that not all of the hairstyles shown in Figure 2 interfere with a respirator facial seal. For example, a small moustache, small Van Dyke beard, or short to medium length sideburns probably will not cause difficulty. However, the full, long beards, long, wide sideburns, or handlebar moustaches will

most certainly present problems, if they interfere with the sealing surface of the mask.

3. Hyatt, et al. concluded that short of almost continuous surveillance of the respirator fit on a bearded worker by use of some means of qualitative or quantitative fitting, the only safe and prudent approach is to require that the facial hair not interfere with the respirator sealing surface, or to require that the individual not work in an area or at a task that requires respiratory protection.

E. Skretvedt and Loschiavo (reference 7) investigated the effect of facial hair on respirator seal leakage by qualitatively and quantitatively fit testing both half mask and full facepiece respirators on 370 male employees, 67 of who had full beards. The bearded workers consistently failed qualitative fit testing. Quantitative fit testing results also indicated that facial hair interfered with the sealing surfaces resulting in respirator leakage. Bearded employees using half masks had a median fit factor of 12, while clean-shaven employees had a median fit factor of 2,950. For full facepiece respirators, bearded workers had a median fit factor of 30 and clean shaven employees had a fit factor of greater than 10,000.

1. Skretvedt and Loschiavo concluded that their data showed that beards protruding into the face seal of negative pressure respirators greatly reduce the effectiveness of the respirators, making workers with facial hair protruding into the face seal at more risk than clean-shaven workers.

2. They stated that, *“Therefore, facial hair must not be permitted if adequate respiratory protection is to be provided.”*

F. McGee and Oestenstad (reference 8) tested eight volunteers on a full facepiece closed circuit, pressure demand, self contained breathing apparatus (SCBA). The volunteers were clean shaven at the beginning of the study. They underwent quantitative fit tests at two week intervals over an eight week beard growth period. Beard growth had a profound, negative effect on the observed fit factors. Most of the volunteers started with fit factors of 20,000 when first fit tested; after eight weeks, these same workers achieved fit factors ranging only from 14 to 1067.

G. DaRoza et al. (reference 9) reviewed scientific investigations on the effects of facial hair on respirator leakage and found that all of the controlled studies of negative pressure respirators were generally consistent showing that the presence of facial hair produced leakage that was 50 to 1,000 times greater than found with clean-shaven individuals. Leakage generally increased as the facial hair length increased. Also, leakage variability was greater in the presence of a beard. Studies that tested both full face and half mask respirators reported half mask leakage as being two to five times greater than leakage with the full face respirators. Negative pressure half mask air purifying respirators provided the least protection as compared to positive pressure respirators.

1. For negative pressure respirators, DaRoza et al. concluded that facial hair should not be permitted when the hair growth is in and/or along the respirator facial sealing surface, – i.e., no beards allowed with negative pressure respirators.

Note: One single hair in the exhalation valve will cause 10% leakage⁴.

2. For positive pressure respirators, DaRoza et al. concluded that the answer remains ambiguous. The only two positive pressure studies were inconclusive.

a. The respirators' positive pressure overcame the leakage effects of facial hair. In other words, the leakage in positive pressure respirators results in air forced from inside the respirator out into the work environment.

b. In contrast, leakage in negative pressure respirators results in workplace air leaking into the facepiece. DaRoza, et al. concluded that prudent work practice dictates that facial hair should not be worn with positive pressure respirators.

Note: Although face seal leakage in positive pressure respirators flows from inside the respirator to the outside environment, slight exposure is possible from leakage in the sealing surface⁴. This leakage is thought to occur by the venturi effect⁵. To elaborate, leakage in the positive pressure respirator sealing surface creates a venturi effect resulting in outside air being aspirated into the facepiece. The leakage is thought to occur by workplace air being suctioned into the facepiece by the venturi effect from outward flow through different areas of the same gap in the respirator sealing surface⁴. Also, positive pressure respirators can be over breathed when operated at the lower end of the operating pressure range when workers' breathing rate is high⁴. Additionally, face seal leakage in positive pressure SCBA reduces the service life of the SCBA air cylinder by air escaping out into the environment through face seal leakage. These are further justifications for fit testing positive pressure respirators.

H. Balkhyour (reference 10) quantitatively fit tested 40 firefighters three times each day for five days while they wore two different brands of full facepiece air-purifying respirators. Firefighters having beards showed a mean leak rate more than 10 times that of non-bearded firefighters. Balkhyour concluded that, *"Having a beard was proved to increase dramatically the leak rate, therefore, it is recommended to prohibit beard growth among firefighters. Beards can be life-threatening during fire extinguishing activities, as well as, during overhaul operations."*

III. VISION PROBLEMS

Issues with respirators and vision include, providing vision correction for full face respirator wearers needing prescription glasses, use of contact lenses with respirators, and respirator facepiece lens fogging. Also included under this topic is eye protection during respirator use.

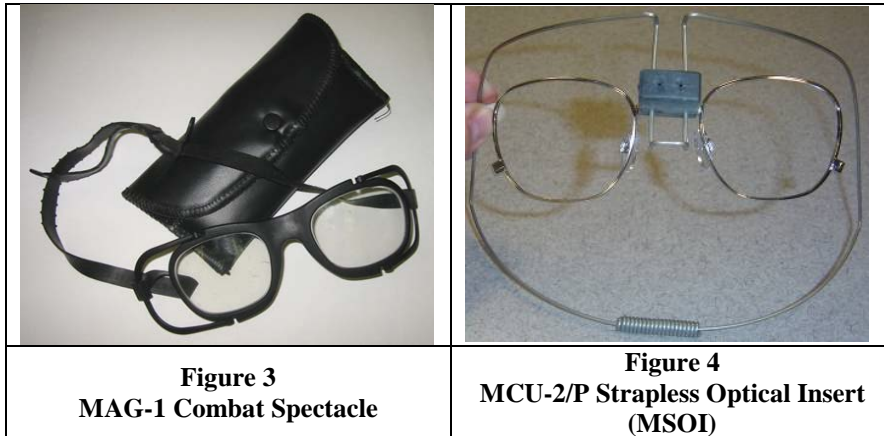
A. Vision Correction That Breaks The Respirator Seal - According to OSHA (reference 1), the National Institute for Occupational Safety and Health (NIOSH) (reference 11), and ANSI Z88.10 (reference 4) corrective eyewear worn with full face respirators must not reduce the protection afforded by the respirator.

⁴ Darrel Bevis *Respirator Fit Testing Course*, Chantilly Virginia ~ April 1988.

⁵ CONVERSATION NIOSH, National Personal Protective Technology Laboratory Christopher Coffey / NMCPhC David Spelce of ~ Jan 2002.

1. OSHA states in paragraph (g)(1)(ii) of reference 1 that:
 - a. *“If an employee wears corrective glasses or goggles or other personal protective equipment, the employer shall ensure that such equipment is worn in a manner that does not interfere with the seal of the facepiece to the face of the user.”*
2. OSHA instructions to compliance officers for inspecting respiratory protection programs state the following policy concerning breaking the respirator seal (paragraph H.1.a. of reference 5):
 - a. *“The CSHO should be alert for ...conditions that could result in facepiece seal leakage or interfere with valve function of tight-fitting respirators, such as ...Corrective glasses or goggles or other personal protective equipment (such as faceshields, protective clothing, and helmets) must not interfere with the seal of the facepiece to the face of the user.”*
3. NIOSH states in Sec.84.75(b) of reference 11 that, *“Full facepieces shall provide for the optional use of corrective spectacles or lenses which shall not reduce the respiratory protective qualities of the apparatus.”*
4. In addition, the ANSI Respirator Standard (reference 12) states in clause 7.5.3.2 that:
 - a. *“Spectacles with straps or temple bars that pass through the sealing surface of either negative or positive pressure respirators shall not be used.”*
 - b. Note that the draft revision of ANSI Z88.2 (revision completed in spring of 2014) has the same language as the 1992 version of the American national respirator consensus standard.
5. Empirical data gained from research performed on full face, negative pressure, air-purifying respirators supports OSHA, NIOSH, and ANSI policies prohibiting use of spectacle kits with straps with full face respirators. Reference 13 conducted a study to determine if leakage is caused by straps of Mag 1 spectacle kits (Figure 3) breaking the respirator sealing surface on three brands of full face respirators and reported, *“...our results clearly demonstrate that the wearing of spectacles [Mag 1 spectacle kits] significantly reduced the fit factor afforded to the wearer and suspect that a substantial reduction in the protection factor would result during actual working conditions.”*
6. As expected, corrective spectacles that break the respirator seal are also an issue with military gas masks. The MAG-1 combat spectacles (Figure 3) were adopted in 1984 as an interim solution to prescription vision correction for the MCU-2/P series gas mask used by the Navy and the Air Force.
 - a. Quantitative test results (reference 14) showed that 38% of personnel wearing the MAG-1 optical inserts with the MCU-2P did not pass quantitative fit testing at the fit factor of 1,667, which at the time was the Air Force minimum requirement. Also, 44% of personnel wearing the MAG-1 did not pass the Navy minimum fit factor requirement of 3,000.

b. Military research developed the MCU-2/P Strapless Optical Insert (MSOI) (Figure 4) to provide warfighters with prescription vision correction that does not result in gas mask face seal leakage. The design of the MSOI does not breach the seal of the mask, or negatively impact the protection afforded by the gas mask.



c. In contrast to the mask leakage caused by the MAG-1, 100% of personnel tested with the new *MCU-2/P MSOI* passed the same quantitative respirator fit test. In addition, personnel wearing the MSOI for vision correction in their MCU-2/P during operational testing found it stable, comfortable and indicated it had a good field of view.

7. The next generation of military gas mask, the M50, Joint Services General Purpose Mask (JSGPM) prohibits wearing vision correction that breaks the gas mask seal. Paragraph 3.3.2.4.11 of reference 15 states that “*The mask [JSGPM] shall provide a method of correcting vision without breaking the seal of the mask, without creating a potential secondary eye hazard (no sharp edges or points), and without compromising protection.*”

8. Corrective spectacles that break the respirator seal by temple bars or straps have a more profound effect on negative pressure respirators than on positive pressure respirators. However, if the positive pressure respirator is an SCBA, any leakage will reduce the service life of the respirator.

a. Reference 16 found no significant difference ($P_{0.05}$) in protection factors of three out of the four brands of positive pressure respirators studied while both wearing and not wearing Mag-1 spectacle kits with straps that break the seal of the full facepiece. This is because air from leakage in positive pressure respirators flows from within the facepiece to the outside.

b. In contrast, reference 16 used quantitative fit testing to compare wearing negative pressure, full face air-purifying respirators with and without Mag-1 spectacle kits designed with headbands that break the face seal. Two out three respirator brands tested with these spectacle kits had lower protection factors than respirators worn without Mag-1 spectacle kits. The lower protection factors resulted from inhalation producing negative pressure inside the

respirators causing air leakage from the Mag-1 spectacle kits to flow from the outside environment to the inside the facepiece.

B. Generic Spectacle Kits – Some brands of generic spectacle kits adhere to the facepiece lens by either glue or suction cup. OSHA’s letter of interpretation in reference 17 allows the use of generic spectacle kits with full face respirators if the device does not interfere with the facepiece seal and if it does not cause any distortion of vision, damage the lens of the facepiece, or cause any physical harm to the wearer during use.

1. However, using any spectacle kit not approved by NIOSH with a full face respirator as part of the NIOSH certified respirator assemblage negates NIOSH approval.

2. Navy policy does not allow using generic spectacle kits because of the Navy requirement to use only NIOSH approved respirators per paragraph 1507.a. of reference 2, which states, “*Activities shall only use respirators that are currently approved by NIOSH or NIOSH and Mine Safety and Health Administration (MSHA).*”

C. Contact Lenses - Unlike the original OSHA Respirator Standard, which prohibited use of contact lenses with respirators, the 1998 OSHA Respirator Standard allows their use by conspicuously not addressing them in the standard.

1. The proposed 1994 OSHA Respirator Standard Rulemaking (reference 18) contained a lengthy explanation of OSHA’s proposal not to prohibit use of contact lenses with respirators in the final rule. The 1994 OSHA proposed rule making, which did not result in a new OSHA Respirator Standard at that time, included the following discussion on this issue:

- a. The main justification for not wearing contact lenses with respirators has been that with full facepiece respirators, if a contaminant got into the employee's eye, the involuntary response would be to remove the mask to attend to the eye, thus removing the respiratory protection.

- b. A second possible problem with contact lenses is that the dry air inside a positive pressure SCBA facepiece could dry out the contact lenses. It has also been suggested that contaminants that get into the facepiece can become lodged under the contact lens, be held against the eye, and enter into the bloodstream. While these possible problem areas have been proposed for contact lenses, OSHA has not found evidence of such problems occurring in the workplace.

2. According to reference 18, OSHA funded a survey on the use of contact lenses by fire fighters, which was conducted by the Lawrence Livermore National Laboratory (LLNL). Of the 403 fire fighters who regularly wore contact lenses with SCBA, only six responded that contact lens created a problem such as a contact lens being out of place or a particle under the lens causing the respirator facepiece to be removed in an environment where the facepiece would normally be worn. Reference 18 further stated that:

- a. Wearing conventional eyeglasses inside the respirator facepiece had a proportionately higher number of problems than wearing contact lenses with respirators.
 - b. The LLNL contact lens firefighter study supports removing the prohibition on use of contact lenses with respirators. No evidence showed that wearing contact lenses with respirators increased safety hazards. The study concluded that prohibition of wearing contact lenses with full facepiece respirators should be withdrawn.
3. Reference 19 is a journal article written by the LLNL authors of the OSHA contact lens study, which provides the following additional insights into the studies' findings.
- a. If the person cannot comfortably wear contacts in everyday non-work situations, then he will probably not adapt well to using them with a full - facepiece respirator.
 - b. Considering the severe conditions under which fire fighters must work, we believe it is unlikely that the working conditions of any other SCBA users would preclude the similar use of contact lenses. This would also include negative pressure air-purifying respirators.
4. Paragraph 1503.h. in the draft revision of Draft OPNAVINST 5100.23H states, "*Wearing contact lenses in contaminated atmospheres with respiratory protection is permitted. Provide suitable eye and face protection for all workers exposed to eye injury hazards, regardless of contact lens wear.*"

D. Full Face Respirator Eye Protection - Full face air-purifying respirators have an assigned protection factor⁶ of 50 times the occupational exposure limits (OELs). For some operations, full face respirators may be required for eye and face protection even when contaminant concentrations are below 10 times the OELs.

1. Per paragraph 84.76 of 42 CFR 84 (reference 11), 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 1968 version of ANSI Z87.1, which tested safety glasses and industrial eye protection made from glass (most modern lenses are made from polycarbonate).
2. The 2003 version of ANSI Z87.1 (reference 20) was the first version of this standard to include full face respirator lens testing. Although OSHA⁷ has not

⁶ Assigned Protection Factor (APF). Per draft ANSI Z88.2, "*The minimum expected workplace level of respiratory protection that would be provided by a properly functioning and used respirator or a class of respirators to properly fitted and trained wearers when all elements of an effective respirator program are established and are being implemented.*"

⁷ OSHA will adopt ANSI Z87.1-2010 through the [Final Rule - Updating OSHA Standards Based on National Consensus Standards: Personal Protective Equipment](#), which incorporates the latest three versions of national consensus PPE standards into law when OSHA determines that new consensus standards provide equal or greater protection. However, OSHA must still undergo rule-making process to incorporate new consensus standards into OSHA PPE standards and use of a new consensus standard prior to this rule making is a *de minimis* violation, which OSHA will not enforce. Although ANSI Z87.1-2010 is not currently incorporated into 29 CFR 1910.133, *Eye and*

formally adopted this standard, and it is not yet required by NIOSH, respirator manufacturer voluntary compliance with ANSI Z87.1 requires tight-fitting full face respirators to meet the impact performance level, optical, and markings requirements of this standard.

- a. According to NIOSH, respirator certification standards will eventually require compliance with ANSI Z87.1, but it will take time for NIOSH to incorporate this important requirement into all their pertinent respirator certification standards. During the interim, purchasing ANSI Z87.1-2010 impact-compliant respirators will ensure use of respirators that have undergone and passed ANSI Z87.1-2010 testing and that they provide proper eye and face protection.
- b. Respirators must pass both the impact testing and optical testing to receive the Z87+ impact marking. According to respirator manufacturers, most respirator lenses meet the high impact requirements, but only a few meet both impact and optical requirements of ANSI Z87.1-2010. For example, the MSA Millennium, worn by Navy CBRN first responders, meets the impact requirements but not all of the optical requirements. According to MSA⁸, the trade-off for this slight optical deficiency is the flexible facepiece, which MSA designed for improved facial fitting characteristics - the flexible facepiece conforms to wearers' facial features for enhanced protection.
- c. If work processes require full face respirators and impact protection, check with the respirator manufacturer to ensure respirator lenses comply with ANSI Z87.1 impact testing requirements.

IV. COMMUNICATION PROBLEMS

A. Communication while wearing respirators is important for workplace efficiency and safety; however, effective speech while wearing respirators can be very challenging. According to reference 21, at hazardous waste sites the ability to "hear and be heard" and comfort issues were identified as the most negative aspects of respirator use.

1. According to reference 22, respirators inhibit oral communication. Even simple words were not able to be understood 27% of the time by workers talking in close proximity, as close as two feet while wearing M-17 military gas masks.
2. Per reference 23 verbal communication, in addition to hearing the words, is largely perceived by watching the face of the one talking, which is difficult with respirators covering the face. This is how hearing impaired people usually perceive speech - being able to see the speaker's lips aids in speech intelligibility. Experimenting with a loose-fitting powered air-purifying respirator (PAPR) with a full face lens, through which the wearer's face is visible, reference 23 modified the PAPR lens with a card to block the line of sight to the speakers' lips and concluded

Face Protection at the time of this writing, ANSI Z87.1-2010 meets and exceeds previous versions of the ANSI Z87.1 Standard.

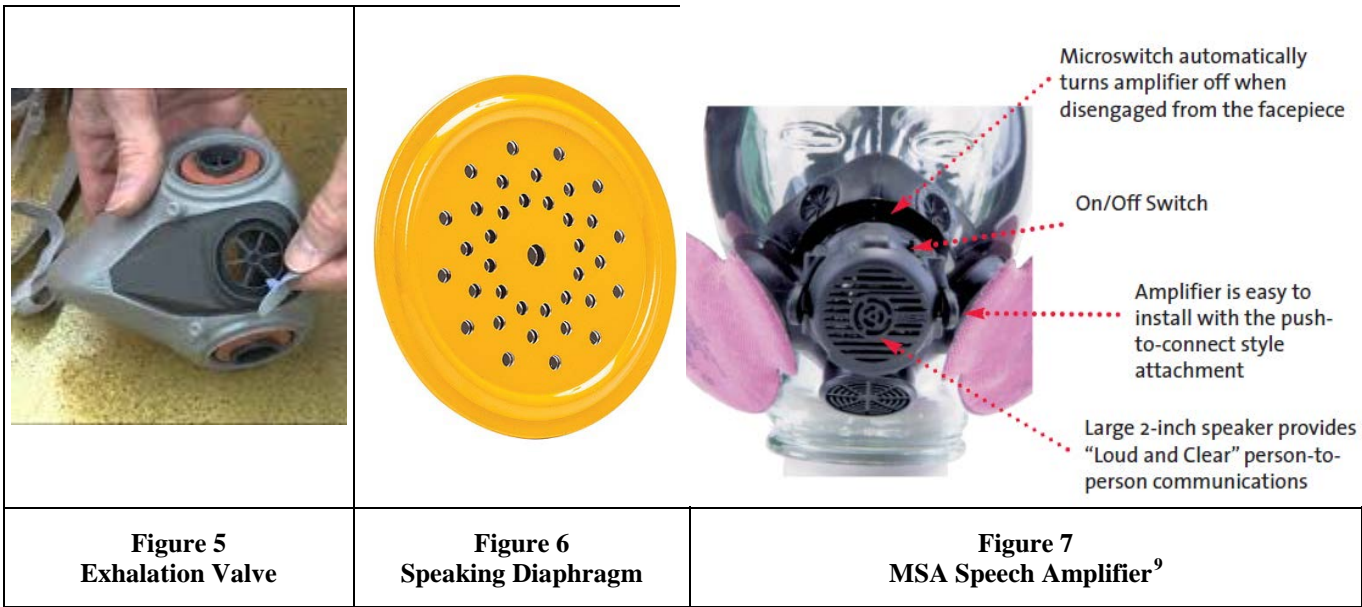
⁸ PHONCON MSA Steve Schmidt / NMCPHC David Spelce of 7 Mar 06.

that seeing the speaker's lips while a respirator is donned increases speech intelligibility.

3. Reference 24 research completely removed facial visual clues from speech by studying speech comprehension as transmitted through telephones while wearing M40 military gas masks. They found that speech using single words over a telephone only degraded by 10% but the time needed to communicate each word was increased by one-third to one-half. Reference 24 also reported that the U.S. Army M7 speech amplifier had no effect on the results.

B. Communication is not only required by OSHA in paragraph (g)(3) of reference 1 but is also critical to ensure workers' life and safety during first response, firefighting, and rescue operations in IDLH atmospheres. The basic types of communication while wearing respirators include exhalation valves, speaking diaphragms, electronic transmitters/ receivers, and cranial, throat, or ear microphones.

1. Exhalation valves (Figure 5) are components of all respirators and function in removal of exhaled breath from the respirator. Exhalation valves are located directly in front of the mouth, which aids in speech comprehension.



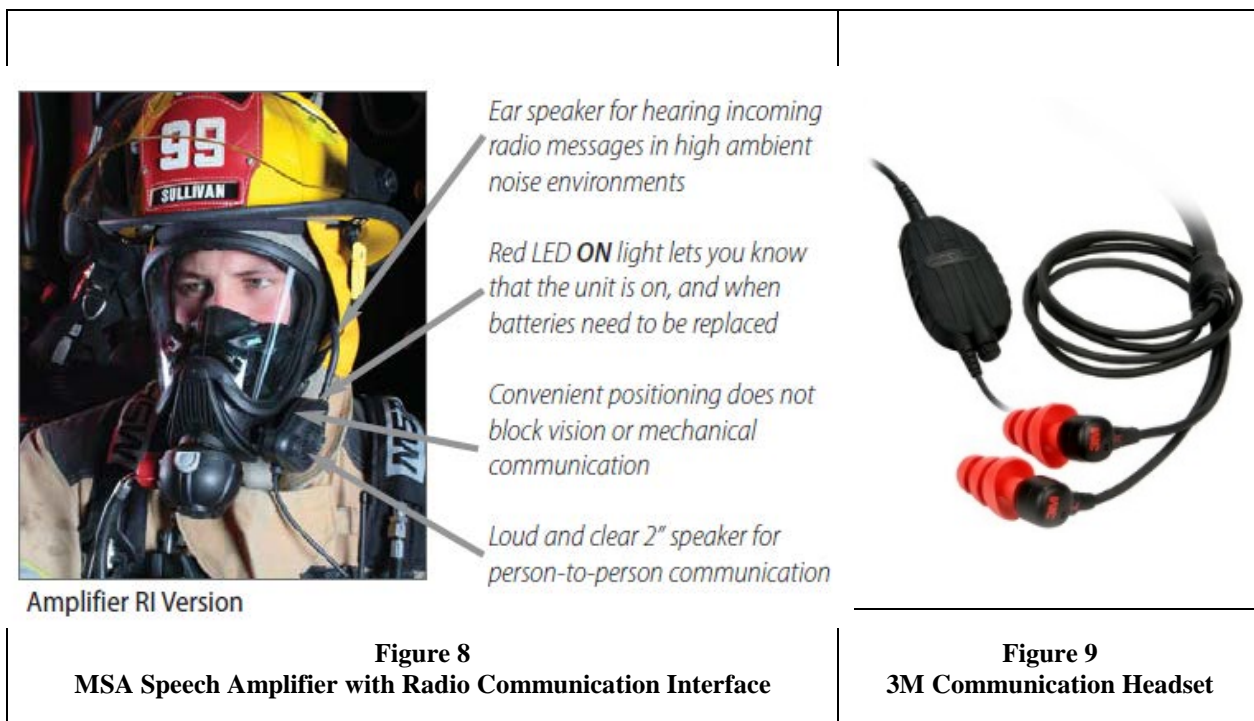
2. Speaking diaphragms (Figure 6) are usually an optional purchase when buying respirators. Speaking diaphragms operate mechanically and are made of a vibrating material that aids transmission of sound. Research results from reference 25 showed that reducing the size of speech diaphragms even to 30% of the original diaphragm size did not significantly degrade speech transmission.

3. Speech amplifiers must not interfere with the respirator seal, or block vision. Many manufacturers include amplifiers as an optional purchase for their full facepiece respirators. The microphone is mounted in a speaking diaphragm housing and the voice is amplified with a battery-powered amplifier. Figure 7 shows an

⁹ These MSA communication systems are intrinsically safe (UL Class I, II, III Division 1, Groups A, B, C, D, E, F and G per ANSI UL 913).

MSA speech amplifier, which is NIOSH approved with the many MSA full face respirators, including the MSA CBRN Millennium.

- a. In some speech transmission systems, such as the MSA model shown in Figure 8, the amplifier interfaces with radio communication via an ear-speaker for incoming radio messages and a push-to-talk assembly. For respirator attached assemblages, the microphone jack must come installed by the manufacturer. Any other installation voids NIOSH approval.



- b. One manufacturer produced an after purchase headset communication device with a microphone that was glued inside the facepiece lens. NIOSH approval was not given because the communication device was not tested by NIOSH as part of the complete respirator assemblage.
- c. Some communication systems are not connected to the respirator at all. Instead, ear microphones are worn in the same manner as a portable radio earphone and function as both a microphone and speaker. Use of these devices does not require making penetrations or attachments to the respirator, and does not impact the NIOSH certification status. They may be used with radios, telephones, loudspeakers, or other means of electronic transmittal, similar to facepiece microphones. All wires and microphones must be worn so that they do not interfere with the respirator sealing surface or the head straps. Some devices are attached to a hard hat or firefighter helmet and the speaker attaches to the lapel. Figure 9 is a 3M communication headset with lapel speaker. Check with the manufacturer to determine if the communication system is intrinsically safe.

V. TEMPERATURE EXTREMES

Wearing respirators causes physiological stress. Not surprisingly, wearing respirators in hot and cold environments adds to the stress of wearing respirators. Thermal stress should be taken into consideration when selecting respirators to be worn in extreme temperature environments. Special equipment is available for equipping both the respirator and the respirator wearer in thermally stressful environments.

A. Cold temperatures may cause detrimental effects on the performance of respirators and may add undue physiological stress as discussed in reference 12. For example, low-temperature environments may result in respirator lens fogging and valves freezing or improperly sealing.

1. Some full facepieces are available with lenses pre-treated during the manufacturing process to reduce fogging. The lenses can be replaced when no longer effective. Coating the inside surface of the lens may inhibit fogging at low atmospheric temperatures approaching 0°C (32°F).
2. Most modern lens coatings are composed of a polysiloxane film. According to reference 26, when exposed to moisture-saturated air, polysiloxane coated polycarbonate substrates, such as respirator facepiece lenses, treated with anti-fogging agents remained free from fogging as the condensed moisture formed a uniform film of water over the lens surface. The rate at which the coating agents remain effective at preventing further fogging is related to how quickly the coatings are removed from the lens by water film drainage off the lens.
3. Full facepieces are available with nose cups that direct the warm, moist exhaled air through the exhalation valve without contacting the lens. Facepieces with nose cups may provide satisfactory vision by controlling lens fogging at temperatures as low as -32°C (-25.6°F).
4. Section 84.98.(f) of reference 11 states that auxiliary low-temperature parts, which are commercially available to the user, may be used on the respirator to meet NIOSH cold temperature requirements.
 - a. The respirator approval may state that below a certain temperature, cold temperature accessories are required to maintain the NIOSH approval.
 - b. In these cases, special elastomeric gaskets and diaphragms designed to retain elasticity at low temperatures must be installed for operation below a certain temperature.
5. The effects of low temperatures must be considered in selecting and maintaining atmosphere-supplying respirators and sources of supplied breathing air. If the ambient temperature falls below the dew point of compressed breathing air, any moisture present can condense and form liquid water. If the ambient temperature is freezing, then regulator and control valves can freeze in atmosphere supplying respirators. The dew point of compressed breathing air must be 10° F lower than the coldest temperature where the respirator is worn.

B. The other thermal extreme is respirator use in high temperature environments. Reference 12 states that high temperatures may affect respirator performance. For

example, elastomeric components of respirators stored in high-temperature environments may deteriorate at an accelerated rate and the facepiece may become permanently distorted. Increased inspection frequency of respirators stored in high temperatures should be considered.

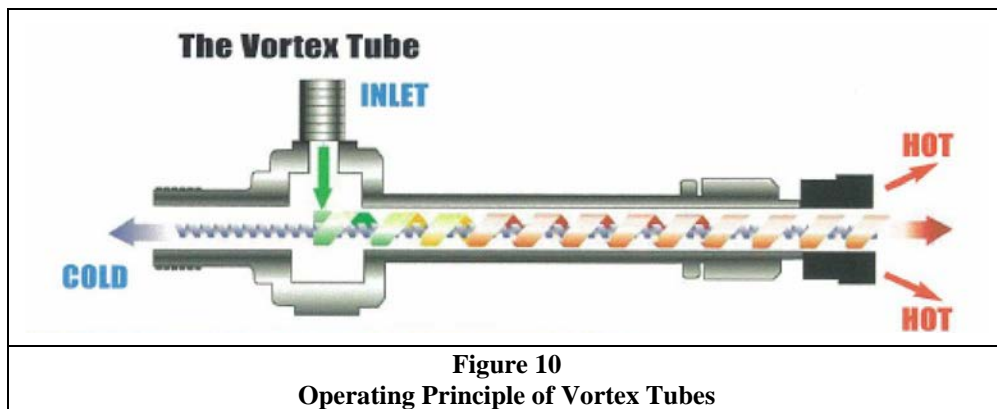
1. In addition to stress on the respirator, per reference 12, people working in high temperatures atmospheres are under additional stress. Wearing respirators in such environments creates added stress on workers. The additional stress should be minimized by using lightweight respirators offering low resistance to breathing and minimal dead-air space increase to the wearers' respiratory system. For example, half mask air-purifying respirators, where they offer adequate protection, are preferable to full face respirators.

a. Respirator lens fogging is also a high temperature problem. Where full face respirators must be worn, equipping them with nose cups will direct the warm, moist exhaled breath through the exhalation valve and away from the rest of the facepiece, which will greatly reduce fogging. Nose cups also decrease the dead-air space volume of full facepieces from 815 cc to about 260 cc.

b. As is used in cold temperatures, polysiloxane anti-fogging coatings applied to the respirator facepiece lens helps to prevent fogging in warm, humid environments.

2. PAPRs have a cooling effect on the respirator wearer in temperate environments; however, they can actually increase the heat load on the body when used in high temperature environments. According to the [OSHA Technical Manual on Heat Stress](#), "Air flowing past the body can cool the body if the air temperature is cool. On the other hand, air that exceeds 35°C (95°F) can increase the heat load on the body." This is the case when wearing a PAPR.

3. Vortex tubes may be used with supplied air systems to cool the respirator wearer. As shown in Figure 10, the vortex tube picture, from [Universal Vortex Products](#), illustrates the operating principle of vortex tubes. Figures 11 and 12 show MSA and North vortex tubes in use, respectively.

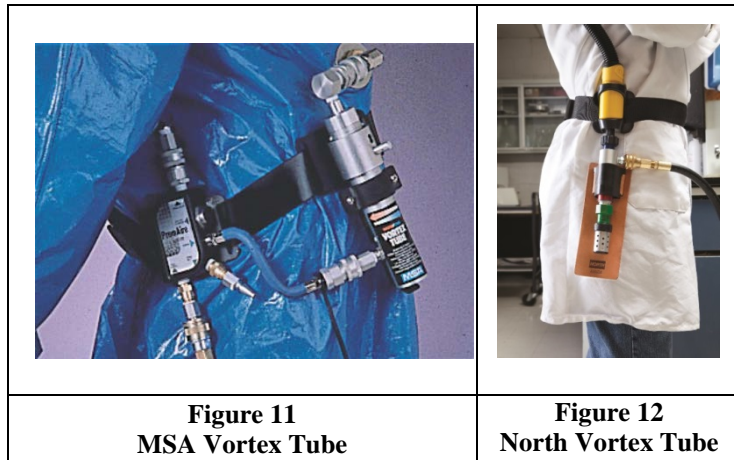


a. Compressed air enters vortex tubes air at very high speeds and is propelled into the vortex generation chamber. The air spins around the circumference of the chamber toward the hot air exhaust. The air can spin up to one million

revolutions per minute. Friction of the spinning air with the vortex tube surface causes air near the surface of the tube to become hot.

b. Some of the hot air leaves the chamber through the hot air exhaust. The hot air exhaust control valve imposes enough pressure on the spinning vortex of air to force some of the air into the center of the chamber, taking it back through the rapidly spinning air at the surface.

c. The air in the center becomes very cold. The cold air leaves the tube through the cold air exhaust and enters the respiratory inlet covering or suit and cools the worker. Either the hot or the cold airstream can be directed into the worker's respiratory inlet covering or suit.



d. There may be a valve attached to regulate the temperature of the air. With a 100 psi compressed air source, the temperature can be adjusted to cool the air as much as 100°F below the temperature of the air entering the air inlet. Issues with vortex tubes include the following:

i. Vortex tubes can only be used on the breathing airline hose if they are NIOSH approved with the airline respirator system as a component of the complete respirator assemblage.

ii. Vortex tubes use a lot of air (15 to 20 cfm) and require large capacity air compressors.

e. Vortex tubes can be used independently from supplied-air respirators. With these vortex tubes, the tube is not connected to the same air hose as the breathing airline hose and is used only to cool the body. Such vortex tubes do not have to be approved with the airline respirator system.

4. According to reference 27, older methods of cooling respirator wearers in hot environments included ice vests, which were heavy and the ice melted quickly. An improvement over ice vests were the phase change gel packs that could be frozen and placed into vests, which were worn by respirator wearers.

a. Reference 27 discussed workers wearing towels soaked in ice water but the water was usually too cold to be comfortable and people tended to put the towels on their head and neck. Intuitively this sounds like a good solution but since the

body's thermostat is the hypothalamus gland, which is in the center of the head, putting a cold towel on the head and neck shuts down the body's cooling system. It is analogous to blowing cold air onto the home thermostat, which shuts off the thermostat from cooling even though the heat in the house continues to rise. This same thing happens when a cold towel is placed on the head and neck - the hypothalamus gland shuts down the cooling mechanisms while the body core continues to heat up¹⁰.

b. Modern cooling apparel, such as the cooling vest shown in Figure 13 is used as a portable cooling station and is very effective in lowering the body core temperature. At the cooling station, workers sit and wear vests with sewn in tubing through which ice-chilled water (40°- 45°F) is circulated from a cooler through tubing in the vest and then back to the cooler.

c. Reference 27 stated that worker's mobility might be increased by wearing these vests connected to waist packs and backpack systems that use battery-powered pumps and bladders for ice and water storage. Waist packs last 45 minutes to an hour and backpack systems last one and a half to two hours before the ice needs recharging.



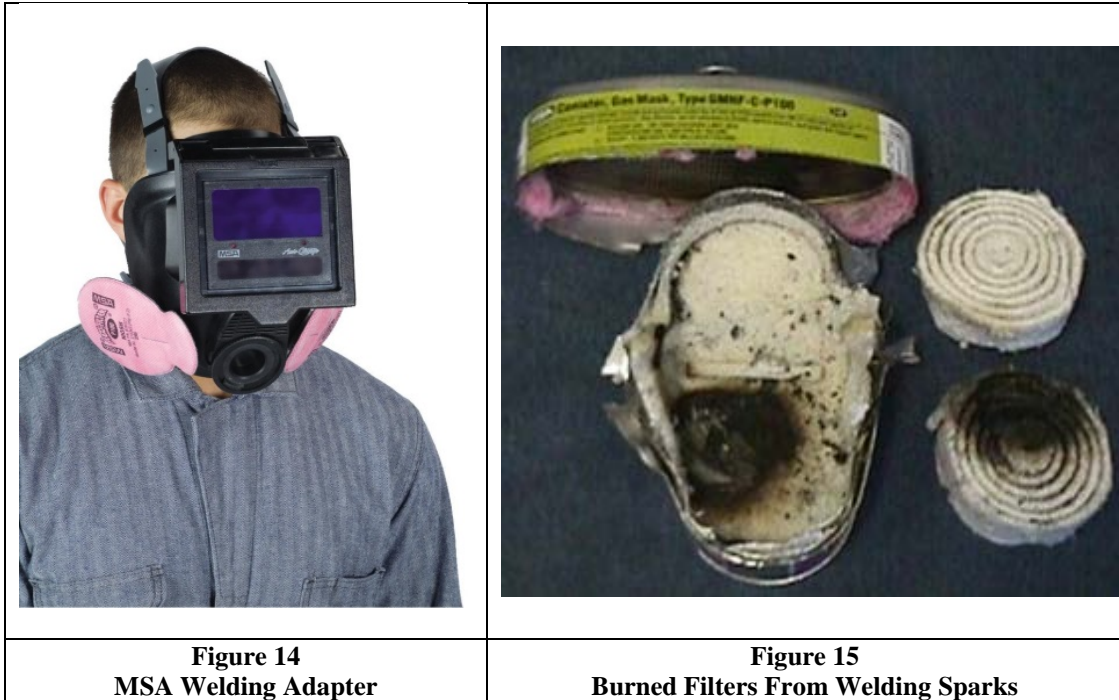
Figure 13
AQUA VEST

VI. WELDING OPERATIONS

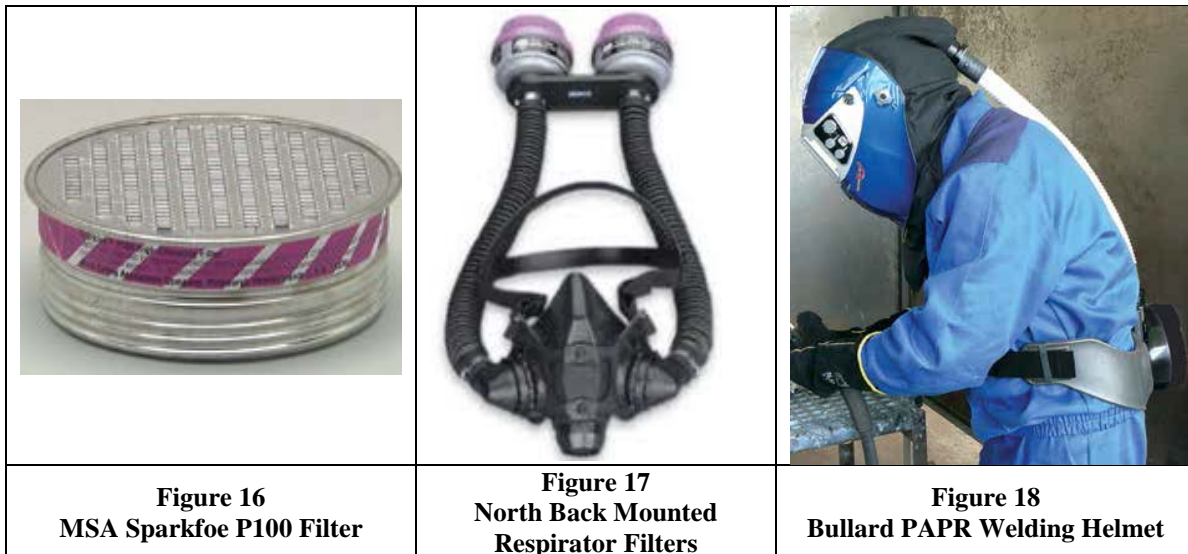
Welding operations cause special problems with respiratory protection, such as air-purifying respirators and cartridges not fitting under a standard welding helmet. Also, welding produces heat, molten welding splatter, and ultraviolet light from which workers must be protected. Welding operations require special respirators to protect workers while performing these operations. There are respirators specifically designed with a variety of respirator accessories to protect welders as discussed below.

A. There are welding adapters (Figure 14) that attach to the lenses of full facepiece respirators. Welding adapters are resistant to high impact, heat, and welding splatter. Different shades of filter plates can be purchased for filtering out ultraviolet light. The lens flips down for welding and up when not welding. A problem with welding adapters is that regular filters are open enough to the filter media to allow sparks to enter which may cause flames to flare up in the filter (Figure 15). Sparkfoe® filters, shown in Figure 16, are specially designed to protect the filters against sparks and molten splatter.

¹⁰ This discussion is concerning preventing heat stress injury by rapid cooling. However, when treating the most serious heat stress injury, which is heat stroke (which means central nervous system [CNS] injury due to heat). The most important target of immediate cooling efforts for a heat injured victim is the CNS. If cooling the CNS is delayed so the rest of the body can be cooled as well, then CNS injury is more likely. If the hypothalamus or any part of the CNS is cooled sufficiently to convince the brain it is not too hot, then preventing heat stroke has been accomplished. At that point, the kidneys, heart, and other organs can be cooled (probably in that order of priority). Also, cooling the head and neck will cool the rest of the body somewhat.



A. As shown in Figure 17, respirator manufacturers also design respirator filters to be worn on the back to prevent welding sparks from entering the filters. Welding helmets protect workers against molten metal splatter and ultraviolet light but not all welding helmets can accommodate respirator filters. Some respirator manufacturers make low profile filters to fit under welding helmets. Also, welding helmets can be altered to allow room for face-mounted filters to fit inside the helmet.



A. The Bullard welding PAPER in Figure 18 is designed with the welding helmet as the respiratory inlet covering. The filters are located on the belt behind the welder and the welding helmet automatically adjusts darkening of the lens in 1/25,000 second, thus eliminating the need to flip the protective lens up and down in between welding operations. Also, the welding helmet is easily converted to a grinding helmet.

VII. ABRASIVE BLASTING

Abrasive blasting operations shoot solid particles from a pressurized air hose and produce dangerous rebounding abrasive material.

Figure 19 is a picture of an abrasive blasting respirator. Type CE supplied-air (airline) respirators are approved by NIOSH for abrasive blasting and are equipped with additional protection for the wearer against impact of rebounding abrasive material.

Abrasive blasting airlines are equipped with hard protective exteriors and protective facepiece lens screens to protect the wearer against rebounding abrasive material. A protective shroud is an integral part of abrasive blasting respirators.



Figure 19
Helmeted Abrasive Blasting Airline Respirator

VIII. HOBBY SHOP PATRON RESPIRATORY PROTECTION

Many Navy respiratory protection program managers are faced with the problem of respiratory protection for auto hobby shop patrons. In reference 28, the *Judge Advocate General, Civil Affairs Office* explained Navy policy on this subject stating that:

- A. It is the activity commander's responsibility to ensure that patrons are properly trained, fit tested and provided with appropriate respiratory protection.
- B. Active duty personnel are assumed to be medically respirator qualified if they have been confirmed as "Fit for Full Duty" and have a current annual Periodic Health Assessment (PHA).
- C. Other patrons, such as dependents and retirees, must provide proof that they are medically qualified to wear respirators.
- D. It is the command's responsibility to implement not only the respirator program but also all requirements under reference 2 (OPNAVINST 5100.23series) to control exposure to hazardous substances while patrons work in the hobby shop.
- E. The Judge Advocate General letter concluded by stating that local commands can decide whether there is funding and manpower to support hobby shop patrons or to eliminate the hazard by not allowing patrons to perform hazardous operations.

IX. LAW ENFORCEMENT

Many law enforcement officers are issued CBRN gas masks for protection during first response to terrorist attack. Besides possible exposure to toxic industrial materials and chemicals, law enforcement officers may also be exposed to nerve gas, which is 26 times

more deadly than cyanide gas and officers may also be exposed to mustard agent, which blisters the skin, eyes and lungs. However, most law enforcement officers treat their CBRN gas masks as just another tool and throw it in their “go-bag” with their other equipment.

A. Per reference 29, in a random sampling, 70% of law enforcement officers failed to achieve the required protection factor while being tested during simulated workplace protection factor (SWPF) studies while they wore the CBRN gas masks they were issued. SWPF studies are similar to quantitative fit testing but measured in a laboratory environment simulating exercises comparable to activities that officers perform in the field.

B. Apparently, lack of concern about their respirators was the underlying cause for so many law enforcement officers failing to achieve the minimum protection factor required to wear their CBRN gas masks. The CBRN gas masks were stowed in the go-bags without being in their protective storage cases.

C. According to NIOSH, CBRN gas masks and tight-fitting CBRN PAPRs must be stored per the *Minimum Packaging Configurations* (MPC) established by NIOSH and the respirator manufacturer. MPC is the protective packaging in which the end user must store or maintain the CBRN respirator and its components after the CBRN respirator has been issued for use. Failure to store CBRN respirators in the respirator manufacturers’ recommended MPC may allow damage to occur that could affect the respirator or its components ability to provide the expected level of protection.

1. Examples of common minimum packaging configurations include hard plastic carriers, clamshell containers, canvas carry bags, drawstring plastic bags, and sealed canister bags.

2. Each respirator manufacturer is likely to have unique MPC requirements. The manufacturer’s user instructions and the NIOSH full approval label will identify the MPC.

D. Per reference 29, failure to maintain their CBRN gas masks according to the MPC resulted in warped facepieces that did not seal properly. Also, the facepieces became soiled, creating problems, such as debris (e.g., hair and fibers) lodging in the inhalation and exhalation valves. In addition, many of the CBRN canisters had expired shelf life dates.

E. According to reference 29, better respirator training would go a long way towards resolving this problem. Officers should be taught to treat their respirators as a life saving device – not just another tool. They should be taught to treat their respirator as they would their weapon, including keeping it as clean as they keep their weapon. Besides officers’ required annual respirator training, officers should take advantage of online respirator training programs provided by the respirator manufactures of the respirators that officers are issued, such as the training on the [MSA-U Training Center](#).

F. It is interesting that the 30% of law enforcement officers who passed the SWPF test all had Hazmat backgrounds, working with very toxic substances. Because of their previous Hazmat work, these officers were mindful of how critically important respirators are for protecting themselves against inhalation hazards. The respect they

gained for their respirators from previous Hazmat experience resulted in them properly taking care of their respirators.

1. To reiterate, the other 70% of law enforcement officers tested could not pass the simulated workplace study with the required protection factor because of their lack of concern for properly maintaining and storing their respirators.
2. Law enforcement is inherently dangerous enough by itself. Failure of law enforcement officers' to maintain their respirators should not add to the inherent risks associated with enforcing the law.

X. SPECIAL MEDICAL CONSIDERATIONS

Most aspects of respirator medical evaluation are covered in guidance of the [Medical Surveillance Procedures Manual/Medical Matrix](#) (reference 30). However, there are two noteworthy medical aspects that are not covered, which deserve consideration. These special medical issues include the olfactory consideration of anosmia and possible personal exposure through perforated eardrums.

A. Anosmia is the inability to perceive smells. Prior to promulgation of the revised OSHA Respirator Standard (reference 1) in 1998, standard practice for replacing respirator cartridges was to change cartridges when the respirator wearer detected chemical warning properties signaling breakthrough of workplace contaminant(s) into the facepiece. Chemical warning properties are detected by smell or irritation when cartridge sorbent material is saturated and continued inhalation through the respirator cartridges results in contaminants breaking through the cartridges and into the respirator facepiece.

1. Before the 1998 OSHA Respirator Standard, personnel with inability to perceive smells (anosmia) were not allowed to wear air-purifying gas/vapor removing respirators because they could not detect when chemical breakthrough occurred, at which point their respirator was no longer protecting them.
 - a. However, the revised, 1998 OSHA Respirator Standard states that warning properties are 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. This allows personnel with anosmia to wear air-purifying respirators as long as a cartridge change out schedule is developed and implemented or the respirator is equipped with a NIOSH approved end-of-service-life-indicator cartridge so that respirator cartridges are changed before chemical breakthrough occurs.
 - i. Individuals with anosmia must otherwise be medically qualified per paragraph 1508 of reference 2.
 - ii. This includes no existing conditions (e.g., claustrophobia or anxiety that would cause the worker to occasionally remove the respirator) or associated abnormalities (abnormal facial shape, lack of other senses, significant past exposure, etc.) that would limit respirator effectiveness or increase risk from minimal undetected exposure.

2. Another issue is fit testing respirator wearers who have anosmia. Most of the qualitative fit testing protocols require having to smell or taste the fit test challenge agent (e.g., smelling banana oil in the isoamyl acetate fit test protocol).
3. If health care providers identify individuals with anosmia on either Appendix 15-A of reference 2 or OPNAV Form 5100/35, respiratory protection program managers can avoid wasting time and effort on trying to fit test these individuals with qualitative fit test protocols that require fit test subjects to smell or taste the fit test challenge agent.
4. Alternatives to fit testing with odor dependent fit test protocols include:
 - a. Using any of the quantitative fit testing methods, in which respirator leakage is detected and measured by the fit testing equipment – and not by detection of the person being fit tested, or
 - b. Using the irritant smoke qualitative fit test, which relies on irritation to detect respirator leakage.

B. Perforated tympanic membranes (eardrums) are a controversial area in respirator medical evaluation worthy of special consideration. The main concern with perforated eardrums is that while wearing negative pressure air-purifying respirators, the negative pressure produced during inhalation could draw contaminated workplace air into the perforation and then down the estuation tube and into the lungs. Intuitively, it seems that the larger the perforation, the greater the quantity of contaminated air that could be inhaled, and, thus the greater the potential exposure. As discussed below, the “bottom line” for issuing medical clearance for workers with perforated eardrums should be determined on a case-by-case basis.

1. OSHA does not address this issue in the final, 1998 OSHA Respirator Standard (reference 1). However, the 1994 OSHA proposed ruling (reference 18), which did not result in a new OSHA Respirator Standard at that time, included the following discussion on this issue:

a. "With respect to the question of perforated tympanic membranes, Shell Oil (Ex. 36-50) submitted a report by Dr. Thomas Milby which reviewed the issue of potential employee exposure to hydrogen sulfide via the route of damaged tympanic membranes. The report stated that there was no valid information in the scientific literature supporting that perforated eardrums would produce an increased risk of contamination for workers. Calculations were performed for the Shell report which showed, in a worst case analysis, ambient air concentrations of H₂S [hydrogen sulfide] would have to reach some 158 ppm before the worst case loss of an ear drum would permit exposure at the PEL of 10 ppm. Shell also included a study by Richard Ronk and Mary Kay White of NIOSH (Ex. 38-11) which concluded that workers with perforated eardrums should not be excluded from working in hydrogen sulfide atmospheres. They stated that in no reasonable case can the presence of a tympanic membrane defect significantly affect respiratory protection. California OSHA (Ex. 36-44) cited the NIOSH study as showing that tympanic membrane perforation was not a problem. Other commenters also recommended that this provision be dropped

since it is not specifically a respirator related problem (Ex. 36-3, 36-18, 36-35, 36-47, 36-52).

b. "In light of the scientific review of tympanic membrane perforation submitted by Shell Oil, and the report by NIOSH which also reports no significant exposure from perforated eardrums, the recommendation for checking for perforated tympanic membranes has not been included in this proposal."

2. ANSI Z88.6-2006, the national consensus standard on respirator medical evaluations (reference 31) states, "*Workers with perforated tympanic membranes should not be routinely excluded [from wearing respirators].*" "*Routinely excluded*" is interpreted to mean that a perforation (or a pressure equalizer tube, which is essentially a controlled eardrum perforation) is not an automatic disqualifier for using a respirator.

3. Although inhalation exposure potential via perforated tympanic membranes is minimal, it is not entirely absent. Thus, a perforated tympanic membrane warrants increased scrutiny where exposure to especially harmful substances is anticipated, such as substances with toxicity at low doses or that are irritating to the middle ear or eustachian tube, or airborne biologicals with a low infectious dose. Patency¹¹ of the eustachian tube and the availability of airtight earplugs may be factors for consideration in such cases.

4. In all cases, when qualitative fit testing reveals that the worker can smell the odoriferous indicator, the worker should be disqualified from using a respirator (whether the leak is due to a perforated tympanic membrane or other reason).

5. Use of positive pressure respirators, such as PAPRs (which, on loss of battery power, tight-fitting PAPRs revert to negative pressure air-purifying respirator mode), may be considered, taking into account the severity of potential injury should the respirator malfunction.

6. In conclusion, this medical decision boils down to the judgment of the physician in the specific use situation. Positive pressure respirators, such as PAPRs, airline respirators, SCBA, and pressurized suits seem compatible with perforated eardrums. For negative pressure respirators, a tiny eardrum perforation and N95 filtering facepiece respirator worn for nuisance dusts protection may be reasonable, and may allow fit testing to proceed; not so for N95 use to prevent tuberculosis exposure.

XI. 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, as amended 8 June 2011.

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

¹¹ Patency is defined as the quality or state of being open or unobstructed.

2 OPNAVINST 5100.23*series*.

<http://doni.daps.dla.mil/Directives/05000%20General%20Management%20Security%20and%20Safety%20Services/05-100%20Safety%20and%20Occupational%20Health%20Services/5100.23G%20w%20CH-1.pdf>

3 OPNAVINST 5100.19*series*.

<http://doni.daps.dla.mil/allinstructions.aspx?RootFolder=/Directives/05000%20General%20Management%20Security%20and%20Safety%20Services/05-100%20Safety%20and%20Occupational%20Health%20Services&View={1FF912B1-1BC6-444A-8943-B769C77880F2}>

4 American National Standards Institute (ANSI)/American Industrial Hygiene Association (AIHA): American National Standard for Respirator Fit Testing Methods (ANSI/AIHA-Z88.10). Fairfax, VA: AIHA, 2010.

<http://www.ansi.org/>

5 Occupational Safety and Health Administration (OSHA): Inspection Procedures for the Respiratory Protection Standard. OSHA Directive CPL 2-0.120, 2014.

https://www.osha.gov/OshDoc/Directive_pdf/CPL_2-0_120.pdf

6 Hyatt, E. C., Pritchard, J. A., Richards, C. P., and Geoffrion, L. A: Effect of Facial Hair on Respirator Performance. Am. Ind. Hyg. Assoc. J. 34:4, 135-142 (1973).

7 Skretvedt, O.T. and Loschiavo, J.G.: Effect of Facial Hair on the Face Seal of Negative-Pressure Respirators. Am. Ind. Hyg. Assoc. J. 45:1, 63-66 (1984).

8 McGee, M.K. and OESTENSTAD, R. K.: The Effect of the Growth of Facial Hair on Protection Factors for One Model of Closed-Circuit, Pressure-Demand, Self-Contained Breathing Apparatus. Am. Ind. Hyg. Assoc. J. 44:7, 480-484 (1983).

9 Stobbe, T. J., DaRoza, R.A. and Watkins, M.A.: Facial Hair and Respirator Fit: A Review of the Literature. Am. Ind. Hyg. Assoc. J. 49:4, 199-204 (1988).

10 Balkhyour, M. A.: Evaluation of Full-Facepiece Respirator Fit on Fire Fighters in the Municipality of Jeddah, Saudi Arabia, Int J Environ Res Public Health, 10:1, 347–360 (2013).

<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3564146/>

11 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.gpo.gov/fdsys/pkg/CFR-2004-title42-vol1/pdf/CFR-2004-title42-vol1-part84.pdf>

12 American National Standards Institute (ANSI): American National Standard for Respiratory Protection (ANSI Z88.2). New York: ANSI, 1992.

<http://www.ansi.org/>

-
- 13 Spear, T.M., et. al.: The Effects of Strapped Spectacles on the Fit Factors of Three Manufactured Brands of Full Facepiece Negative Pressure Respirators. *Am. Occup. Hyg.*, Vol 43, No 3, pp 193 - 199: 1999.
- 14 Protection Factor Testing of the MCU-2series Chemical-Biological Protective Mask with MAG-1 Combat Spectacles. Naval Surface Warfare Center, Panama City FL. 14 Nov 2006.
- 15 Performance Specification Joint Service General Purpose Mask (JSGPM) of 30 Sep 03.
- 16 Reed, Karen. A, Moore, Tom. O., The Use of MAG-1 Spectacles with Positive-and Negative-Pressure Respirators. NUREG/CR-3953 LA-10229-MS. Feb 85.
- 17 Occupational Safety and Health Administration (OSHA): Letter of Interpretation to Mr. John Hale on Generic Respirator Spectacle Kits, of 7 April 1987.
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=INTERPRETATIONS&p_id=19539
- 18 Occupational Safety and Health Administration (OSHA): 29 CFR Parts 1910 and 1926 Respiratory Protection; Proposed Rule. Federal Register 59 FR 58921: 1218-0099. Washington, D.C.: U.S. Government Printing Office, Office of the Federal Register, November 15, 1994.
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FEDERAL_REGISTER&p_id=13426
- 19 da Roza, R.A. and Weaver. C.: Is It Safe to Wear Contact Lenses with a Full-Facepiece Respirator? *J. Int. Soc. Res. Prot.* (Fall 1990).
Note: This report was originally released as UCRL-53653, Lawrence Livermore National Laboratory, Livermore, CA 94550, August 16, 1985. This work was supported by the U.S. Department of Labor Occupational Safety and Health Administration, Directorate of Technical Support, under contract MOR-W9F 20017.
- 20 American National Standards Institute (ANSI) Z87.1-2010, American National Standard Practice for Occupational and Educational Eye and Face Protection.
<http://www.ansi.org/>
- 21 Salazar, M.K., Connon, C, Takaro, T.K., Beaudet, N. and Barnhart, S.: An Evaluation of Factors Affecting Hazardous Waste Workers' Use of Respiratory Protective Equipment, *Am. Ind. Hyg. Assoc. J.* 62:2, 236-245 (2001).
- 22 Coyne, K.M., Johnson, A.T., Yeni-Komshian, G.H. and Dooly, C.R.: Respirator performance ratings for speech intelligibility. *Am. Ind. Hyg. Assoc. J.* 59:257-260 (1998).
- 23 Kapoor, V.:Extending the Perception of Speech Intelligibility in Respiratory Protection. *J. Int. Soc. Res. Prot.* Vol. 31, No. 1 (2014).
- 24 Johnson, A.T., Scott, W.H., Lausted, C.G., Coyne, K.M., Sahota, M.S., Johnson, M.M., Yeni-Komshian, G. and Caretti, D.M.: Communication Using a Telephone While Wearing a Respirator, *Am. Ind. Hyg. Assoc. J.* 61:2, 264-267 (2000).
- 25 Caretti, D.M., Strickler, L.C.: Speech Intelligibility During Respirator Wear: Influences of Respirator Speech Diaphragm Size and Background Noise. *Am. Ind. Hyg. Assoc. J.* 64:846-850 (2010).

26 Willis, C.R.: Investigations into the Efficiency of Anti-Fogging Agents J. Int. Soc. Res. Prot. (Spring 1993).

27 Baker, B.: Keep your cool – and your productivity – Avoid heat stress and extend work time. Industrial Safety & Hygiene News June 2011.

28 Navy JAG (Civil Affairs) ltr 5103 Ser 121/5853 of 10 Nov 86 (NOTAL).

29 PHONCON MSA Steve Schmidt / NMCPHC David Spelce of 29 Sep 14.

30 NMCPHC Technical Manual OM 6260 , Occupational Medical Surveillance Procedures Manual and Medical Matrix edition 11, of July 2011.

<http://www.med.navy.mil/sites/nmcphc/occupational-and-environmental-medicine/oemd/Pages/medical-surveillance-certification.aspx>

31 American National Standards Institute (ANSI): American National Standard for Respiratory Protection-Respirator Use-Physical Qualifications for Personnel (ANSI Z88.6). New York: ANSI, 2006.

<http://www.ansi.org/>