Respirator Classification

1. Approved Respirators

The Occupational Safety and Health Administration (OSHA) respirator standard (reference 1) requires using National Institute for Occupational Safety and Health (NIOSH) approved respirators to protect workers against inhalation hazards. The NIOSH respirator certification procedures are detailed under 42 CFR 84 – Approval of Respiratory Protective Devices (reference 2). Previously, respirators were jointly approved by NIOSH and the Mine Safety and Health Administration (MSHA) under 30 CFR Part 11.

a. NIOSH is the sole respirator certification agency. MSHA certifies jointly with NIOSH if the respirator is being tested specifically for mine emergencies and mine rescue. Both NIOSH approved and NIOSH/MSHA approved respirators are approved for use. NIOSH identifies approved respirators in the NIOSH Certified Equipment List, reference (3). In the past, respirator certification was covered by 30 CFR 11, which was promulgated in 1972 per reference (4). Per reference (2), the new regulation, 42 CFR 84, became effective on July 10, 1995, and replaces 30 CFR 11 regulation under which NIOSH and MSHA jointly certified respirators before that date.

b. The Bureau of Mines (BM) was the first agency to test and certify respirators. A historical summary of respirator approval schedules is provided in Table 1, excluding combination respirators.

Table 1. Approval Schedules

Respirator Certification Regulatory Authority	Gasmask	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
42 CFR 84	TC-14G	TC-19C	TC-13F	TC-84A	TC-23C

2. Respirator Assigned Protection Factors

a. The thousands of respirators approved under NIOSH respirator certification schedules are classified by their modes of operation, types of respiratory inlet covering, and their capabilities & limitations into respirator classes, which are discussed later in this chapter.

b. Each class of respirator is identified as providing a specific level of protection, which is called the assigned protection factors (APF). APFs are determined by statistical analysis of workplace protection factor (WPF) studies and simulated workplace protection factor (SWPF) studies, which evaluate the amount of leakage into the respiratory inlet coverings (e.g., facepieces) at sealing surfaces, 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.

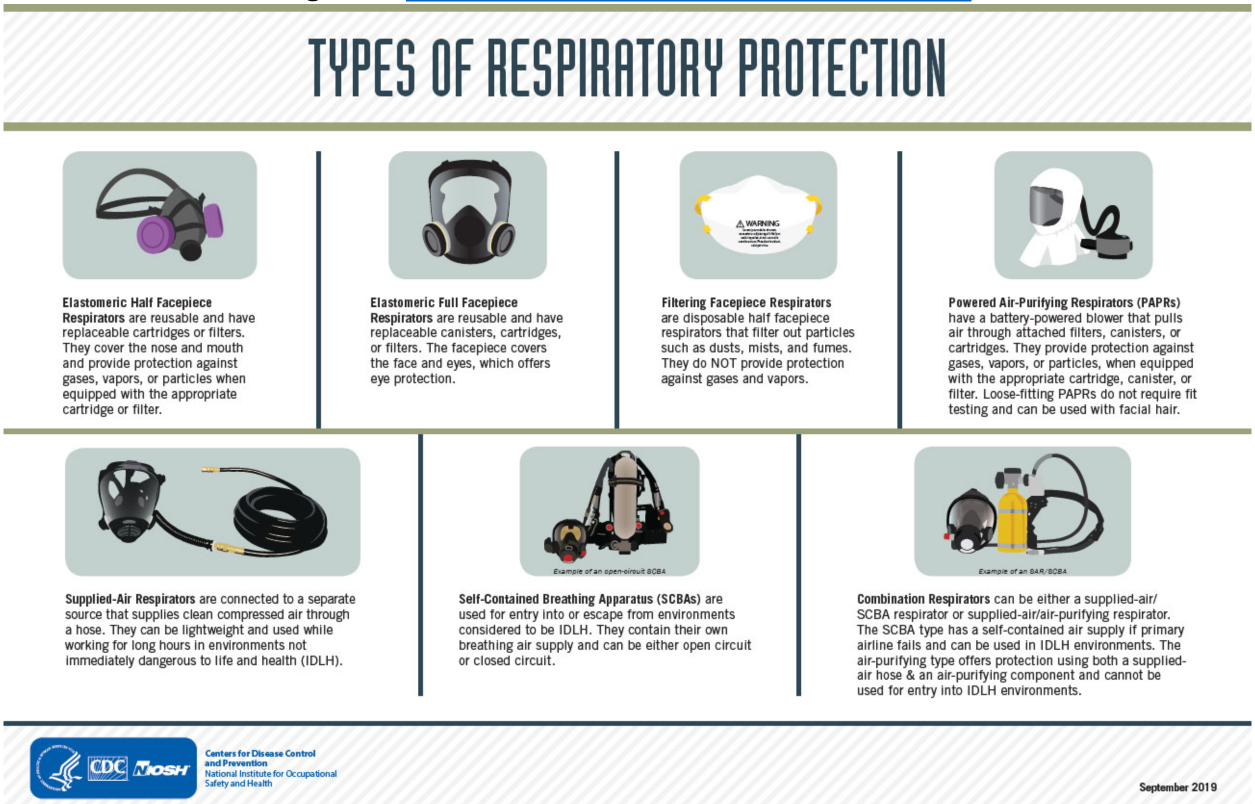
(1) WPFs measure the level of protection expected to be provided by respirators in the workplace by dividing the measured workplace contaminant concentration outside the respirator (C_{out}) by its concentration inside the respirator (C_{in}). SWPF studies are similar to WPF but are measured in a simulated laboratory environment instead of in the workplace.

(2) APFs represent the minimum ratio of C_{out} to C_{in} and only apply when respirators are used within the context of a comprehensive respirator program. OSHA defines APFs as “the workplace level of respiratory protection that a respirator or class of respirators is expected to provide to employees when the employer implements a continuing, effective respiratory protection program.” Appendix A contains the table of assigned protection factors.

3. Respirator Inlet Coverings

a. Respiratory inlet coverings are the respirator components connecting the wearer's respiratory tract to an air-purifying or an atmosphere-supplying respirator. Respiratory inlet coverings can be either tight fitting or loose fitting. Figure 1 is a visual representation of most types of respirators per NIOSH. OSHA also has a video showing the types of respirators, which can be found on the website listed in reference (5).

Figure 1- Types of Respiratory Protection per NIOSH



b. Types of respiratory inlet coverings include the following designs:
   (1) Tight fitting respiratory inlet coverings seal tightly to the face or tightly around the neck via neck dams and are referred to as facepieces and tight fitting or tight sealing hoods, respectively.
      (a) Facepieces are held in place with straps and have a sealing surface where the facepiece surface seals against the face to ensure that air entering the respirator passes only through the respirator filters or the breathing air hoses. Navy APFs for each type of respirator facepiece are detailed below, according to the information in references (6) and (7). This is also presented in Appendix A.
      (b) Filtering facepiece respirators are half masks in which the filter is an integral part of the facepiece or with the entire facepiece composed of the filtering medium (reference 1). Note, the Navy APF for this type of respirator is five (protects up to five times the occupational exposure limit [OEL]), which is more conservative than the OSHA APF of 10 for this respirator.
      (c) Elastomeric facepieces are usually made of rubber, silicone, or neoprene. Types of elastomeric facepieces include quarter masks, half masks, full facepieces and mouthpiece respirators. Half mask and full facepieces can be respiratory inlet coverings for both air-purifying and atmosphere-supplying respirators.

1. Quarter masks fit from between the lower lip and the chin to the bridge of the nose and have a very small sealing surface; therefore, they are prone to leakage and are easily dislodged. These respirators are not common. There are only negative pressure air-purifying quarter masks. The Navy APF for air-purifying quarter masks is five (protects up to five times the OEL.
2. Half mask elastomeric respirators fit from bridge of nose to under the chin and are the most common respirator found in the workplace today. Half masks respirators are designed to seal more reliably than quarter masks because they have a larger sealing surface. Navy APF for half mask negative pressure air-purifying respirators is 10 (protects up to ten times the OEL).
3. Full facepiece respiratory inlet coverings enclose the face from hairline to underneath the chin, have the greatest sealing surface, and are the hardest types of facepieces to dislodge; therefore, they provide the most reliable fit. Full face respirators provide eye protection. Navy APF for full face negative pressure air-purifying respirators is 50 (protects up to 50 times the OEL). See Appendix A for the APFs of other respirator classes with full facepiece respiratory inlet coverings. Gas masks are full facepiece air-purifying respirators that are approved with a canister worn on the facepiece, chest, or back.

(d) Tight fitting hoods are designed with tight sealing neck dams that seal tightly around the neck. Tight sealing hooded chemical/ biological/ radiological/nuclear (CBRN) powered air-purifying respirators (PAPRs), are examples of hooded respirators that seal tightly around the neck and have an APF of 1,000.

(2) Loose fitting hoods and helmets have no sealing surfaces and are respiratory inlet coverings for certain types of PAPRs and continuous-flow supplied-air respirators.

(a) Loose fitting hoods are respiratory inlet coverings that completely cover the head and neck and may cover portions of the shoulders.

(b) Helmets loosely cover about the same area as hoods, but are hard or rigid and may be approved for abrasive blasting operations if equipped with impact-resistant viewing lenses and protective exterior designed for deflecting rebounding particles. A protective shroud is an integral part of abrasive blasting respirators.

(3) Tight Fitting respirators cannot be worn by people with beards or facial features, such as deep scars because of interference with the respirator seal. Only continuous flow supplied-air respirators or PAPRs with loose fitting hoods, helmets, and facepieces can be worn by these individuals if the loose fitting hooded respirator APF is sufficiently high for the exposure (See Appendix A, Assigned Protection Factors).

4. Modes of Respirator Operation

Respirators operate either in negative or positive pressure mode. Each mode of operation is described in the following discussions.

a. Negative Pressure Respirators. Respirators in which the air pressure inside of the respirator is positive during exhalation, but negative during inhalation, with respect to the ambient air pressure. Examples of negative pressure respirators are non-powered air-purifying and demand atmosphere-supplying respirators. Any break in the seal of negative pressure respirators causes the surrounding atmosphere and contaminants to flow into the respiratory inlet covering and be inhaled by the wearer.

b. Positive Pressure Respirators. Respirators in which the air pressure inside the respirator is normally positive with respect to the ambient air pressure during inhalation and exhalation. Examples include pressure demand SCBA, continuous flow airline respirators, and powered air-purifying respirators (PAPRs).
   (1) A break in the face seal of positive pressure respirators produces an outward flow of air, forcing contaminants away from the face.
   (2) This means that a break in the seal would require delivery of an additional amount of air to the facepiece to compensate for the leak, which could make SCBA air cylinders run to of air sooner. This is a good reason to fit test positive pressure respirators.

5. Classes of Respirators

The two main categories of respirators are air-purifying respirators and atmosphere-supplying respirators. The following classes of respirators are listed below for quick reference. More information is provided later in the chapter.

a. Air-Purifying Respirators (APR). Respirators that purify ambient air by drawing it through an air-purifying element, which removes aerosols, vapors, gases, or a combination of these contaminants. Per reference (8), air-purifying respirators are grouped into three general types of air-purifying respirators. They are particulate removing, vapor and gas removing, and a combination of these two.

b. Atmosphere-Supplying Respirators. Respirators that provide air from a source independent of the surrounding atmosphere instead of removing contaminants from the atmosphere.

6. Air Purifying Respirators

Air-purifying respirators remove air contaminants by filtering out particles or removing gases and vapors, or by removing both gases/vapors and particulates. Air-purifying respirators are not allowed to be worn in oxygen deficient or immediately dangerous to life or health (IDLH) atmospheres. Per reference (1), IDLH is defined as an atmosphere that poses an immediate threat to life, would cause irreversible adverse health effects, or would impair an individual's ability to escape from a dangerous atmosphere. As mentioned above, the three types of air-purifying respirators are: (1) particulate filtering respirators; (2) gas and vapor removing respirators; and (3) combination gas and vapor removing/particulate filtering respirators

a. <u>Particulate Filtering Respirators</u>. Classes of negative pressure (non-powered) air-purifying particulate respirator filters are discussed in this section.
   (1) NIOSH will certify three classes of filters, N-, R-, and P-series, with three levels of filter efficiency, 95%, 99%, and 99.97%, in each class per reference (2).
   (2) N means Not resistant to oil; R for Resistant to oil; and P for oil Proof.
   (3) High efficiency particulate air (HEPA) filter is a filter that is at least 99.97% efficient in removing monodisperse particles of 0.3 micrometers in diameter and larger. The equivalent NIOSH 42 CFR part 84 particulate filters are the N100, R100, and P100 filters.
   (4) Per NIOSH, reference (9), there are limitations for non-powered air-purifying particulate filter respirators, some of which include the following:
      (a) N-Series Limitations: These filters can be limited by considering hygiene, damage, and breathing resistance. NIOSH does not have a recommended service time limit in most workplaces; however workplaces with high aerosol (solid or water-based) concentrations may require a time limitation. NIOSH recommends 8 hours of use (continuous or intermittent) in this situation, and "service time should only be extended beyond 8 hours of use (continuous or intermittent) by performing an evaluation in specific workplace settings that demonstrates (a) that extended use will not degrade the filter efficiency below the certified efficiency level, or (b) that the total mass loading of the filter is less than 200 mg (100 mg per filter for dual-filter respirators)."
      (b) R-Series Limitations: These filters can also be limited by considering hygiene, damage, and breathing resistance. NIOSH does not have a service life recommendation for these filters when oil aerosols are not present; however, workplaces with oil aerosols may require time limitation. Per NIOSH, "service time may be extended beyond 8 hours of use (continuous or intermittent) by demonstrating (a) that extended use will not degrade the filter efficiency below the certified efficiency level, or (b) that the total mass loading of the filter is less than 200 mg (100 mg per filter for dual-filter respirators)."
      (c) P-Series Limitations: Consideration of hygiene, damage, and breathing resistances are the limits for these types of filters.
   (5) Filters are very efficient at filtering very large particles by sedimentation, impaction, and interception and very small particles are captured by diffusion. See Figure 2 for a visual description.
      (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 and usually occurs when the velocity of airstreams is high, the particles are large (>1 micron), and heavy. 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 lighter in weight and size (0.5 – 1 micron) 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.

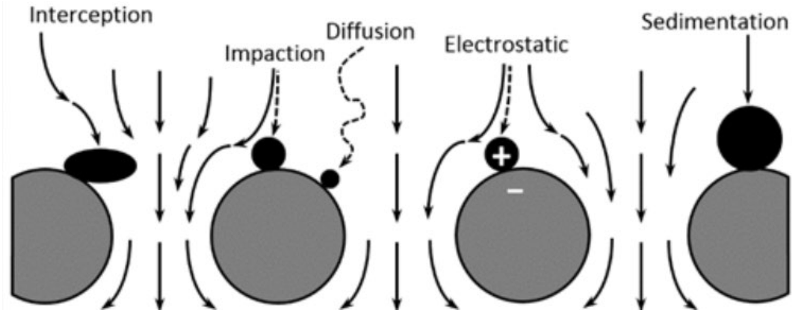
(c) Sedimentation. Only large particles (2 microns and above) are affected by sedimentation. Sedimentation works only at low air flow rates. As particles fall through the airstreams by the force of gravity, they are captured by the fiber.

(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 particles will contact another object). Slower velocity means particles remain near filter fibers for a longer time, which increases the probability that particles will contact the fibers 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.

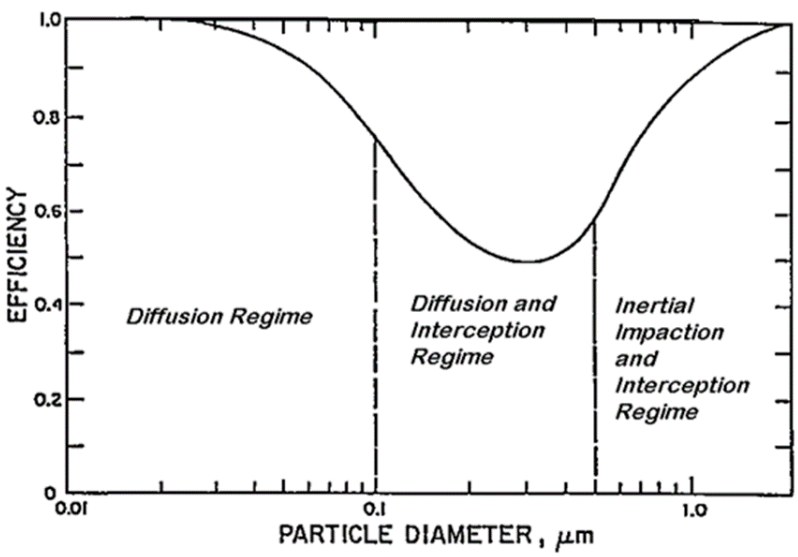
1. The original method consisted of impregnating a blend of wool and synthetic fibers with wood resin, which is then dried and energized by a mechanical needling process. This creates a positive charge on the fibers and a negative charge on the resin. Unfortunately, this mechanism is not effective for oil mist or atmospheres with high humidity, which dissipate the electrostatic charge.
2. 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.

Figure 2. Filter Collection Mechanisms



(6) Figure 3, illustrates filter efficiency of vs. particle diameter.
   (a) The most penetrating particle size (MPPS) for N95 filters is illustrated in figure 3 as the lowest point on the filter efficiency curve. 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 efficient on either side of the 0.3 micron dip in efficiency. See Figure 3.

Figure 3. N95 Respirator Filtration Efficiency



   (b) Field industrial hygienists often have to decide between selecting a 95% versus a 100% efficient filter especially when the particulate contaminant is in the most penetrating particle size range. Appendix B provides guidance on selecting the appropriate filter efficiency for 0.1 to 0.4 micron sized particles.

(7) Change schedules for particulate respirators. OSHA does not require establishing change schedules for particulate respirators. However, since N and R filters must be replaced before 200 mg loading is reached, change schedules can be calculated if we know the workplace concentration and the daily breathing volume. One study,

reference (10), determined that the average normal breathing rate was 16.7 L/min and the average deep breathing rate was 27.8 L/min.

(a) Let's assume a worker inhales 10 m^3 air per day, which equates to a 20 L/min 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 schedule for an operation in which the Upper Tolerance Limit (UTL95%, 95%), was 8 mg/m^3 for total dust. The UTL95%, 95% is the concentration below which we are 95 percent confident that 95 percent of exposures occur. Since no oil is present, a half mask respirator equipped with N95 filters was selected for protection.

(b) 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 schedules. If P filters are used, replace them according to respirator manufacture's recommendations.

(8) Welding Spark Resistant Filters. Sparks produced during welding can enter filters and set the filtering media on fire. Respirator manufacturers make specially designed filters that are shielded to prevent sparks from entering into the filter media. There are also plenum respirators with the filters worn on the back to avoid sparks. Ensure respirators with filters are flame resistant when used for welding or other hotwork operations.

b. <u>Gas and Vapor Removing Air-Purifying Respirators</u>. Gas and vapor removing air-purifying respirators, remove specific individual contaminants or a combination of contaminants by catalytic reaction or sorption.

(1) 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.

(a) 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.

(b) 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.

(2) 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.

(a) In adsorption, the contaminant adheres to the surface of the sorbent. The primary sorbent used is activated charcoal. 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.

1. 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.

2. 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.

(b) 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 vapor 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.

(3) 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 gas mask 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 determined by the lesser of either the calculated maximum use concentration (MUC) or a MUC established by respirator manufacturers. The MUC is calculated as follows: MUC = APF X OEL. The IDLH concentration always takes precedence over the calculated MUC.

(4) Reference (1) requires establishing a change schedule for chemical canisters and cartridges based on objective information that will ensure that they are changed before the end of their service life. For more information, see the toolbox chapter on Chemical Cartridge Change-Out Schedules.

c. Combination Particulate, Vapor, and Gas-Removing Respirators. In combination respirators the filter may be permanently attached as part of the cartridge/canister or may be a separate replaceable filter used with the sorbent containing component of the cartridge. Combination particulate/gas and vapor removing respirators combine the respirator characteristics of both particulate and gas/vapor removing air-purifying respirators and are approved under 42 CFR 84 (reference 2) under approval schedule TC-84A because the particulate filter is the cartridge component providing the least protection for the respirator wearer. Unlike respirators approval schedules in 30 CFR 11, there are no pesticide or spray painting cartridge respirators approved under 42 CFR 84. Instead, either an organic vapor cartridge with a prefilter or a combination organic vapor cartridge/ particulate filter is used.

d. Powered Air-Purifying Respirators (PAPR). 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 supply a minimum of 4 cubic feet per minute (CFM) [equal to 115 liter per minute] of air to the user. Loose fitting PAPRs supply a minimum of 6 CFM [equal to 170 liter per minute]. PAPRs with loose fitting hoods and helmets may be worn by individuals when conditions like facial hair prevent a good facepiece to face seal as long as these PAPRs provide the required level of protection. Replace PAPR high efficiency filters when the PAPR the airflow indicator shows that the minimum airflow cannot be maintained.

e. Multi-Functional Air-Purifying Respirators. These are respirators are a combination of a negative pressure air-purifying respirator and a PAPR. Basically, these are tight-sealing PAPRs that are also approved to operate in negative pressure mode in case the motor fails. The tight seal allows the wearer to draw air through the filters when the motor is not running by producing a negative pressure inside the respiratory inlet covering during inhalation. They are also used in law enforcement for clandestine operations, when the sound of the PAPR motor is undesirable during stealthy movement.

f. Color Coding. ANSI Z88.7-2010, reference (11), which replaced ANSI K13.1 1973, details the coding standard for air-purifying respirator canisters, cartridges, and filters, which is detailed in Table 2. 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.

(1) NIOSH is not required to use or accept ANSI Z88.7. The NIOSH color coding requirements for canister and cartridge labels are based on paragraphs 84.113 and 84.193 of 42 CFR 84, respectively, which are based on ANSI K13.1 1973. NIOSH further clarifies standard samples of colors specified for respirator labeling in reference (12).

(2) It is important to note that NIOSH states that ANSI Z88.7 “supersedes ANSI K13.1-1973: American National Standard for Identification of Air-Purifying Respirator Canisters and Cartridges, which is incorporated by reference into many national and international standards” per reference (12). Atmosphere-supplying respirators provide a respirable atmosphere to the respirator wearer that is independent of the ambient air. Atmosphere-supplying respirators include supplied-air respirators and self-contained breathing apparatus. The air must meet the Grade D requirements of reference (13). For more information on compressed breathing air, see the Respirator Toolbox chapter on Compressed Breathing Air.

Table 2. Respirator Filter Color Coding[A]

Contaminant(s)	Color Code[B]	Contaminant Examples [C]
Acid gases	White	chlorine (Cl), chlorine dioxide (ClO_2), hydrogen sulfide (H_2S), hydrogen chloride (HCl), sulfur dioxide (SO_2), hydrogen fluoride (HF)
Organic vapors	Brown	most organic vapors [e.g., xylene ($C_6H_4(CH_3)_2$), toluene ($C_6H_5(CH_3)$)]
Basic gases	Green	ammonia (NH_3), methylamine (CH_3NH_2)
Formaldehyde	Tan	formaldehyde (HCHO)
Carbon monoxide	Blue	carbon monoxide (CO)
Mercury Vapors	Orange	mercury (Hg)
Other vapors and gases or combinations not listed above		nitrogen oxides (NOx), hydrogen cyanide (HCN), methyl bromide (CH_3Br), ethylene oxide ($(CH_2)_2O$), arsine (AsH_3)
All aerosols (High Efficiency filter)	Purple	dusts, mists, fumes, droplets, bacteria, viruses, radionuclides
CBRN	Black	See note D.

[A] Adapted from ANSI Z88.7-2010
[B] Multiple contaminant filtering elements, except for CBRN, have all applicable colors.
[C] Not all cartridges or canisters are suitable for all contaminants within the contaminant class. See the filter labels for specific contaminant designations for which the filtering element is suitable.
[D] CBRN canisters are suitable for many of the contaminants within all of the classes listed.

g. Supplied-Air Respirators. OSHA defines supplied air respirators, also called airline respirators, as “an atmosphere supplying respirator for which the source of breathing air is not designed to be carried by the user.” Airline respirators must not be worn in IDLH environments. Because air supply from the hose can be interrupted (e.g., severed, pinched, or disconnected hose), airline respirators are limited to operations in which the wearer can safely escape without the respirator. Also, airline hoses restrict the wearers’ movement. Airline respirators are used in place of chemical cartridge, air-purifying respirators when a cartridge change schedule has not been established and implemented or there are no appropriate end-of-service-life indicator respirators. Supplied-air respirators are classified into the following subgroups per 42 CFR 84.130, reference (2): Type A and AE, Type B and BE, Type C and CE.

(1) Type A and AE, Type B and BE supplied-air respirators are obsolete and no approved respirators are found when searching reference (3). The definition of these respirator types can be found in reference (2).

(2) Reference (2) defines a Type C supplied air respirator as "an airline respirator, for entry into and escape from atmospheres not immediately dangerous to life or health, which consists of a source of respirable breathing air, a hose, a detachable coupling, a control valve, orifice, a demand valve or pressure demand valve, an arrangement for attaching the hose to the wearer, and a facepiece, hood, or helmet." Type CE has abrasive blasting approval and is equipped with additional protection for the wearer against impact of rebounding abrasive material. Reference (2) defines a Type CE respirator as "a type "C" supplied-air respirator equipped with additional devices designed to protect the wearer's head and neck against impact and abrasion from rebounding abrasive material, and with shielding material such as plastic, glass, woven wire, sheet metal, or other suitable material to protect the window(s) of facepieces, hoods, and helmets which do not unduly interfere with the wearer's vision and permit easy access to the external surface of such window(s) for cleaning."

(3) Type C airline 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 air supply hoses and quick disconnect fittings are parts of the approved respirator assembly and substituting other hoses voids the NIOSH approval. The operating pressure and hose lengths are specified by the respirator 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. Per reference (14), the minimum and maximum airflow into the facepiece for tight-fitting facepieces is 4 CFM and 15 CFM, respectively. The minimum and maximum airflow for hoods, helmets, and loose fitting face pieces is 6 CFM and 15 CFM, respectively.

(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 airline respirators are no longer manufactured but are still available. Along with hose masks and hose masks with blowers, demand airline respirators should not be worn because of the low level of protection provided to the wearer.

(c) The pressure demand Type C regulator maintains positive pressure inside the facepiece at all times.

h. Self-Contained Breathing Apparatus (SCBA). OSHA defines a SCBA as "an atmosphere-supplying respirator for which the breathing air source is designed to be carried by the user." SCBAs provide the wearer with a large independent supply of breathable air that is carried by the wearer. Full-face pressure-demand SCBAs are approved for IDLH atmospheres. SCBA are classified as closed-circuit or open-circuit.

(1) Closed-circuit SCBAs are referred to as rebreather devices because they recirculate the user's exhaled breath within the respirator after CO_2 is removed and O_2 is replaced. There are two types of closed-circuit SCBAs, one of which uses a cylinder of compressed oxygen and the other uses a solid oxygen generating substance per reference (15).

(a) NIOSH, reference (15), states that in the first type of closed-circuit SCBA where there is a cylinder of compressed oxygen, "Breathable air is supplied from an inflatable bag. The exhaled air passes through a granular solid adsorbent that removes the carbon dioxide, thereby reducing the flow back into the breathing bag. The bag collapses so that a pressure plate bears against the admission valve, which opens and admits more pure oxygen that reinflates the bag. Thus, the consumed oxygen is replaced."

(b) The closed-circuit SCBA that contains a solid oxygen generating substance typically contains potassium superoxide (KO_2). Per NIOSH, reference (16), oxygen is released when water and carbon dioxide from exhaled breath reacts with the KO_2, however the oxygen is not released until the exhaled breath reaches the canister. This causes a short lag time for oxygen generation to begin. To better understand how a closed-circuit SCBA works, see figures 2-41 through 2-43 of reference (15). Closed-circuit SCBAs can be negative pressure or positive pressure respirators.

(2) Open-circuit SCBAs exhaust the exhaled air to the atmosphere. Per reference (15), a cylinder of high pressure compressed air supplies air to a regulator that reduces the pressure prior to delivery to the facepiece.

(a) The service life of an open-circuit SCBA is much lower than a closed-circuit SCBA because there is to recirculation of exhausted air.

(b) Open-circuit SCBAs are available in demand or pressure demand modes. Per reference (15) a demand-mode open-circuit SCBA is no more protective than an air purifying respirator and should not be used in IDLH atmospheres. Reference (15) provides images of open-circuit SCBAs in figures 2-44 through 2-45b.

(c) For more information on SCBAs, see references (1), (15), and (16).

(3) Escape-only SCBAs 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 have half mask, full face, hooded, or mouthpiece respiratory inlet coverings. Reference (7) prohibits the use of demand style SCBAs, except for the two instances below, because negative pressure inside the facepiece causes any face seal leakage to enter into the demand respirator. The first exception is the Onenco Incorporated M-20.2

Emergency Escape Breathing Device (EEBD), which is a self-contained, demand style closed-circuit breathing apparatus that is NIOSH approved and provides ten minutes of oxygen delivery per reference (17). This device is used shipboard. The other exception is the Emergency Air Breathing (EAB) system on submarines, which is a military unique system and the primary respiratory protection required on submarines at sea per reference (7).

i. <u>Combination Type Atmosphere-Supplying Respirators</u>.

(1) NIOSH/MSHA certify a Type-C supplied-air and air purifying respirator. This respirator is certified under the air-purifying respirator because it is the least protective. The supplied air component may be a type C continuous-flow or pressure demand. Per NIOSH, reference (15), "an advantage of this type of respirator is that the wearer has respiratory protection while entering (in some cases) and leaving without being connected to an airline. The disadvantage is that they have the limitations of the air-purifying element, and therefore, can be used only for specific conditions." The air purifying element of the respirator assembly may have restrictions per reference (15), such as only being used to enter an area prior to connecting to an air supply, to egress after disconnecting from and air supply or when there is a loss of air supply, to move from one air supply to another, or to escape only after loss of air.

(2) Combination Supplied Air/SCBA Respirators are Type C or CE supplied-air respirators used in combination with an SCBA cylinder as an auxiliary air supply. This combination is typically used for entry into Immediately Dangerous to Life and Health (IDLH) atmospheres because the auxiliary air supply has a short service time. Pressure demand, multi-functional Type C/SCBAs are approved for entry into IDLH atmospheres. Continuous flow supplied-air respirators are not compatible for use with an auxiliary SCBA. If 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. Per reference (15) the auxiliary supply is certified for three, five, or ten minute service times, or for 15 minutes or longer. If the auxiliary air supply is rated three, five, or ten minutes, then the airline mode of operation shall 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. To escape from an IDLH atmosphere if the airline function fails, the respirator wearer must switch to the self-contained air supply, disconnect the air supply hose, and leave the area.

NOTE: Per OSHA, reference (1), specific respirators are permitted for use in IDLH atmospheres. These include a full facepiece pressure demand SCBA certified by NIOSH for a minimum service life of thirty minutes or a combination full facepiece pressure demand supplied-air respirator with auxiliary self-contained air supply.

(3) Combination Supplied-Air/Air-Purifying Respirators are approved as air-purifying cartridge respirators per reference (15). 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 Type continuous flow or pressure-demand. Depending on the respirator, the air-purifying component can be approved for:
(a) Escape-only following loss of air supply;
(b) Entry and exit to and from air supply, including movement between air supplies;
(c) No restrictions.

7. Nullification of Respirator Approval

a. Per reference (2), NIOSH respirator approval means "a certificate or formal document issued by the Institute stating that an individual respirator or combination of respirators has met the minimum requirements of this part, and that the applicant is authorized to use and attach an approval label to any respirator, respirator container, or instruction card for any respirator manufactured or assembled in conformance with the plans and specifications upon which the approval was based, as evidence of such approval."

b. 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 reference (2) and after the manufacturer's quality assurance and control plan is determined to be satisfactory. To determine whether a respirator has been approved by NIOSH, visit The National Personal Protective Technology Laboratory (NPPTL) Certified Equipment List, reference (3). A respirator's approval is nullified when:
(1) Unapproved components are used (e.g., components between different types or makes of respirators are mixed, such as brand X cartridges on brand Y respirators or brand X supplied-air hose on brand Y airline respirator).
(2) Non-NIOSH authorized additions or changes to the respirator void the approval. Further clarification on this important issue is found in the NIOSH Respirator User Notice of May 4, 2007, reference 18, 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. An example is airborne concentrations exceeding either the calculated maximum use concentration (MUC) or the MUC established by the manufacturer.
(4) A 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.

8. References

1. 29 CFR 1910.134, OSHA Respiratory Protection Standard
2. 42 CFR 84 – Approval of Respiratory Protective Devices
3. National Institute of Occupational Safety and Health Certified Equipment List
4. NIOSH Guide to the Selection and Use of Particulate Respirators. DHHS (NIOSH) Publication Number 96-101 of January 1996.
5. Occupational Safety and Health Administration. OSHA Training Video Respirator Types.
6. OPNAVINST 5100.23 Series, Navy Safety and Occupational Health Program Manual
7. OPNAVINST 5100.19 Series, Navy Safety and Occupational Health (SOH) Program Manual for Forces Afloat
8. OSHA Technical Manual, OSHA Instruction TED 01-00-015 [TED 1-0.15A], Section VIII: Chapter 2, Respiratory Protection.
9. National Institute of Occupational Safety and Health Certified Equipment List. General Cautions and Limitations for 84A – Non-powered Air-Purifying Particulate Filter Respirators. Available at https://wwwn.cdc.gov/NIOSH-CEL/Limitations/A84
10. Sergey A. Grinshpun , Hiroki Haruta , Robert M. Eninger , Tiina Reponen , Roy T. McKay & Shu-An Lee (2009) Performance of an N95 Filtering Facepiece Particulate Respirator and a Surgical Mask During Human Breathing: Two Pathways for Particle Penetration, Journal of Occupational and Environmental Hygiene, 6:10, 593-603, DOI: 10.1080/15459620903120086
11. ANSI/AIHA/ASSP Z88.7-2010. Color Coding of Air-Purifying Respirator Canisters, Cartridges, Filters.
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13. CGA G-7.1-2018, Commodity Specification for Air. Seventh Edition.
14. National Institute for Occupational Safety and Health. National Personal Protective Technology Laboratory. Determination of Airflow – Continuous-Flow, Type C and CE, Supplied-Air Respirators Standard Testing Procedure (STP) of 26 Sep 05
15. National Institute of Occupational Safety and Health. A NIOSH Technical Guide… NIOSH Guide to Industrial Respiratory Protection of 1 Sep 87. Available at

http://niosh.dnacih.com/nioshdbs/respprot/www.osha-slc.gov/SLTC/respiratory_advisor/oshafiles/resp_toc.html

16. National Institute of Occupational Safety and Health Certified Equipment List. General Cautions and Limitations for 13F- Self-Contained Breathing Apparatus. Available at https://wwwn.cdc.gov/NIOSH-CEL/Limitations/F13.
17. Onenco Incorporated. Product information for M-20.2 EEBD available at https://www.ocenco.com/products/m-202/. Retrieved 16 Jul 20.
18. Department of Health & Human Services, Public Health Service. Respirator Users Notice Subject: Use of Replacement and Spare Parts. 4 May 07. Available at https://www.cdc.gov/niosh/npptl/usernotices/pdfs/UsersNotice05042007-508.pdf

Appendix A – Assigned Protection Factors[D]

Type of Respirator [A, B]	Quarter Mask	Half Mask	Full Facepiece	Helmet/Hood	Loose-Fitting Facepiece
Air-Purifying Respirator	5	10	10/50[G]	———	———
Filtering Facepiece Respirators	———	5	———	———	———
Powered Air-Purifying Respirator (PAPR)	———	50	1,000	25/1,000 [C]	25
Supplied-Air Respirator (SAR) [Airline Respirator] [E]					
Demand mode	———	10	10/50[G]	———	———
Continuous flow mode	———	50	1,000	25/1,000 [C]	25
Pressure-demand or other positive-pressure mode (i.e., Continuous flow SAR meeting NIOSH pressure demand requirements are approved as pressure demand SAR.)	———	50	1,000 [F]	———	———
Self-Contained Breathing Apparatus (Open & Closed Circuit SCBA)					
Demand	———	10	10/50[G]	50	———
Pressure-demand	———	———	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 according to the Respirator Chapter of OPNAVINST 5100.23 Series.
[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. OSHA accepts respirator manufacturers' empirical test data demonstrating that hooded respirators provide an APF of 1,000. In the absence of such testing, these respirators are to be treated as loose-fitting facepiece respirators, and receive an APF of 25.

[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 reference 9-1 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.
[G] APF is 10 when qualitatively fit tested and 50 when quantitatively fit tested.

Appendix B – Selection Between 95% Versus 100% Particulate Filter

1. Guidance for Selection

This guidance is for 0.1 to 0.4 micron sized particles, which historically are the most filter penetrating sized particles in typical workplaces per reference (1). This guidance requires introducing the concepts of respirator protection factor (PF) and assigned protection factors (APFs).

a. The protection factor is an expression of respirator performance based on the ratio of two measured variables, the challenge agent concentration outside the respirator ($C_{(out)}$) to the challenge agent inside the respirator facepiece ($C_{(in)}$).

$$PF = \frac{C_{out}}{C_{in}}$$

b. APFs are defined as the workplace levels of respiratory protection provided by properly functioning and properly worn respirators or class of respirators when all elements of an effective respiratory protection program are established and are being enforced. APFs indicate the protection level of a respirator or a class of respirators. For example, the APF of 10 for half mask respirators correlates to the workplace contaminant concentration being ten times lower inside the respirator than outside – protects up to 10 times the occupational exposure limit.

c. The PF equals 100 divided by % respirator leakage.

$$PF \ = \frac{100}{\%\ leakage} \%\ leakage$$

Half mask and full face, negative pressure air-purifying respirators have an assigned protection factor (APF) of 10 and 50, respectively. As shown below, 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 the filter efficiency needed, filter efficiency must also be considered as shown below.

(1) First calculate the hazard ratio (HR) to determine what APF is required and therefore what class of respirator is needed.

$$HR = \frac{Exposure}{OEL}$$

(2) Next rearrange PF equation and calculate leakage for the class of respirator.

$$\%\ leakage = \frac{100}{APF}$$

$$\%\ leakage_{(half\ mask)} = \frac{100}{10} = 10\%$$

$$\%\ leakage_{(full\ face)} = \frac{100}{50} = 2\%$$

(3) Then calculate total leakage by adding filter leakage and respirator class leakage. For example, 95% filters have 5% leakage, so:

$$\%\ leakage_{(Total)} = \ \%\ leakage_{(Respirator\ Class)} + 5\%_{(Filter\ Leakage)}$$

(4) Finally, calculate protection factor using the total % leakage

$$PF = \frac{100}{\%\ leakage_{(Total)}}$$

(a) If $PF > HR$ then a 95% filter is sufficient;
(b) If $PF < HR$ then a 100% filter is required.

Examples for Selection of 95% Versus 100% Filter

100% Filter is Required	95% Filter is Sufficient
Exposure = 250 ppm; OEL = 15 ppm $$HR = \frac{250\ ppm}{15\ ppm} = 16.7$$ Must use full face: APF = 50; Leakage = 2% $$\%\ leakage = \frac{100}{APF}$$ $$\%\ leakage = \frac{100}{50} = 2\%$$ Total leakage % $$\%\ leakage_{(Total)} = \%\ leakage_{(Respirator\ Class)} + 5\%_{(Filter\ Leakage)}$$ $$\%\ leakage_{(Total)} = 2\% + 5\% = 7\%$$ Recalculate PF $$PF = \frac{100}{\%\ leakage_{(Total)}}$$ $$PF = \frac{100}{7\%} = 14.3$$ Since PF (14.3) < HR (16.7) use a 100% filter.	Exposure = 50 ppm; OEL = 20 ppm $$HR = \frac{50\ ppm}{20\ ppm} = 2.5$$ Can use half mask: APF = 10; Leakage = 10% $$\%\ leakage = \frac{100}{APF}$$ $$\%\ leakage = \frac{100}{10} = 10\%$$ Total leakage % $$\%\ leakage_{(Total)} = \%\ leakage_{(Respirator\ Class)} + 5\%_{(Filter\ Leakage)}$$ $$\%\ leakage_{(Total)} = 10\% + 5\% = 15\%$$ Recalculate PF $$PF = \frac{100}{\%\ leakage_{(Total)}}$$ $$PF = \frac{100}{15\%} = 6.7$$ Since PF (6.7) > HR (2.5) use a 95% filter.

2. References

1. Spelce D, Rehak TR, Metzler RW, Johnson JS. History of U.S. Respirator Approval (Continued) Particulate Respirators. *J Int Soc Respir Prot*. 2019;36(2):37-55.