A NIOSH Technical Guide . . .

NIOSH GUIDE TO INDUSTRIAL RESPIRATORY PROTECTION

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
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CHAPTER 1

NIOSH AND RESPIRATORY PROTECTION

This report is intended to provide respirator users with a single source of respirator information. It covers the selection, use, and maintenance of respiratory protective devices available in 1987, and therefore serves as an update to the 1976 ***Guide to Industrial Respiratory Protection.***

When the National Institute for Occupational Safety and Health (NIOSH) was established in 1971, the professional staff recognized the crucial need for establishing the correct role of respiratory protection in workplaces. While dedicating the majority of its resources to the fundamental concepts of industrial health and safety, NIOSH has devoted a significant part of those resources to three areas of respiratory protection--research, training, and certification.

NIOSH has had an ongoing respirator research program since the early 1970s. Most of the recent research has been dedicated toward improving the quality and reliability of respirators through development of new and revised performance requirements for respirator certification.

Respirator training has been a focal point of the NIOSH activities in respiratory protection. The basic respirator training courses which are available from several sources today are based on the respirator course developed by NIOSH personnel.

NIOSH and OSHA established a Joint Respirator Committee in 1973, for the purpose of developing standard respirator selection criteria and tables for the approximately 400 hazardous materials regulated by OSHA. This committee, assisted by contractors from Los Alamos Scientific Laboratory and Arthur D. Little, Inc., developed the respirator selection tables that appear in NIOSH criteria documents and in the initial ***NIOSH/OSHA Pocket Guide to Chemical Hazards.*** The committee also participated in development of the initial ***Respirator Decision Logic,*** which has been revised for this publication.

The respirator certification work of NIOSH is a direct offshoot of the approval of mine rescue breathing apparatus by the Bureau of Mines. Under authorization of the Coal Mine Health and Safety Act of 1969 and the Federal Mine Safety and Health Act of 1977, NIOSH has established an evaluation and certification program for respirators. All certifications are issued jointly with the Mine Safety and Health Administration (MSHA).

The goal of the certification program is to help increase worker protection from airborne contaminants by certifying respirators that meet the minimum

performance requirements which appear in Title 30, Code of Federal Regulations, Part 11 (30 CFR 11). NIOSH certification evaluations include a laboratory evaluation of the respirator, an evaluation of the manufacturer's quality control (QC) plan, audit testing of certified respirators, and investigations of problems with MSHA/NIOSH certified respirators. In accordance with 30 CFR 11, MSHA/NIOSH certifications are issued for respirators specifically for use in mines and mining. However, the wide variety of respirators used in mines and mining ensures the availability of certified respirators for most other applications.

NIOSH has proposed significant revisions to 30 CFR 11. Once revised regulations are in effect, NIOSH expects to push vigorously for other improvements in respirator performance standards over the ensuing several years.

NIOSH also monitors respirators over the lifetime of their certification. Samples of "off the shelf" respirators are evaluated in NIOSH laboratories to see if they continue to meet applicable minimum performance requirements. In addition, NIOSH performs in-plant QC audits in order to determine if manufacturers are complying with the QC plans submitted in their approval applications. Reports of problems received from regulatory agencies, labor organizations, respirator users, and respirator manufacturers are investigated and resolved.

CHAPTER 2

TYPES OF RESPIRATORS

The basic purpose of any respirator is, simply, to protect the respiratory system from inhalation of hazardous atmospheres. Respirators provide protection either by removing contaminants from the air before it is inhaled or by supplying an independent source of respirable air. The principal classifications of respirator types are based on these categories.

A respirator that removes contaminants from the ambient air is called an **air-purifying respirator.** A respirator that provides air from a source other than the surrounding atmosphere is an **atmosphere-supplying respirator.** Both types can be further subclassified by the type of inlet covering and the mode of operation. Figures 2-1 through 2-6 detail the subclassifications of respirators that will be discussed in this chapter.

I. Respiratory Inlet Coverings

The respiratory inlet covering serves as a barrier against the contaminated atmosphere and as a framework to which air-purifying or atmosphere-supplying elements may be attached.

A. Tight-fitting coverings

Tight-fitting coverings, usually called "facepieces," are made of flexible molded rubber, silicone, neoprene, or other materials. Present designs incorporate rubber or woven elastic headstraps that are attached at two to six points. They buckle together at the back of the head, or may form a continuous loop of material.

Facepieces are available in three basic configurations. The first, called a "quarter-mask," covers the mouth and nose, and the lower sealing surface rests between chin and mouth (Fig. 2-7). Good protection may be obtained with a quarter-mask, but it is more easily dislodged than other types. Quarter-masks are most commonly found on dust and mist respirators.

A second type, the "half-mask," fits over the nose and under the chin (Fig. 2-8). Half-masks are designed to seal more reliably than quarter-masks, so they are preferred for use against more toxic materials.

A third type, the "full-facepiece," covers from roughly the hairline to below the chin (Fig. 2-9). On the average they provide the greatest protection, usually seal most reliably, and provide some eye protection

AIR-PURIFYING RESPIRATORS

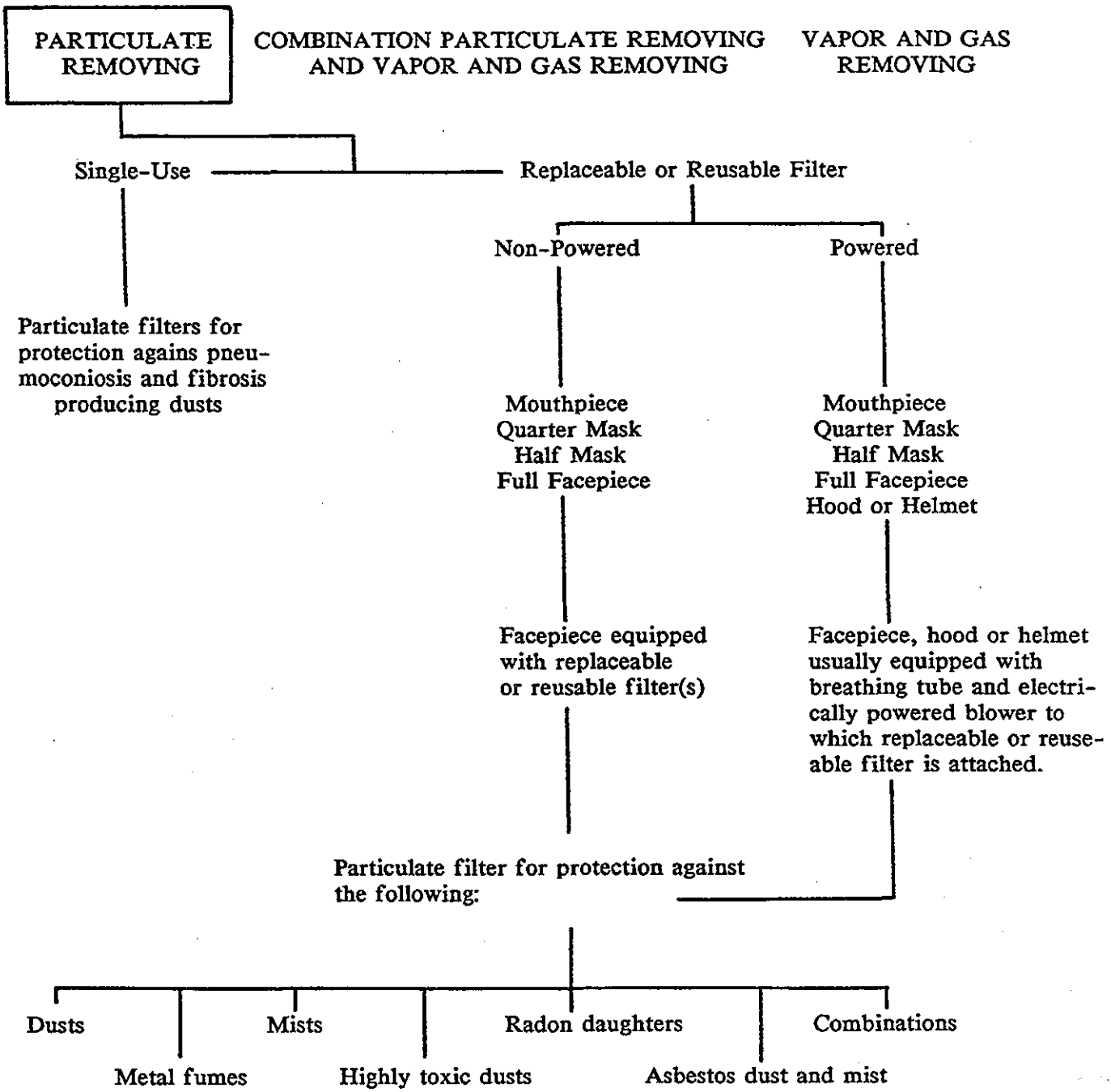

Figure 2-1. **Particulate removing respirators**

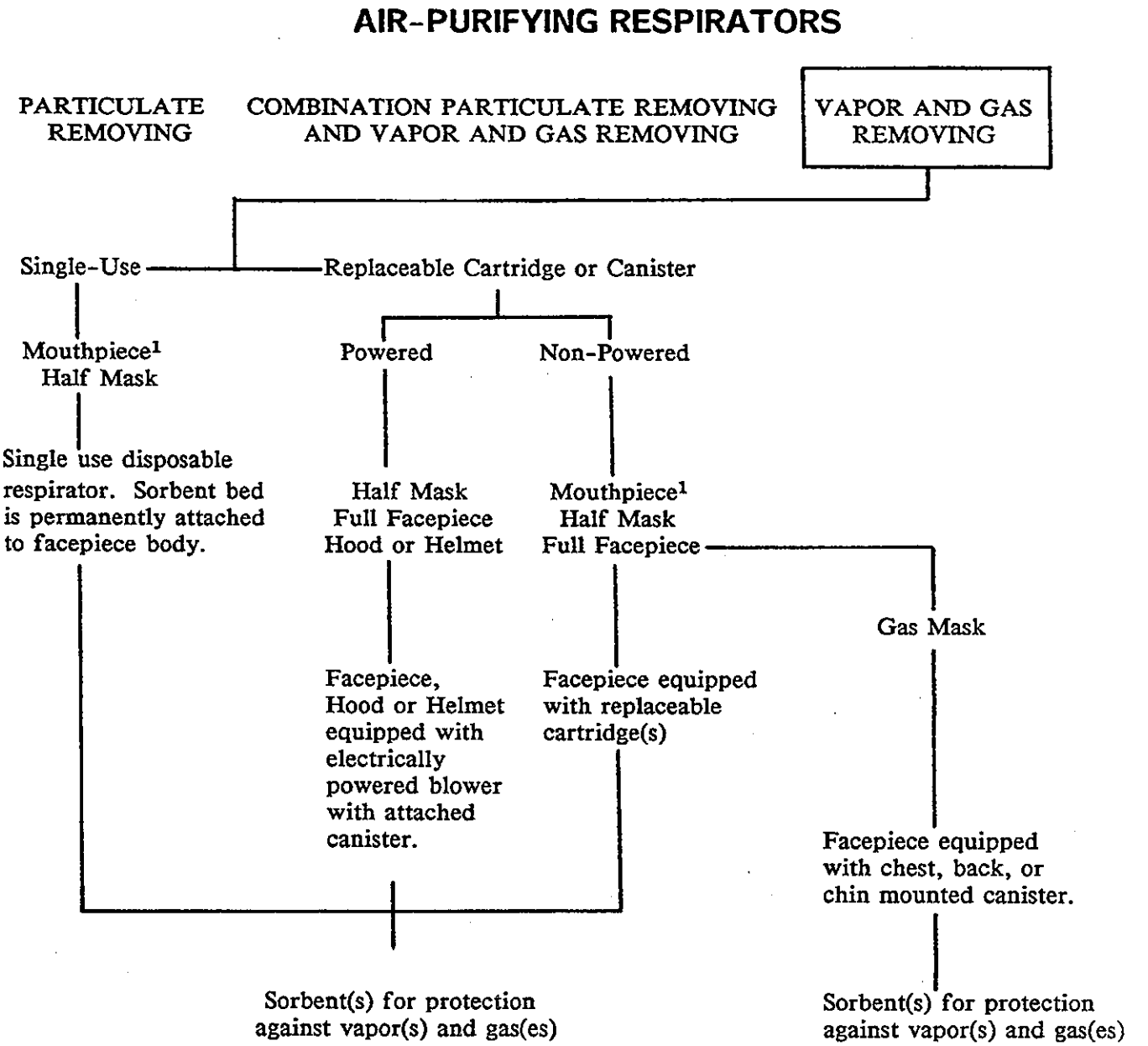

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Figure 2-2. **Vapor and gas removing respirators**

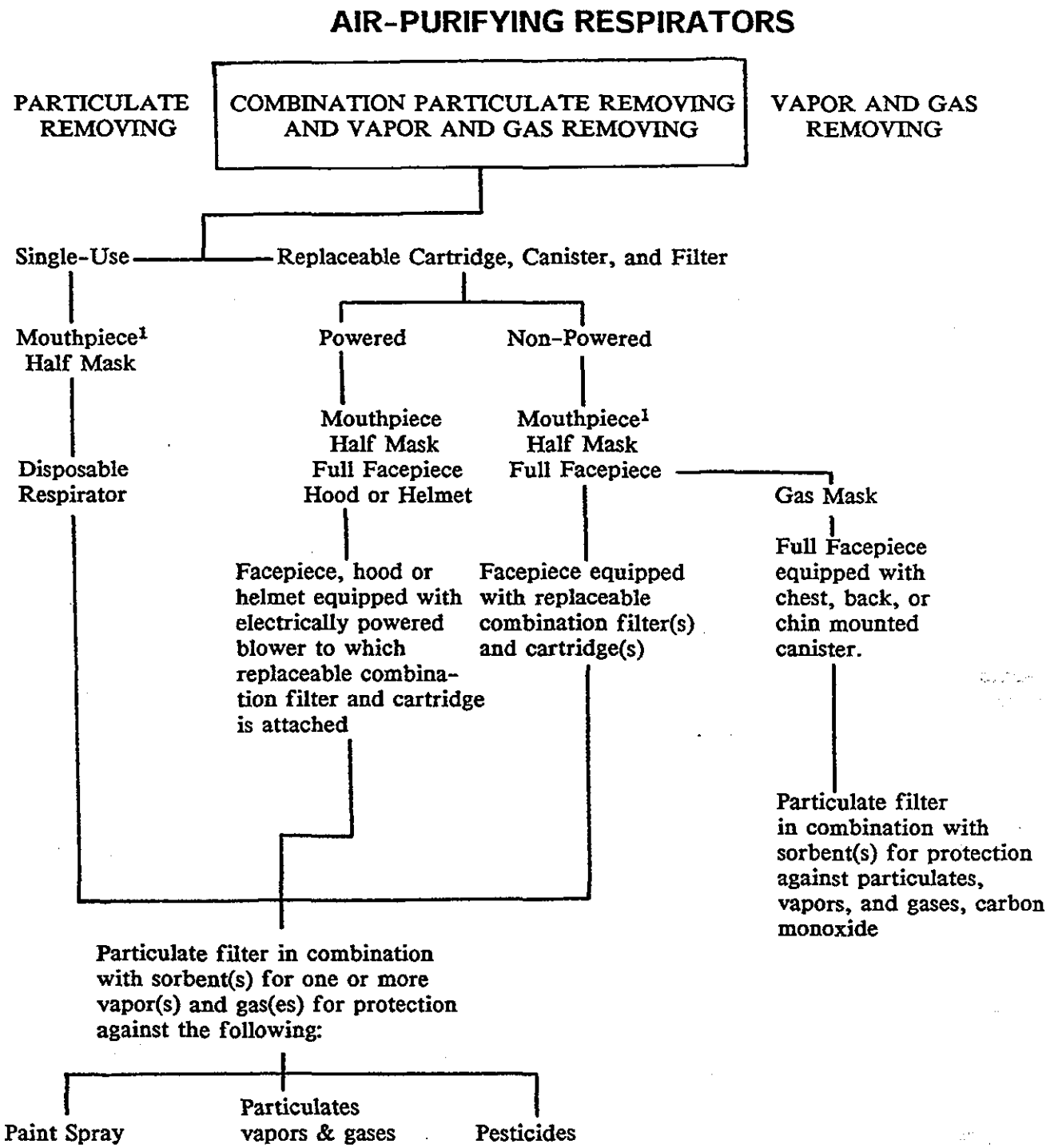

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Figure 2-3. **Combination particulate and vapor and gas removing respirators**

ATMOSPHERE-SUPPLYING RESPIRATORS

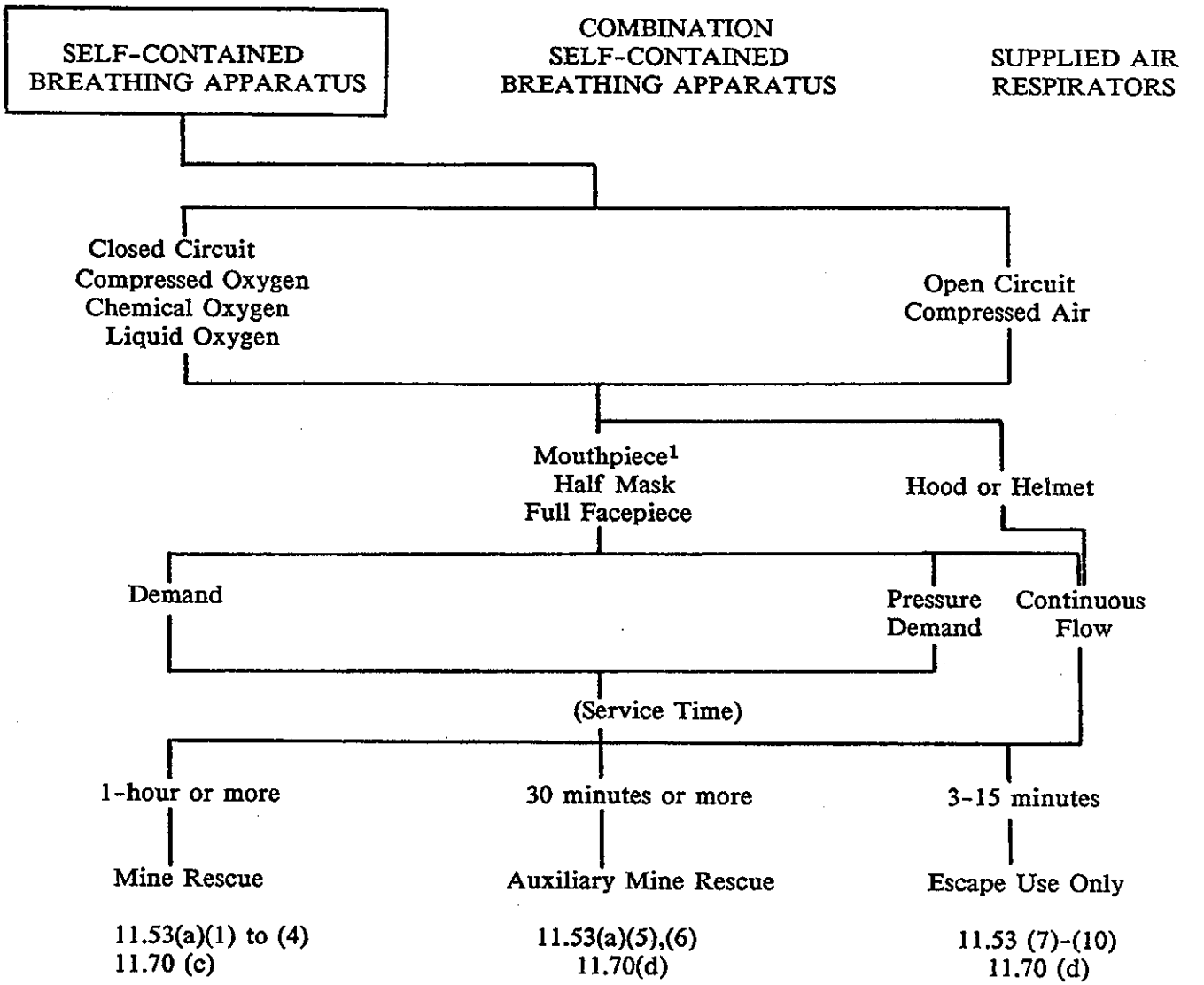

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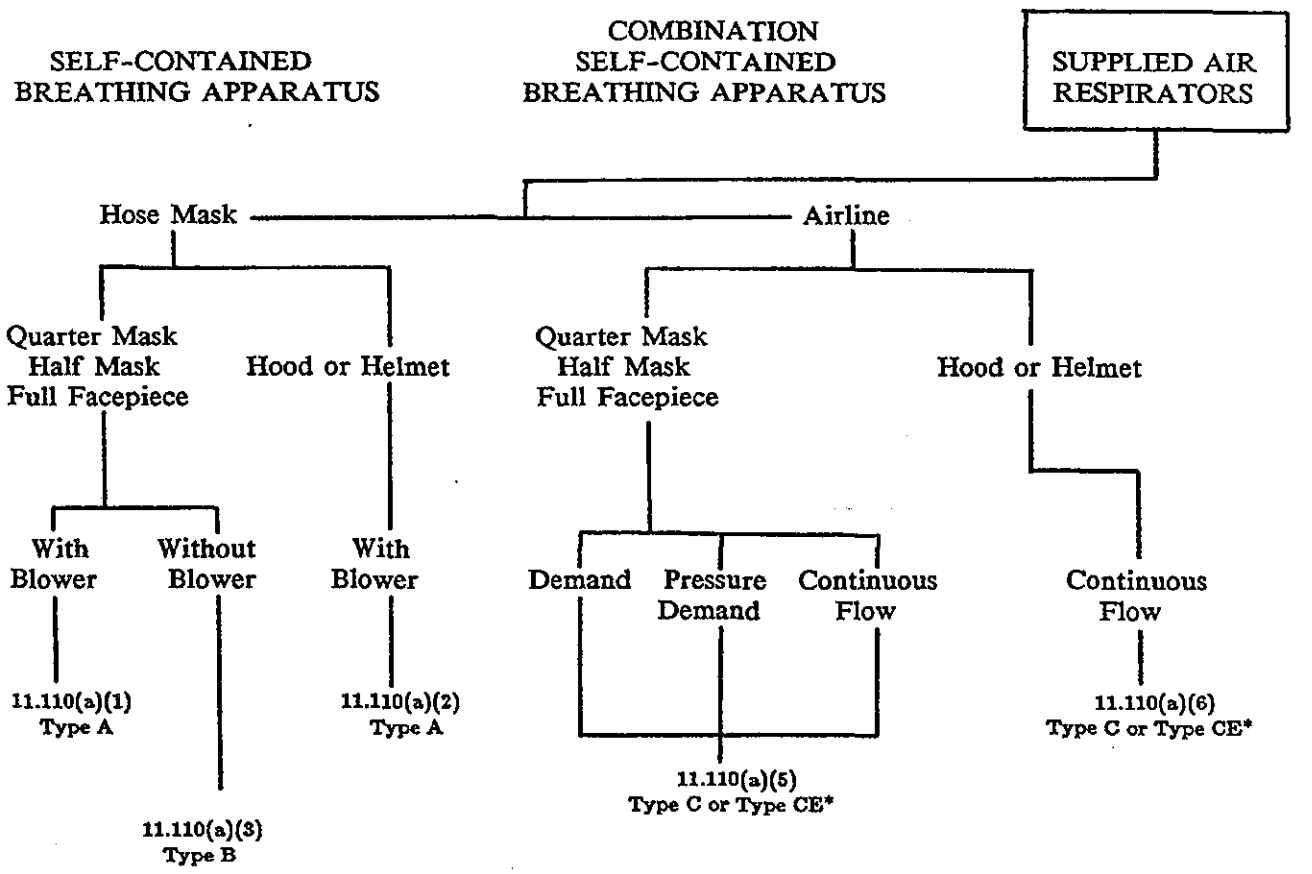
Figure 2-4. **Self-contained breathing apparatus**

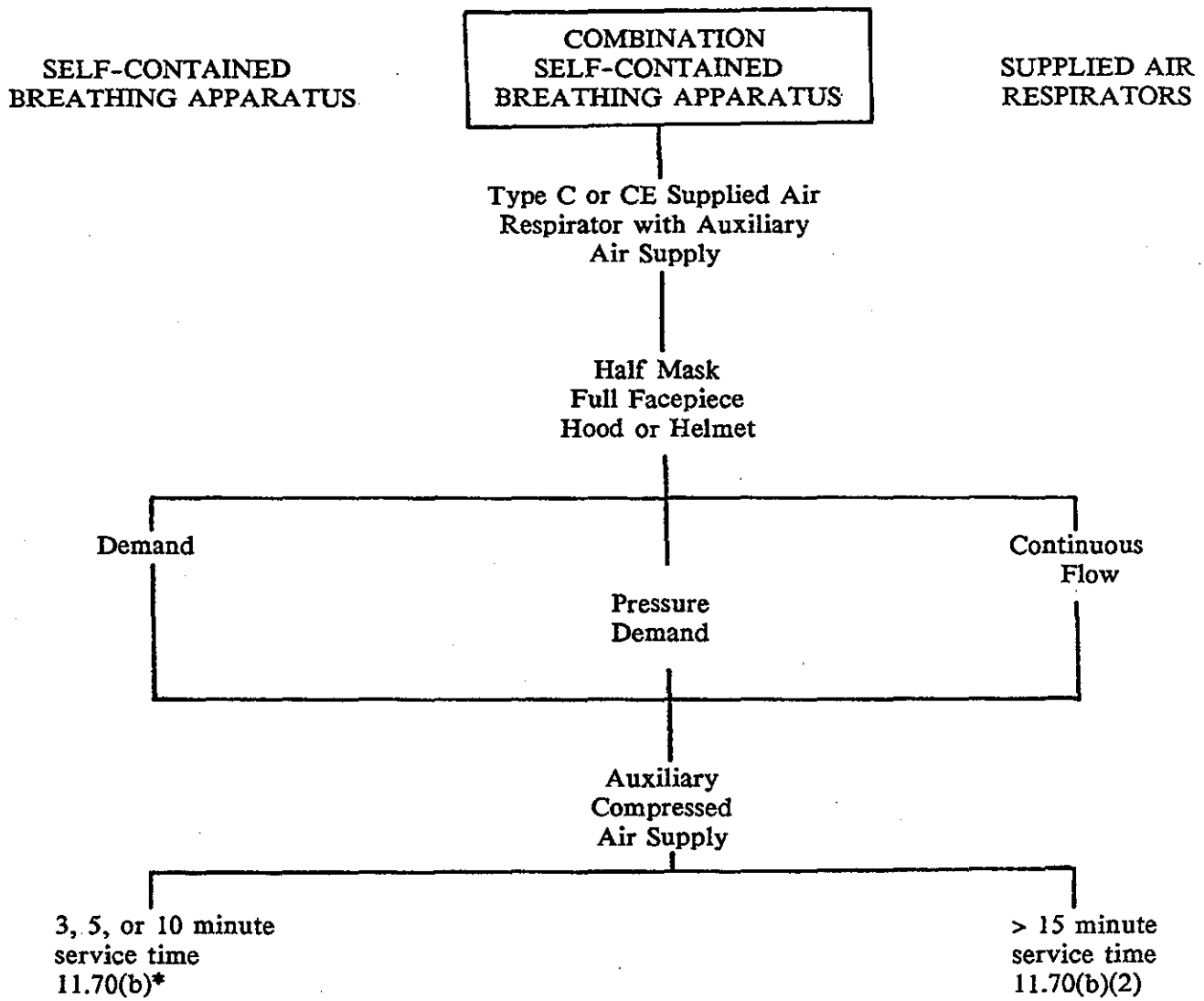
ATMOSPHERE-SUPPLYING RESPIRATORS



* Type CE respirators must have a means of protecting the wearer's head and neck against impact and abrasions from rebounding abrasive material and with shielding material such as plastic, glass, woven metal wire, etc.

Figure 2-5. **Supplied-air respirators**

ATMOSPHERE-SUPPLYING RESPIRATORS



* SCBA can be used for egress only.

Figure 2-6. **Combination SCBA and supplied-air respirators**

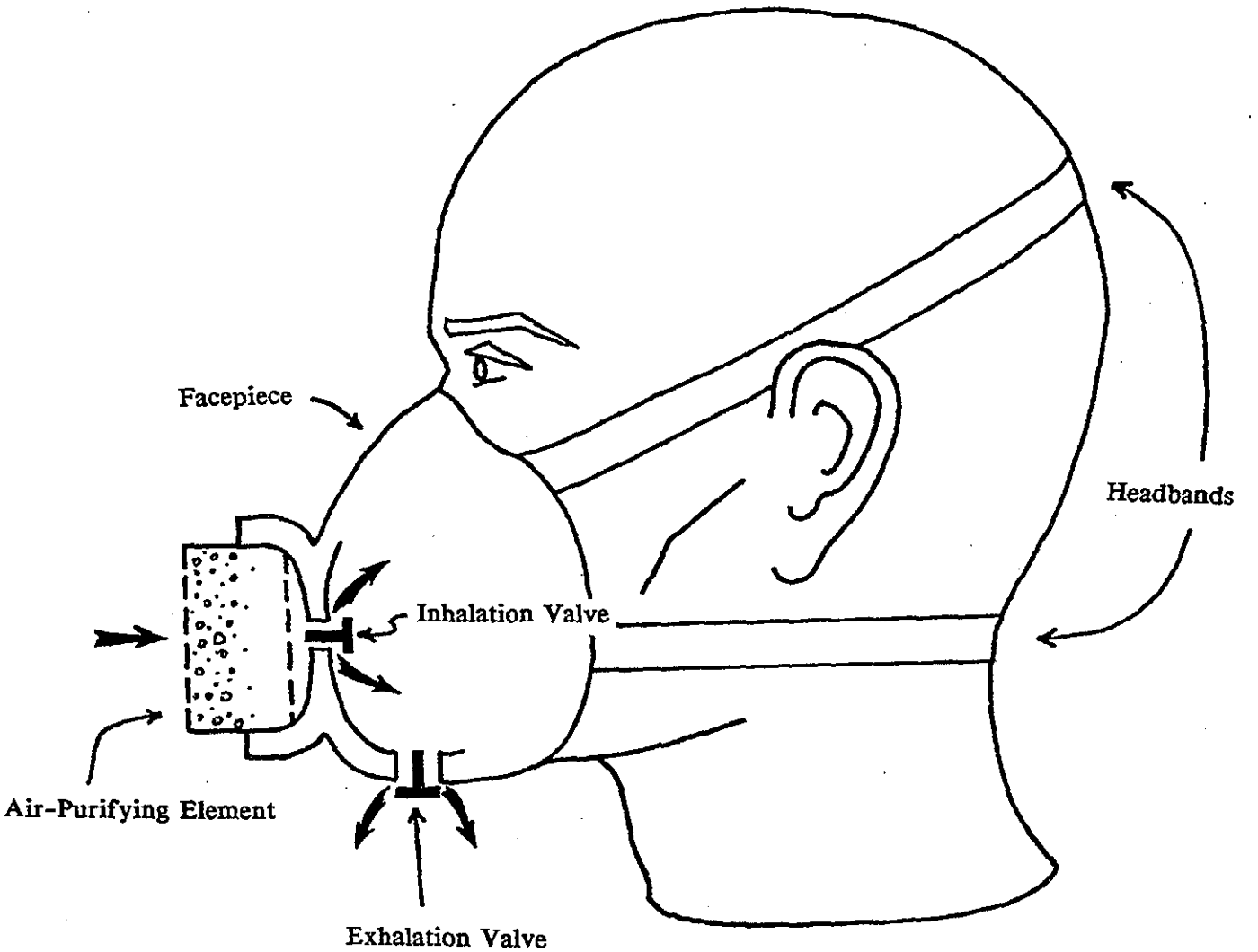


FIGURE 2-7. **Typical quarter-mask respirator**

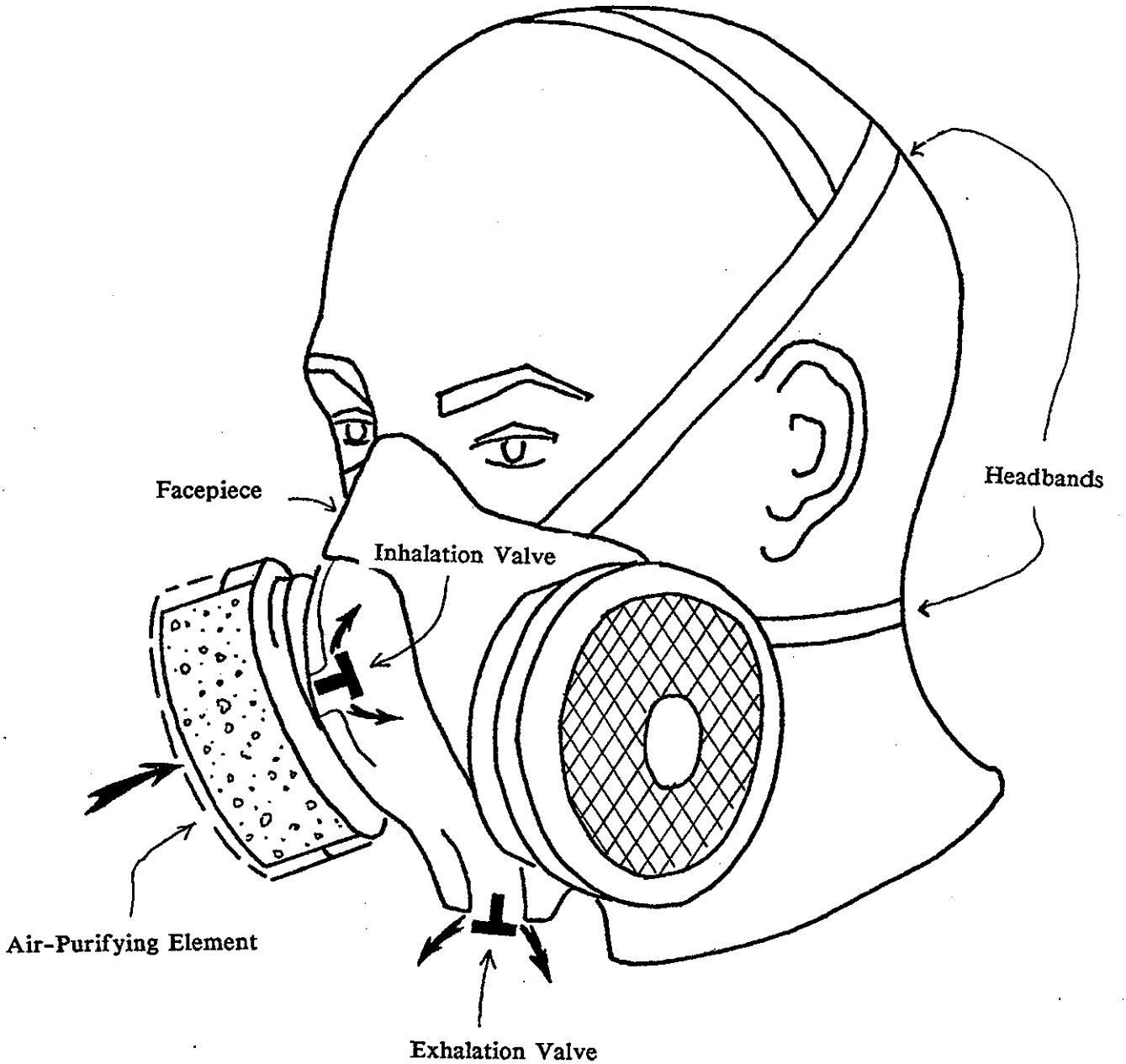


FIGURE 2-8. **Typical half-mask respirator**

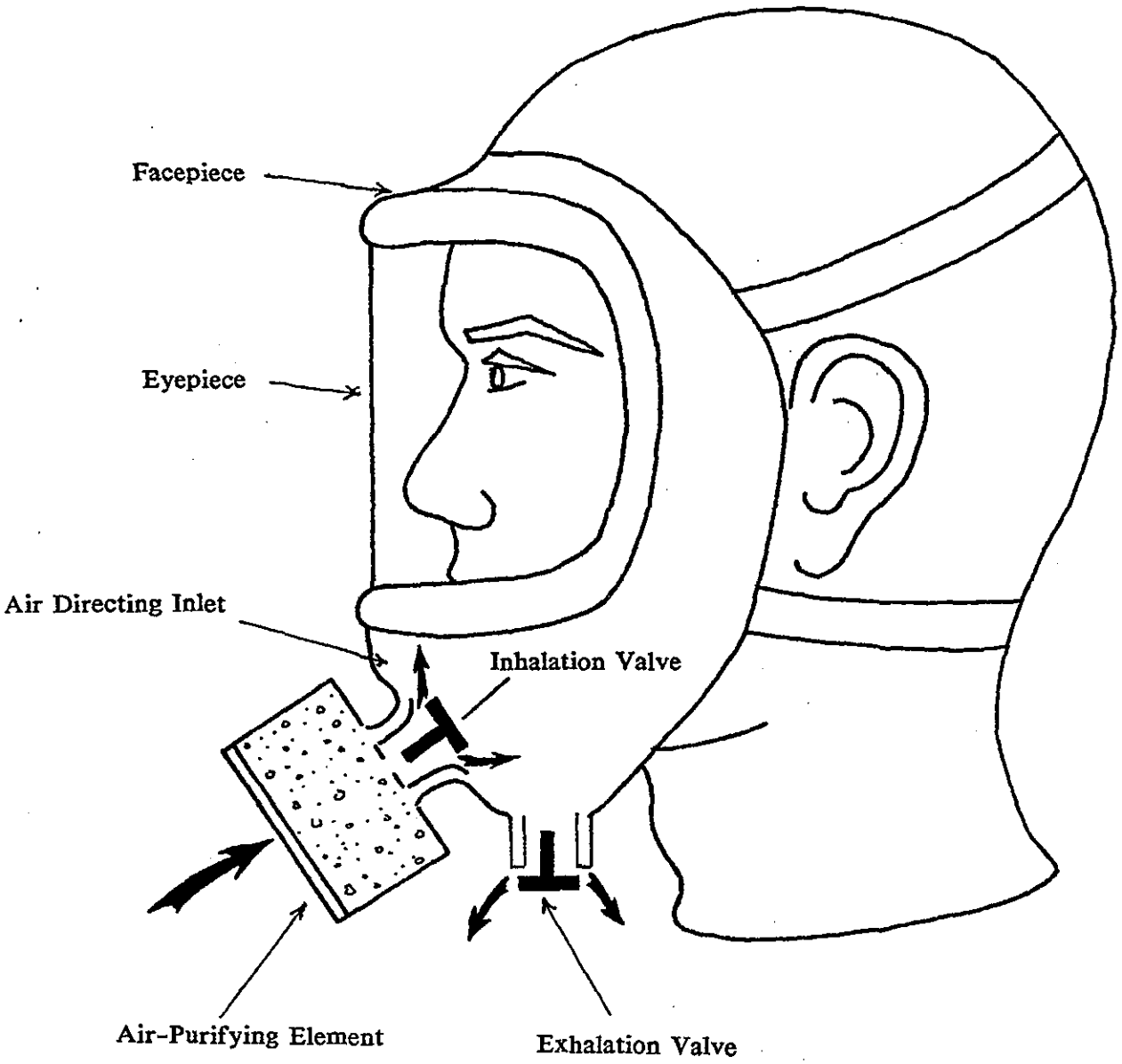


FIGURE 2-9. **Typical full-facepiece respirator**

as well. Full-facepiece respirators, both air-purifying and atmosphere-supplying, are designed for use in higher concentrations of toxic materials than are quarter- or half-mask respirators.

The mouthpiece consists of a mouthpiece held in the teeth (the lips seal around it) and a clamp that closes the nostrils (Fig. 2-10). Mouthpiece respirators should provide a good seal, but they eliminate communication, may cause fatigue, and provide no eye protection. Therefore, mouthpiece respirators are certified for use as escape-only respirators.

B. Loose-fitting coverings

Loose-fitting coverings include hoods, helmets, suits, and blouses. The wide variety of designs precludes any simple description, but Fig. 2-11 shows a blouse which typifies the basic principles of construction and operation of all such devices.

Generally, loose-fitting respirators enclose at least the head. A light flexible device covering only the head and neck, or head, neck, and shoulders is called a hood. If rigid protective headgear is incorporated into the design, it is called a helmet. Blouses extend down to the waist, and some have wrist-length sleeves. The enclosure includes a system through which clean compressed air is distributed around the breathing zone.

A special type of loose-fitting covering in common use is the abrasive-blasting hood (Fig. 2-12). The hood material is designed to withstand rebounding particles of abrasive material. Also, there is usually an impact-resistant glass or plastic viewing lens with additional plastic, glass, or woven wire shielding that deflects the rebounding particles.

II. Air-Purifying Respirators

A. Particulate Filtering Respirators

Particulate filtering respirators are used for protection against dusts, fumes, and/or mists. A dust is a solid, mechanically produced particle. A fume is a solid condensation particulate, usually of a vaporized metal. A mist is a liquid condensation particle.

Presently, all particulate filtering respirators use fibrous material (a filter) to remove the contaminant. As a particle is drawn onto or into the filter, it is trapped by the fibers. The probability that a single particle will be trapped depends on such factors as its size relative to the fiber size; its velocity; and, to some extent, the composition, shape, and electrical charge of both particle and fiber. With current filter media, any filter designed to be 100% efficient in removing particles would be unacceptably difficult to breathe through.

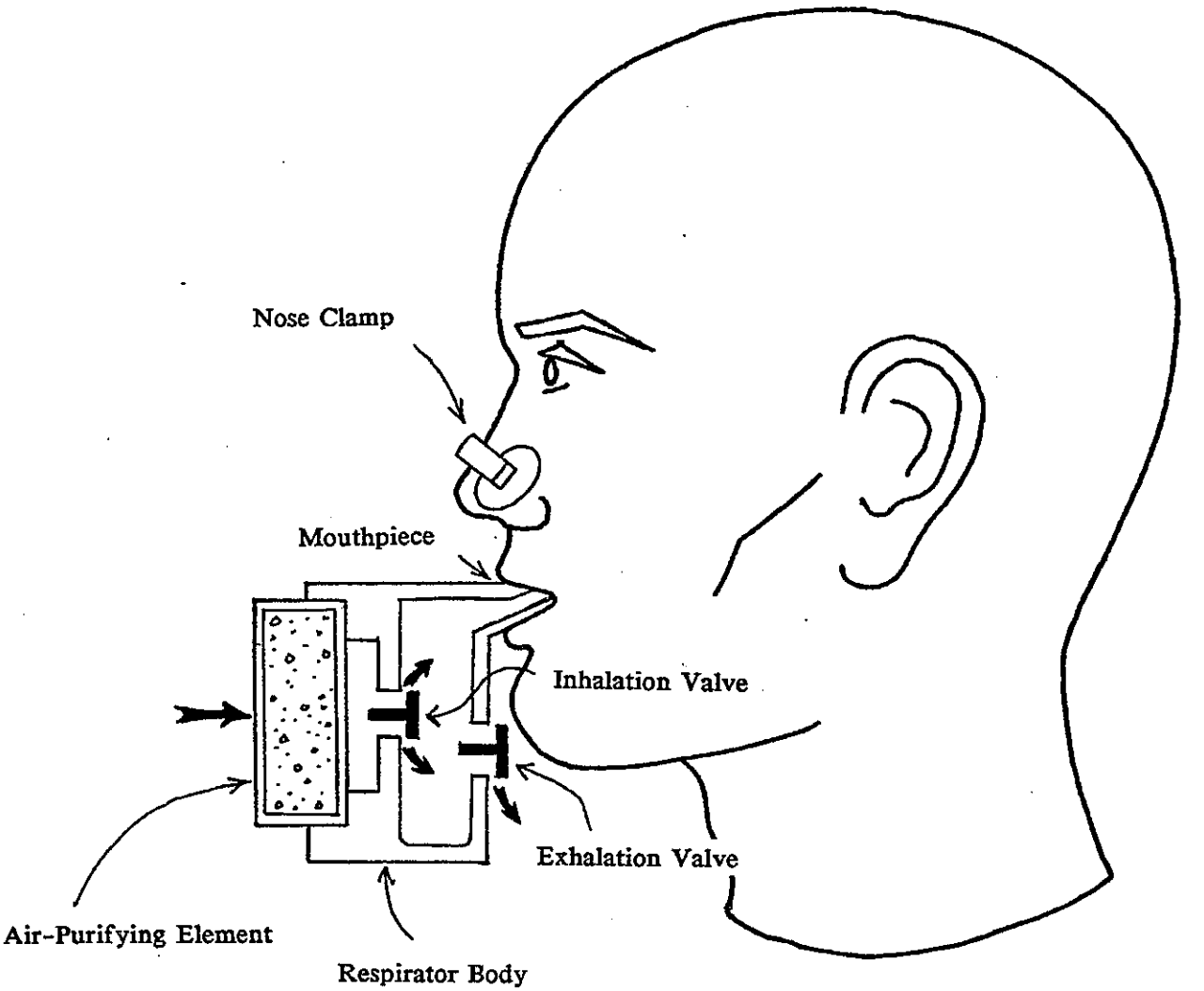


FIGURE 2-10. **Typical "mouthpiece" respirator**

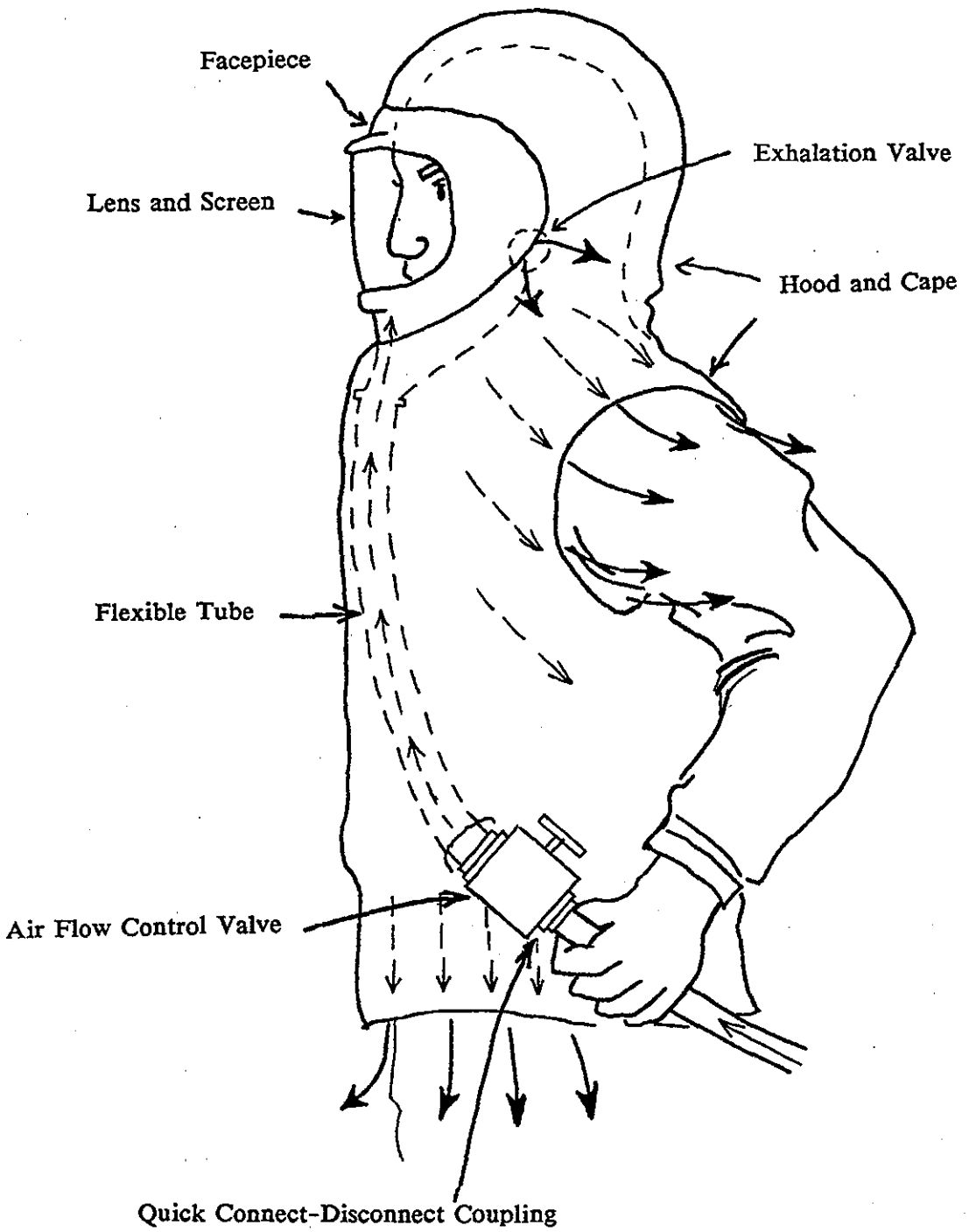


FIGURE 2-11. **Loose-fitting blouse**

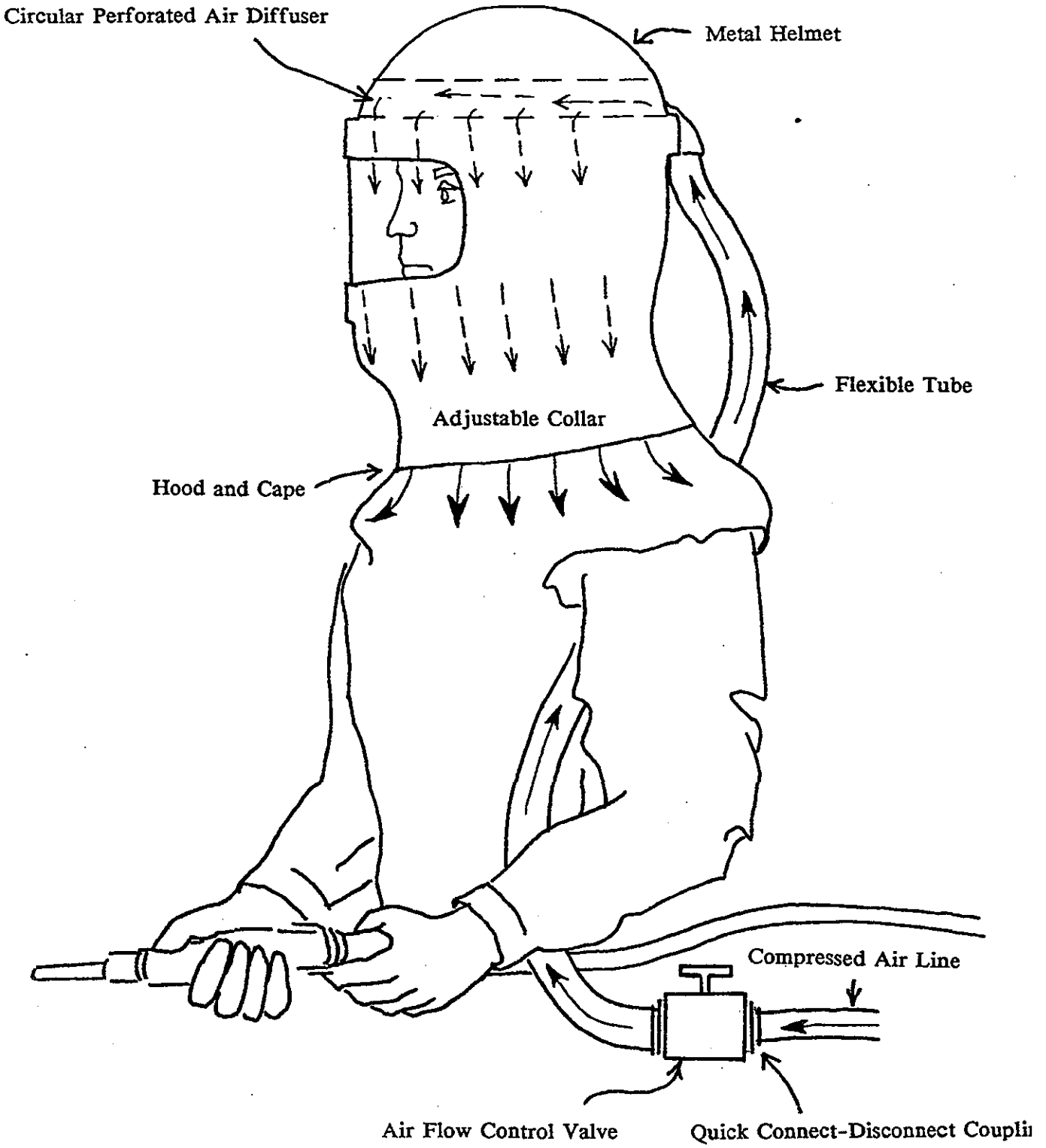


FIGURE 2-12. **Typical abrasive blasting hood**

Manufacturers try to produce the most efficient filter with the lowest breathing resistance. As the particulate respirator is used particulate material collects on the filter and the openings between fibers become smaller. This results in an increase in the breathing resistance. The filter may also become more efficient.

There are several designs of respirator filters. Each can be described by its filtration mechanism(s), production methods or type, the aerosol against which it is designed to provide protection, and the filtering efficiency.

1. Filtration Mechanisms

Particulate filters are of two types: absolute and non-absolute. Absolute filters use screening to remove particles from the air; that is, they exclude the particles which are larger than the pores. However, most respirator filters are non-absolute filters, which means they contain pores which are larger than the particles to be removed. They use combinations of interception capture, sedimentation capture, inertial impaction capture, diffusion capture, and electrostatic capture to remove the particles. The exact combination of filtration mechanisms which come into play depends upon the flowrate through the filter and the size of particle. Brief descriptions of these filtration mechanisms follow.

a. Interception Capture

As the air streams approach a fiber lying perpendicular to their path, they split and compress in order to flow around the fiber and rejoin on the other side (Figure 2-13). If the center of a particle in these airstreams comes within one particle radius of the fiber, it encounters the fiber surface and it is captured. As particle size increases, the probability of interception capture increases. The particles do not deviate from their original streamline in this mechanism.

b. Sedimentation Capture

Only large particles (2 μ and larger) are captured by sedimentation. Since this type of capture relies on gravity to pull particles from the airstream, flowrate through the filter must be low (Figure 2-14).

c. Inertial Impaction Capture

As the airstreams split and change direction suddenly to go around the fiber, particles with sufficient inertia cannot change direction sufficiently to avoid the fiber. Thus they impact on the surface of the fiber (Figure 2-15). A particle's size, density, speed and shape determine its inertia.

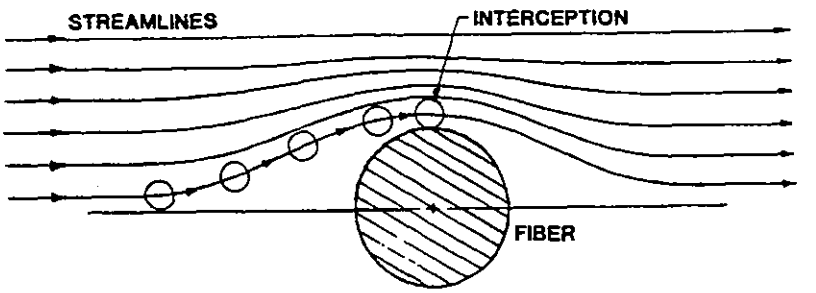


FIGURE 2-13. **Interception capture mechanism[1]**

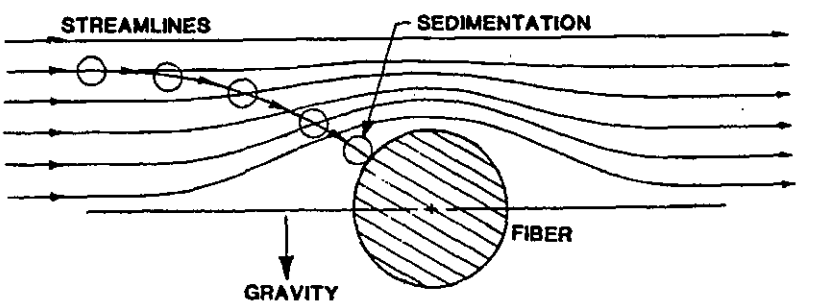


FIGURE 2-14. **Sedimentation capture mechanism[1]**

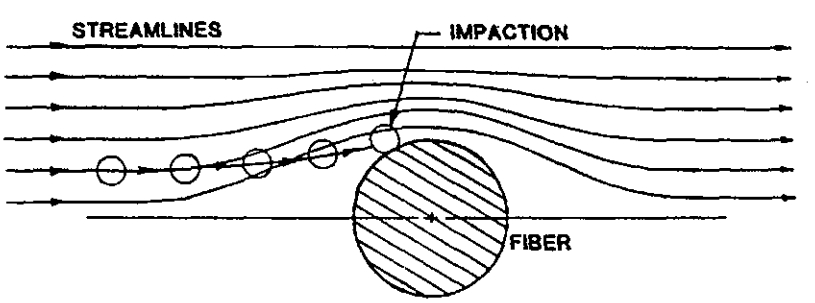


FIGURE 2-15. **Impaction capture mechanism[1]**

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[1] Japuntich, Daniel A. Respiratory Particulate Filtration. J. Ind. Soc. Respir. Prot. 1984; 2(1):137-169.

d. Diffusion Capture

The motion of smaller particles is affected by air molecules colliding with them. The particles then can randomly cross the airstream and encounter the fiber as they pass (Figure 2-16). This random motion is dependent on particle size and the air temperature. As the particle size decreases and air temperature increases the diffusive activity of the particle increases. This increases the probability of capture. Lower flowrate through the filter also increases the probability of capture because the particle spends more time in the area of the fiber.

e. Electrostatic Capture

In electrostatic capture, the particle is charged and the filter fibers have the opposite charge. Therefore, the particles are attracted to the fibers (Figure 2-17). The electrostatic capture mechanism aids the other capture mechanisms, especially interception and diffusion.

As was mentioned previously, the exact combination of capture mechanisms taking place depends upon several factors. However, some generalizations can be made. Large heavy particles are usually removed by inertial impaction and interception. Large light particles are removed by diffusion and interception. Diffusion removes very small particles.

2. Types of Filters

Three types of particulate filter predominate. The most common type presently available is a machine made flat disk of random laid non-woven fiber material which is carefully controlled to produce maximum filter efficiency and minimum resistance.

Another type (Figure 2-18) is a flat disk of compressed natural wool or synthetic fiber felt, or a blend, to which an electrostatic charge is imparted during manufacture by impregnating the material with a resin and mechanically beating or "needling" it. This charge increases the filter efficiency by electrostatically attracting the particles to the fibers. These filters protect adequately against most industrial dusts, but one precaution should be observed in their use. Certain agents, such as oil mists, and storage in very humid air remove the electrostatic charge. Therefore this type of filter should be stored in its original package, kept out of oil mists and high (>80%) humidity, and used as soon as possible after purchase.

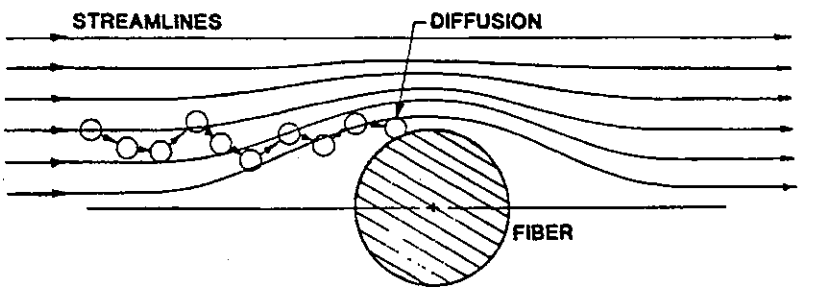


FIGURE 2-16. **Diffusion capture mechanism[1]**

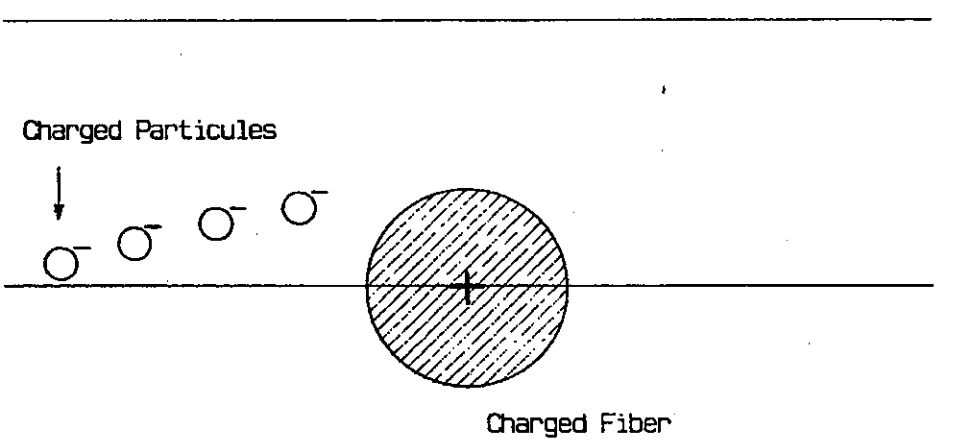


FIGURE 2-17. **Electrostatic capture**

1 Japuntich, Daniel A. Respiratory Particulate Filtration. J. Ind. Soc. Respir. Prot. 1984; 2(1):137-169.

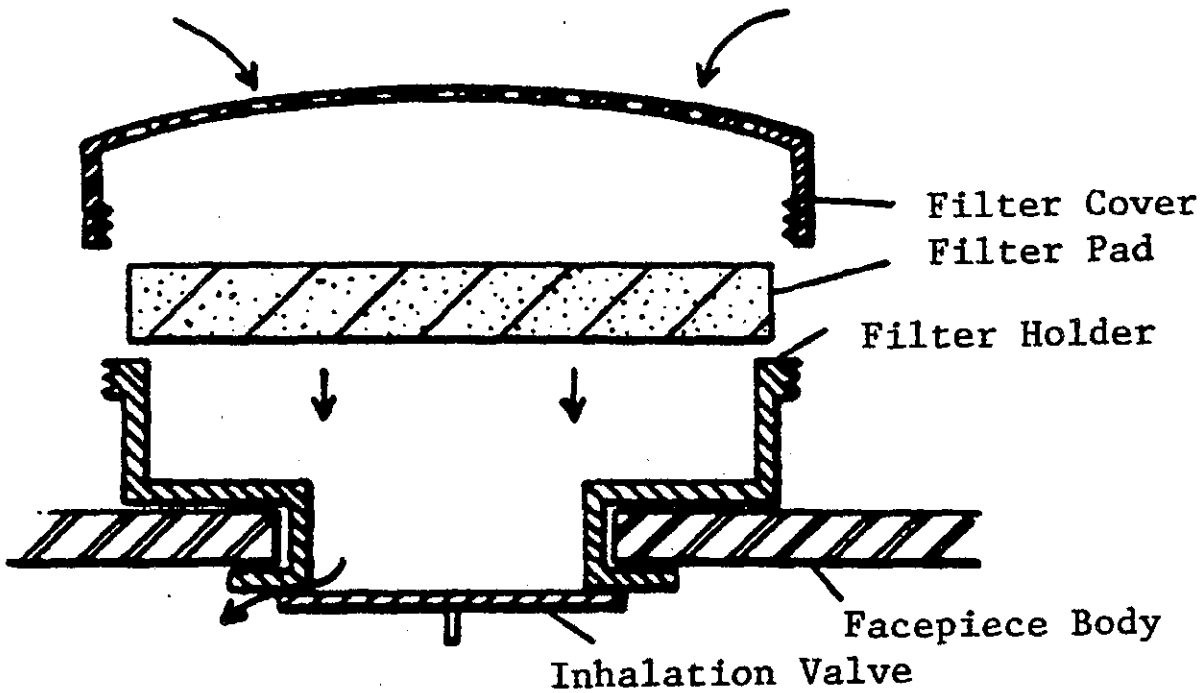


FIGURE 2-18. **Typical resin-impregnated felt dust filter**

The resin impregnated felt filter is readily identified by rubbing it between the fingers and then rubbing the fingers together. The fingers will feel slightly sticky.

Another type of dust filter is shown in Figure 2-19. The filtering medium is only loosely packed in the filter container so it is much thicker than the compressed type. Such filters are generally made of fibrous glass, although nonfelted, resin impregnated natural wool fibers have been used. They are not as common as the felted type. Typical dust respirators are shown in Figure 2-20.

Figure 2-21 shows a typical high efficiency dust, fume, and mist filter and Figure 2-22 shows high efficiency respirators. The filter is a flat sheet of material that is pleated and placed in the filter container. The pleating provides a large filtering area to improve the particle loading capacity and lower the breathing resistance. When viewed from the top, this type of filter shows a series of concentric rings or rows of pleats. This configuration is common, but other methods of construction are also used.

3. *Particulate Respirator Classifications*

For the 30 CFR 11 Subpart K certification tests particulate respirators are classified as designed for protection against a variety of dusts, fumes, mists. The following types are presently certified by MSHA/NIOSH:

a. Replaceable or Reusable Dust and Mist

Respirators, either with replaceable or reusable filters, designed as respiratory protection against (1) dusts and mists having an exposure limit not less than 0.05 milligram per cubic meter of air, or (2) dusts and mists having an exposure limit not less than 2 million particles per cubic foot of air.

b. Replaceable Fume

Respirators, with replaceable filters, designed as respiratory protection against fumes of various metals having an exposure limit not less than 0.05 milligram per cubic meter.

c. Replaceable Dust, Fume, and Mist

Respirators, with replaceable filters, designed as respiratory protection against dusts, fumes, and mists of materials having an exposure limit less than 0.05 milligram per cubic meter or 2 million particles per cubic foot of air.

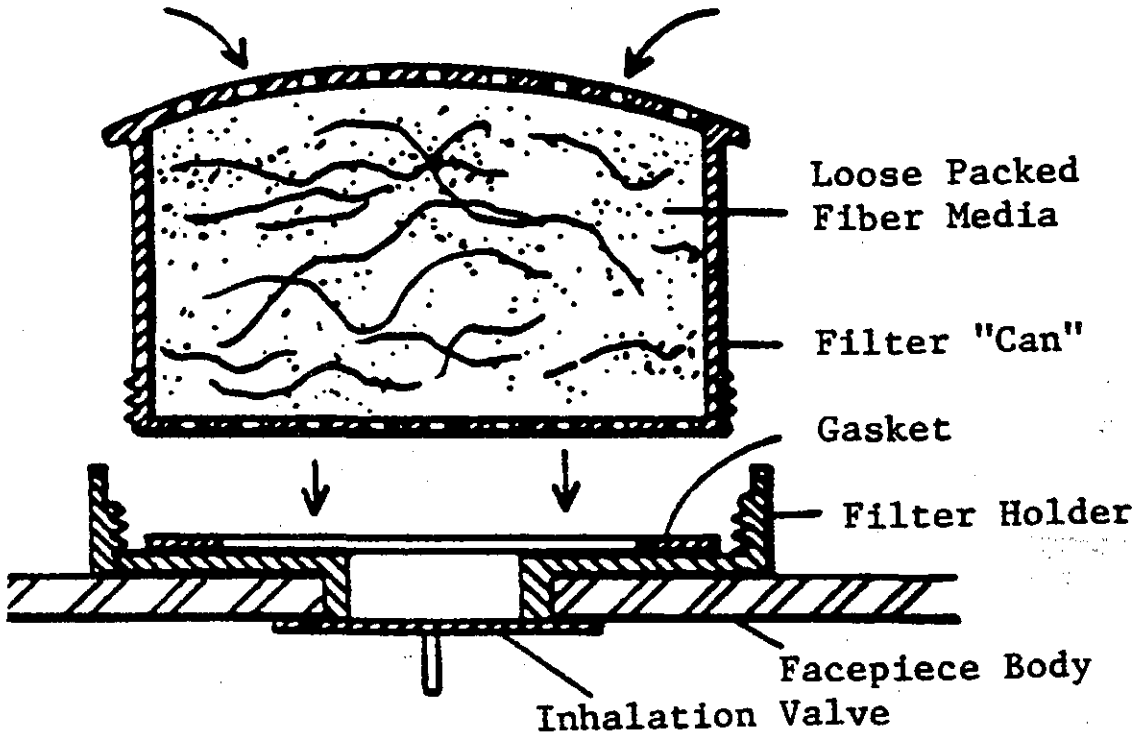
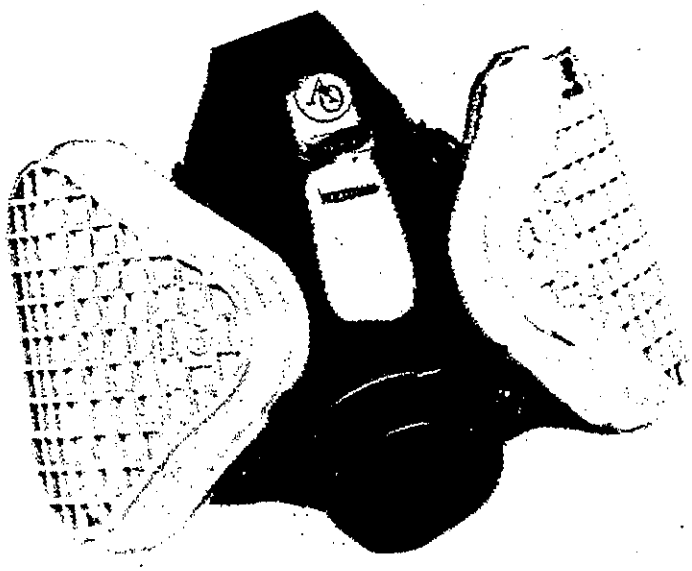
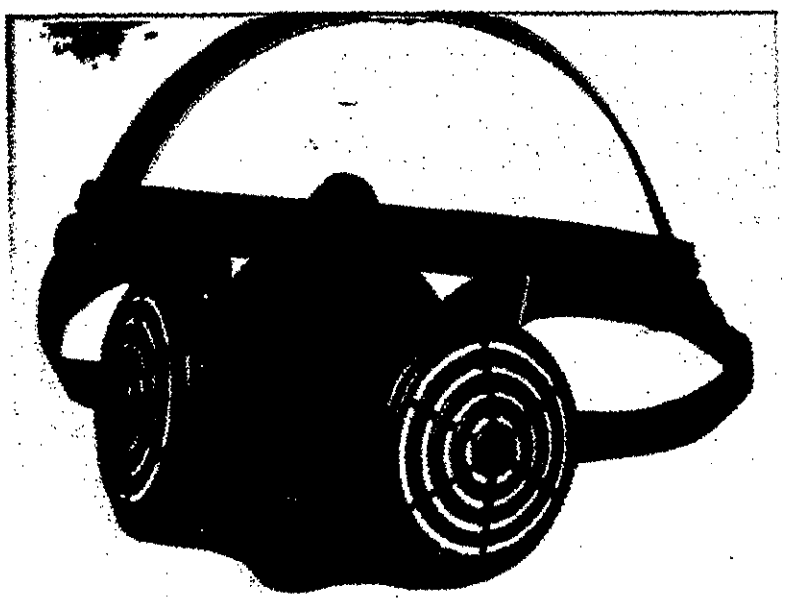


FIGURE 2-19. **Typical dust filter with loose packed medium**



Photograph courtesy of American Optical Corporation



Photograph courtesy of U.S. Safety S

FIGURE 2-20.

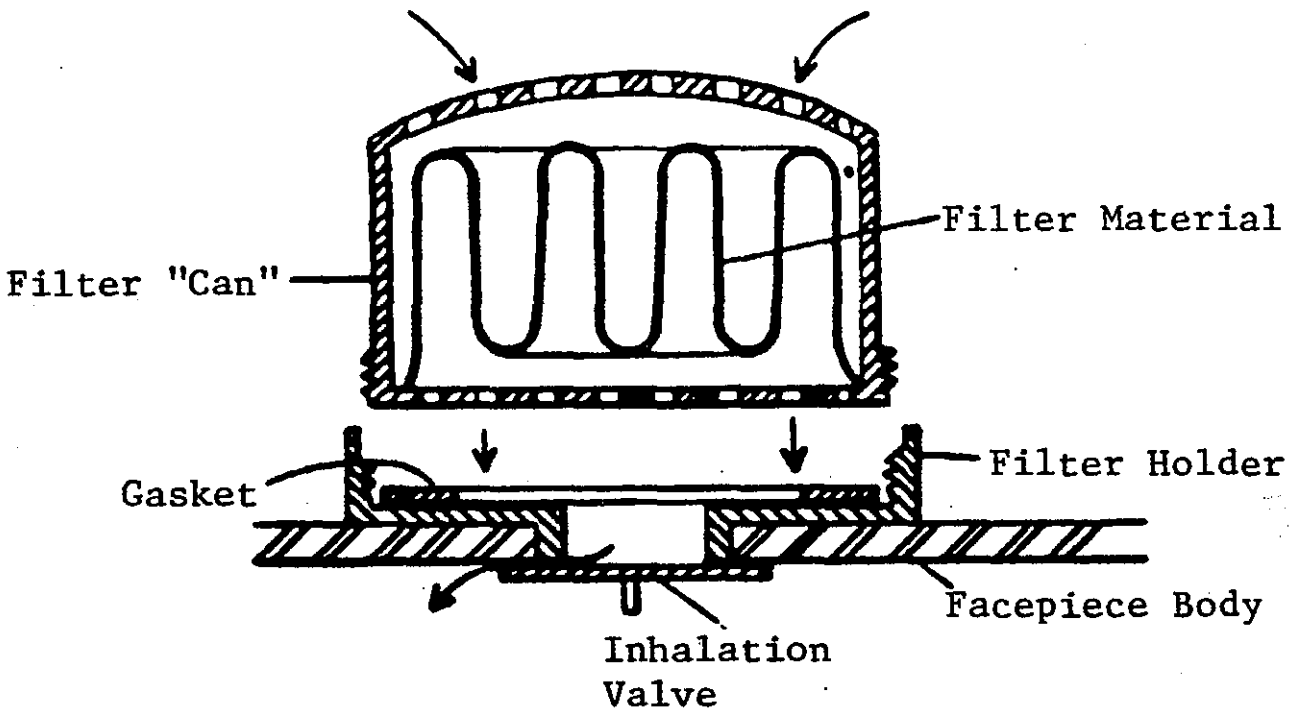


FIGURE 2–21. **Typical high efficiency filter**

Photograph Courtesy of U.S. Safety Service

Photograph Courtesy of Willson Safety Products

FIGURE 2-22. **Typical half- and full-facepiece high efficiency respirators**

d. Single-use

Respirators designed as respiratory protection against pneumoconiosis- and fibrosis-producing dusts, or dusts and mist. In the single-use respirator, the filter is either an integral part of the facepiece or it is the entire facepiece itself (see Figure 2-23).

4. Filter Efficiency

Filter efficiency may be classified as follows:

a. High Efficiency

The highest efficiency filters (99.97 percent against 0.3μ dioctyl phthlate particle) are used on high efficiency respirators certified for protection against dusts, fumes, and mists having an exposure limit less than 0.05 milligram per cubic meter or 2 million particles per cubic foot of air.

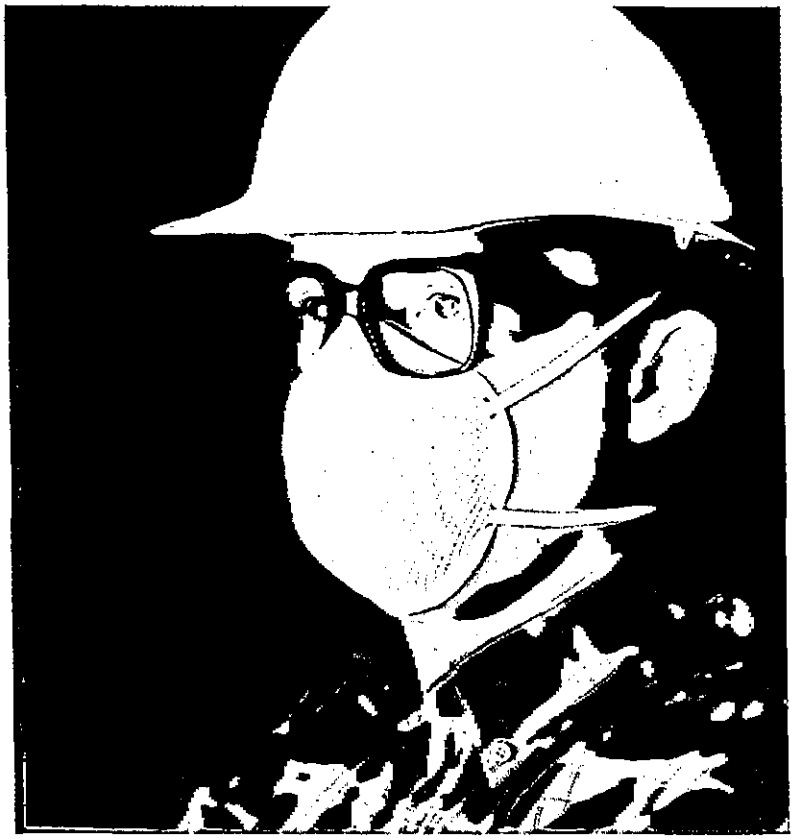
b. Lower Efficiency

Respirators for dusts, fumes, and mists having an exposure limit not less than 0.05 milligram per cubic meter, have lower efficiency filters as classified in 30 CFR 11 (approximately 99 percent against a lead fume aerosol).

Dust, mist, single-use dust and mist respirators also have lower efficiency filters as classified in 30 CFR 11 (approximately 99 percent against a silica dust particle with a geometric mean diameter of 0.4 to 0.6μ and a standard geometric mean deviation not greater than 2).

B. Vapor and Gas Removing Respirators

The other major class of airborne contaminants consists of gases and vapors. Air-purifying respirators are available for protection against both specific gases and vapors, such as ammonia gas and mercury vapor, and classes of gases and vapors, such as acid gases and organic vapors. In contrast to filters, which are effective to some degree no matter what the particulate, the cartridges and canisters used for vapor and gas removal are designed for protection against specific contaminants.



Photograph Courtesy of Moldex-Metric Inc.

Photograph Courtesy of Louis M. Gerson Co., Inc.

FIGURE 2-23. **Typical single use respirators**

1. Removal Mechanisms

Vapor and gas removing respirators normally remove the contaminant by interaction of its molecules with a granular, porous material, commonly called the sorbent. The general method by which the molecules are removed is called sorption. In addition to sorption, some respirators use catalysts which react with the contaminant to produce a less toxic gas or vapor.

Three removal mechanisms are used in vapor and gas removing respirators.

a. Adsorption

Adsorption retains the contaminant molecule on the surface of the sorbent granule by physical attraction. The intensity of the attraction varies with the type of sorbent and contaminant. Adsorption by physical attraction holds the adsorbed molecules weakly. If chemical forces are involved, however, in the process called chemisorption, the bonds holding the molecules to the sorbent granules are much stronger and can be broken only with great difficulty.

A characteristic common to all adsorbents is a large specific surface area, up to 1500 m^2/g of sorbent. Activated charcoal is the most common adsorbent. It is used primarily to remove organic vapors, although it does have some capacity for adsorbing acid gases. Activated charcoal also can be impregnated with other substances to make it more selective against specific gases and vapors. Examples are activated charcoal impregnated with iodine to remove mercury vapor, with metallic oxides to remove acid gases, and with salts of metals to remove ammonia gas. Other sorbents which could be used in vapor and gas removing respirators include molecular sieves, activated alumina, and silica gel.

b. Absorption

Absorbents may also be used to remove gases and vapors. Absorbents differ from adsorbents in that, although they are porous, they do not have as large a specific surface area. Absorption is also different because the gas or vapor molecules usually penetrate deeply into the molecular spaces throughout the sorbent and are held there chemically. Probably, absorption cannot occur without prior adsorption on the surface of the particles. Furthermore, adsorption occurs instantaneously, whereas absorption is slower. Most absorbents are used for protection against acid gases. They include mixtures of sodium or potassium hydroxide with lime and/or caustic silicates.

c. Catalysis

A catalyst is a substance that influences the rate of chemical reaction between other substances. A catalyst used in respirator cartridges and canisters is hopcalite, a mixture of porous granules of manganese and copper oxides which speeds the reaction between toxic carbon monoxide and oxygen to form carbon dioxide.

As applied to respirators, the foregoing processes are essentially 100% efficient until the sorbent's capacity to adsorb gas and vapor or catalyze their reaction is exhausted. Then the contaminant will pass completely through the sorbent and into the facepiece. This is in contrast to mechanical particulate removing filters which become more efficient as matter collects on them and plugs the spaces between the fibers. This difference is important to remember. Water vapor reduces the effectiveness of some sorbents and increases that of others. For example, increasing moisture content of a sorbent designed to sorb acid gases may increase sorbent efficiency since most acid gases normally dissolve in water. Vapor and gas removing cartridges should be protected from the atmosphere while in storage.

2. ***Cartridges vs. Canisters.***

a. Sorbent Volume

The basic difference between cartridges and canisters is the volume of sorbent contained, not its function. Cartridges are vapor and gas removing elements that may be used singly or in pairs on quarter- and half-masks and on full-facepieces. The sorbent volume of a cartridge is small, about 50-200 cm^3, so the useful lifetime is usually short, particularly in high gas or vapor concentrations. Therefore, use of respirators with cartridges generally is restricted to low concentrations of vapors and gases. The user should refer to NIOSH recommendations, certification labels, or specific standards set forth by regulatory agencies for specific maximum use concentrations.

Canisters have a larger sorbent volume and may be chin-, front- or back-mounted. Respirators with canisters can be used in higher vapor and gas concentrations (up to the immediately dangerous to life or health level) than those with cartridges. Chin-style canisters have a volume of about 250-500 cm^3 and are used on full-facepiece respirators. Front- or back-mounted canisters are held in place by a harness and connected to the facepiece by a corrugated, flexible breathing tube. They have a sorbent volume of 1000-2000 cm^3. Front- or back-mounted and chin-style canisters are used with full-facepieces as part of "gas masks." The "gas mask" is certified for single or specific classes of gases and vapors. It differs from the chemical cartridge respirator only in

its larger sorbent volume and the higher concentrations of vapors and gases against which it provides protection.

b. Labeling

As vapor and gas removing cartridges and canisters are designed for protection against specific contaminants, or classes thereof, how does the user know he has the proper device? The printed certification label clearly lists these contaminants. An American National Standard, ANSI K13.1-1973, established a color code for the various types of sorbent cartridges and canisters which identifies the contaminants they are designed to protect against. Users should not rely on memorizing the color code, but should always **READ THE LABEL!** This is the only foolproof way of ensuring use of the correct cartridge or canister. The color code of the ANSI K13.1 standard has been included verbatim in the OSHA regulations, 29 CFR 1910.134(g).

c. Construction

The type of sorbent found in vapor and gas removing cartridges and canisters for use against a particular substance may vary from manufacturer to manufacturer. However, cartridge and canister construction varies little. The basic construction problems are the same: to provide enough sorbent bed depth and volume to ensure that 1) the contaminant is totally removed in the times specified in 30 CFR 11 bench tests, and 2) the sorbent remains mechanically stable in the container.

Figure 2-24 shows a typical chemical cartridge certified for use with a half-mask. The bed of sorbent granules is retained in the cylindrical "can" by a screen and coarse filter pad at the top and by a coarse particulate filter pad and a screen at the bottom (Figure 2-25). The pads only keep the fine granules in the sorbent from escaping from the cartridge; they are not designed for protection against particulate contaminants. Various precautions for use of these cartridges are discussed in Chapter 5, **Respirator Use Under Special Conditions.**

One problem in design and manufacture of sorbent canisters is to prevent passage of large quantities of air through small areas of the bed of packed sorbent granules. Such air channeling through the canister reduces its useful service life. Selection of the proper sorbent granule size and careful packing in the canister minimize air channeling. There is a tendency toward channeling where the irregular sorbent granules touch the smooth canister wall. Sometimes channeling is prevented by forming ridges in the canister shell like those in Figure 2-26. The retaining screens and pads hold the granular sorbent bed in place. The spring ensures that the sorbent remains tightly packed.

Photograph Courtesy of Glendale Protective Technology

FIGURE 2-24. **Typical half-mask chemical cartridge**

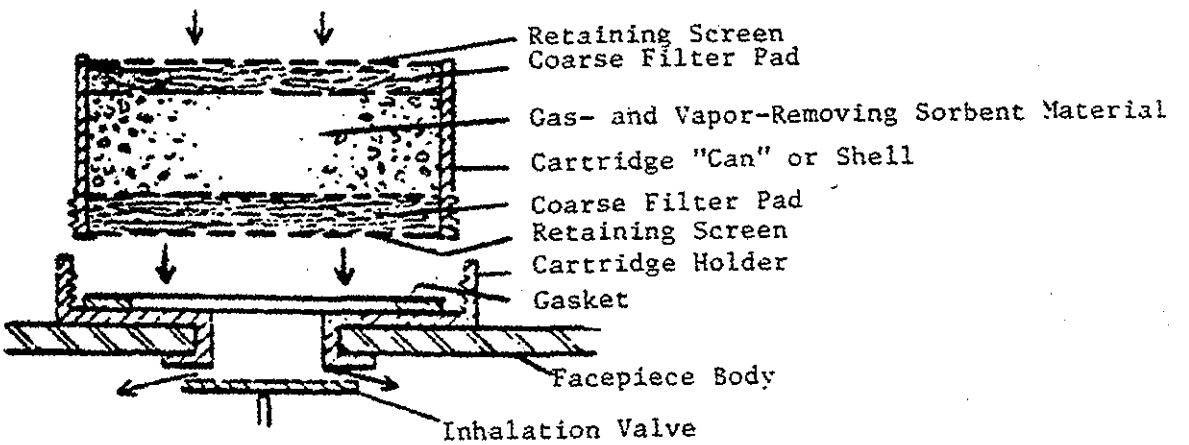


FIGURE 2-25. **Typical chemical cartridge**

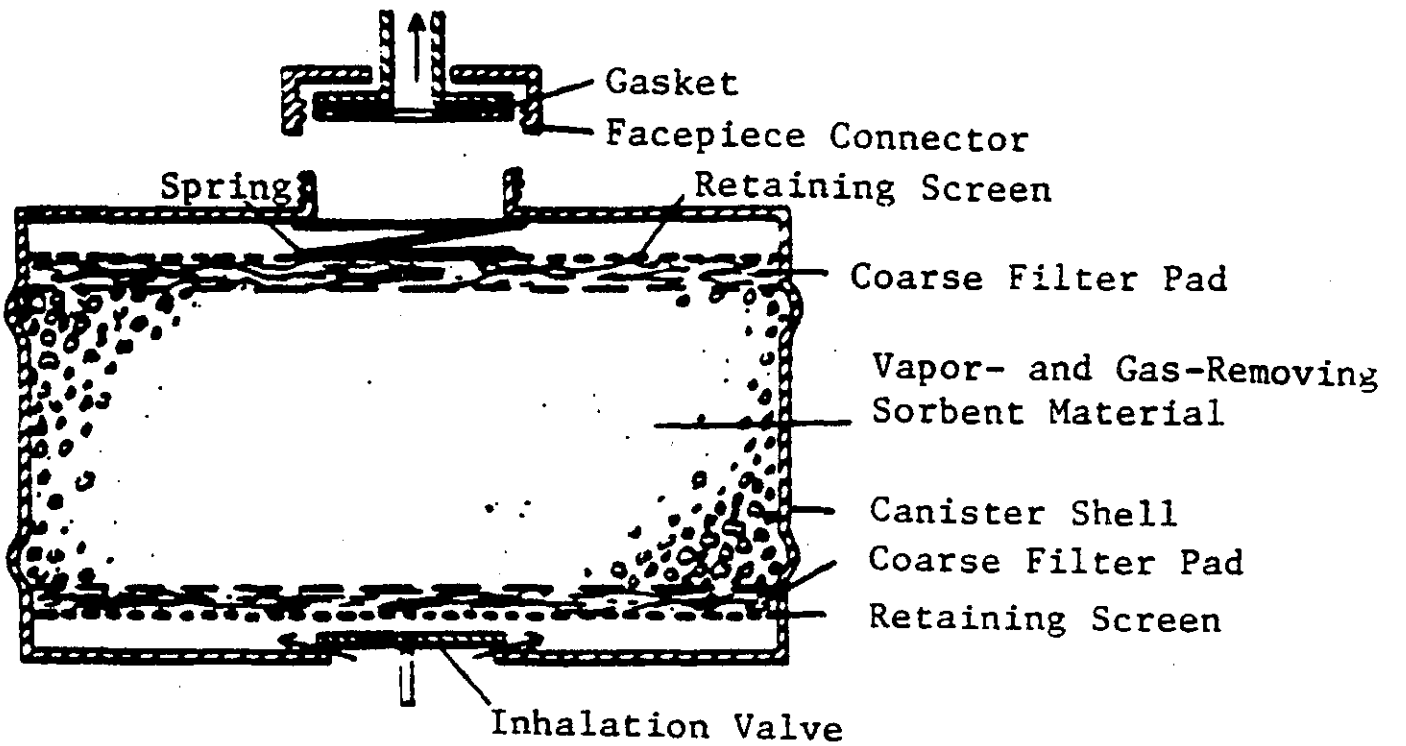


FIGURE 2-26. **Typical chin style canister**

Even with these precautions, sorbent canisters may be damaged by dropping. This can crush the granules, disturb the retaining screens or pads, or create channels between the sorbent granules and the canister wall. Cartridges and canisters should also be stored upright. In short, treat sorbent canisters with care.

3. *Vapor and Gas Respirator Classifications*

a. Chemical Cartridge Respirators

Figure 2-27 shows a typical chemical cartridge air-purifying respirator with an array of various cartridges that can be used with it. Chemical cartridge respirators can be either powered or non-powered, and either disposable or with replaceable cartridges or canisters. A listing of the vapors and gases and maximum concentrations for which chemical cartridge respirators are certified is included in 30 CFR 11.150. Note the accompanying restrictions on maximum use. These concentrations pertain to the cartridge and thus are the limiting concentration for the respirator regardless of whether a full or half facepiece is used.

In addition to the gases and vapors listed, 30 CFR 11.150 also allows MSHA/NIOSH to certify chemical cartridge respirators for gases and vapors other than those listed. Fox example, MSHA/NIOSH have certified respirators for use against:

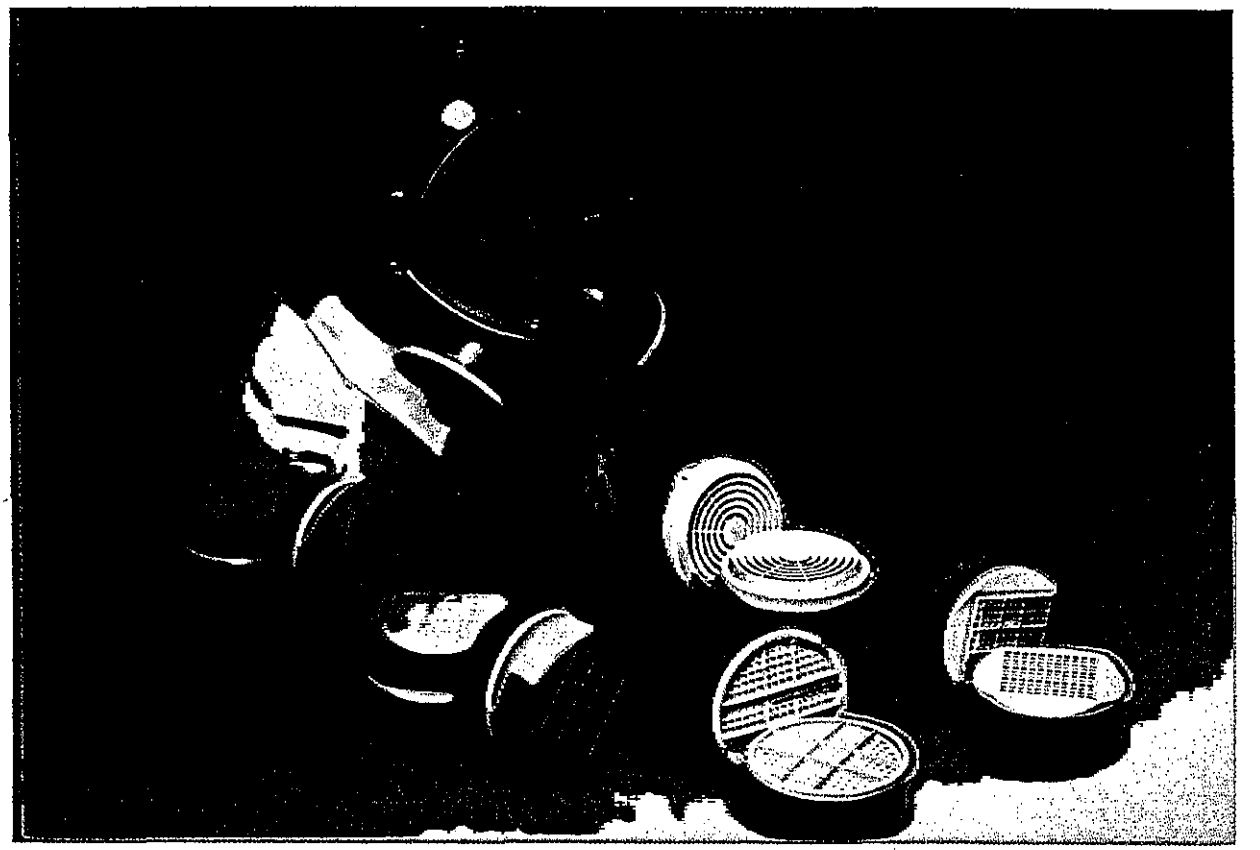
Gas/Vapor	*Maximum Use Concentration*
Mercury*	0.5 mg/m^3
Hydrogen sulfide*	100 parts per million
Chlorine dioxide	1 part per million
Formaldehyde	30 parts per million

*Respirators may be certified for gases and vapors with poor warning properties if there is a regulatory agency standard which permits their use and an effective end-of-service-life indicator is provided (Reference: FR 49 No. 140 pages 29270-29272, July 19, 1984).

b. Gas Masks

The following types of gas masks have been certified by MSHA/NIOSH:

Front- or back-mounted canisters
Chin-style canisters
Escape



Photograph Courtesy of SurvivAir

FIGURE 2-27. **Full-facepiece chemical cartridge respirator with alternate cartridges**

Front- or back-mounted. Front- or back-mounted canisters are usually certified for use with a full-facepiece. However, some half-mask or mouthpiece gas masks are certified. A "super size" or "industrial" size canister is fastened to the user's body, and a breathing tube connects the canister to the facepiece inlet. A typical front-or back-mounted canister is shown in Figure 2-28. Note that the construction does not differ markedly from that of the chemical cartridge shown in Figure 2-24. Other than the volume of sorbent contained (1000-2000 cm^3), the greatest difference is that the canister, rather than the facepiece, usually contains the inhalation valve. Figures 2-29 and 2-30 show typical front- and back-mounted canister gas masks.

Canisters can be designed for one or more type(s) of gas(es) or vapor(s). Several specific gases and vapors for which MSHA/NIOSH can issue certifications are listed in 30 CFR 11.90. In addition, MSHA/NIOSH have certified gas masks for gases and vapors not listed but which have adequate warning properties (e.g., hydrogen fluoride, formaldehyde and phosphine). MSHA/NIOSH have also certified gas masks for ethylene oxide. However, since ethylene oxide has poor warning properties, these canisters are required to have an end-of-service-life indicator.

Canisters designed for protection against more than one vapor or gas have their sorbents either arranged in layers or intermixed. Figure 2-31 shows these two arrangements as either might appear in a chin-style canister. In certain instances, one type of construction has an advantage over the other, but mostly it is a matter of manufacturing convenience.

Chin-style. Chin-style gas masks typically have a medium-sized (250-500 cm^3) canister rigidly attached to a full-facepiece (Figure 2-32). The useful lifetime is less than that of a front- or back-mounted canister (owing to the smaller sorbent volume), but greater than that of chemical cartridges. Gas masks can either be powered or non-powered. The maximum use concentration for both the front- or back-mounted and chin style gas masks is the immediately dangerous to life or health (IDLH) level of the substance.

Escape masks. Gas masks for use during escape from (not entry or reentry into) atmospheres immediately hazardous to life and health are certified under 30 CFR 11, Subpart I. They consist of a facepiece or mouthpiece, a canister, and associated connections. Where eye irritation is a consideration, a full-facepiece gas mask is necessary. An example of an escape gas mask is the "filter" self-rescuer for carbon monoxide used in escaping from mines (Figure 2-33).

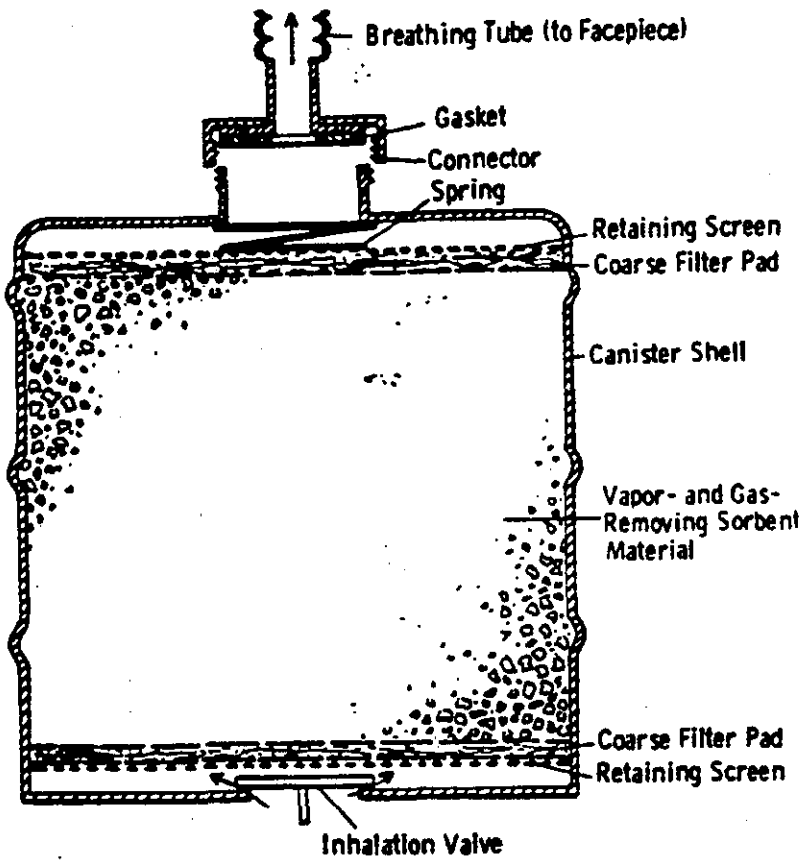


FIGURE 2-28. **Typical front- or back-mounted canister**

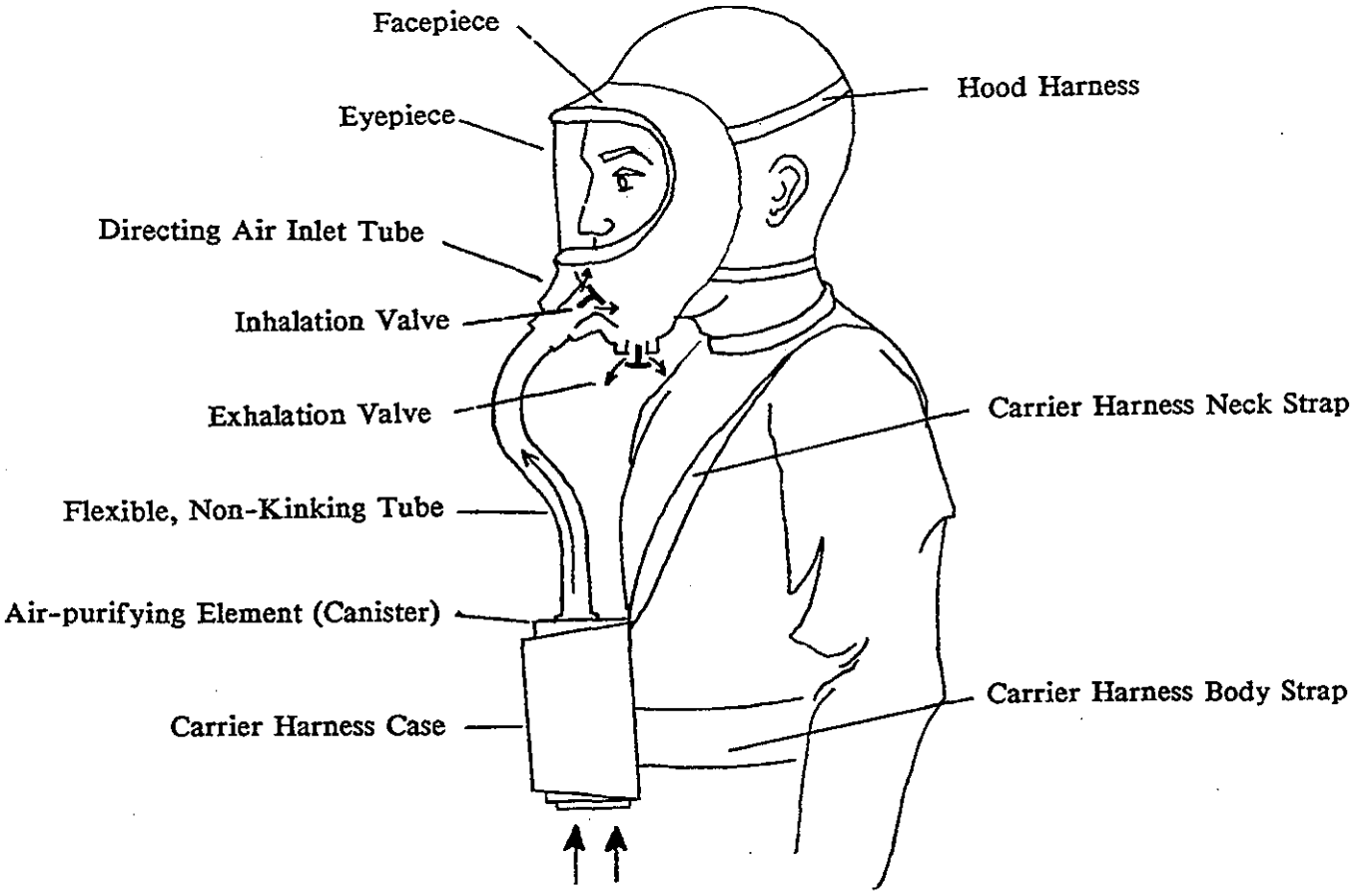


FIGURE 2-29. **Typical front- and back-mounted canister gas mask**

Photograph Courtesy of Mine Safety Appliances

FIGURE 2-30. **Typical back-mounted canister gas mask**

4

```
  CCCC  HH   HH  UU   UU  RRRRRR  LLLL     EEEEEEE YY   YY
 CC  CC HH   HH  UU   UU   RR  RR  LL       EE    E YY   YY
CC      HH   HH  UU   UU   RR  RR  LL       EE E    YY   YY
CC      HHHHHH   UU   UU   RRRRR   LL       EEEE     YYYY
CC      HH   HH  UU   UU   RR RR   LL    L  EE E      YY
 CC  CC HH   HH  UU   UU   RR  RR  LL   LL  EE    E   YY
  CCCC  HH   HH  UUUUUU  RRR  RR LLLLLLL EEEEEEE  YYYY
```

```
  11    555555   8888
 111    55      88  88
  11    55555   88  88
  11        55   8888
  11        55  88  88
  11    55  55  88  88
111111   5555    8888
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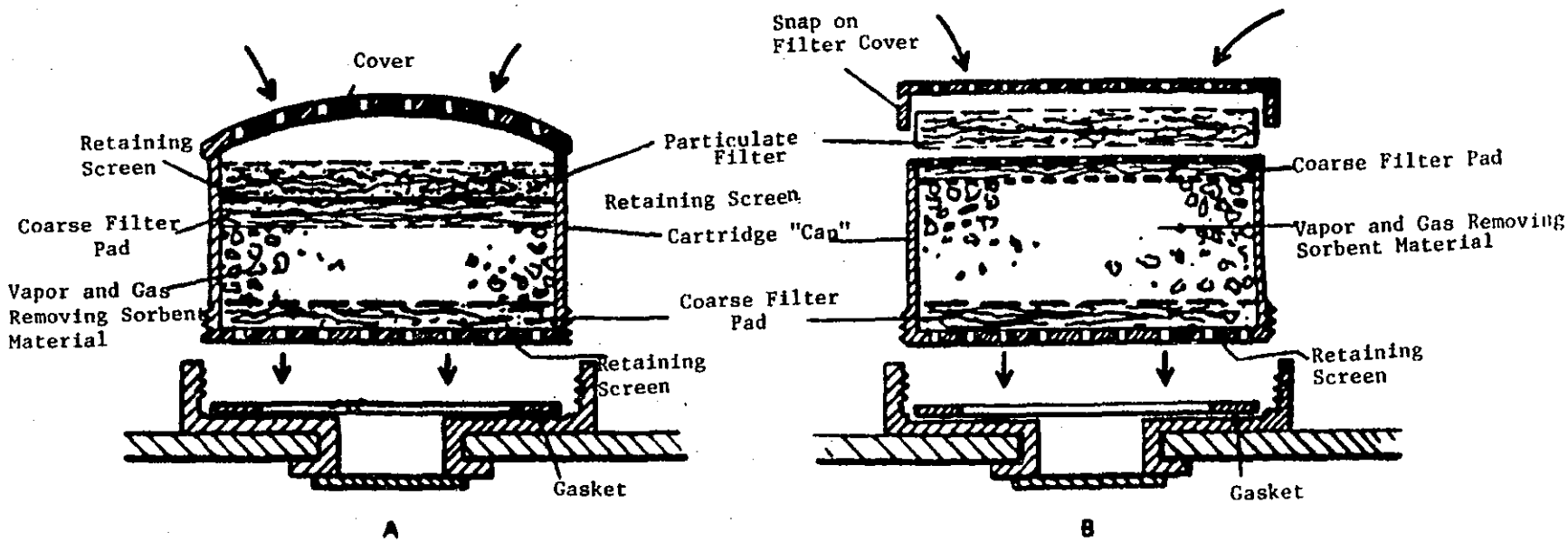


FIGURE 2-34. **Typical combination particulate- and gas- and vapor-removing cartridges**

Photograph Courtesy of SurvivAir

Photograph Courtesy of North

FIGURE 2-35. **Combination particulate-, gas- and vapor-removing respirator**

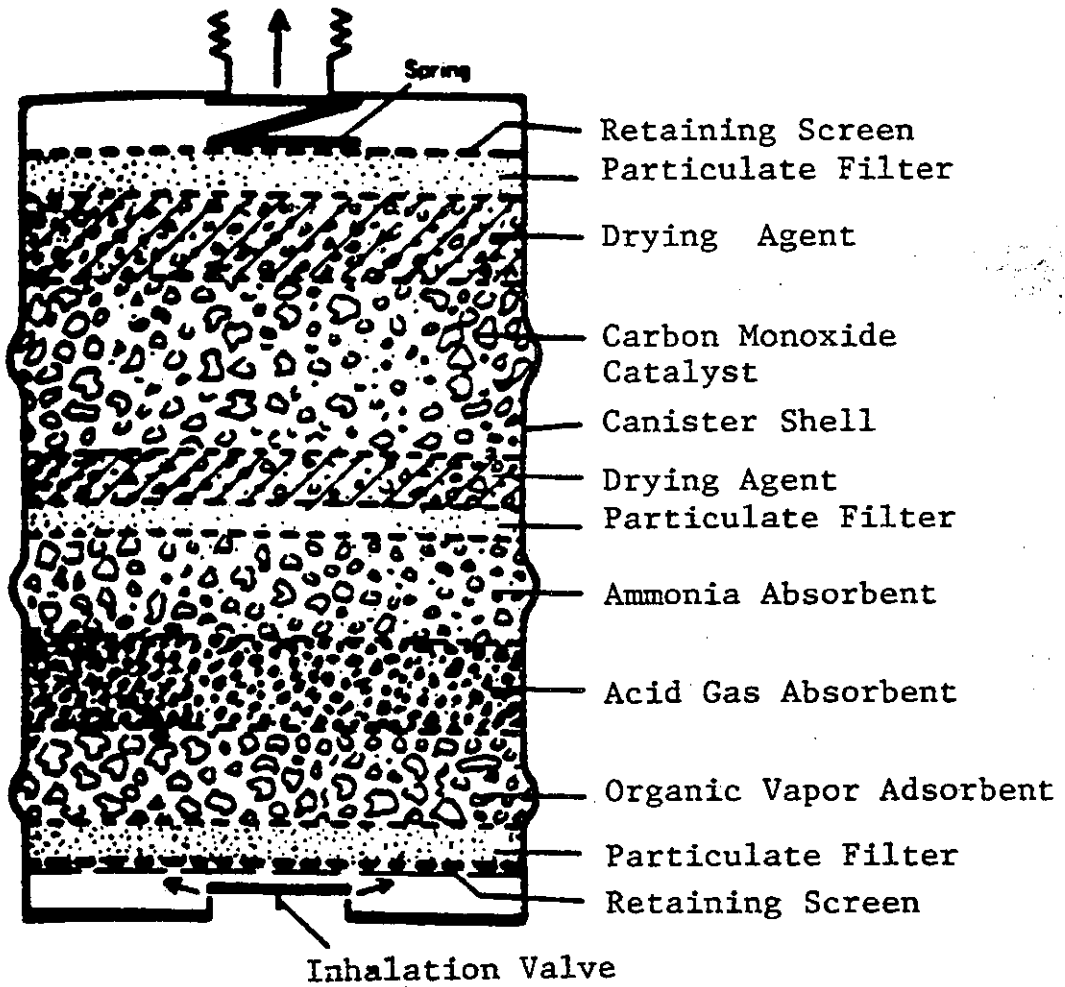


FIGURE 2-36. **Typical Type N canister**

Figure 2-37 shows a typical front-mounted Type N canister attached to a full-facepiece.

C. Powered Air-Purifying Respirators

The powered air-purifying respirator (PAPR) uses a blower to pass contaminated air through an element that removes the contaminants and supplies the purified air to a respiratory inlet covering. The purifying element may be a filter to remove particulates, a cartridge to remove vapors and gases or a combination filter and cartridge, canister or canister and filter. The covering may be a facepiece, helmet, or hood. These respirators are certified under 30 CFR 11, Subparts I, K, L, and M.

Powered air-purifying respirators come in several different configurations. One configuration consists of the air-purifying element(s) attached to a small blower which is worn on the belt and is connected to the respiratory inlet covering by a flexible tube as shown in Figure 2-38. This type of device is usually powered by a small battery (either mounted on the belt separately or as part of the blower), although some units are powered by an external DC or AC source.

Another type consists of the air-purifying element attached to a stationary blower, usually mounted on a vehicle, powered by a battery or an external power source and connected by a long flexible tube to the respiratory inlet covering.

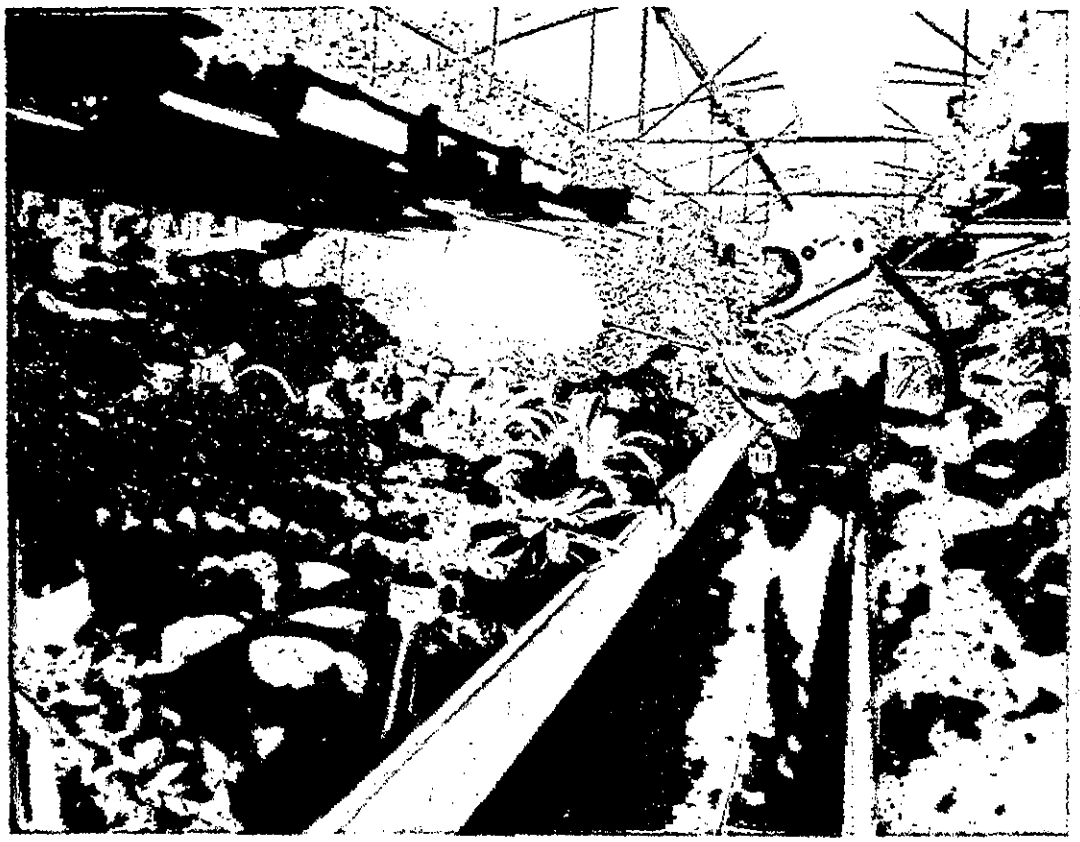
The third type of powered air-purifying respirator consists of a helmet or facepiece to which the air-purifying element and blower are attached. Only the battery is carried on the belt.

The respiratory inlet covering for a powered air-purifying respirator may be a tight fitting half-mask (Figure 2-39) or full-facepiece, or a loose fitting hood or helmet (Figure 2-40). A powered air-purifying respirator with a tight fitting facepiece must deliver at least four cubic feet of air per minute (115 liters per minute). A powered air-purifying respirator with a loose fitting hood or helmet must deliver at least six cubic feet of air (170 liters per minute) at all times.

One potential disadvantage of powered air-purifying respirators is that since there is a constant flow through the air-purifying element instead of flow only during inhalation; the useful service lifetimes of the air-purifying elements on powered air-purifying respirators could be shorter than the service lifetimes of comparable elements attached to a negative pressure respirator. In order to overcome this problem, some powered air-purifying respirators have a spring loaded exhalation valve assembly. This causes the blower assembly to slow down when the wearer exhales. This helps to extend the service lifetime of the air-purifying elements.

Photograph Couresy of Mine Safety Appliances

FIGURE 2-37. **Typical front-mount Type N canister gas mask**

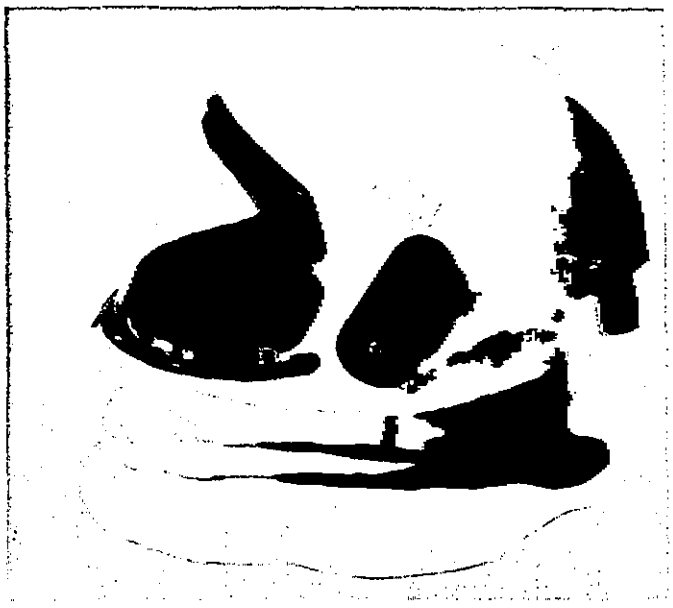


Photograph Courtesy of Kasco Inc.

FIGURE 2-38. **Powered air-purifying respirator with chemical cartridges and breathing tube**

Photograph Courtesy of Neoterik

FIGURE 2-39. **Tight fitting half-mask powered air-purifying respirator**



Photograph courtesy of 3M Company

Photograph Courtesy of Racal Airstream

FIGURE 2–40. **Helmeted powered air-purifying respirator**

Powered air-purifying respirators using chemical cartridges and canisters have the same limitations, insofar as the air-purifying elements are concerned, as the negative pressure respirators approved for the same gases or vapors.

In the past, powered air-purifying respirators were considered positive pressure respirators, since they normally supplied air at positive pressure. It was assumed that any leakage was outward from the facepiece. They were given correspondingly high protection factors. However, recent field studies by NIOSH and others have indicated that the level of protection provided by these respirators may not be as high as previously reported. Because of the potential for overbreathing at the minimum airflow rates, NIOSH now recommends much lower protection factors.

D. Advantages and Disadvantages of Air-Purifying Respirators

Air-purifying respirators are generally small and are easily maintained. (The exceptions to this are the combination Type C supplied-air and air-purifying respirator and powered air-purifying respirator.) They restrict the wearer's movements the least. The many combinations of facepieces, mouthpieces, filters, cartridges and canisters allow the user to match the respirator to the particular situation.

Air-purifying respirators should not be used in atmospheres containing less than 19.5 percent oxygen nor in atmospheres immediately dangerous to life or health (except escape gas masks). They should not be used for protection against gases or vapors with poor warning properties except for escape only or where permitted by a regulatory agency and the respirator is equipped with an end of service life indicator for that particular substance. The cost of replacement elements for air-purifying respirators can be high. Chemical cartridge respirators have fairly low maximum use concentrations, even when used with a full-facepiece.

1. Particulate Respirators

The advantages of particulate filter respirators include their light weight, small size and ease of maintenance. In general, these respirators will not affect the mobility of the worker and may present little physiological strain to the wearer. The air flow resistance of a particulate-removing respirator filter element increases as the quantity of particles it retains increases. This resistance increases the breathing resistance offered by a nonpowered respirator and may reduce the rate of air flow in a powered respirator. Filter element plugging by retained particles may also limit the continuous use time of a particulate filter type

respirator. Rapid plugging means that the element has to be replaced frequently. Elements should be replaced at least daily or more often if breathing resistance becomes excessive or if the filter suffers physical damage (tears, holes, etc.). Filter elements designed to be cleaned and reused also should be cleaned at least daily in accordance with the manufacturer's instructions. Between uses, reusable respirators should be packaged to reduce exposure to conditions which cause filter degradation, such as high humidity.

Performance of some fibrous filter materials (electrostatic felts) is hurt by storage in very humid atmospheres, so care should be taken in storing filter elements. Performance also may deteriorate during use because of water vapor or oil mists in the workplace atmosphere. Airborne liquid particles (aqueous and nonaqueous) and extremely small solid particles may deteriorate the functioning of these materials. Solid particles plug fibrous filter materials (including electrostatic felts), and, although this plugging increases the resistance to air flow and hence may exacerbate respirator faceseal leakage, significant plugging increases the materials' efficiency in removing particles from air.

2. *Vapor and Gas Removing Cartridges and Canisters*

Gas and vapor removing cartridges and canisters have the same advantages as particulate filter respirators. Certain cartridges and canisters have higher breathing resistance than particulate filter respirators and thus will present a slightly higher physiological burden to the wearer. If a vapor or gas lacks adequate warning properties (odor, taste, irritation) in a concentration above the established breathing time-weighted average concentration (TWA), a vapor and gas removing air-purifying respirator should not be used unless the respirator incorporates an adequate end of service life indicator .

Another disadvantage is the limited capacity of the cartridges and canisters in these respirators to remove vapors and gases from air, or to catalyze a reaction converting toxic vapors or gases to nontoxic products or products that can be removed from air. Theoretically, cartridges and canisters containing sorbents are totally efficient against vapors and gases until their capacity for adsorption or catalysis is exhausted. Then, the vapor or gas passes through the sorbent bed of the cartridge or canister and into the facepiece. If the wearer detects an odor or taste of gas in the inspired air, or feels eye or throat irritation, he/she should leave the hazardous area immediately and go to a safe area that contains respirable air. Then the wearer should replace the cartridge or canister. Because of the limited useful service time

of canisters and cartridges, they should be replaced daily or after each use, or even more often if the wearer detects odor, taste, or irritation. Discarding the cartridge/canister is recommended at the end of the day, even if the wearer does not detect odor, taste or irritation. This is due to the possibility of desorption of the gas or vapor occurring during overnight storage.

If a respirator wearer detects an odor, taste, or irritation for a very short time and then the sensation disappears, penetration of an air contaminant into the respiratory inlet covering has not necessarily ceased. The nerve endings that cause a sensation of odor, taste, or irritation often are fatigued or their response is dulled by low concentrations of substances. Thus, one may fail to detect low concentrations of some substances in air. This often happens when the concentration increases very slowly.

In addition to odor thresholds, users can institute change-out schedules based on reliable service-life data. Users should be warned to replace cartridges whenever they detect the odor of the substance and at the end of the service time indicated by the change-out schedule.

Some sorbents used in cartridges and canisters are harmed by high humidity, whereas others are harmed by very dry atmospheres. Therefore, when replacing these elements, unsealed cartridges and canisters should not be used. Also, remember that if the hazardous atmosphere is very moist or dry, the useful service time may be markedly reduced.

3. *Nonpowered Air-Purifying Respirators*

In addition to those limitations imposed by respiratory inlet coverings (see Chapter 2), particulate filter elements, and sorbent cartridges and canisters, further limitations of nonpowered air-purifying respirators should be considered.

An important disadvantage is the negative air pressure created inside the respiratory inlet covering during inhalation which can cause air contaminants to penetrate the covering if it fits poorly. Care should be taken to provide each wearer with a respirator that fits properly. This can best be accomplished by individual fittings and fit tests.

Other disadvantages of nonpowered air-purifying respirators include resistance to breathing and need for frequent replacement of air-purifying elements (except for disposable respirators).

4. *Powered Air-Purifying Respirators*

One advantage of powered air-purifying respirators is that they provide an airstream to the wearer. This airstream has the advantage of providing a cooling effect in warm temperatures, but can present a problem in cold temperatures. The decreased inhalation resistance makes the respirator possibly more comfortable to wear. Powered air-purifying respirators with loose fitting hoods or helmets have the advantage that since there are no large sealing surfaces on the face, some people who cannot wear a tight-fitting facepiece for such a reason as facial scars or facial hair can wear them.

Powered air-purifying respirators normally do not restrict mobility. In addition, these respirators offer minimal breathing resistance since the blower supplies the filtered air to the breathing zone of the wearer. Powered air-purifying respirators have limitations in addition to those imposed by respiratory inlet coverings, particulate filter elements and cartridges containing sorbents. A powered respirator's battery should be recharged periodically to ensure that the blower will deliver enough respirable air to the respiratory inlet covering. A battery has a limited useful life and cannot be recharged indefinitely. Battery replacement can be expensive.

The blower in most powered respirators has a high speed motor which will eventually wear out. Therefore, the blower will have to be replaced periodically. If the blower fails, the wearer of a powered respirator should go to the nearest safe area.

Other disadvantages include weight, bulk, complex design, the need for continual maintenance, at least daily replacement of air-purifying elements, and periodic replacement of batteries and blowers. Out-of-doors use presents special problems if hot or very cold air is supplied to the respiratory inlet covering.

Until recently, powered air-purifying respirators were considered positive pressure devices. Field studies by NIOSH as well as others, have indicated that these devices are not positive pressure, and that their assigned protection factors are inappropriately high.

III. Atmosphere-Supplying Respirators

Examples of respirators that provide breathing gas from a source independent of the surrounding atmosphere instead of purifying the atmosphere are shown in Figures 2-4 thru 2-6. The different types are classified according to the method by which the breathing gas is supplied and used and the method used to regulate the gas supply.

A. Self-Contained Breathing Apparatus

The distinguishing feature of all self-contained breathing apparatus (SCBA) is that the wearer need not be connected to a stationary breathing gas source, such as an air compressor. Instead, enough air or oxygen for up to 4 hours, depending on the design, is carried by the wearer. As Fig. 2-4 shows, SCBAs are classified as "closed circuit" or "open circuit."

1. Closed Circuit

Another name for closed-circuit SCBAs is "rebreather" device, indicative of the mode of operation. The breathing gas is rebreathed after the exhaled carbon dioxide has been removed and the oxygen content restored by a compressed or liquid oxygen source or an oxygen generating solid. Descriptions and certification tests for the closed-circuit apparatus are given in Subpart H of 30 CFR 11.

These devices are designed primarily for 1 to 4 hour use in oxygen deficient and/or IDLH atmospheres such as might be encountered during mine rescues or in confined spaces. They have been used since the early 1900's when the Gibbs and McCaa devices were developed. Few major design changes have been made since then, a significant commentary on their acceptance and good performance. [NOTE: 30 CFR 11 prescribes certification for mine rescue only devices that give 1-hour or more performance. Devices that give 30-minute or longer performance may be certified for auxiliary mine rescue service.]

Because negative pressure is created in the facepiece of non-positive pressure apparatus during inhalation, there is increased leakage potential. Therefore, negative pressure closed-circuit SCBA should be used in atmospheres immediately dangerous to life or health (IDLH) only where their long term use capability is necessary, as in mine rescue. For use in oxygen deficient atmospheres over long periods, closed-circuit SCBA are satisfactory. Positive pressure closed-circuit SCBA are a significant new respirator development and are described in Chapter 6, **New Developments at NIOSH.**

Two basic types of closed-circuit SCBA are presently available. One uses a cylinder of compressed oxygen and the other a solid oxygen generating substance. Figure 2-41 shows a typical closed-circuit SCBA with a small 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. The advantage of the rebreathing process is that only the oxygen supply need be provided, as all the other air constituents except the waste carbon dioxide are recirculated. The advantage of this type of device is its long term (1- to 4-hour) protection. Disadvantages include the bulk of the SCBA and the negative pressure created in the facepiece during inhalation from some closed-circuit SCBA. As previously discussed, it is now possible for certification of positive pressure devices which offer a higher level of protection. Figure 2-42 shows a closed-circuit SCBA in use.

The second type of closed-circuit SCBA (Fig. 2-43) uses an oxygen-generating solid, usually potassium superoxide (KO_2). The H_2O and CO_2 in the exhaled breath react with the KO_2 to release O_2.

$$2\ KO_2 + CO_2 + H_2O \text{ --> } K_2CO_3 + 1.5\ O_2 + H_2O,$$
$$2\ KO_2 + 2CO_2 + H_2O \text{ --> } 2KH\ CO_3 + 1.5\ O_2.$$

The O_2 is not released until the wearer's exhaled breath reaches the canister. Thus, there is a short time lag between when the canister is initiated and O_2 flow begins. This has been overcome in some devices by providing a "quick start" feature known as a chlorate candle, a canister section filled with mixed sodium chlorate and iron. Oxygen flow is started by striking the device, somewhat like lighting a match. This is designed to provide enough oxygen until the potassium superoxide in the canister begins to function.

Oxygen is continually released at a high flow rate into the breathing bag(s) which acts as a reservoir to accommodate breathing fluctuations. A pressure relief valve and saliva trap release the excess pressure created in the facepiece by oxygen flow and nitrogen buildup.

This closed-circuit apparatus is lighter and simpler than the cylinder type. However, it is useful for only about one hour and, once initiated, cannot be turned off. The precautions are the same as for the compressed oxygen unit.

Recently, as a result of regulations promulgated by MSHA under the Coal Mine Health and Safety Act, a new device of closed-circuit SCBA, known as a self-contained self-rescuer (SCSR) was certified for use in underground mines in emergency situations. These devices are similar in design and operation as those already described. They include both compressed-oxygen and oxygen-generating types and offer a duration of one hour.

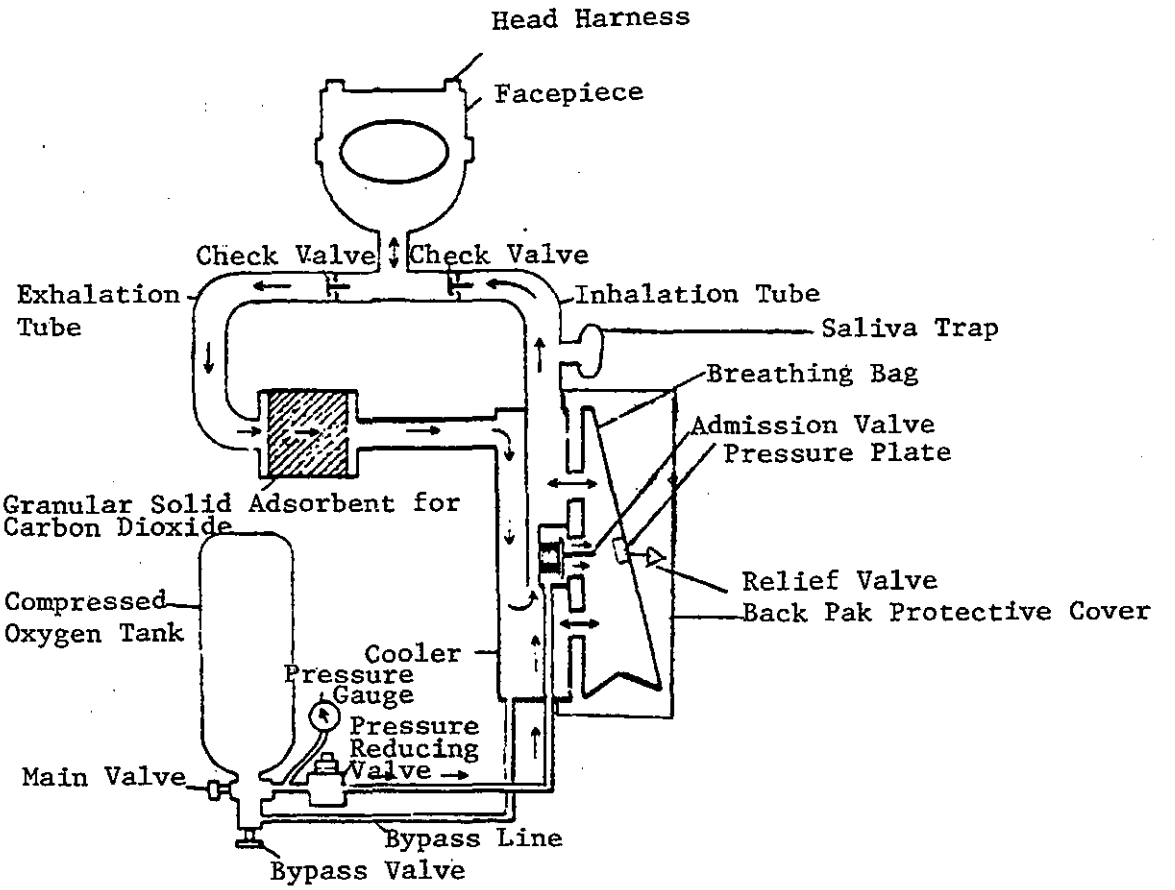
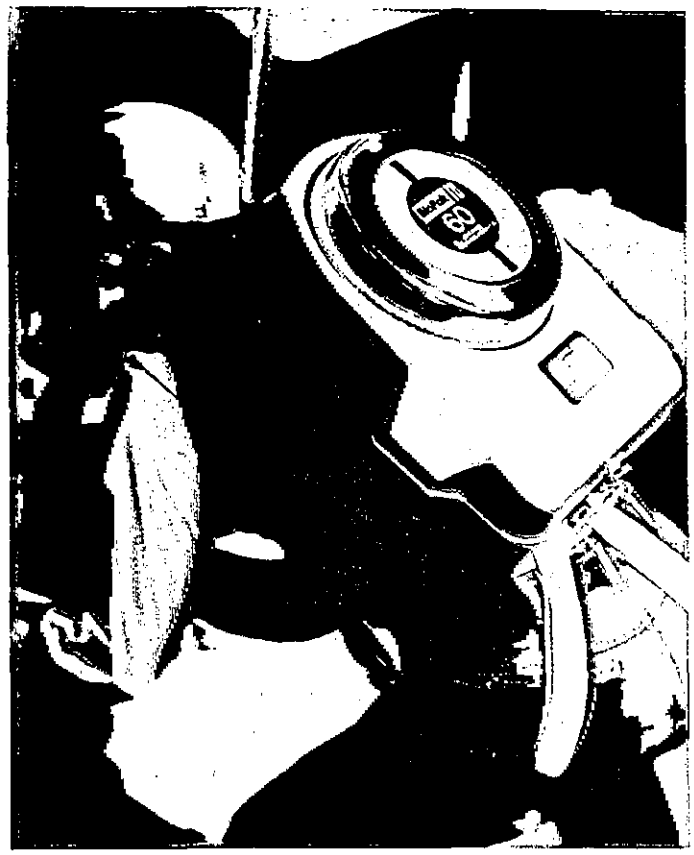


FIGURE 2-41. **Closed-circuit SCBA**

Photograph Courtesy of Draegerwerk



Photograph Courtesy of Rexnord

FIGURE 2-42. **Closed-circuit SCBA**

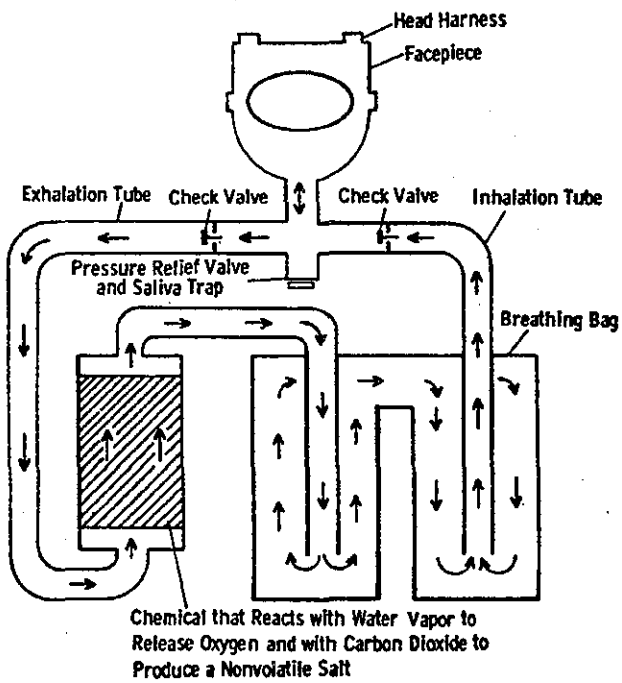


FIGURE 2-43. **Oxygen-generating closed-circuit SCBA**

SCSR are much smaller and weigh considerably less than closed-circuit SCBA for entry. Their weights range between 7 and 16 pounds. The SCSR are escape only apparatus and need not meet all the entry unit requirements of 30 CFR 11. Factors contributing to size and weight reduction include: a mouthpiece in place of a facepiece; the elimination of structural breathing bag protection; filament wound pressure gas vessels; smaller candles; lighter breathing bag material; single pendulum flow breathing tube; the elimination of bypass valve and warning whistle requirements; a more efficient utilization of carbon dioxide sorbent and/or oxygen-generating chemicals; lighter weight packaging material; and others. Figure 2-44 shows an oxygen-generating SCSR. These devices are not usually worn by the miner during mining operations as were the former filter self-rescuers (CO scrubbing only or air-purifying respirators), because they are larger and heavier than the filter self-rescuer. MSHA has strict enforceable storage and location requirements for SCSR. Since they are sealed and may not be opened except for emergency use, there are specific daily and 90 day required SCSR inspection periods and inspection procedures. SCSR with pressure vessels use active pressure gauge indicators. The chemical SCSR use passive storage life color indicators and inspection criteria.

2. Open Circuit

An open-circuit SCBA exhausts the exhaled air to the atmosphere instead of recirculating it. 30 CFR 11 does not specify which breathing gas must be used for these devices, but it is almost always compressed air. Compressed oxygen cannot be used in a device designed for compressed air because minute amounts of oil or other foreign matter in the device components can cause an explosion. In fact, 30 CFR 11 prohibits certification of any device designed to permit interchangeable use of oxygen and air. It is an accepted safety rule that :

OXYGEN NEVER BE USED IN A DEVICE UNLESS IT IS SPECIFICALLY DESIGNED FOR THAT PURPOSE.

Figure 2-45 shows typical open-circuit SCBA. A cylinder of high pressure (2000-4500 psi) compressed air supplies air to a regulator that reduces the pressure for delivery to the facepiece. This regulator also serves as a flow regulator by passing air to the facepiece on demand. The regulator is either mounted directly to the facepiece or a flexible corrugated hose connects the regulator to the respiratory inlet covering, usually a full-facepiece.

Photograph Courtesy of Draegerwerk

FIGURE 2-44. **Oxygen-generating self-contained self-rescuer**

Photograph Courtesy of Scott Aviation

Photograph Courtesy of Survivair

FIGURE 2-45. **Open-circuit SCBA**

Because it has to provide the total breathing volume requirements, since there is no recirculation, the service life of the open-circuit SCBA is usually shorter than the closed-circuit SCBA. Most open-circuit SCBA have a service life of 30 minutes to 60 minutes based on NIOSH breathing machine tests as prescribed in 30 CFR 11 (11.85-10). NIOSH certifies units with less than 1 hour, but not less than 30 minutes service for auxiliary mine rescue. Open-circuit SCBA are widely used in fire fighting and for industrial emergencies. SCBA with less than 30 minutes service time are certified, generally for escape use only. Escape SCBAs are also certified in combination with supplied-air, airline respirators.

Two types of open-circuit SCBA are available, "demand" or "pressure demand." The difference is very important and best explained by describing the operation of a typical open-circuit SCBA regulator. In a "demand" or negative pressure type regulator, air at approximately 2000 psi is supplied to the regulator through the main valve (Fig. 2-46). A bypass valve passes air to the facepiece in case of regulator failure. Downstream from the main valve, a two-stage regulator reduces the pressure to approximately 50-100 psi at the admission valve, which is actuated by movement of a diaphragm and its associated levers. The admission valve stays closed as long as positive pressure in the facepiece (during exhalation) forces the diaphragm away from the valve assembly. Inhalation creates negative pressure in the facepiece, and the diaphragm contracts, opening the admission valve and allowing air into the facepiece. In other words, air flows into the facepiece only on "demand" by the wearer, hence the name.

Recent studies indicate that a demand-type SCBA is no more protective than an air-purifying respirator with the same facepiece. Therefore, a demand-type open-circuit SCBA should not be used in IDLH atmospheres. Like closed-circuit SCBA, however, they may be adequate against oxygen-deficient atmospheres.

A pressure-demand or positive pressure regulator is very similar to a demand type except that there is usually a spring between the diaphragm and the outside case of the regulator. This spring tends to hold the admission valve slightly open, theoretically allowing continual air flow into the facepiece. This would be true except that all pressure-demand devices have a special exhalation valve that maintains about 1.5-3 inches H_2O positive back pressure in the facepiece, and opens only when the pressure exceeds that value. This combination of modified regulator and special exhalation valve is designed to maintain positive pressure in the facepiece at all times. Under certain conditions of work a momentary negative pressure may occur in the wearer's breathing zone, although the regulator still supplies additional air on

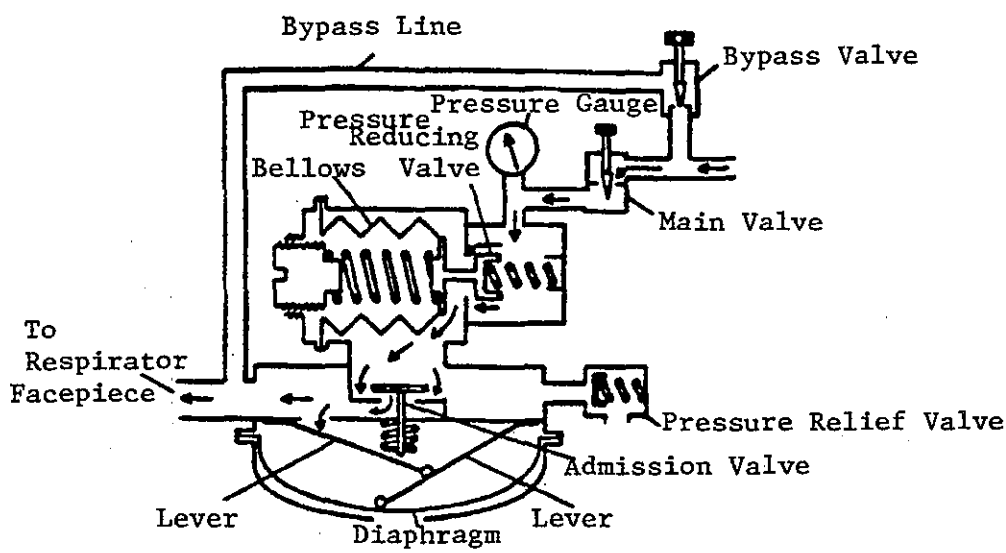


FIGURE 2-46. **Open-circuit demand SCBA regulator**

"demand." Because of the positive pressure, any leakage should be outward; therefore, a pressure-demand SCBA provides very good protection. Contrary to common belief, the pressure-demand SCBA has the same service time as a demand version of the same device, if it seals well on the wearer's face. Any leakage increases air consumption and decreases service time.

A FACEPIECE WHOSE EXHALATION VALVE IS DESIGNED FOR DEMAND OPERATION CANNOT BE USED WITH A PRESSURE-DEMAND REGULATOR, AS AIR WILL FLOW CONTINUALLY AND QUICKLY EXHAUST THE AIR SUPPLY.

Some open-circuit SCBA can be switched from demand to pressure-demand operation. The demand mode should be used only for donning and adjusting the apparatus in order to conserve air and should be switched to "pressure demand" for actual use.

Several required safety features on all certified entry (both closed and open circuit) SCBA provide additional protection. Among these are:

- pressure gauges or liquid level gauges visible to the wearer which indicate the quantity of gas or liquid (air or oxygen) remaining in the cylinder

- remaining service life indicators or warning devices that signal alarm when only 20-25% of service time or service volume remains

- bypass valves, in case the first and second stage reducer or regulator fails and it is necessary to conserve or provide respirable air

- fittings on devices that use compressed or liquid oxygen which are incompatible with compressed or liquid air fittings.

The choice of demand or pressure-demand open-circuit SCBA should be based on thorough evaluation of the respiratory hazards. MSHA and NIOSH continue to issue certifications for both types since the demand type is still used in many industrial applications. In a potentially IDLH atmosphere, a pressure-demand SCBA should most certainly be used.

In addition to entry, SCBA are also certified for escape from IDLH. These escape-only SCBA are generally of short duration, that is, 3, 5 or 10 minutes, and are small in both size and weight. The compressed-air container is usually hip- or back-mounted with the air valve in a readily accessible position

for immediate activation. The facepiece may be donned quickly by simply tightening the headband straps or a hood may be furnished for quick donning of the escape SCBA. Figure 2-47 shows two hood-type, escape-only SCBA.

B. Supplied-Air Respirators

1. Airline respirators (Types C and CE)

Airline respirators as described in 30 CFR 11, Subpart J use compressed air from a stationary source delivered through a hose under pressure. 30 CFR 11 specifies that the pressure shall not exceed 125 psi at the point where the hose attaches to the air supply. A manufacturer submitting an airline respirator for certification must specify the operating pressure and the hose length, from 25 to 300 feet. At the lowest pressure and longest hose length, the device must deliver at least 170 Lpm to a helmet or hood. At the highest pressure and shortest hose length the flowrate must not exceed 425 Lpm to a helmet or hood. The equivalent airflows to a tight-fitting facepiece are 115 Lpm and 425 Lpm, respectively.

Airline respirators are available in demand, pressure-demand, and continuous-flow configurations (see Figure 2-5). The respiratory inlet covering may be a facepiece, helmet, hood, or complete suit, although there are presently no approval tests for suits.

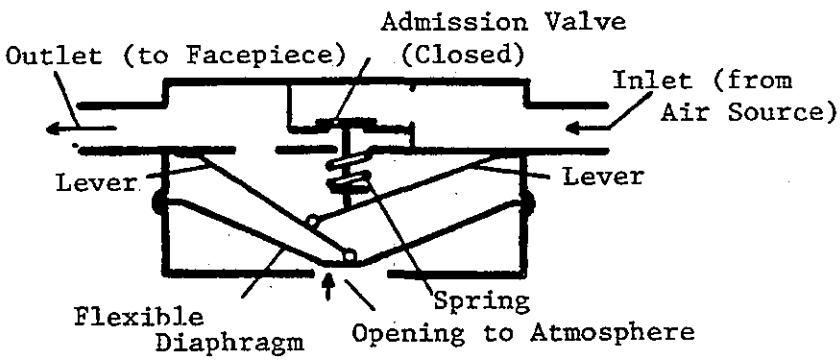
A demand or pressure-demand airline respirator is very similar in basic operation to a demand or pressure-demand open circuit SCBA, except that the air is supplied through a small diameter hose from a stationary source of compressed air rather than from a portable air source. Because the air pressure is limited to 125 psi, regulators for demand and pressure-demand airline respirators need only single stage reduction. Otherwise, the demand and pressure-demand airline regulators are similar in operation to the demand and pressure-demand SCBA regulators respectively. Figure 2-48 shows a typical demand type regulator. Figure 2-49 shows a typical pressure-demand airline respirator with a tight-fitting facepiece. Note that the regulator sometimes is mounted on the facepiece or worn on the wearer's chest.

Continuous-flow airline respirators maintain air flow at all times, rather than only on demand. In place of a demand or pressure-demand regulator, an air flow control valve or orifice partially controls the air flow. According to 30 CFR 11, a flow of at least 115 Lpm to a tight fitting facepiece and 170 Lpm to

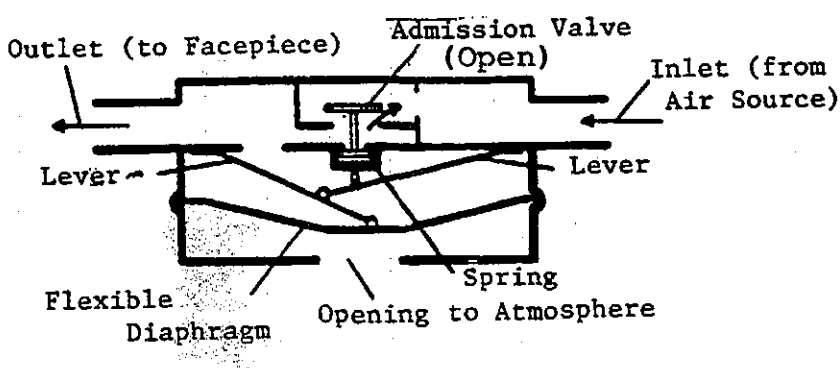
Photograph Courtesy of ISI

Photograph Courtesy of North

FIGURE 2-47. **Typical escape-only ESCBA**

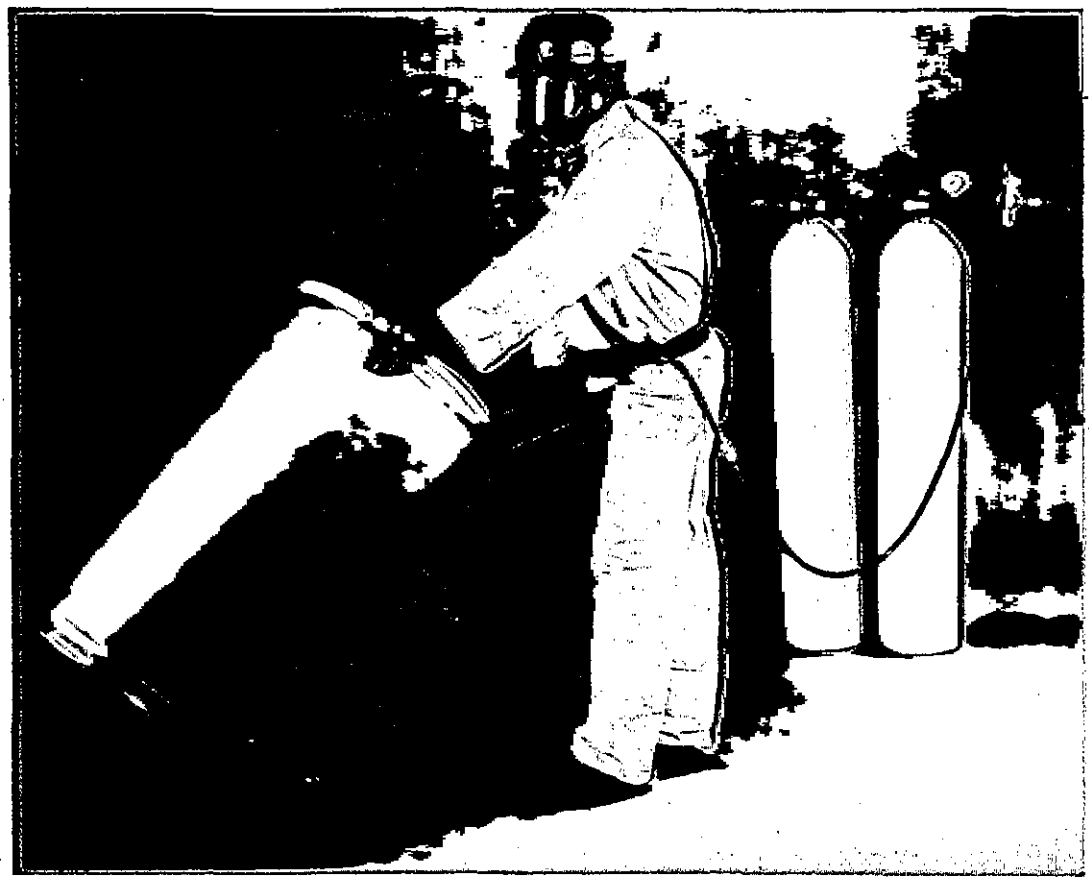


EXHALATION. High pressure of exhaled air stretches diaphragm. Resulting lever movement and spring action close admission valve, and air flow ceases.



INHALATION. Low pressure created by inhalation pulls diaphragm inward. Resulting lever movement compresses spring and opens admission valve. Air flows through valve.

FIGURE 2-48. **Typical demand-type air flow regulator**



Photograph Courtesy of ISI

FIGURE 2-49. **Pressure-demand airline respirator**

a loose-fitting hood or helmet must be maintained at lowest air pressure and longest hose length specified. This means that by design, either the control valve cannot be closed completely, or a continually open bypass is provided to allow air to flow around the valve and maintain the required minimum rates.

Some special valves known as vortex tubes are available with some certified airline respirators. These valves fractionate the airstream into two high speed airflow components. One component becomes cool from adiabatic expansion while the other component becomes warm from adiabatic compression. Either component can be utilized in valve design to cool or heat the respirable air provided to the user for comfort and physiological support.

Figure 2-50 depicts a typical continuous-flow airline respirator with a tight-fitting facepiece. Notice the air-purifying element on the air-supply line. Figure 2-51 shows typical airline respirators, which may be obtained with half masks and full-facepieces. Figure 2-52 shows continuous-flow airline respirators with hoods.

Although addition of an air-purifying element in the supply line upstream of the air-supply hose attachment can help clean the air, other precautions also should be taken to ensure breathing air quality. The air supply to airline respirators is required to meet the requirements for Type I gaseous air (Grade D or higher quality) set forth by the Compressed Gas Association Commodity Specification for Air, G-7.1. Furthermore, OSHA requires that a breathing air compressor have certain safety devices to protect the air quality (see Chapter 3).

Airline respirators with special items to protect the wearer's head and neck from rebounding abrasive material may have facepieces, helmets, or hoods. Plastic, glass, and metal wire screen are used to protect the lenses of facepieces and the windows of helmets and hoods against the rebounding material. These respirators are known as abrasive-blasting airline respirators or Type "CE" supplied-air respirators.

Figure 2-53 shows Type "CE" respirators in use. Note the protective screen over the lens and the heavy apron on the abrasive- blasting hood.

Full suit airline respirators are available. They provide air not only for breathing but also to isolate the whole body from the surrounding atmosphere. They are used against substances that irritate or corrode the skin or which may penetrate the

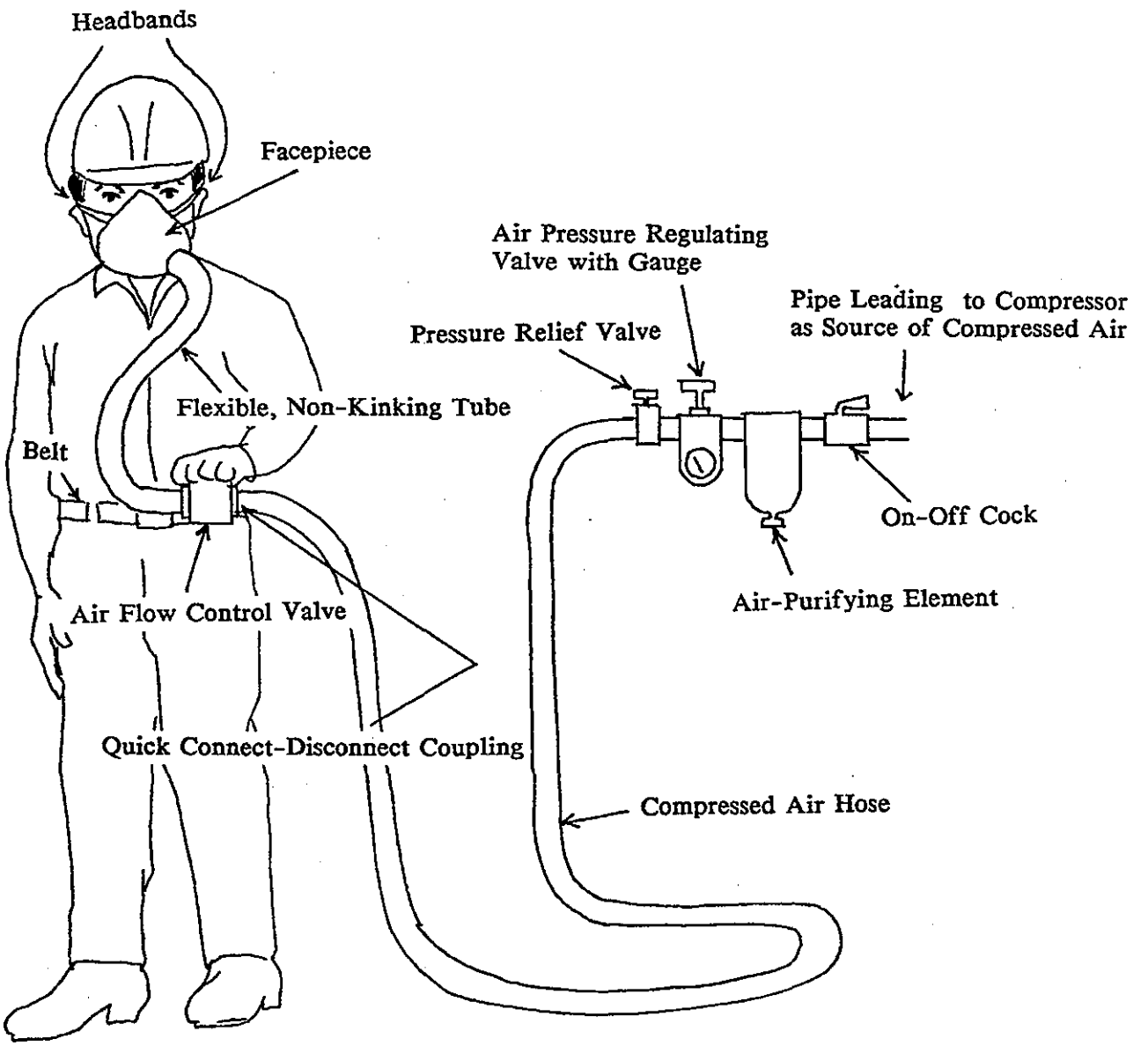


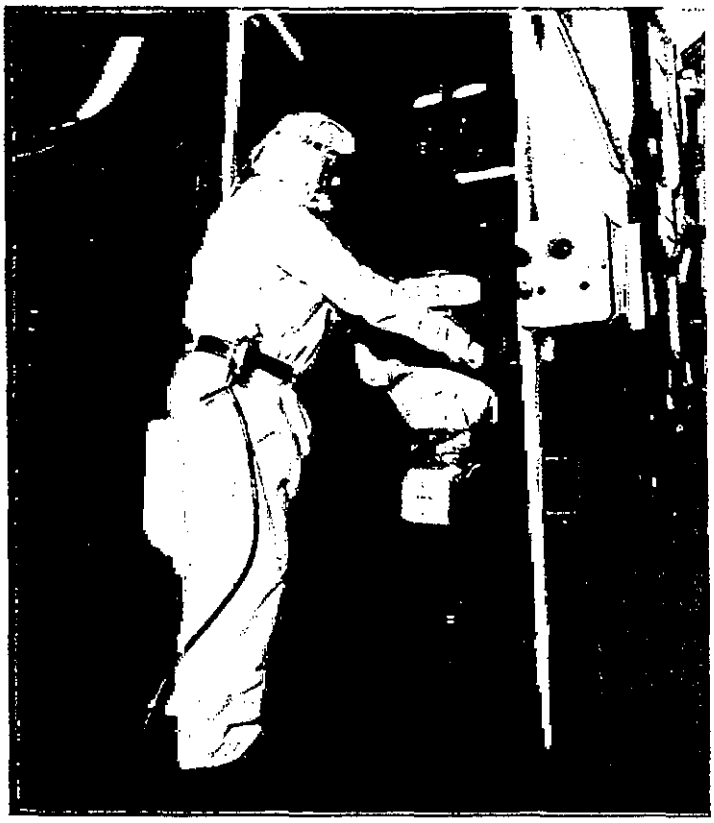
FIGURE 2-50. **Continuous-flow airline respirator**

Photograph Courtesy of U.S. Safety Service

Photograph Courtesy of Willson Safety Products

FIGURE 2-51. **Half mask and full-facepiece continous flow airline respirators**

Photograph Courtesy of Standard Safety Equipment

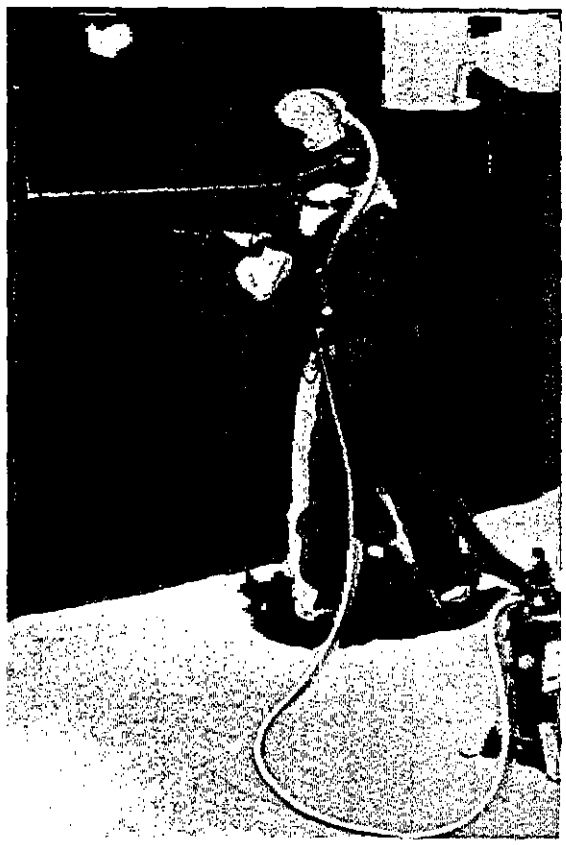


Photograph Courtesy of Safety Products Limited

Photograph Courtesy of Mohawk Industries

FIGURE 2-52. **Continuous flow airline respirators with hoods**

Photograph Courtesy of Bullard



Photograph Courtesy of Clemco

FIGURE 2-53. **Typical Type CE abrasive-blast airline respirator**

skin to produce toxic effects. Presently, 30 CFR 11 does not provide for certification of airline suits.

2. Hose Masks

Hose masks supply air from an uncontaminated source through a strong, large diameter hose to a respiratory inlet covering. Two types are available. One has a hand or motor operated air blower that pushes low pressure air through the hose to the respiratory inlet covering. The blower is designed so that air flows freely through it when it is not in operation. Therefore, if the blower fails, the wearer can still inhale respirable air by normal breathing. The other type of hose mask has no blower and requires the wearer to inhale through the hose.

The hose mask with a blower is categorized by 30 CFR 11 Subpart J as a Type "A" supplied-air respirator and is certified for use in atmospheres not immediately dangerous to life or health. The hose mask without a blower is categorized as Type "B" and is certified for use only in atmospheres not immediately dangerous to life or health. The hose mask with blower may have a facepiece, helmet, or hood, but the hose mask without blower must have a tight fitting facepiece. Hose masks may have special equipment to protect the wearer's head and neck from rebounding material during abrasive blasting. Such a hose mask with blower is classified as a Type "AE" supplied-air respirator, and the one without blower is classified as Type "BE."

A certified hose mask with blower may have up to 300 feet of air supply hose in multiples of 25 feet, but one without blower may have only up to 75 feet in multiples of 25 feet. The hand or motor operated blower must deliver air through the maximum length of hose at not less than 50 Lpm. The motor operated blower of a device with 50 feet of hose must deliver no more than 150 Lpm. However, no maximum air flow rate is specified for the hand operated blower.

Currently there are only three hose masks certified. They are not widely used in industrial applications. They are heavy, cumbersome and offer only a very low protection factor.

C. Combination Respirators

MSHA/NIOSH may certify respirators assembled from two or more types of respirators in combination as prescribed in 30 CFR 11.63(b).

To date MSHA/NIOSH have certified several types of air-purifying units or SCBA in combination with the Type C supplied-air respirator.

1. *Combination Supplied-Air/Air-Purifying Respirator*

One type of combination respirator that MSHA/NIOSH has certified is the Type C supplied-air and air-purifying respirator as shown in Figure 2-54. These devices are certified under the class of the air-purifying element since it is the component in the combination which provides the least protection to the user. This type of respirator consists of facepiece; regulator or control valve, if necessary; breathing tube, if necessary; belt or harness; supplied-air hose; and air-purifying element. The air-purifying element may be a canister, chemical cartridge, or particulate filter. It is mounted either directly on the facepiece or on an adapter which is worn on the belt.

The supplied-air portion of the respirator can be either Type C continuous-flow or pressure-demand.

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 air-purifying element weighs less than a self-contained breathing apparatus cylinder. The disadvantage is that they have the limitations of the air-purifying element, and therefore, can be used only for specific conditions. Depending upon the specific respirator, the air-purifying element will have one of the following restrictions (consult the certification label of the respirator to determine which applies):

a. no restrictions

b. air-purifying element can be used only to: (1) enter prior to connecting to air supply, (2) egress after disconnecting or loss of air, or (3) to move from one air supply to another

c. escape only after loss of air.

2. *Combination Supplied-Air/SCBA Respirator*

To be usable in an IDLH atmosphere, an airline respirator must have an auxiliary air supply to protect against potential failure of the primary supply. This is provided by adding a self-contained cylinder of high pressure compressed air to a Type "C" or "CE" airline respirator. The auxiliary air supply may be certified for 3-, 5-, or 10-minute service time, or for 15 minutes or longer (see Figure 2-55). The certification tests for these combination devices are found in 30 CFR 11, Subpart H, "Self-Contained Breathing Apparatus." The devices shown in Figure 2-55 are only representative of this general class; designs vary widely.

Photograph Courtesy of North Safety Products, Inc.

Photograph Courtesy of Racal Airstream

FIGURE 2-54. **Combination supplied-air respirator with escape only high efficiency filter**

Photograph Courtesy of Powermaster, Inc.

Photograph Courtesy of Interspiro

FIGURE 2-55. **Combination supplied-air/SCBA**

Because of the short service time of the self-contained breathing air supply, combination units generally are used for emergency entry into and escape from IDLH atmospheres. The self-contained portion of the device is used only when the airline portion fails and the wearer must escape, or when it may be necessary to disconnect the air line temporarily while changing locations. A combination airline and SCBA may be used for emergency entry into a hazardous atmosphere (to connect the airline), if the SCBA part is classified for 15 minutes or longer service and not more than 20% of the air supply's rated capacity is used during entry. It is seldom used as a routine means of protection, as the open-circuit SCBA might be.

D. Advantages and Disadvantages of Atmosphere-Supplying Respirators

1. Airline Respirators

A great advantage of the airline respirator is that it may be used for long continuous periods. Other advantages are minimal breathing resistance and discomfort, light weight, low bulk, moderate initial cost, and relatively low operating cost.

The biggest disadvantage of supplied-air respirators is that loss of the source of respirable air supplied to the respiratory inlet covering eliminates any protection to the wearer. Such loss may be caused by cutting, burning, kinking, or crushing the supply air hose, by air compressor failure, or by depletion of the respirable air in a storage tank. Possible loss of respirable air supports the NIOSH recommendation against airline respirator use in IDLH atmospheres. However, an airline respirator with an auxiliary self-contained air supply could be used in such atmospheres because the auxiliary self-contained air supply always can be used in escape.

The trailing air supply hose of the airline respirator severely restricts the wearer's mobility. This may make the airline respirator unsuitable for those who move frequently between widely separated work stations. A combination airline and self-contained breathing apparatus may be suitable if the supply of self-contained breathing air is adequate for the time required to move from place to place. A coiled airline hose provided with some MSHA/NIOSH certified devices will further promote wearer mobility at the worksite.

Airline respirators that operate in the demand mode have negative air pressure inside the respiratory inlet covering during inhalation which permits the contaminated atmosphere to leak into the respiratory inlet covering if it fits poorly. However, airline respirators that operate in the pressure-demand mode are designed

to have positive air pressure inside the respiratory inlet covering which helps to ensure that contaminated air will not leak in. Thus, an airline respirator operating in the pressure-demand mode provides much better protection than one that operates in the demand mode.

2. *Hose Masks*

Advantages of the hose mask without blower are its theoretically long use periods and its simple construction, low bulk, easy maintenance, and minimal operating cost. An advantage of the hose mask with blower is its minimal resistance to breathing.

Obviously, air pressure inside the respiratory inlet covering of the hose mask with no blower is negative during inhalation, so contaminated air may leak in if the covering fits poorly. Therefore, hose masks, with and without blower, are certified only for use in non-IDLH atmospheres.

The trailing air supply hose of the hose mask also severely limits mobility, so it may be unsuitable for those who move frequently among widely separated work stations.

A severe restriction of the hose mask without blower is that it is limited to a maximum hose length of only 75 ft. Also, it requires the wearer to inhale against the resistance to air flow offered by the air hose which may become significant during heavy work. Inhaling against this resistance strains the wearer and may cause fatigue.

3. *Self-Contained Breathing Apparatus*

Because the SCBA wearer carries his own supply of respirable air, he is independent of the surrounding atmosphere. A great advantage of such apparatus is that it allows comparatively free movement over an unlimited area.

The bulk and weight of most SCBAs make them unsuitable for strenuous work or use in a constricted space. The limited service life makes them unsuitable for routine use for long continuous periods. The short service life of open-circuit type devices may limit them to use where the wearer can go conveniently and quickly from a hazardous atmosphere to a safe atmosphere to change the tank of supply air.

Open-circuit SCBA are normally less expensive to purchase and use than closed-circuit SCBA. Additionally, the open-circuit SCBA requires less maintenance and fewer inspections.

The demand-type open-circuit SCBA and most closed-circuit SCBA have negative air pressure inside the respiratory inlet covering during inhalation so contaminated air can leak in if they fit poorly. The pressure-demand type open-circuit SCBA and those closed-circuit SCBA that are positive pressure devices provide very good protection because the air inside the respiratory inlet covering is normally at positive pressure which helps to keep the contaminated atmosphere from leaking in.

CHAPTER 3

RESPIRATOR SELECTION

I. Regulatory Requirements

The selection, use, and maintenance of respirators in the United States is presently regulated by several Federal agencies. The agencies, the acts which authorize their activities, and the current regulations relating to selection, use, and maintenance of respirators, are as follows:

Act	Agency	Regulation(s)
Federal Mine Safety and Health Act of 1977	Mine Safety and Health Administration; Department of Labor	Title 30 CFR Parts 11 , 70
	National Institute for Occupational Safety and Health, Centers for Disease Control, Department of Health and Human Services	Title 30 CFR Part 11
Occupational Safety and Health Act of 1970	Occupational Safety and Health Administration, Department of Labor	Title 29 CFR Part 1910
Toxic Substances Control Act	Environmental Protection Agency	Title 40 CFR Part 750
Title II of the Energy Reorganization Act of 1974	Nuclear Regulatory Commission	Title 10 CFR Part 20

The Federal regulations cited above and Guidelines issued in accordance with those regulations, with few exceptions, call for selection and use of respirators that have been certified by MSHA and NIOSH. Exceptions to that principle include the MSHA allowance of use of certain Bureau of Mines-approved mine rescue breathing apparatus, the OSHA acceptance of cylinder interchange and "buddy breathing systems" for use by fire fighters in 29 CFR 1910.156, and the NRC acceptance of supplied-air suits tested by Los Alamos National Laboratory.

Since 1972, with promulgation of Title 30 CFR 11, MSHA and NIOSH have tested and certified various types of respiratory protective devices. The present regulations in Part 11 are the result of amendment of the 1972 regulation. NIOSH currently recognizes that certain requirements of Part 11 are inadequate and incomplete, and a proposed revision of Part 11 has been published for public comment as a Notice of Proposed Rulemaking 42 CFR Part 84. Final publication is expected following a public hearing and further revision of Part 84.

II. General Selection Information

NIOSH recommends that respirators only be used when engineering controls are not feasible or effective, while controls are being installed or repaired, or for emergency and other temporary (intermittent) situations. Respirator selection is very complex and should be performed by an Industrial Hygienist or other professional knowledgeable in respiratory protective devices.

In 1975, NIOSH and the Occupational Safety and Health Administration (OSHA) as part of the Standards Completion Program developed a Respirator Decision Logic. That Logic incorporated fit factor data developed by the Los Alamos National Laboratory (LANL) under contract to NIOSH and incorporated requirements from 30 CFR 11.

The Decision Logic was modified by NIOSH in 1987 to include:

1. the NIOSH respirator carcinogen policy,

2. respiratory protective devices developed since 1975, and

3. a revision of assigned protection factors for those respirators for which valid workplace protection factor studies had been performed.

The selection of a specific respirator should be made by individuals knowledgeable of the limitations associated with each class of respirator (see Chapter 2), and familiar with the actual work environment including job tasks to be performed. For example, mobility of the worker and temperature and humidity of the work environment should all be considered in making an adequate respirator selection.

III. NIOSH Respirator Decision Logic

The NIOSH Respirator Decision Logic is reproduced as part of Appendix E of this document. This Logic contains a set of questions which will lead the user to the proper respirator selection table and identifies the criteria necessary to determine the classes of respirators which will provide adequate protection.

IV. NIOSH Certified Equipment List

The *NIOSH Certified Equipment List* (NCE) is published annually and lists the coal mine dust personal sampler units and respirators certified by NIOSH as well as provides updated information on the products, certifications, respirator complaints and problems, and NIOSH respirator policy.

In 1985, the format of this publication was modified. Respirators are now listed by specific certification class. General cautions and limitations for each certification class are listed (see page 84). However, these limitations are by no means all inclusive. The respirator manufacturer may also identify further limitations or cautions for their respirators. In addition, regulatory agencies may also place a limit on the use of respirators in their standards. An example of the listing for entry into and escape open-circuit SCBA is given on page 85.

Single, complimentary copies of the NCE will be provided by NIOSH while the supply lasts. Multiple copies can be ordered from the Government Printing Office (GPO). Requests for single copies should be sent to:

Publication Dissemination, DSDTT
NIOSH
4676 Columbia Parkway
Cincinnati, Ohio 45226-1998

EXAMPLE OF LISTING FROM NIOSH CERTIFIED EQUIPMENT LIST

A. Self-contained Breathing Apparatus

1. Entry Into and Escape

a. Open circuit pressure demand

Approval

Certified as approved for respiratory protection during entry into or escape from oxygen deficient atmospheres, gases and vapors.

Limitations

Use only for temperatures above the temperature listed on approval label.

Approved only when compressed air reservoir is fully charged with air meeting the requirements of the Compressed Gas Association Specification G-7.1 for Type 1, Grade D air, or equivalent specifications.

The air container shall meet applicable DOT specifications.

Use adequate skin protection when worn in gases or vapors that poison by skin absorption.

Refer to certification label and instruction and maintenance manuals for additional information on use and maintenance of these respirators.

In making renewals and repairs, parts identical with those furnished by the manufacturer under the pertinent approval shall be maintained.

Demand mode shall be used only when donning apparatus.

This respirator shall be selected, fitted, used and maintained in accordance with Mine Safety and Health Administration and other applicable regulations.

Recommendations

NIOSH recommends that SCBA be inspected weekly if stored and immediately before use, if used regularly, for breathing gas pressure.

SCBA ENTRY INTO AND ESCAPE OPEN CIRCUIT PRESSURE DEMAND

Approval Number TC-13-F-	Approval Issued to	Model Number(s)	Service Life (min.)	Facepiece Type	Regulator Position
30	MSA	95069 96338 461696 461704 461946 461947 463814 463815 463831 463833 466209 470444 470445 470448 470449	30	FF	Bm
40	Scott	900014-00 900014-01/05/06/12/30/31/39/50/51 900214-00/01/05/06/50/51	30	FF	Bm
42	Scott	900015-00 900015-01/05/06	15	FF	Bm
45	USD	9038-20* 9038-22*/70*/72* 9838-22/70*/72* 9848-20/22 9849-20*/22* U9038-00 U9838-00/02 M9838-20*	30	FF	Bm
47	MSA	95063 460262 461697 461703	15	FF	Bm

CHAPTER 4

RESPIRATOR USE

I. Federal Regulatory Requirements

OSHA 1910.134 states that when effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used pursuant to the following requirements:

- o respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee
- o the employer shall provide the respirators which are applicable and suitable for the purpose intended
- o the employer shall be responsible for the establishment and maintenance of a respiratory protection program.

The respirator protection program prescribed by OSHA contains provisions for the following:

- o written standard operating procedures
- o respirators selected on basis of hazards
- o instruction and training of user
- o cleaning and disinfection
- o storage
- o inspection
- o surveillance of work area conditions
- o evaluation of respirator protection program
- o medical review
- o use of certified respirators.

A. Employer Responsibility

1. Determination of Wearer's Exposure to Hazards

Appropriate surveillance of work area conditions and of worker exposure to respiratory hazards should be carried out using good industrial hygiene practices. This means that the concentration of the respiratory hazard to which workers are exposed should be determined periodically, using NIOSH sampling methods where available, and records should be kept. The monitoring should cover conditions throughout a full work shift as activities in the work area vary during the shift and change the hazard concentration. The time-weighted average concentration and ceiling (peak) concentration of the hazard during the work shift should be determined. Preferably, the air in the work area should be sampled in the workers' breathing zones.

2. Fit Testing Before Use

In order to obtain adequate respiratory protection, there should be a proper match between respirator and wearer. To assure selection of the best fitting respirator, the wearer should be fit tested using a quantitative fit test procedure. Quantitative fit testing procedures are included in Appendix B of this document.

Respirator facepieces should be tested for fit each time they are worn. The wearer can make either the positive or the negative-pressure test before entering a hazardous atmosphere, but a qualitative check using either isoamyl acetate or irritant fume is much preferred. Qualitative fit testing procedures are included in Appendix B of this document.

3. Random Inspection

Respirators in use should be randomly inspected frequently to ensure that those selected for the job are being used and that they are in good condition. Respiratory protection is no better than the respirator in use. Periodic monitoring of respirator use should include:

- o determination that the proper respirators are being used
- o determination that respirators are being worn properly

o consultation with wearers about:

-discomfort
-resistance to breathing
-fatigue
-interference with vision
-interference with communications
-restriction of movement
-interference with job performance
-confidence in the respirator.

In addition to general assessment of overall respiratory protection, specific evaluations should also be conducted of cleaning, inspection, maintenance and storage. Problems discovered during the inspections should be rectified.

B. Employee Responsibility

Proper supervision of respirator use should ensure that each worker understands that he/she has certain responsibilities. Each worker should:

o check the respirator fit after each donning as instructed

o use the respirator as instructed

o guard against damaging the respirator

o go immediately to an area having respirable air if the respirator fails to provide proper protection

o report any respirator malfunction to a person responsible for the respirator program.

III. Program Elements

A. Program Administration

Providing suitable respirators to workers seems simple, but issue of an unsuitable respirator may result in worker injury or death, so the matter cannot be treated lightly. The person responsible for issuing respirators should be adequately trained to make sure that the correct respirator is provided for each job. The respirator program administrator should have the technical and professional background in order to make sound judgments based on hazard evaluation input from the workplace.

Without a definite chain of supervision, there is no assurance that written standard operating procedures will be followed. Therefore, responsibility for the entire respirator program should be assigned to one person.

The large user may find it practical and economical to have a staff of personnel involved in the respirator program, each with his own area of responsibility. Each of these people should report to the one administrator who has overall responsibility for the program. The administrator's technical and professional background should enable him or her to make sound judgments based on hazard evaluation input from the workplace. The Administrator may be a safety engineer, industrial hygienist, health physicist, or physician. The Administrator should have the full support of higher level management; without it, an effective respirator program is difficult to initiate and maintain.

Respirator purchasing should be controlled by the program administrator for good reasons. Several respirator manufacturers produce a wide variety of devices for protection against specific hazards. Although most manufacturers today produce several size facepieces to choose from, not all workers may be able to receive an adequate fit if only one brand of respirator is purchased. However, if more than one brand of respirator is purchased, thus providing a variety of facepiece sizes, it is possible to fit most of a working population. Sometimes more than one type of respirator may be adequate against a particular hazard. The program administrator should select what he/she considers to be the best types of devices, considering comfort and worker acceptance, and ensure that they are purchased. It is unwise to select a respirator on the basis of price alone. A program administrator, with comprehensive knowledge, should have a strong influence on, if not absolute control over, respirator purchases.

Small volume respirator users often feel they cannot afford (and may not need) to involve several people specifically in a respirator program. However, they have to meet the same requirements as the program administrator for the large user because the hazards do not differentiate between large and small volume users. In a small firm, where only a few workers wear respirators for protection against one or very few different hazards, the program administrator may be a foreman or other supervisor. Where only one or two workers wear respirators, the entire program may be the responsibility of the company owner. In an extremely small operation, the entire program may be the responsibility of the worker.

The administrator should keep the respirator program as flexible as possible. Although the written operating procedures meet today's situation, they may not meet tomorrow's. New hazards are continually being identified, and allowable exposure limits often are revised as more knowledge becomes available. The program administrator should stay abreast of these changes by subscribing to pertinent publications, and should not hesitate to modify the program to meet changing conditions.

Thus, the administrator, of a large or small program, should establish a respirator program that meets current needs, ensure that it is carried out satisfactorily, and ensure that it remains effective by continual examination and modification to meet changing conditions.

In summary, the program administrator can be a highly trained professional who oversees several employees responsible for specific phases of the respirator program, or a single employee responsible for the employee's own respirator. Like the written operating procedures, the exact administration of the respirator program should be tailored to the individual situation.

B. Program Components

Unfortunately, respirators can be misused or taken too much on faith, primarily because of lack of knowledge. Such misuse can be avoided by establishing written procedures for respirator selection and use and through proper supervision of all aspects of the respirator program. Following are detailed methods for ensuring that a respirator program remains effective.

1. Written Standard Operating Procedures

The importance of written standard operating procedures is emphasized in OSHA 29 CFR Part 1910.134 which gives the first requirement for a "minimal acceptable (respirator) program" as establishment of "written standard operating procedures governing the selection and use of respirators." Part 1910.134, which is currently undergoing revision, does not provide any guidance on preparation of these procedures and does not differentiate between large and small users. However, the general content of written procedures has been established, and from that information as provided by NIOSH and others, any user, large or small, can formulate procedures.

The written standard operating procedures should contain all information needed to maintain an effective respirator program to meet the user's individual requirements. They should be written so as to be useful to those directly involved in the respirator program, the program administrator, those fitting the respirators and training the workers, respirator maintenance workers, and the supervisors responsible for overseeing respirator use on the job. It is not necessary that the operating procedures be written for the wearer, although in a very small program it may be desirable to direct their content to the wearer. Only analysis of the individual program will show to what extent information for the wearer should be included.

The procedures should contain all information needed to ensure proper respiratory protection of a specific group of workers against a specific hazard or several particular hazards. The hazard(s) should have been assessed thoroughly; otherwise the written procedures will have only limited validity. Generally, the procedures should contain the following:

- o guidance for selection of the approved respirator(s) for protection against particular hazard(s)

- o detailed instructions for training workers in proper use of the respirator(s), including respirator fitting

- o detailed maintenance procedures for:

  -cleaning and disinfection
  -drying
  -inspection
  -repair or replacement of worn or defective components
  -storage

- o administrative procedures for:

  -purchase of approved or accepted respirator(s)
  -control of inventory of spare parts, new respirators, and respirators ready for reissue after maintenance
  -issuance of respirators to ensure use of the proper one for a given hazard
  -guidance of supervisory personnel in continued surveillance of respirator use and determination of workers' exposure to respiratory hazards

- o instructions for respirator use during emergencies, including fire, which can create an atmosphere immediately hazardous to life or health

- o guidelines for medical surveillance of workers, including pre-employment physical examinations to eliminate those physically or psychologically unfit to wear respirators, and periodic physical examinations to review the overall effectiveness of the respirator program on the basis of physiological factors

- o procedures for evaluating the respirator program's effectiveness

Obviously, the above essentially restates the OSHA requirements for a minimal acceptable respirator program. The point is that all the information needed to establish and maintain an adequate respirator program should be written down.

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The exact format of written standard operating procedures may vary widely. The large user who has many workers wearing respirators and, perhaps, several respiratory hazards to consider, may formulate separate procedures for selection and use of respirators for each hazard. For a small user, who has only a few workers to protect from only one or very few hazards, a much simplified document may serve; but it must cover the same subjects. In general, the complexity of the procedures increases as respirator use increases. The procedures also become more extensive as the toxicity of the respiratory hazard(s) increases, demanding better and more reliable protection. It is better to be overly detailed in developing written operating procedures than not detailed enough.

Some firms have developed an elaborate system wherein each wearer is issued a card that specifies what type of respirator the wearer can be issued for protection against a particular hazard. The wearer is required to show this card to the issuer, who can issue only the type of respirator listed. Often, such a card lists a particular brand of respirator on the basis of fitting tests.

When practical, a respirator should be assigned to each worker for exclusive use, and should be permanently marked to indicate to whom it is assigned. Care should be taken to ensure that the marking does not affect the respirator performance. If possible, records should be kept on the issuance and use of each respirator. To do so, each should be permanently identified. Records should include the date of initial issue, the dates of reissue, and a listing of repairs.

Particularly important are procedures for respirator use during emergencies such as fire, large spillage of toxic material, accidental release of a potentially lethal substance, or failure of a ventilation system. All possible emergencies should be considered in advance and prepared for in the written procedure. In the stress of an emergency, memories may be faulty. Furthermore, these emergency procedures should be used in training emergency response teams. A sample of and a check list for a respirator standard operating procedure are included in Appendix A.

2. Medical Surveillance

OSHA 29 CFR 1910.134 states that no one should be assigned a task requiring use of respirators unless found physically able to do the work while wearing the respirator. In addition, some regulatory standards for specific substances and occupations may also contain requirements for medical examinations. Both types of standards declare that a physician should determine what health and physical conditions are pertinent, and that respirator wearers' medical status should be reviewed periodically.

Pre-placement medical examinations should screen out those who are physically or psychologically unfit to wear respirators. As another part of this examination, medical tests pertinent to the respiratory hazards that workers may encounter should be made to get baseline data against which to assess physiological changes in respirator wearers. In addition, the workers' previous medical and employment history should also be considered.

The types of information which should be obtained from the worker include:

a. History of respiratory disease--identifies workers with a history of asthma, emphysema, or chronic lung disease. These people may be at risk when wearing a respirator.

b. Work history--identifies workers who have been exposed to asbestos, silica, cotton dust, beryllium, etc., within the past ten years, or workers who have worked in occupations or industries where such exposure was probable. If past exposures are identified, medical tests can be obtained for comparison. Some of the specific items of information which might be obtained include:

- o previous occupations
- o problems associated with breathing during normal work activities
- o past problems with respirator use.

c. Any other medical information -which might offer evidence of the worker's ability or inability to wear and use respirators, such as:

- o psychological problems or symptoms including claustrophobia
- o any known physical deformities or abnormalities, including those which may interfere with respirator use
- o past and current usage of medication
- o tolerance to increased heart rate, which can be produced by heat stress.

Periodic routine medical examinations should be made to determine whether respirator wearers have been exposed to harmful levels of respiratory hazards. Examination frequency should be tailored to particular situations and in accordance with specific substance standards. Tests to determine whether harmful amounts of hazardous substances have been taken into the body should be used. The results of the periodic examinations should be compared with those

of the pre-employment examinations and previous periodic examinations to determine whether the respirators used are adequate. If possible, periodic biochemical tests should be made to measure respirator wearers' exposures to respiratory hazards.

3. *Training*

a. *Elements of an adequate training program*

Selecting the respirator appropriate to a given hazard is important, but equally important is using the selected device properly. Proper use can be ensured by carefully training both supervisors and workers in selection, use, and maintenance of respirators. This implies that there should be a training program.

Like the overall respirator program, the content of the training program can vary widely, depending on circumstances. However, OSHA 29 CFR 1910.134 requires that training of both workers and supervisors include the following, no matter what the circumstances:

- an opportunity to handle the respirator
- proper fitting
- test of facepiece-to-face seal, and
- a long familiarizing period of wear in normal air.

Furthermore, OSHA requires that the wearer receive fitting instructions including demonstrations and practice in wearing, adjusting, and determining the fit of the respirator.

Training of supervisors and workers also should include:

- discussion of the engineering and administrative controls in use and why respirators also are needed
- explanation of the nature of the respiratory hazard and what happens if the respirator is not used properly
- explanation of why a particular type of respirator has been selected, and
- discussion of how to recognize and handle emergencies.

These training requirements apply to large and small organizations, with no differentiation to meet individual needs. The training the supervisor needs may differ from that for the individual worker, and both may differ markedly from that needed by members of

emergency response teams. This chapter summarizes methods for satisfying the OSHA requirements and suggests ways that respiratory protection training may be tailored to individual needs based on job function.

The exact format of the training program will vary widely, depending upon the organization. The large user may need a full-time professional instructor. At the other extreme is the very small user who may be forced into a do it yourself training program. Respirator training courses are available from NIOSH and others. It must be emphasized again, however, that the OSHA requirements apply to large and small users alike.

b. Supervisor Training

Supervisors, at least those who oversee the daily activities of one or more workers who wear respirators frequently, should have a reasonably comprehensive knowledge of respirators and respiratory protection practices. Their training should include, but not necessarily be limited to, knowledge of the following:

- worker training and instruction
- basic respiratory protection practices
- selection and use of respirators to protect each worker against every respiratory hazard to which the worker may be exposed
- the nature and extent of the respiratory hazards to which the workers may be exposed
- the structure and operation of the entire respirator program, and
- the legal requirements pertinent to use of respirators in their respective situations.

The supervisor should understand the responsibility to facilitate functioning of the program, including maintenance that the worker may be expected to do, issuance of respirators, control of their use, and evaluation of the program's effectiveness.

These suggestions obviously apply to the large organization. A smaller organization may have to combine the supervisor training with that of the workers. This benefits the workers as they receive more comprehensive training.

c. Worker Training

The extent and frequency of the workers' training depends primarily on the complexity of the respirator, nature and extent of the hazard. Training for respiratory protection against highly toxic chemicals may need to be more stringent than for less toxic chemicals. If the hazard is a nuisance particulate, for example, the danger from misuse of the respirator is not likely to be as serious as with a highly toxic particulate where a single misuse may have serious consequences. The same holds true, of course, for gases and vapors. If the respirator is to be used in an emergency, training in its use should be very thorough and complete. In any case, the worker should be given some instruction in respiratory protection practices.

As a bare minimum, both worker and supervisor should be trained in basic respiratory protection practices. Also, each should be trained in use of the respirators selected for a particular situation. Because proper respirator use depends especially upon the wearer's motivation, it is important that the need for the respirator be explained fully. ANSI Standard Z88.2 (1969), Section 7.4 lists the following points to be included in a minimal acceptable respirator program:

> "(1) Instruction in the nature of the hazard, whether acute, chronic, or both, and an honest appraisal of what may happen if the respirator is not used.
> (2) Explanation of why more positive control is not immediately feasible. This shall include recognition that every reasonable effort is being made to reduce or eliminate the need for respirators.
> (3) A discussion of why this is the proper type of respirator for the particular purpose.
> (4) A discussion of the respirator's capabilities and limitations.
> (5) Instruction and training in actual use of the respirator (especially a respirator for emergency use) and close and frequent supervision to assure that it continues to be properly used.
> (6) Classroom and field training to recognize and cope with emergency situations.
> (7) Other special training as needed for special use."

A major thrust in this training is toward explaining as much as possible about the need and reasons for wearing a respirator. This, of course, is to motivate the user to accept the fact that protection is necessary, and to instill the desire to wear and maintain a respirator properly. Just handing a respirator to a worker with orders to wear it because OSHA says so is one of the easiest ways to ensure its misuse.

At best, a respirator may cause discomfort and inconvenience, so there is a natural resistance toward wearing it conscientiously. Much of this natural resistance can be overcome by taking the time and effort to inform the wearer as thoroughly as possible why the respirator is necessary. This effort will create acceptance of respirators and contribute to correct use.

4. *Fitting*

All the care that goes into the design, manufacture and certification of a respirator to ensure its maximum efficiency will not protect the wearer if there is an improper match between facepiece and wearer or improper wearing practices. The problem is twofold. Assuming that more than one brand of a particular type of facepiece is available, the first problem is to determine which fits best. The second problem is to ensure that the user knows when the respirator fits properly. Both problems can be solved by use of some sort of fitting test, which is one of the OSHA requirements.

Determination of facepiece fit should involve both qualitative and quantitative tests. A qualitative test relies on the wearer's subjective response. A quantitative test uses some other means of detecting facepiece leakage. The general advantages and disadvantages of each are as follows:

Advantages of Qualitative Tests:

Usually, qualitative tests are fast, require no complicated, expensive equipment, and are easily performed in the field.

Disadvantages of Qualitative Tests:

Most qualitative tests rely on the wearer's subjective response, so they may not be entirely reliable.

Advantages of Quantitative Tests:

The greatest advantage of a quantitative test is that it does not rely on a subjective response. The quantitative test is recommended when facepiece leakage must be minimized for work in highly toxic atmospheres or those immediately dangerous to life or health.

Disadvantages of Quantitative Tests:

Quantitative fitting tests require expensive equipment that can be operated only by highly trained personnel. Each test respirator must be equipped with a sampling probe to allow removal of a continuous air sample from the facepiece, so the same facepiece cannot be worn in actual service.

In addition, recent NIOSH studies have indicated that the sampling bias for the current quantitative fit tests technique is unsatisfactory. NIOSH is performing research into probe location and probe design in an effort to decrease this sampling bias (see Chapter 6).

Selection of a qualitative and/or quantitative fitting test depends upon circumstances such as the severity and extent of the respiratory hazard and the size of the organization. Ideally, both qualitative and quantitative tests should be used. A quantitative test can be used in selecting the best respirator for each worker during training. To supplement the periodic quantitative fitting, a qualitative test can be used before each entry into a contaminated atmosphere. Again, this is only a suggested procedure that can be modified on the basis of an objective professional evaluation of the circumstances.

Quarter- and half-masks, and full-facepieces have inherently different fitting characteristics. Moreover, several brands of each are marketed, each having slightly different fitting characteristics. Although every manufacturer designs facepieces to fit as broad a section of the working population as possible, no respirator marketed will fit everyone. Therefore, more than one brand of a given type of respirator should be purchased to take advantage of the different fitting characteristics of each. In this way, the chances of properly fitting all workers are increased. Having more than one facepiece to choose from also gives the worker a better chance of finding a respirator that is reasonably comfortable while providing good protection. It is in this process of matching the respirator to the individual user that the fitting test, particularly the quantitative test, has the greatest impact.

Respirator fit testing procedures are included in Appendix B.

5. *Respirator Inspection, Cleaning, Maintenance, and Storage*

Scrupulous respirator maintenance should be made an integral part of the overall respirator program. Manufacturers' instructions for inspection, cleaning, and maintenance of respirators should be followed to ensure that the respirator continues to function properly. Wearing poorly maintained or malfunctioning respirators may be more dangerous than not wearing a respirator at all. The

worker wearing a defective device may falsely assume that protection is being provided. Emergency escape and rescue devices are particularly vulnerable to inadequate inspection and maintenance, although they generally are used infrequently, and then in the most hazardous and demanding circumstances. The possible consequences of wearing a defective emergency escape and rescue device are lethal.

The OSHA standards strongly emphasize the importance of an adequate maintenance program, but permit its tailoring to the type of plant, working conditions, and hazards involved. However, all programs are required to include at least:

- inspection for defects (including a leak check)
- cleaning and disinfecting
- repair, and
- storage.

A proper maintenance program ensures that the worker's respirator remains as effective as when it was new.

a. Inspection for Defects

Probably the most important part of a respirator maintenance program is frequent inspection of the devices. If conscientiously performed, inspections will identify damaged or malfunctioning respirators before they can be used. The OSHA requirements outline two primary types of inspection, that while the respirator is in use and that while it is being cleaned. In a small operation, where workers maintain their own respirators, the two types of inspection become essentially one and the same. In a large organization with a central respirator maintenance facility, the inspections differ. A sample respirator inspection record is included in Appendix A.

b. Frequency of Inspection

OSHA requires that "all respirators be inspected before and after each use," and that those not used routinely, i.e. emergency escape and rescue devices, "shall be inspected after each use and at least monthly..." NIOSH, however, recommends that all stored SCBA be inspected weekly. In one case, the respirator is to be inspected both before and after each use, in the other case, only after use. However, it is highly unlikely that anyone needing a respirator in a hurry, as during an emergency, is going to inspect it. In fact, it could be dangerous to take time to do so.

c. Inspection Procedures

Inspection procedures differ depending upon whether air-purifying or atmosphere-supplying devices are involved, and whether the inspection is to be conducted in the field during use, or during routine cleaning.

The OSHA standards require that respirator inspection include:

- o a check of the tightness of the connections,
- o a check of the facepiece, valves, connecting tube, canisters, and
- o a check of the regulator and warning devices on SCBA for prope: functioning.

d. Field inspection of air-purifying respirators

Routinely used air-purifying respirators should be checked as follows before and after each use:

i. Examine the facepiece for:

- o excessive dirt
- o cracks, tears, holes, or distortion from improper storage
- o inflexibility (stretch and massage to restore flexibility)
- o cracked or badly scratched lenses in full-facepieces
- o incorrectly mounted full-facepiece lens or broken or missing mounting clips, and
- o cracked or broken air-purifying element holder(s), badly worn threads, or missing gasket(s) (if required).

ii. Examine the headstraps or head harness for:

- o breaks
- o loss of elasticity
- o broken or malfunctioning buckles and attachments, and
- o excessively worn serrations on the head harness which might permit slippage (full-facepieces only).

iii. After removing its cover, examine the exhalation valve for:

- o foreign material, such as detergent residue, dust particles, or human hair under the valve seat
- o cracks, tears, or distortion in the valve material
- o improper insertion of the valve body in the facepiece
- o cracks, breaks, or chips in the valve body, particularly in the sealing surface
- o missing or defective valve cover, and
- o improper installation of the valve in the valve body.

iv. Examine the air-purifying elements for:

- o incorrect cartridge, canister, or filter for the hazard
- o incorrect installation, loose connections, missing or worn gaskets, or cross-threading in holder
- o expired shelf-life date on cartridge or canister
- o cracks or dents in outside case of filter, cartridge, or canister, and
- o evidence of prior use of sorbent cartridge or canister, indicated by absence of sealing material, tape, foil, etc., over inlet.

v. If the device has a corrugated breathing tube, examine it for:

- o broken or missing end connectors, gaskets, or o-rings
- o missing or loose hose clamps, and
- o deterioration, determined by stretching the tube and looking for cracks.

vi. Examine the harness of a front- or back-mounted gas mask for:

- o damage to wear to the canister holder which may prevent its being held securely in place, and
- o broken harness straps or fastenings.

e. Field Inspection of Atmosphere-Supplying Respirators

For a routinely used atmosphere-supplying device, use the following procedures.

i. If the device has a tight-fitting facepiece, use the procedures outlined above for air-purifying respirators, except those pertaining to the air-purifying elements.

ii. If the device is a hood, helmet, blouse, or full suit, use the following procedures:

- Examine the hood, blouse, or full suit for rips and tears, seam integrity, etc.
- Examine the protective headgear, if required, for general condition, with emphasis on the suspension inside the headgear.
- Examine the protective faceshield, if any, for cracks or breaks or impaired vision due to rebounding abrasive particles.
- Make sure that the protective screen is intact and secured correctly over the faceshield of abrasive blasting hoods and blouses.

iii. Examine the air supply system for:

- integrity and good condition of air supply lines and hoses, including attachments and end fittings, and
- correct operation and condition of all regulators, valves, or other air-flow regulators.

On SCBA, determine that the high pressure cylinder of compressed air or oxygen is sufficiently charged for the intended use, preferably fully charged (mandatory on an emergency device). On closed circuit SCBA, make sure that a fresh canister of CO_2 sorbent is installed before use, or in accordance with manufacturers instructions. On open-circuit SCBA, recharge the cylinder if less than 80% of the useful service time remains. However, it is much preferred that an open-circuit SCBA be fully charged before use.

When an air-purifying or atmosphere-supplying device is used nonroutinely, all the above procedures should be followed after each use. OSHA requires that devices for emergency use be inspected once a month and that "a record shall be kept of inspection dates and findings for respirators maintained for emergency use." NIOSH recommends that such inspections be conducted at least weekly, because of the hazard that undetected loss of breathing gas from emergency SCBA will present to the wearer.

If defects are found during any field inspection, two remedies are possible. If the defect is minor, repair and/or adjustment may be made on the spot as in Figure 4-1. If it is major, the device should be removed from service until it can be repaired. **UNDER NO CIRCUMSTANCES SHOULD A DEVICE THAT IS KNOWN TO BE DEFECTIVE BE USED OR STORED FOR FUTURE USE.**

f. Inspection during cleaning

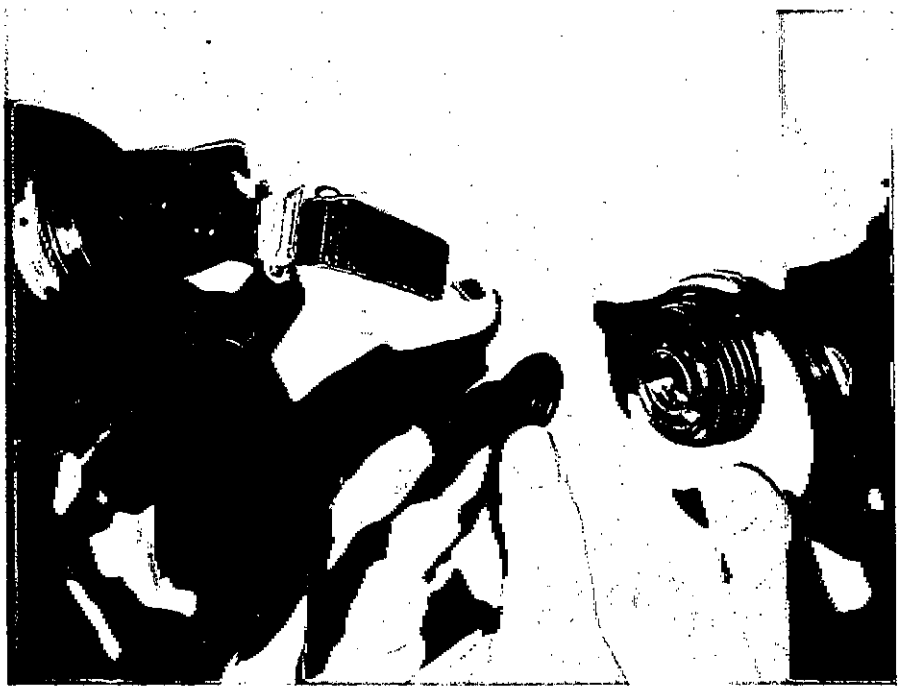
Because respirator cleaning usually involves some disassembly, it presents a good opportunity to examine each respirator thoroughly. Figure 4-2 shows inspection of the valve. The procedures outlined above for a field inspection should be used, but only after the respirator is cleaned and reassembled prior to returning it to service.

During this inspection, the respirator should be leak checked, as OSHA requires. The exact meaning of "leak check" has been much discussed, but no universal definition has emerged. Generally, a "leak check" is an examination of the freshly cleaned and reassembled respirator to determine that the complete assembly is gastight.

Several methods could be devised for meeting this requirement. One is worthy of mention as it is being used in several existing respirator programs. The respirator facepiece is placed over a machined metal head form with an inflated sealing surface. The straps are fastened down, and the inflatable seal built into the headform is pressurized to provide gastight seal between the headform and the facepiece. A continuous air sample is withdrawn from inside the facepiece, through the headform, and is passed through an aerosol detector like that described in Appendix B. An aerosol stream is directed through a small diameter tube around the potential leak points in the facepiece. Any leaks are shown by the penetration meter or recorder of the aerosol analyzing system, if it is set on the most sensitive scale.

Photograph Courtesy of Powermaster, Inc.

FIGURE 4-1. **Repair of a Helmet**



Photograph Courtesy of ISI

FIGURE 4-2. **Inspection of the Valve**

This procedure will detect leak sources and indicate the magnitude of the leak. However, it must be considered a qualitative, rather than quantitative, test. Some users have built a small test chamber around the headform. Instead of the aerosol being passed around the facepiece, the chamber contains an aerosol-laden atmosphere that permits actual quantitative determination of leakage in a manner similar to a quantitative fitting test.

This test requires use of the expensive aerosol system which is practical only for large organizations. The small respirator user is in the difficult position of not being able to afford this sophisticated equipment, although bound by the same requirements as the larger user. The best advice for the small user is to use ingenuity and devise a method that will satisfy the basic purpose of the leak check without adversely affecting the filter element, and assure that the reassembled respirator is leak free.

g. Cleaning and disinfecting

The OSHA requirements in 29 CFR 1910.134 are not specific about cleaning and disinfecting procedures, stating that "routinely used respirators shall be collected, cleaned, and disinfected as frequently as necessary to insure that proper protection is provided." and that emergency use respirators "shall be cleaned and disinfected after each use."

In a large respirator program in which respirators are used routinely, they should be exchanged daily for cleaning and inspection. In a small program involving only occasional respirator use, this period could be weekly or monthly. Each worker who maintains a respirator should be thoroughly briefed on cleaning and disinfecting it. Although a worker may not be required to maintain the respirator, briefings on the cleaning procedure will encourage acceptance of the respirator by providing assurance that the worker will receives a clean, disinfected, properly maintained device. This is particularly important where respirators are not individually assigned. Where respirators are individually assigned, they should be durably identified to ensure that the worker always receives the same device. Identification markers should neither penetrate the facepiece nor block filters, cartridge ports, or exhalation valves.

In a small respirator program, or where workers clean their own respirators, washing with detergent in warm water using a brush, thorough rinsing in clean water, and air drying in a clean place is generally accepted as sound procedure. Precautions should be taken to prevent damage from rough handling during this procedure. Precautions should also be taken to prevent exposure of the person cleaning the respirator to the contaminant in the respirator and to cleaning agents.

In a large program, there may be a centralized cleaning and maintenance facility with specialized equipment and personnel trained in respirator maintenance. Figure 4-3 shows a typical, hypothetical, large respirator maintenance facility. Good features are the separate areas for disassembly of used respirators and assembly of freshly cleaned and maintained devices which ensure that the clean respirators do not become contaminated.
Also, there is ample storage space for the clean respirators, and spare parts (filters, exhalation valves, headbands, etc.) are readily available. There is also a test bench for checking the operation of SCBA regulators as well as a leak test system. A facility of this type would take up about 500 ft^2.

In the following discussion of cleaning and maintenance procedures, reference to Figure 4-3 should help in understanding the overall process.

h. Disassembly

The used respirators are collected and deposited in a central location, (A) of Figure 4-3. They are taken to an area (C) where the filters, cartridges, or canisters are removed and discarded. Canisters and cartridges should be intentionally damaged to prevent reuse. If the facepieces are equipped with reusable dust filters, they may be cleaned with compressed air in a hood (B) that prevents dust from getting into the room and affecting the maintenance personnel. The air tanks from SCBA are removed and connected to the charging station (J), and the rest of the unit is sent to the SCBA test bench (I) where the regulator is tested. SCBA facepieces are cleaned like air-purifying respirator facepieces.

CAUTION: Improper disposal of an oxygen-generating canister from a closed circuit SCBA is dangerous. Mine Safety Appliances Company suggests the following procedure for disposing of their "Chemox" oxygen generating canister:

"Punch a hole in the front, back, and bottom of the canister, and gently place it in a bucket of clean water deep enough to cover it by at least 3 inches. When bubbling stops, any residual oxygen has been dissipated and the canister is expended. Pour the water, which is caustic, down a drain or dispose of it in any other suitable manner." This procedure is safe. Not following this procedure recommended by the manufacturer, particularly, can cause a violent explosion.

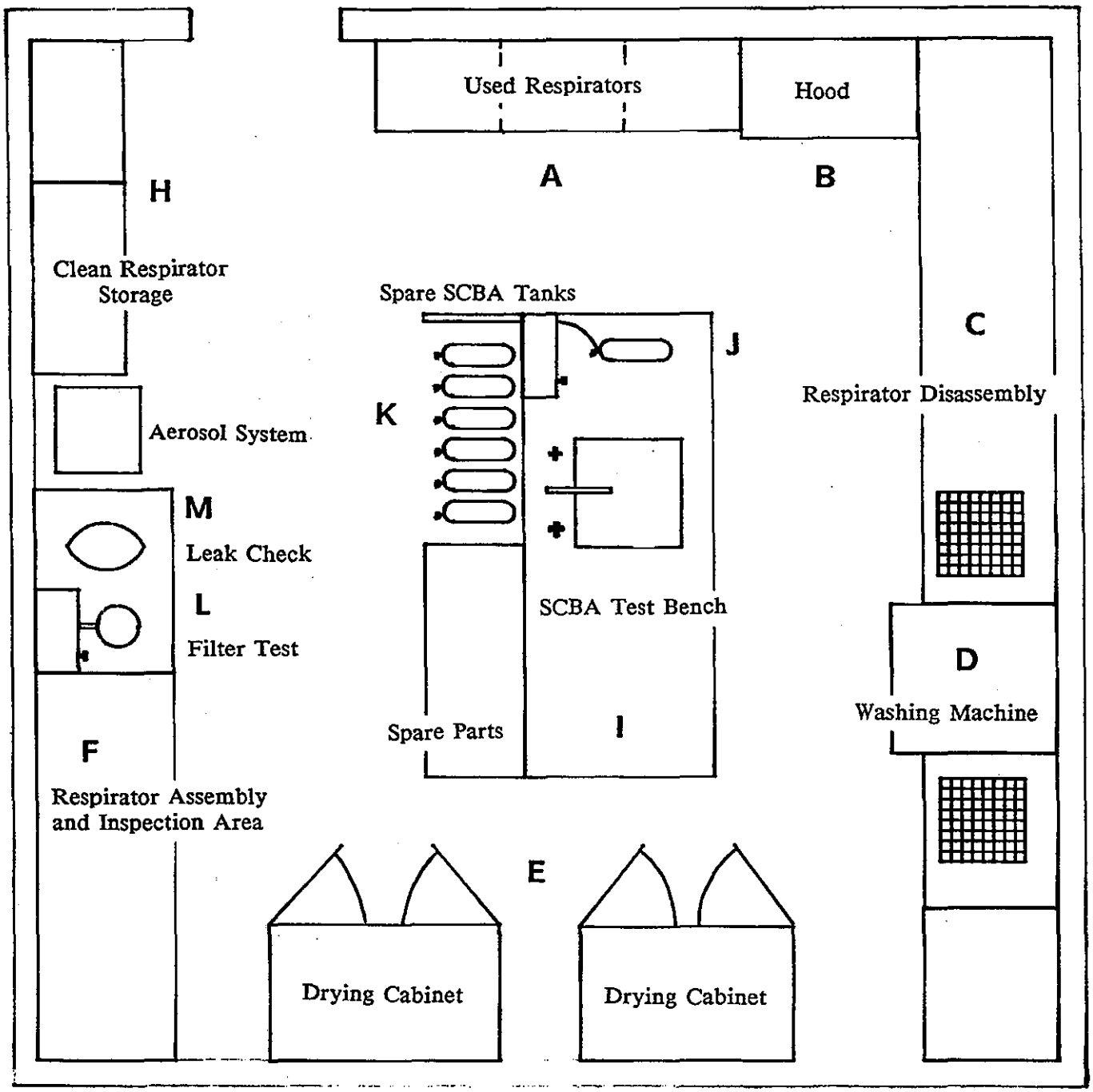


FIGURE 4-3. **Typical Large Respirator Maintenance Facility**

i. Cleaning and sanitizing

The Manufacturer's instructions should be followed for cleaning and sanitizing respirators, especially in regard to maximum temperatures.

The actual cleaning may be done in a variety of ways. In Figure 4-3, it is assumed that a commercial dishwasher (D) is used. A standard domestic type clothes washer also may be used if a rack is installed around the agitator to hold the facepieces in fixed positions. If the facepieces are placed loose in a washer, the agitator may damage them. A standard domestic dishwasher also may be used, but it is not preferred because it will not immerse the facepieces.

Any good detergent may be used, but cleaner and sanitizer solutions that clean effectively and contain a bactericide are available. The bactericide is generally a quaternary ammonium compound, which has some disadvantages, because its concentration must be adjusted to the composition of the local water to provide a constant degree of disinfection. Also, there is a possibility of dermatitis if the quaternary ammonium salts are not completely rinsed from the respirator.

An alternative is to wash the respirators in detergent, followed by a disinfecting rinse. Disinfection is not absolutely necessary if the respirator is reused by the same worker. However, where individual issue is not practiced, disinfection is strongly recommended. Reliable, effective disinfectants may be made from readily available household solutions, including:

- Hypochlorite solution (50 ppm of chlorine) made by adding approximately 2 ml of hypochlorite (laundry) bleach to 1 liter of water. A 2-minute immersion disinfects the respirators.

- Aqueous solution of iodine (50 ppm of iodine) made by adding approximately 0.8 ml tincture of iodine per liter of water. The iodine is approximately 7% ammonium and potassium iodide, 45% alcohol, and 48% water. Again, a 2-minute immersion is sufficient.

If the respirators are washed by hand, a separate disinfecting rinse may be provided. If a washing machine is used, the disinfectant should be added to the rinse cycle, and the amount of water in the machine at that time will have to be measured to determine the correct amount of disinfectant.

To avoid damaging the rubber and plastic in the respirator facepieces, the cleaner and disinfectant temperatures should not exceed 140°F, but they should not be less than 120°F to ensure adequate cleaning.

j. Rinsing

The cleaned and disinfected respirators should be rinsed thoroughly in clean water (140°F maximum) to remove all traces of detergent, cleaner and sanitizer, and disinfectant. This is very important to prevent dermatitis.

k. Drying

The respirators may be allowed to dry by themselves on a clean surface. They also may be hung from a horizontal wire, like drying clothes, but care must be taken not to damage the facepieces. A better method is to use a commercially available, electrically heated steel storage cabinet, Figure 4-3(E), with a built-in circulating fan, and replacing the solid shelves with steel mesh, if necessary.

l. Reassembly and Inspection

The clean dry respirator facepieces should be reassembled and inspected in an area, Figure 4-3(F), separate from the disassembly area to avoid contamination. The inspection procedures have been discussed, but there may be more things to look for because of the cleaning. The most common is detergent or soap residue left by inadequate rinsing. This appears most often under the seat of the exhalation valve, and can cause valve leakage or sticking.

At this time, the respirators should be thoroughly inspected and all defects corrected. New or retested filters, or new cartridges and canisters should be installed, and the completely reassembled respirator should be tested for leaks, Figure 4-3(M).

The facepiece of a SCBA can now be combined with the tested regulator from (I) and a full charged cylinder from the storage rack (K), and an operational check can be performed.

m. Maintenance and Repair

The OSHA standards state that "replacement or repairs shall be done by experienced persons with parts designed for the respirator." Besides being contrary to OSHA requirements, substitution of parts from a different brand or type of respirator invalidates MSHA/NIOSH certification of the device. Therefore, the user would be wearing an uncertified device, in violation of the OSHA requirement.

Maintenance personnel should be thoroughly trained. They should be aware of their limitations and never try to replace components or make repairs and adjustments beyond manufacturer's recommendations, unless they have been specially trained by the manufacturer.

These restrictions apply primarily to maintenance of the more complicated devices, especially closed and open circuit SCBA, and even more specifically their reducing or admission valves (regulators) which "... shall be returned to the manufacturer or to a trained technician for adjustment or repair." Figure 4-4 shows a complicated inspection being performed at the factory prior to delivery of the respirator to a user. There should be no problems in repairing and maintaining most other respirators, particularly the most commonly used air-purifying types.

An important aspect of any maintenance program is having enough spare parts on hand. Only continual surveillance of replacement rate will determine what parts in what quantities should be kept in stock. It is desirable to have some sort of recordkeeping system to indicate spare parts usage and the inventory on hand.

n. Storage

All the care that has gone into cleaning and maintenance of a respirator can be negated by improper storage. OSHA requires that respirators be stored to protect against:

- dust
- sunlight
- heat
- extreme cold
- excessive moisture, and
- damaging chemicals.

What is omitted, though implied in a later statement, is protection against mechanical damage. Leaving a respirator unprotected, as on a workbench, or in a tool cabinet or tool box among heavy wrenches, etc., may damage it.

It is strongly recommended that freshly cleaned respirators be placed in heat-sealed or reusable plastic bags until reissue. They should be stored in a clean, dry location away from direct sunlight. They should be stored in a single layer with the facepiece and exhalation valve in a more or less normal position to prevent the rubber or plastic from taking a permanent distorted "set."

4

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e. Field Inspection of Atmosphere-Supplying Respirators

For a routinely used atmosphere-supplying device, use the following procedures.

i. If the device has a tight-fitting facepiece, use the procedures outlined above for air-purifying respirators, except those pertaining to the air-purifying elements.

ii. If the device is a hood, helmet, blouse, or full suit, use the following procedures:

- Examine the hood, blouse, or full suit for rips and tears, seam integrity, etc.
- Examine the protective headgear, if required, for general condition, with emphasis on the suspension inside the headgear.
- Examine the protective faceshield, if any, for cracks or breaks or impaired vision due to rebounding abrasive particles.
- Make sure that the protective screen is intact and secured correctly over the faceshield of abrasive blasting hoods and blouses.

iii. Examine the air supply system for:

- integrity and good condition of air supply lines and hoses, including attachments and end fittings, and
- correct operation and condition of all regulators, valves, or other air-flow regulators.

On SCBA, determine that the high pressure cylinder of compressed air or oxygen is sufficiently charged for the intended use, preferably fully charged (mandatory on an emergency device). On closed circuit SCBA, make sure that a fresh canister of CO_2 sorbent is installed before use, or in accordance with manufacturers instructions. On open-circuit SCBA, recharge the cylinder if less than 80% of the useful service time remains. However, it is much preferred that an open-circuit SCBA be fully charged before use.

When an air-purifying or atmosphere-supplying device is used nonroutinely, all the above procedures should be followed after each use. OSHA requires that devices for emergency use be inspected once a month and that "a record shall be kept of inspection dates and findings for respirators maintained for emergency use." NIOSH recommends that such inspections be conducted at least weekly, because of the hazard that undetected loss of breathing gas from emergency SCBA will present to the wearer.

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f. Inspection during cleaning

Because respirator cleaning usually involves some disassembly, it presents a good opportunity to examine each respirator thoroughly. Figure 4-2 shows inspection of the valve. The procedures outlined above for a field inspection should be used, but only after the respirator is cleaned and reassembled prior to returning it to service.

During this inspection, the respirator should be leak checked, as OSHA requires. The exact meaning of "leak check" has been much discussed, but no universal definition has emerged. Generally, a "leak check" is an examination of the freshly cleaned and reassembled respirator to determine that the complete assembly is gastight.

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Photograph Courtesy of Powermaster, Inc.

FIGURE 4-1. **Repair of a Helmet**

Photograph Courtesy of ISI

FIGURE 4-2. **Inspection of the Valve**

This procedure will detect leak sources and indicate the magnitude of the leak. However, it must be considered a qualitative, rather than quantitative, test. Some users have built a small test chamber around the headform. Instead of the aerosol being passed around the facepiece, the chamber contains an aerosol-laden atmosphere that permits actual quantitative determination of leakage in a manner similar to a quantitative fitting test.

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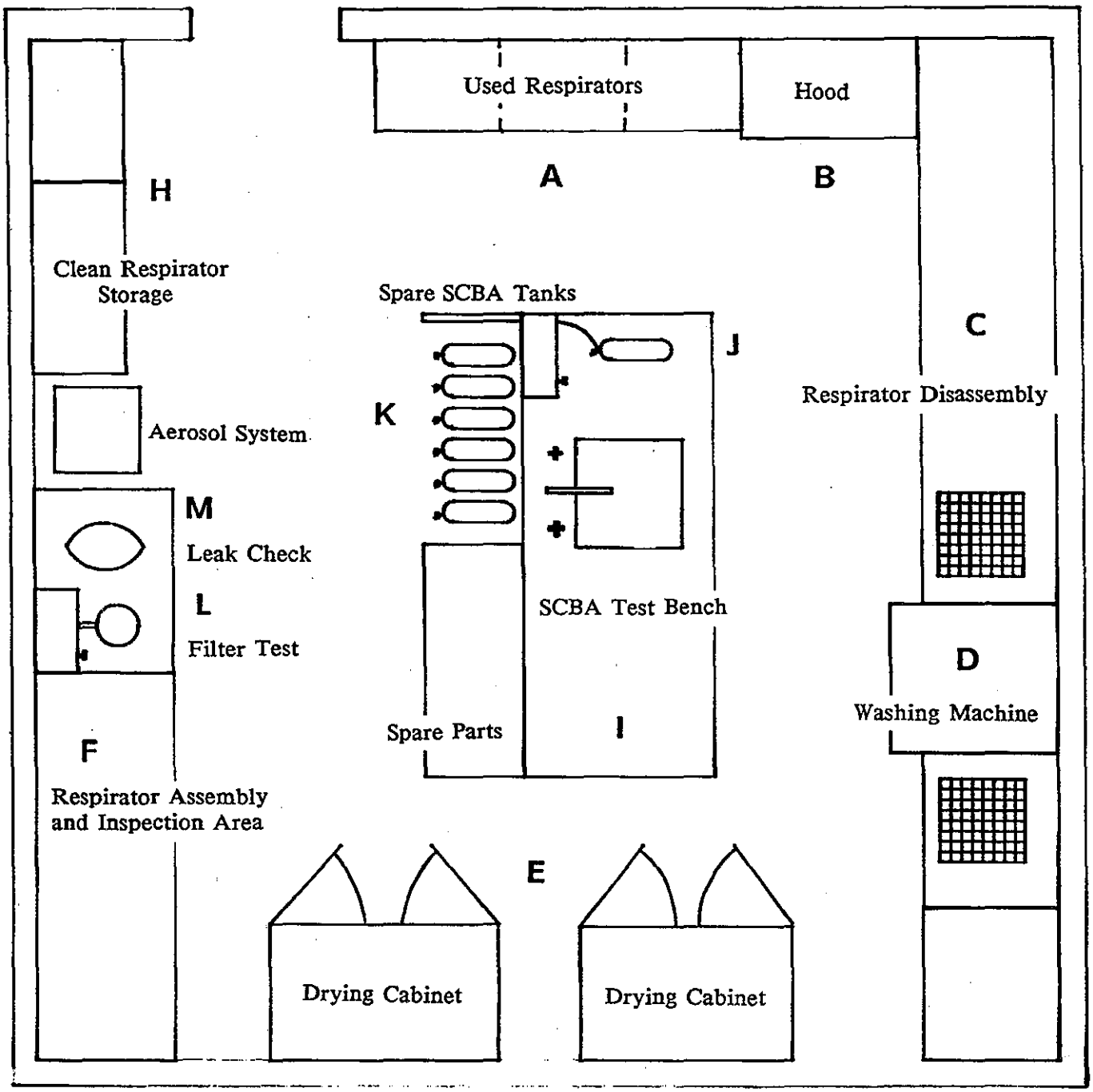


FIGURE 4-3. **Typical Large Respirator Maintenance Facility**

i. Cleaning and sanitizing

The Manufacturer's instructions should be followed for cleaning and sanitizing respirators, especially in regard to maximum temperatures.

The actual cleaning may be done in a variety of ways. In Figure 4-3, it is assumed that a commercial dishwasher (D) is used. A standard domestic type clothes washer also may be used if a rack is installed around the agitator to hold the facepieces in fixed positions. If the facepieces are placed loose in a washer, the agitator may damage them. A standard domestic dishwasher also may be used, but it is not preferred because it will not immerse the facepieces.

Any good detergent may be used, but cleaner and sanitizer solutions that clean effectively and contain a bactericide are available. The bactericide is generally a quaternary ammonium compound, which has some disadvantages, because its concentration must be adjusted to the composition of the local water to provide a constant degree of disinfection. Also, there is a possibility of dermatitis if the quaternary ammonium salts are not completely rinsed from the respirator.

An alternative is to wash the respirators in detergent, followed by a disinfecting rinse. Disinfection is not absolutely necessary if the respirator is reused by the same worker. However, where individual issue is not practiced, disinfection is strongly recommended. Reliable, effective disinfectants may be made from readily available household solutions, including:

- Hypochlorite solution (50 ppm of chlorine) made by adding approximately 2 ml of hypochlorite (laundry) bleach to 1 liter of water. A 2-minute immersion disinfects the respirators.

- Aqueous solution of iodine (50 ppm of iodine) made by adding approximately 0.8 ml tincture of iodine per liter of water. The iodine is approximately 7% ammonium and potassium iodide, 45% alcohol, and 48% water. Again, a 2-minute immersion is sufficient.

If the respirators are washed by hand, a separate disinfecting rinse may be provided. If a washing machine is used, the disinfectant should be added to the rinse cycle, and the amount of water in the machine at that time will have to be measured to determine the correct amount of disinfectant.

To avoid damaging the rubber and plastic in the respirator facepieces, the cleaner and disinfectant temperatures should not exceed 140°F, but they should not be less than 120°F to ensure adequate cleaning.

j. Rinsing

The cleaned and disinfected respirators should be rinsed thoroughly in clean water (140°F maximum) to remove all traces of detergent, cleaner and sanitizer, and disinfectant. This is very important to prevent dermatitis.

k. Drying

The respirators may be allowed to dry by themselves on a clean surface. They also may be hung from a horizontal wire, like drying clothes, but care must be taken not to damage the facepieces. A better method is to use a commercially available, electrically heated steel storage cabinet, Figure 4-3(E), with a built-in circulating fan, and replacing the solid shelves with steel mesh, if necessary.

l. Reassembly and Inspection

The clean dry respirator facepieces should be reassembled and inspected in an area, Figure 4-3(F), separate from the disassembly area to avoid contamination. The inspection procedures have been discussed, but there may be more things to look for because of the cleaning. The most common is detergent or soap residue left by inadequate rinsing. This appears most often under the seat of the exhalation valve, and can cause valve leakage or sticking.

At this time, the respirators should be thoroughly inspected and all defects corrected. New or retested filters, or new cartridges and canisters should be installed, and the completely reassembled respirator should be tested for leaks, Figure 4-3(M).

The facepiece of a SCBA can now be combined with the tested regulator from (I) and a full charged cylinder from the storage rack (K), and an operational check can be performed.

m. Maintenance and Repair

The OSHA standards state that "replacement or repairs shall be done by experienced persons with parts designed for the respirator." Besides being contrary to OSHA requirements, substitution of parts from a different brand or type of respirator invalidates MSHA/NIOSH certification of the device. Therefore, the user would be wearing an uncertified device, in violation of the OSHA requirement.

Maintenance personnel should be thoroughly trained. They should be aware of their limitations and never try to replace components or make repairs and adjustments beyond manufacturer's recommendations, unless they have been specially trained by the manufacturer.

These restrictions apply primarily to maintenance of the more complicated devices, especially closed and open circuit SCBA, and even more specifically their reducing or admission valves (regulators) which "... shall be returned to the manufacturer or to a trained technician for adjustment or repair." Figure 4-4 shows a complicated inspection being performed at the factory prior to delivery of the respirator to a user. There should be no problems in repairing and maintaining most other respirators, particularly the most commonly used air-purifying types.

An important aspect of any maintenance program is having enough spare parts on hand. Only continual surveillance of replacement rate will determine what parts in what quantities should be kept in stock. It is desirable to have some sort of recordkeeping system to indicate spare parts usage and the inventory on hand.

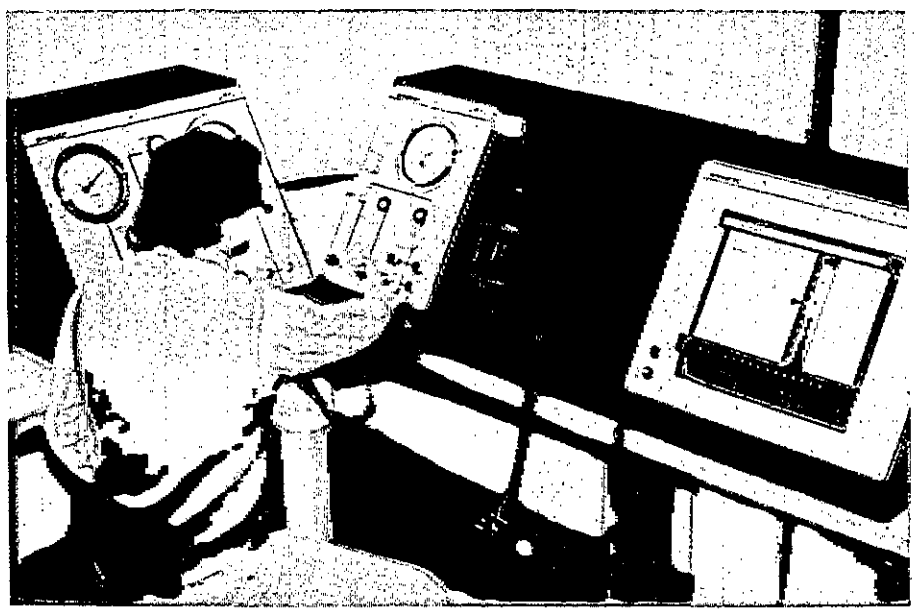
n. Storage

All the care that has gone into cleaning and maintenance of a respirator can be negated by improper storage. OSHA requires that respirators be stored to protect against:

- dust
- sunlight
- heat
- extreme cold
- excessive moisture, and
- damaging chemicals.

What is omitted, though implied in a later statement, is protection against mechanical damage. Leaving a respirator unprotected, as on a workbench, or in a tool cabinet or tool box among heavy wrenches, etc., may damage it.

It is strongly recommended that freshly cleaned respirators be placed in heat-sealed or reusable plastic bags until reissue. They should be stored in a clean, dry location away from direct sunlight. They should be stored in a single layer with the facepiece and exhalation valve in a more or less normal position to prevent the rubber or plastic from taking a permanent distorted "set."



Photograph Courtesy of Interspiro

FIGURE 4-4. **Inspection at the Factory**

Air-purifying respirators kept ready for nonroutine or emergency use should be stored in a cabinet in individual compartments. A steel wall-mounted cabinet, with six compartments is shown in Figure 4-5. Note that each compartment is clearly labeled with the user's name and that the respirators are in plastic bags. Note also that the respirator in the lower right compartment is stored improperly. Another acceptable method of storage in a standard steel storage cabinet is shown in Figure 4-5. Note that the respirators are stored in a single layer.

The storage cabinet should be readily accessible, and all workers should be made aware of its location, as is done for fire extinguishers. Avoidance of serious injury from inhalation of a toxic substance may depend entirely on how quickly workers can get to the emergency respirators. This type of storage should be encouraged for routinely used respirators if it does not interfere with the normal work routine. A little inconvenience here is justified to prevent use of a respirator damaged by improper storage.

A chest or wall mounted case, Figure 4-6, may be purchased from the respirator manufacturer for storing a SCBA for use in emergencies. Again, the locations of SCBA should be well known and clearly marked. Unlike fire extinguishers, however, they should be located in an area that will predictably remain uncontaminated. Even highly trained workers take 30 seconds to 1 minute to put on these devices. In a highly contaminated atmosphere such as might be created by massive release of a toxic material, this may be too long a time to stay safely in the area. Therefore, the first reaction should be to escape to an uncontaminated area, then put on the SCBA which should be located there and re-enter the hazardous area for whatever task must be done. There are undoubtedly exceptions to this general rule, and only thorough evaluation of the potential hazard, taking into account the physical configuration of the work area, will permit a final decision about the correct storage location for a SCBA.

Routinely used respirators may be stored in a variety of ways if they are protected against the substances and conditions listed at the beginning of this section. This means that when a respirator is not in use, it should be stored in a plastic bag inside a rigid container. The OSHA requirements suggest that respirators be stored in the cartons in which they came, but these usually provide only minimal protection from mechanical damage.

The adequately trained worker should develop a respect for respirators which will automatically provide incentive to protect it from damage. Besides providing better assurance of adequate protection, this training will lower maintenance costs because of decreased damage.

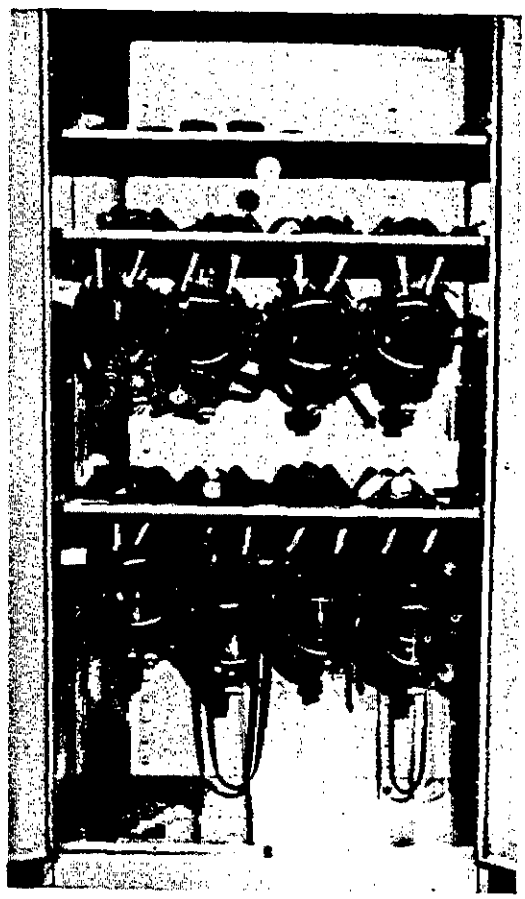


FIGURE 4-5. **Storage Cabinet for Facepieces**

FIGURE 4-6. **Wall-mounted Storage Cabinet for SCBA**

6. Surveillance of Work Area Conditions and Worker Exposure

OSHA 29 CFR 1910.134 states, "appropriate surveillance of work area conditions and degree of employee exposure or stress shall be maintained." This necessitates periodic monitoring of the air contaminant concentration to which the respirator wearer is exposed. Many things such as changes in the operation or process, air movement, temperature, or humidity, affect the concentration of a substance in the work area atmosphere. Therefore, the air contaminant should be sampled. Preferably, sampling should be in the respirator wearer's breathing zone. Both the time-weighted average and peak concentrations of the contaminant should be determined. Comparing the measured time-weighted average concentration with the maximum use concentration determined for the type of respirator being used is a means of checking that the proper respirator has been selected.

7. Respirator Program Evaluation

OSHA 29 CFR 1910.134 states, "There shall be regular inspection and evaluation to determine the continued effectiveness of the program." Periodic monitoring is necessary to ensure that workers are adequately protected. The program should be evaluated at least annually, and the written operating procedures should be modified to reflect the evaluation results if necessary. A sample respirator program and checklist are included in Appendix A.

Frequent inspection of respirator use will determine whether the correct respirators are being used and worn properly. Examination of respirators in use and in storage will indicate how well they are maintained. Wearers should be consulted periodically about their acceptance of respirators, including the discomfort, resistance to breathing, fatigue, interference with vision and communication, restriction of movement, and interference with job performance, and their confidence in the respirator's effectiveness.

The results of periodic inspections of respirator use, consultations with wearers, measurements of hazard levels in work areas, and medical surveillance of wearers should be reviewed, studied, and analyzed to determine the effectiveness of the respirator program. Evidence of excessive exposure to hazards should be followed up to determine why inadequate protection was provided, and action should be taken to remedy the problem. The results of the program evaluation should be presented in a written report that lists plans to correct faults and the target dates for their implementation.

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CHAPTER 5

RESPIRATOR USE UNDER SPECIAL CONDITIONS

The following are special problems which may be encountered in the wearing and use of respiratory protective equipment:

A. Facial Hair

Facial hair that lies along the sealing area of the respirator, such as beards, sideburns, moustaches, or even a few days growth of stubble, should not be permitted on employees who are required to wear respirators that rely on a tight facepiece fit to achieve maximum protection. Facial hair between the wearer's skin and the sealing surfaces of the respirator will prevent a good seal. A respirator that permits negative air pressure inside the facepiece during inhalation may allow leakage and, in the case of positive pressure devices, will either reduce service time or waste breathing air. A worker should not enter a contaminated work area when conditions prevent a good seal of the respirator facepiece to the face.

B. Eye Glasses

Ordinary eye glasses should not be used with full-facepiece respirators. Eye glasses with temple bars or straps that pass between the sealing surface of a full-facepiece and the worker's face will prevent a good seal, and should not be used. Special corrective lenses can be mounted inside a full-facepiece respirator and are available from all manufacturers of full-facepiece respirators. To ensure good vision, comfort, and proper sealing of the facepiece, these corrective lenses should be mounted by an individual designated by the manufacturer as qualified to install accessory items.

Eye glasses or goggles may interfere with the half facepieces. When interference occurs, a full-facepiece with special corrective lenses should be provided and worn.

C. Contact Lenses

Several factors may restrict or even prohibit the use of contact lenses while wearing any type of respiratory device. This is especially true of atmosphere-supplying respirators. With full-facepieces, incoming air directed toward the eye can cause discomfort from dirt, lint, or other debris lodging between the contact lens and the pupil.

OSHA is considering a change in their respiratory standard, with regard to use of contact lenses under respirators. Data generated by Lawrence Livermore National Laboratory is being taken into consideration.

D. Facial Deformities

Facial deformities, such as scars, deep skin creases, prominent cheekbones, severe acne, and the lack of teeth or dentures, can prevent a respirator from sealing properly.

E. Communications

Talking while wearing a respirator equipped with a facepiece may break the seal of the facepiece. When communication is necessary within a contaminated area, it should be done with the help of special communicating equipment obtained from the manufacturer of the respirator.

F. In Dangerous Atmospheres

Written procedures should be prepared for safe respirator use in IDLH atmospheres that may occur in normal operations or emergencies. Personnel should be familiar with these procedures and respirators. At least one standby person, equipped with proper rescue equipment including an SCBA should be present in the nearest safe area for emergency rescue of those wearing respirators in an IDLH atmosphere. Communications (visual, voice, signal line, telephone, radio, or other suitable type) should be maintained among all persons present (those in the IDLH atmosphere and the standby person or persons). The respirator wearers should be equipped with safety harnesses and safety lines to permit their removal from the IDLH atmosphere if they are overcome.

Confined spaces are enclosures that are difficult to get out of, such as storage tanks, tank cars, boilers, sewers, tunnels, pipelines, pits, and tubs. The atmospheres in a confined space may be immediately dangerous to life or health because of toxic air contaminants or lack of oxygen. Before anyone enters a confined space, tests should be made to determine the presence and concentration of any flammable vapor or gas, or any toxic airborne particulate, vapor, or gas, and to determine the oxygen concentration.

The confined space should be force-ventilated to keep the concentration of a flammable substance at a safe level. No one should enter if a flammable substance exceeds the lower explosive limit. No one should enter without wearing the proper type of respirator if any air contaminant exceeds the established permissible exposure limit or if there is an oxygen deficiency. Even if the contaminant concentration is below the established breathing time-weighted average limit and there is

enough oxygen, the safest procedure is to ventilate the entire space continuously and to monitor the contaminant and oxygen concentrations continuously if people are to work in the confined space without respirators.

Airline and hose mask type supplied-air respirators or appropriate air-purifying respirators may be worn in a confined space only if tests show that the atmosphere contains adequate oxygen and that air contaminants are below levels immediately dangerous to life or health. While people wearing these types of respirators are in a confined space, its atmosphere should be monitored continuously.

If the atmosphere in a confined space is immediately dangerous to life or health owing to a high concentration of air contaminant or oxygen deficiency, those who must enter the space should wear a pressure-demand SCBA or a combination pressure-demand airline and self-contained breathing apparatus that always maintains positive air pressure inside the respiratory inlet covering. This is the best safety practice for confined spaces.

While personnel are in a confined space, at least one standby person with proper rescue equipment, including an SCBA, should be present outside for emergency rescue. Communications (visual, voice, signal line, telephone, radio, or other suitable type) should be maintained with those inside. Also, those inside the space should be equipped with safety harnesses and safety lines to allow their removal in case they are overcome.

G. In Low and High Temperatures

Low temperatures may fog respirator lenses. Coating the inner surface of the lens with the anti-fogging compound normally available from the respirator manufacturer should prevent fogging down to 32°F, but severe fogging may occur below 0°F. Full facepieces with nose cups that direct the warm, moist exhaled air through the exhalation valve without its touching the lens, are available. They should provide satisfactory vision at as low as -30°F. At very low temperatures, exhalation valves may freeze due to moisture. Dry respirable air should be used with airline respirators and with the type of SCBA that has an air cylinder when they are used in low temperatures.

NIOSH performs cold temperature testing on SCBA. The minimum temperature that the SCBA has been tested to and approved for is listed on the approval label.

A person working in high temperature air is under stress. Wearing a respirator causes additional stress which should be minimized by using a light-weight respirator with low breathing resistance. In atmospheres that are not immediately dangerous to life or health the airline type supplied-air respirator is recommended. Such a respirator used in low or high temperature atmospheres may be equipped with a vortex tube to either warm or cool the air supplied.

H. Physiological Response of Respirator Use

Wearing any respirator, alone or in conjunction with other types of protective equipment, will impose some physiological stress on the wearer. Weight of the equipment, for example, increases the energy requirement for a given task. Selection of respiratory protective devices should be based on the breathing resistance, weight of the respirator, the type and amount of protection needed as well as the individual's tolerance of the given device.

Use of respirators in conjunction with protective clothing can greatly affect the human response and endurance, especially in hot environments. Normally, in hot environments or during heavy work, the body relies a great deal on heat loss through the evaporation of sweat. With impermeable clothing, the heat loss by water evaporation is not possible. Additionally, the weight of the respirator (up to 35 pounds for an SCBA) adds to the metabolic rate of workers, increasing the amount of heat the body produces. The net effect is one of heat stress.

NIOSH studies of workers wearing chemical protective clothing (CPC) and firefighters' ensembles have indicated that heat stress is a serious consideration. Significant physiological stress was observed, even at low work intensities (30% of maximum work capacity--level walking at 3.4 miles per hour) in a neutral environment (23°C and 55% R.H.). With the chemical protective (CPC) ensemble, worker tolerance time was reduced by 56% as compared to light work clothing only. Elevated rectal temperatures (in excess of 39.0°C) were observed in three of the nine subjects. With the heavier firefighters' ensemble, tolerance time was reduced by 84% as compared to light work clothing only and heart rates averaged 25-50 beats per minute higher than with lightweight work clothing. At higher work intensities (60% of maximum), tolerance time was decreased by as much as 96%.

Based upon this limited research, the following recommendations are made:

1. Select the lightest weight protective ensembles and respiratory protective devices that adequately protect the worker. This will minimize the physiological demands placed on the worker by carrying the weight of this equipment.

2. If available, select protective clothing made of material that will allow evaporation of water vapor, while providing skin protection from the contaminant.

3. Reduce work rate by:

   a. adjusting the work/rest schedules,

   b. using automated procedures and/or mechanical assistance where possible, and

   c. minimizing the work intensity,

4. Educate workers on the symptoms and prevention of heat illness and schedule periodic fluid replacement breaks,

5. Reduce heat stress by scheduling work at night or early morning or by providing external cooling, where possible (either through cooling garments and/or by providing cool respirable breathing air through pressure-demand air supplied respirators), and

6. When conducting pipe/boiler lagging removal, ensure that steam lines are cool to minimize heat exposure from these sources.

CHAPTER 6.

NEW DEVELOPMENTS AT NIOSH

While conducting the MSHA/NIOSH-certification program for respirators, NIOSH has been actively interested in new developments in respiratory protection. To support such development work, which is dedicated toward improvement of worker protection, NIOSH has funded respirator research through contracts and grants, has sponsored meetings and workshops on respirator research, and has conducted in-house research projects. Most of the NIOSH respirator research projects have been directed toward improving the performance of respirators through development of new and more severe requirements for 30 CFR 11. However, some fundamental research projects in respiratory physiology, filtration mechanics, sorption technology, and quantitative respirator efficiency testing, have been undertaken.

A. Respiratory Physiology

To develop guidelines for workers wearing respirators and associated protective clothing, NIOSH has undertaken several research projects examining physiological response and worker tolerance at a variety of work rates and temperatures. The initial studies examined the effects of wearing four types of clothing/respirator ensembles while the subjects were performing at 30 and 60 percent of their individual aerobic capacity. Thermal, cardiovascular, respiratory, and subjective parameters were measured. Further work has recently been conducted examining responses at 10, 20 and 30 degrees Centigrade. Additional types of protective ensembles have also been studied. Preliminary results show that significant stress occurs with workload and temperature. These factors, as well as type of ensemble should be considered in determining safe work practices.

B. Filtration Mechanics

Research projects are underway and are planned to study the effects of several parameters, such as particle size, particle weight, particle shape, and material, on the efficiency of various filter materials. A study with a lead aerosol indicated that particle weight had no significant effect on filter efficiency. A study of fibrous aerosols is beginning. A filtration study with variably sized latex spheres is nearly complete.

C. Sorption Technology

In addition to conducting tests of MSHA/NIOSH-certified respirator cartridges against a variety of organic vapors, to determine the relation of the service times and resistances to the carbon tetrachloride test now in 30 CFR 11, NIOSH is studying the applicability of the Jonas Kinetic Model for predicting organic vapor permeation. Test data indicate that sorbents tested against carbon tetrachloride have above average service life, in comparison with other organic vapors tested thus far.

D. Quantitative Respirator Efficiency Testing

NIOSH is presently conducting research studies to evaluate published assigned protection factors and to determine the causes of known variability in quantitative fit testing. Quantitative workplace fit tests of powered air-purifying respirators have demonstrated that the previously assigned protection factors for that type of respirator were too high. The lower assigned protection factors for powered air-purifying respirators, prescribed in this publication, reflect this research. A similar study of pressure-demand self-contained breathing apparatus during firefighting operations has been initiated in 1987. NIOSH has determined that several factors variously affect the magnitude of a respirator leak, during quantitative fit testing, both in the laboratory and in workplace studies. The greatest effects have been found to be from leak site and probe location.

E. Certification of New Types of Respirators

Acting in accordance with the authority in 30 CFR 11 Section 11.30 (b), which permits MSHA/NIOSH to certify other types of respirators not described in 30 CFR 11, NIOSH has issued a number of special minimum requirements documents which permit the testing and certification of special respirators. NIOSH issues such requirements only after thorough investigation of the respirators and their use, and after extensive discussion and review by users, regulatory agencies and respirator manufacturers.

Other types of respirators which have been or may be certified under these special requirements include vinyl chloride, formaldehyde and other chemical cartridge respirators, and combination high-efficiency filter and supplied-air respirators.

On November 18, 1985, a Federal Register Notice was published detailing the requirements for certification of positive pressure closed-circuit self-contained breathing apparatus. Basically, there are two types which may be certified: (1) apparatus which use a breathing gas of pure oxygen, and (2) apparatus which use a breathing gas in which the oxygen

concentration is not greater than 30 percent by volume. The following requirements, limitations, and cautions apply under present 30 CFR 11 Federal regulations:

Requirements for Certification of Positive-Pressure Closed-Circuit Self-Contained Breathing Apparatus

1. Where the apparatus uses a breathing gas (other than pure oxygen) the breathing gas will be respirable and not contain more than 30 percent by volume of oxygen.

2. The positive pressure closed-circuit self-contained breathing apparatus will meet all applicable requirements of 30 CFR 11 as prescribed for closed-circuit self-contained breathing apparatus, including those designed as demand flow devices.

3. The positive pressure closed-circuit self-contained breathing apparatus will maintain a positive pressure in the facepiece during all pressure and flow tests.

Certification Label Specifications

The following minimum limitations and conditions apply to positive pressure closed-circuit self-contained breathing apparatus and will appear on the certification label for each device:

Limitations

1. Do not use this apparatus where there is direct exposure to open flames or in high radiant heat. (This limitation applies to 100 percent oxygen apparatus only.)

2. Provide proper care, training, and maintenance of the apparatus as specifically described in the manufacturer's instructions and maintenance manuals.

3. After each use of this apparatus, a fully charged breathing gas container and a recharge of carbon dioxide scrubber shall be installed.

4. Thorough cleaning and disinfecting of facepiece, breathing tube, and breathing bag must be done in accordance with the manufacturer's instructions.

Cautions

1. Keep exposed hair to a minimum when using apparatus near open flames or in high radiant heat.

2. A good facepiece seal is important since facepiece leakage will seriously reduce service time.

3. Use of pure oxygen or oxygen enriched air increases flammability and lowers the ignition temperature of most materials.

In addition, presently available information indicates that the use of pure oxygen during direct exposure to open flames and/or high radiant heat should not be permitted. Further, NIOSH has determined that until it has been demonstrated satisfactorily that these devices can be worn safely under such conditions they should be presently limited to use which do not involve exposure to open flames or high radiant heat. Therefore, the oxygen concentration in a mixed gas system is limited to between 23 and 30 percent for use under these conditions. These limitations are based on what is physiologically safe for the necessary oxygen level at the lower end and on the effects of increased oxygen concentrations on both combustion and ignition temperatures at the upper end. These requirements are in addition to those presently listed in 30 CFR 11, both of which must be met by the SCBA prior to certification.

Consequently, when positive pressure closed-circuit breathing apparatus become available as certified devices, then the present closed circuit limitations and recommendations will be expanded to give users more selection guidance for safe application. That is, apparatus selection could become more performance oriented versus design oriented as present considerations and practices require.

F. NIOSH Respirator Problem Investigation

Since July 1, 1982, NIOSH has been investigating reports of problems with MSHA/NIOSH-certified respirators. These reports are from NIOSH audits of certified respirators, and from regulatory agencies and users and manufacturers of respirators. As of August 1, 1987, a total of 215 reports were received. The total includes 15 fatalities of employees who were wearing self-contained breathing apparatus at the time of their deaths.

The goals of the program are to increasingly justify the user's reliance on the MSHA/NIOSH respirator certification program and to indicate to respirator manufacturers that NIOSH is sincere in its desire to increase the safety and reliability of certified respirators.

During the last year of the program, NIOSH has noted that more manufacturers are receiving and directly investigating reports of problems on their own. They are advising NIOSH of the receipt of each problem and are providing NIOSH with follow-up information concerning the investigation and resolution of each problem. NIOSH regards this as an advantageous development, since it promotes more prompt response to and resolution of problems, increases customer satisfaction, and offers the manufacturer opportunities to learn about users' needs and wishes on a first-hand basis.

NIOSH will continue this program and encourages users to contact respirator manufacturers and NIOSH concerning problems with MSHA/NIOSH-certified respirators.

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APPENDIX A

SAMPLE RESPIRATOR PROGRAM

RESPIRATOR PROGRAM EVALUATION CHECK LIST

The following is a sample respirator program:

A B C COMPANY

RESPIRATOR PROGRAM

Purpose:

The purpose of this operating procedure is to ensure the protection of all employees from respiratory hazards, through proper use of respirators. Respirators are to be used only where engineering control of respirator hazards is not feasible, while engineering controls are being installed, or in emergencies.

Responsibility

The company Safety Officer is _____ _____. He/she is solely responsible for all facets of this program and has full authority to make necessary decisions to ensure success of this program. This authority includes hiring personnel and equipment purchases necessary to implement and operate the program. The Safety Officer will develop written detailed instructions covering each of the basic elements in this program, and is the sole person authorized to amend these instructions.

The ABC Company has expressly authorized the Safety officer to halt any operation of the company where there is danger of serious personal injury. This policy includes respiratory hazards.

Program Elements

1. The Safety Officer will develop detailed written standard operating procedures governing the selection and use of respirators, using the NIOSH Respirator Decision Logic as a guideline. Outside consultation, manufacturer's assistance, and other recognized authorities will be consulted if there is any doubt regarding proper selection and use. These detailed procedures will be included as appendices to this respirator program. Only the Safety Officer may amend these procedures.

2. Respirators will be selected on the basis of hazards to which the worker is exposed. All selections will be made by the Safety Officer. Only MSHA/NIOSH-certified respirators will be selected and used.

3. The user will be instructed and trained in the proper use of respirators and their limitations. Both supervisors and workers will be so instructed by the Safety Officer. Training should provide the employee an opportunity to handle the respirator, have it fitted properly, test its facepiece-to-face seal, wear it in normal air for a long familiarity period, and finally to wear it in a test atmosphere. Every respirator wearer will receive fitting instructions, including demonstrations and practice in how the respirator should be worn, how to adjust it, and how

to determine if it fits properly.

Respirators should not be worn when conditions prevent a good face seal. Such conditions may be a growth of beard, sideburns, a skull cap that projects under the facepiece, or temple pieces on glasses. No employees of A B C, who are required to wear respirators, may wear beards. Also the absence of one or both dentures can seriously affect the fit of a facepiece. The worker's diligence in observing these factors will be evaluated by periodic checks. To assure proper protection, the facepiece fit will be checked by the wearer each time the wearer puts on the respirator. This will be done by following the manufacturer's facepiece-fitting instructions.

4. Where practicable, the respirators will be assigned to individual workers for their exclusive use.

5. Respirators will be regularly cleaned and disinfected. Those issued for the exclusive use of one worker will be cleaned after each day's use, or more often if necessary. Those used by more than one worker will be thoroughly cleaned and disinfected after each use. The Safety Officer will establish a respirator cleaning and maintenance facility and develop detailed written cleaning instructions.

6. The central respirator cleaning and maintenance facility will store respirators in a clean and sanitary location.

7. Respirators used routinely will be inspected during cleaning. Worn or deteriorated parts will be replaced. Respirators for emergency use such as self-contained devices will be thoroughly inspected at least once a month and after each use. Inspection for SCBA breathing gas pressure will be performed weekly.

8. Appropriate surveillance of work area conditions and degree of employee exposure or stress will be maintained.

9. There will be regular inspection and evaluation to determine the continued effectiveness of the program. The Safety Officer will make frequent inspections of all areas where respirators are used to ensure compliance with the respiratory protection programs.

10. Persons will not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment. The ABC Company physician will determine what health and physical conditions are pertinent. The respirator user's medical status will be reviewed annually.

11. Certified respirators will be used.

John Doe
President, ABC Company

The following is a sample respirator program evaluation checklist:

Respirator Program Evaluation Checklist

In general, the respirator program should be evaluated for each job or at least annually, with program adjustments, as appropriate, made to reflect the evaluation results. Program function can be separated into administration and operation.

A. Program Administration

_____ (1) Is there a written policy which acknowledges employer responsibility for providing a safe and healthful workplace, and assigns program responsibility, accountability, and authority?

_____ (2) Is program responsibility vested in one individual who is knowledgeable and who can coordinate all aspects of the program at the jobsite?

_____ (3) Can feasible engineering controls or work practices eliminate the need for respirators?

_____ (4) Are there written procedures/statements covering the various aspects of the respirator program, including:

_____ designation of an administrator;
_____ respirator selection;
_____ purchase of MSHA/NIOSH certified equipment;
_____ medical aspects of respirator usage;
_____ issuance of equipment;
_____ fitting;
_____ training;
_____ maintenance, storage, and repair;
_____ inspection;
_____ use under special condition; and
_____ work area surveillance?

B. Program Operation

(1) Respiratory protective equipment selection

_____ Are work area conditions and worker exposures properly surveyed?

_____ Are respirators selected on the basis of hazards to which the worker is exposed?

_____ Are selections made by individuals knowledgeable of proper selection procedures?

_____ (2) Are only certified respirators purchased and used; do they provide adequate protection for the specific hazard and concentration of the contaminant?

_____ (3) Has a medical evaluation of the prospective user been made to determine physical and psychological ability to wear the selected respiratory protective equipment?

_____ (4) Where practical, have respirators been issued to the users for their exclusive use, and are there records covering issuance?

(5) Respiratory protective equipment fitting

_____ Are the users given the opportunity to try on several respirators to determine whether the respirator they will subsequently be wearing is the best fitting one?

_____ Is the fit tested at appropriate intervals?

_____ Are those users who require corrective lenses properly fitted?

_____ Are users prohibited from wearing contact lenses when using respirators?

_____ Is the facepiece-to-face seal tested in a test atmosphere?

_____ Are workers prohibited from wearing respirators in contaminated work areas when they have facial hair or other characteristics may cause faceseal leakage?

(6) Respirator use in the work area

_____ Are respirators being worn correctly (i.e., head covering over respirator straps)?

_____ Are workers keeping respirators on all the time while in the work area?

(7) Maintenance of respiratory protective equipment

Cleaning and Disinfecting

_____ Are respirators cleaned and disinfected after each use when different people use the same device, or as frequently as necessary for devices issued to individual users?

_____ Are proper methods of cleaning and disinfecting utilized?

Storage

_____ Are respirators stored in a manner so as to protect them from dust, sunlight, heat, excessive cold or moisture, or damaging chemicals?

_____ Are respirators stored properly in a storage facility so as to prevent them from deforming?

_____ Is storage in lockers and tool boxes permitted only if the respirator is in a carrying case or carton?

Inspection

_____ Are respirators inspected before and after each use and during cleaning?

_____ Are qualified individuals/users instructed in inspection techniques?

_____ Is respiratory protective equipment designated as "emergency use" inspected at least monthly (in addition to after each use)?

_____ Are SCBA incorporating breathing gas containers inspected weekly for breathing gas pressure?

_____ Is a record kept of the inspection of "emergency use" respiratory protective equipment?

Repair

_____ Are replacement parts used in repair those of the manufacturer of the respirator?

_____ Are repairs made by manufacturers or manufacturer-trained individuals?

(8) Special use conditions

_____ Is a procedure developed for respiratory protective equipment usage in atmospheres immediately dangerous to life or health?

_____ Is a procedure developed for equipment usage for entry into confined spaces?

(9) Training

_____ Are users trained in proper respirator use, cleaning, and inspection?

_____ Are users trained in the basis for selection of respirators?

_____ Are users evaluated, using competency-based evaluation, before and after training?

SAMPLE RESPIRATOR INSPECTION RECORD

1. TYPE _____ 2. NO. _____

3. DEFECTS FOUND:

A. Facepiece _____

B. Inhalation Valve _____

C. Exhalation Valve Assembly _____

D. Headbands _____

E. Cartridge Holder _____

F. Cartridge/Canister _____

G. Filter _____

H. Harness Assembly _____

I. Hose Assembly _____

J. Speaking Diaphragm _____

K. Gaskets _____

L. Connections _____

M. Other Defects _____

_____

_____

_____

_____

_____

_____

_____

APPENDIX B

FIT TESTING PROCEDURES

APPENDIX B.1. PROCEDURES FOR FIT CHECKING

The seal of a respirator should be tested prior to entering a contaminated atmosphere by procedures recommended by the manufacturer or by the following fit checks.

Irritant or Odorous Chemical Agent

The wearer is exposed to an irritant smoke, isoamyl acetate vapor, or other suitable test agent easily detectable by irritation, odor, or taste. An air-purifying respirator must be equipped with the appropriate air-purifying element. If the wearer is unable to detect penetration of the test agent, the respirator is probably tight enough.

FIGURE B-1. **Odorous vapor check test**

Negative Pressure Test

The wearer can perform this test by himself in the field. The wearer should use this test (Figure B-1) just before entering any toxic atmosphere. It consists merely of closing off the inlet of the canister, cartridge(s), or filter(s) by covering with the palm(s) or replacing the seal(s), or of squeezing the breathing tube so that it does not pass air; inhaling gently so that the facepiece collapses slightly; and holding the breath for 10 seconds. If the facepiece remains slightly collapsed and no inward leakage is detected, the respirator is probably tight enough. This test, of course, can be used only on respirators with tight fitting facepieces.

FIGURE B-2. **Negative pressure test**

Positive Pressure Test

This test is very like the negative pressure test, and it has the same advantages and limitations. It is conducted by closing off the exhalation valve and exhaling gently into the facepiece. The fit is considered satisfactory if slight positive pressure can be built up inside the facepiece without any evidence of outward leakage. For some respirators, this method requires that the wearer remove the exhalation valve cover and then carefully replace it after the test, often a difficult task. Removing and replacing the exhalation valve cover often disturbs the respirator fit even more than does the negative pressure test. Therefore, this test should be used sparingly if it requires removing and replacing a valve cover. The test is easy for respirators whose valve cover has a single small port that can be closed by the palm or a finger. The wearer should perform this test (Figure B-2) just before entering any hazardous atmosphere.

FIGURE B-3. **Positive pressure test**

APPENDIX B.2. QUALITATIVE FIT TEST PROCEDURES

[Note: The following procedures are found in the OSHA Lead Standard (29 CFR 1910.1025) Appendix D.]

This appendix specifies the only allowable qualitative fit test protocols permissible for compliance with paragraph (f)(3)(ii).

I. Isoamyl Acetate Protocol

A. Odor Threshold Screening

1. Three 1-liter glass jars with metal lids (e.g. Mason or Bell jars) are required.

2. Odor-free water (e.g. distilled or spring water) at approximately 25°C shall be used for the solution.

3. The isoamyl acetate (IAA) (also known as isopentyl acetate) stock solution is prepared by adding 1 cc of pure IAA to 800 cc of odor free water in a 1-liter jar and shaking for 30 seconds. The solution shall be prepared new at least weekly.

4. The screening test shall be conducted in a room separate from the room used for actual fit testing. The two rooms shall be well ventilated but may not be connected to the same recirculating ventilation system.

5. The odor test solution is prepared in a second jar by placing 4 cc of the stock solution into 500 cc of odor free water using a clean dropper or pipette. Shake for 30 seconds and allow to stand for two to three minutes so that the IAA concentration above the liquid may reach equilibrium. This solution may be used for only one day.

6. A test blank is prepared in a third jar by adding 500 cc of odor free water.

7. The odor test and test blank jars shall be labeled 1 and 2 for jar identification. If the labels are put on the lids they can be periodically dried off and switched to avoid people thinking the same jar always has the IAA.

8. The following instructions shall be typed on a card and placed on the table in front of the two test jars (i.e. 1 and 2):

"The purpose of this test is to determine if you can smell banana oil at a low concentration. The two bottles in front of you contain water. One of these bottles also contains a small amount of banana oil. Be sure the covers are on tight, then shake each bottle for two seconds. Unscrew the lid of each bottle, one at a time, and sniff at the mouth of the bottle. Indicate to the test conductor which bottle contains banana oil."

9. The mixtures used in the IAA odor detection test shall be prepared in an area separate from where the test is performed, in order to prevent olfactory fatigue in the subject.

10. If the test subject is unable to correctly identify the jar containing the odor test solution, the IAA QLFT may not be used.

11. If the test subject correctly identifies the jar containing the odor test solution he may proceed to respirator selection and fit testing.

B. Respirator Selection

1. The test subject shall be allowed to select the most comfortable respirator from a large array of various sizes and manufacturers that includes at least three sizes of elastomeric half facepieces and units of at least two manufacturers.

2. The selection process shall be conducted in a room separate from the fit test chamber to prevent odor fatigue. Prior to the selection process, the test subject shall be shown how to put on a respirator, how it should be positioned on the face, how to set strap tension and how to assess a "comfortable" respirator. A mirror shall be available to assist the subject in evaluating the fit and positioning of the respirator. This may not constitute his formal training on respirator use, only a review.

3. The test subject should understand that he is being asked to select the respirator which provides the most comfortable fit for him. Each respirator represents a different size and shape and, if fit properly, will provide adequate protection.

4. The test subject holds each facepiece up to his face and eliminates those which are obviously not giving a comfortable fit. Normally, selection will begin with a half-mask and if a fit cannot be found here, the subject will be asked to go to the full-facepiece respirators. (A small percentage of users will not be able to wear any half-mask.)

5. The more comfortable facepieces are recorded; the most comfortable mask is donned and worn at least five minutes to assess comfort. Assistance in assessing comfort can be given by discussing the points in #6 below. If the test subject is not familiar with using a particular respirator, he shall be directed to don the mask several times and to adjust the straps each time, so that he becomes adept at setting proper tension on the straps.

6. Assessment of comfort shall include reviewing the following points with the test subject:

   o Chin properly placed.
   o Positioning of mask on nose.
   o Strap tension.
   o Fit across nose bridge.
   o Room for safety glasses.
   o Distance from nose to chin.
   o Room to talk.
   o Tendency to slip.
   o Cheeks filled out.
   o Self-observation in mirror.
   o Adequate time for assessment.

7. The test subject shall conduct the conventional negative and positive-pressure fit checks (e.g. see ANSI Z88.2-1980). Before conducting the negative-or positive-pressure checks, the subject shall be told to "seat" his mask by rapidly moving the head side-to-side and up and down, taking a few deep breaths.

8. The test subject is now ready for fit testing.

9. After passing the fit test, the test subject shall be questioned again regarding the comfort of the respirator. If it has become uncomfortable, another model of respirator shall be tried.

10. The employee shall be given the opportunity to select a different facepiece and be retested if during the first two weeks of on-the-job wear the chosen facepiece becomes unacceptably uncomfortable.

C. Fit test.

1. The fit test chamber shall be substantially similar to a clear 55 gallon drum liner suspended inverted over a 2 foot diameter frame, so that the top of chamber is about 6 inches above the test subject's head. The inside top center of the chamber shall have a small hook attached.

2. Each respirator used for the fitting and fit testing shall be equipped with organic vapor cartridges or offer protection against organic vapors. The cartridges or masks shall be changed at least weekly.

3. After selecting, donning, and properly adjusting a respirator himself, the test subject shall wear it to the fit testing room. This room shall be separate from the room used for odor threshold screening and respirator selection, and shall be well ventilated, as by an exhaust fan or lab hook, to prevent general room contamination.

4. A copy of the following test exercises and rainbow (or equally effective) passage shall be taped to the inside of the test chamber:

   Test Exercises

   i. Normal breathing

   ii. Deep breathing. Be certain breaths are deep and regular.

   iii. Turning head from side-to-side. Be certain movement is complete. Alert the test subject not to bump the respirator on the shoulders. Have the test subject inhale when his head is at either side.

   iv. Nodding head up-and-down. Be certain motions are complete and made about every second. Alert the test subject not to bump the respirator on the chest. Have the test subject inhale when his head is in the fully up position.

   v. Talking. Talk aloud and slowly for several minutes. The following paragraph is called the Rainbow Passage. Reading it will result in a wide range of facial movements, and thus be useful to satisfy this requirement. Alternative passages which serve the same purpose may also be used.

Rainbow Passage

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one every finds it. When a man looks for something beyond reach, his friends say he is looking for the pot of gold at the end of the rainbow.

vi. Normal breathing.

5. Each test subject shall wear his respirator for at least 10 minutes before starting the fit test.

6. Upon entering the test chamber, the test subject shall be given a 6 inch by 5 inch piece of paper towel or other porous absorbent single ply material, folded in half and wetted with three-quarters of one cc of pure IAA. The test subject shall hang the wet towel on the hook at the top of the chamber.

7. Allow two minutes for the IAA test concentration to be reached before starting the fit test exercises. This would be an appropriate time to talk with the test subject, to explain the fit test, the importance of his cooperation, the purpose for the head exercises, or to demonstrate some of the exercises.

8. Each exercise described in No. 4 above shall be performed for at least one minute.

9. If at any time during the test, the subject detects the banana-like odor of IAA, he shall quickly exit from the test chamber and leave the test area to avoid olfactory fatigue.

10. Upon returning to the selection room, the subject shall remove the respirator, repeat the odor sensitivity test, select and put on another respirator, return to the test chamber, etc. The process continues until a respirator that fits well has been found. Should the odor sensitivity test be failed, the subject shall wait about 5 minutes before retesting. Odor sensitivity will usually have returned by this time.

11. If a person cannot be fitted with the selection of half-mask respirators, include full-facepiece models in the selection process. When a respirator is found that passes the test, its efficiency shall be demonstrated for the subject by having him break the face seal and take a breath before exiting the chamber.

12. When the test subject leave the chamber he shall remove the saturated towel, returning it to the test conductor. To keep the area from becoming contaminated, the used towels shall be kept in a self-sealing bag. There is no significant IAA concentration buildup in the test chamber from subsequent tests.

13. Persons who have successfully passed this fit test may be assigned the use of the tested respirator in atmospheres with up to 10 times the PEL of airborne lead. In other words this IAA protocol may be used to assign a protection factor no higher than 10.

II. SACCHARIN SOLUTION AEROSOL PROTOCOL

A. Taste Threshold Screening.

1. Threshold screening as well as fit testing employees shall use an enclosure about the head and shoulders that is approximately 12 inches in diameter by 14 inches tall with at least the front portion clear and that allows free movement of the head when a respirator is worn. An enclosure substantially similar to the 3M hood assembly of part #FT 14 and FT 15 combined is adequate.

2. The test enclosure shall have a three-quarter inch hole in front of the test subject's nose and mouth area to accommodate the nebulizer nozzle.

3. The entire screening and testing procedure shall be explained to the test subject prior to the conduct of the screening test.

4. The test subject shall don the test enclosure. For the threshold screening test, he shall breathe through his open mouth with tongue extended.

5. Using a DeVilbiss Model 40 Inhalation Medication Nebulizer, the test conductor shall spray the threshold check solution into the enclosure. This nebulizer shall be clearly marked to distinguish it from the fit test solution nebulizer or equivalent.

6. The threshold check solution consists of 0.83 grams of sodium saccharin, USP in water. It can be prepared by putting 1 cc of the test solution (see C6 below) in 100 cc of water.

7. To produce the aerosol, the nebulizer bulb is firmly squeezed so that it collapses completely then released and allowed to fully expand.

8. Ten squeezes are repeated rapidly and then the test subject is asked whether the saccharin can be tasted.

9. If the first response is negative, ten more squeezes are repeated rapidly and the test subject is again asked whether the saccharin is tasted.

10. If the second response is negative, ten more squeezes are repeated rapidly and the test subject is again asked whether the saccharin is tasted.

11. The test conductor will take note of the number of squeezes required to elicit a taste response.

12. If the saccharin is not tasted after 30 squeezes (Step 9), the test subject may not perform the saccharin fit test.

13. If a taste response is elicited, the test subject shall be asked to take note of the taste for reference in the fit test.

14. Correct use of the nebulizer means that approximately 1 cc of liquid is used at a time in the nebulizer body.

15. The nebulizer shall be thoroughly rinsed in water, shaken dry, and refilled at least each morning and afternoon or at least every four hours.

B. Respirator Selection.

Respirators shall be selected as described in section IB above, except that each respirator shall be equipped with a particular filter cartridge.

C. Fit Test.

1. The fit test uses the same enclosure described in B1 and B2 above.

2. Each test subject shall wear his respirator for at least 10 minutes before starting the fit test.

3. The test subject shall don the enclosure while wearing the respirator selected in section A above. This respirator shall be properly adjusted and equipped with a particular filter cartridge.

4. The test subject may not eat, drink (except plain water), or chew gum for 15 minutes before the test.

5. A second DeVilbiss Model 40 Inhalation Medication nebulizer is used to spray the fit test solution into the enclosure. This nebulizer shall be clearly marked to distinguish it from the screening test solution nebulizer or equivalent.

6. The fit test solution is prepared by adding 83 grams of sodium saccharin to 100 cc of warm water.

7. As before, the test subject shall breathe through the open mouth with tongue extended.

8. The nebulizer is inserted into the hole in front of the enclosure and the fit test solution is sprayed into the enclosure using the same technique as for the taste threshold screening and the same number of squeezes required to elicit a taste response in the screening. (See B10 above).

9. After generation of the aerosol the test subject shall be instructed to perform the following exercise for one minute each:

   a. Normal breathing.

   b. Deep breathing. Be certain breaths are deep and regular.

   c. Turning head from side-to-side. Be certain movement is complete. Alert the test subject not to bump the respirator on the shoulders. Have the test subject inhale when his head is at either side.

   d. Nodding head up-and-down. Be certain motions are complete and made about every second. Alert the test subject not to bump the respirator on the chest. Have the test subject inhale when his head is in the fully up position.

2. Each test subject shall wear his respirator for at least 10 minutes before starting the fit test.

3. The test subject shall don the enclosure while wearing the respirator selected in section A above. This respirator shall be properly adjusted and equipped with a particular filter cartridge.

4. The test subject may not eat, drink (except plain water), or chew gum for 15 minutes before the test.

5. A second DeVilbiss Model 40 Inhalation Medication nebulizer is used to spray the fit test solution into the enclosure. This nebulizer shall be clearly marked to distinguish it from the screening test solution nebulizer or equivalent.

6. The fit test solution is prepared by adding 83 grams of sodium saccharin to 100 cc of warm water.

7. As before, the test subject shall breathe through the open mouth with tongue extended.

8. The nebulizer is inserted into the hole in front of the enclosure and the fit test solution is sprayed into the enclosure using the same technique as for the taste threshold screening and the same number of squeezes required to elicit a taste response in the screening. (See B10 above).

9. After generation of the aerosol the test subject shall be instructed to perform the following exercise for one minute each:

   a. Normal breathing.

   b. Deep breathing. Be certain breaths are deep and regular.

   c. Turning head from side-to-side. Be certain movement is complete. Alert the test subject not to bump the respirator on the shoulders. Have the test subject inhale when his head is at either side.

   d. Nodding head up-and-down. Be certain motions are complete and made about every second. Alert the test subject not to bump the respirator on the chest. Have the test subject inhale when his head is in the fully up position.

e. Talking. Talk aloud and slowly for several minutes. The following paragraph is called the Rainbow Passage. Reading it will result in a wide range of facial movements, and thus be useful to satisfy this requirement. Alternative passages which serve the same purpose may also be used.

Rainbow Passage

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of god at one end. People look, but no one every finds it. When a man looks for something beyond reach, his friends say he is looking for the pot of gold at the end of the rainbow.

10. Every 30 seconds, the aerosol concentration shall be replenished using one-half the number of squeezes as initially (C8).

11. The test subject shall so indicate to the test conductor if at any time during the fiat test the taste of saccharin is detected.

12. If the saccharin is detected the fit is deemed unsatisfactory and a different respirator shall be tried.

13. Successful completion of the test protocol shall allow the use of the tested respirator in contaminated atmospheres up to 10 times the PEL. In other words this protocol may be used to assign protection factors no higher than ten.

III. IRRITANT FUME PROTOCOL

A. Respirator Selection.

Respirators shall be selected as described in section 1B above, except that each respirator shall be equipped with high efficiency cartridges.

B. Fit Test.

1. The test subject shall be allowed to smell a weak concentration of the irritant smoke to familiarize him with its characteristic odor.

2. The test subject shall properly don the respirator selected as above, and wear it for at least 10 minutes before starting the fit test.

3. The test conductor shall review this protocol with the test subject before testing.

4. The test subject shall perform the conventional positive pressure and negative pressure fit checks. Failure of either check shall be cause to select an alternate respirator.

5. Break both ends of a ventilation smoke tube containing stannic oxychloride, such as the MSA part No. 5645, or equivalent. Attach a short length of tubing to one end of the smoke tube. Attach the other end of the smoke tube to a low pressure air pump set to deliver 200 milliliters per minute.

6. Advise the test subject that the smoke can be irritating to the eyes and instruct him to keep his eyes closed while the test is performed.

7. The test conductor shall direct the stream of irritant smoke from the tube towards the faceseal area of the test subject. He shall begin at least 12 inches from the facepiece and gradually move to within one inch, moving around the whole perimeter of the mask.

8. The following exercises shall be performed while the respirator seal is being challenged by the smoke. Each shall be performed for one minute.

   a. Normal breathing

   b. Deep breathing. Be certain breaths are deep and regular.

   c. Turning head from side-to-side. Be certain movement is complete. Alert the test subject not to bump the respirator on the shoulders. Have the test subject inhale when his head is at either side.

   d. Nodding head up-and-down. Be certain motions are complete and made about every second. Alert the test subject not to bump the respirator on the chest. Have the test subject inhale when his head is in the fully up position.

   e. Talking--slowly and distinctly, count backwards from 100.

f. Normal breathing

9. If the irritant smoke produces an involuntary reaction (cough) by the test subject, the test conductor shall stop the test. In this case the test respirator is rejected and another respirator shall be selected.

10. Each test subject passing the smoke test without evidence of a response shall be given a sensitivity check of the smoke from the same tube to determine whether he reacts to the smoke. Failure to evoke a response shall void the fit test.

11. Steps B4, B7, B8 of this protocol shall be performed in a location with exhaust ventilation sufficient to prevent general contamination of the testing area by the irritant smoke.

12. Respirators successfully tested by the protocol may be used in contaminated atmospheres up to ten times the PEL. In other words this protocol may be used to assign protection factors not exceeding ten.

APPENDIX B.3. QUANTITATIVE FIT TEST PROCEDURES

Except for procedures peculiar to instrument operation and calibration, quantitative respirator fitting tests are practically identical. The following is a suggested procedure for use in all types of test systems.

I. PRELIMINARY CHECKOUT PROCEDURES

A. Start up and calibrate the test system according to manufacturer's instructions. Be sure that the system is stable and that the aerosol or gas concentration in the enclosure has reached equilibrium.

B. Inspect all respirators to be used in the tests for defects and cleanness according to the procedures described in this guide.

II. QUANTITATIVE FITTING TEST PROCEDURES

A. Recheck the respirator before handing it to the test subject, paying particular attention to the sampling probe and line attached to the facepiece.

B. Describe the test to the subject, making sure that the subject fully understands its purpose, the procedures, and the actions expected.

C. If the subject is not familiar with wearing respirators, demonstrate correct wearing procedures. The subject's level of expertise usually becomes apparent as the subject puts on the respirator. The untrained or poorly trained subject will put the respirator on incorrectly or be hesitant in movements.

D. Have the subject put on the respirator, according to manufacturer's instructions. Be sure the subject does not tighten the headstraps to the point of discomfort. Remember that this test should approximate working conditions in which the subject might have to wear the respirator continuously for an hour to two at a time.

In testing a half- or quarter-mask, check its compatibility with safety glasses. If the subject's safety glasses interfere, try other brands of respirators of the same type. The subject may have to wear a full-facepiece, which provides eye protection, if a half- or quarter-mask compatible with safety glasses cannot be found.

E. Once it has been determined that the respirator is worn properly, the fit can be checked quickly using a qualitative fitting test. Make sure that the correct filter, cartridge, or canister for the particular test is installed in the respirator. Also make sure that the subject pinches off the sampling hose. If leakage is detected, try to determine its source and cause. If the leakage is from a poorly fitting facepiece, try another brand of the same type of respirator. In fact, several different brands of respirators should be made available so the subject can choose the most comfortable, a very important aspect of fitting respirators.

F. After the best possible qualitative fit has been obtained, the subject enters the test enclosure and connects the sampling hose. If necessary, and without disturbing the facepiece fit, replace the filter, cartridge, or canister used during the qualitative test with the air-purifying element required for the quantitative test. To minimize filter leakage, use high-efficiency particulate filters when the test agent is an aerosol. Allow enough time (2-3 minutes) at this point for the test enclosure concentration to stabilize. Then recheck the test system calibration.

G. In response to verbal instructions, the subject begins head and facial movements simulating those made during normal work.

(1) Normal breathing with head motionless for 1 minute;

(2) Deep breathing (simulating that during hard work) with head motionless for 30 seconds. Do not prolong this exercise because of the danger of hyperventilation;

(3) Turning head slowly up and down while breathing normally, pausing for at least two breaths before changing direction. Continue for at least 1 minute;

(4) Moving head slowly up and down while breathing normally, pausing for at least two breaths before changing direction. Continue for at least 1 minute;

(5) Reading from a prepared text, slowly and clearly, and loudly enough to be heard and understood by the test operator. Continue for 1 minute;

(6) Normal breathing with head motionless for at least 1 minute.

These exercises are more or less "standard" and have been found to provide a meaningful evaluation of respirator performance. Therefore, if they are used, the data can be compared with published information. The times suggested for each are minimal and may be extended if needed to obtain better data.

H. After the test, the subject leaves the test enclosure and removes the respirator. The operator should then ask about the respirator comfort and note any marks on the subject's face which indicate pressure points. If the test indicated a good fit, any discomfort may be due to a mismatch between the subject and the facepiece or to headstraps that are too tight. Every effort should be made to provide the most comfortable respirator possible.

I. The test results may be analyzed and the protection level determined by one of two methods. The first involves watching a meter during the test to determine that penetration does not exceed a certain value.

The second, much preferred, method is to record the entire test using a strip chart recorder operated at a chart speed of about 2 inches per minute.

The first information should uniquely identify the test by number, date, subject, and type of respirator. Next comes the test system calibrations after the subject has entered the test enclosure, to establish the maximum span of the penetration-measuring instrument ("100% calibration). This should be done at least twice to ensure that the calibration is correct.

Next follow the five exercises, separated by horizontal lines across the chart. As the penetration-measuring instrument has several ranges, the range should be shown next to the right margin of the chart. When it becomes necessary to change the penetration range, as in the example under turning head from side to side (TH), make a short mark where the change was made and indicate the new scale setting.

Each exercise should be identified by some notation. For example, the following notation could be used on the strip chart recording:

Normal Breathing	NB
Deep Breathing	DB
Turning Head from Side to Side	TH
Moving Head Up and Down	UD
Talking	T

These are suggested notations; others may be used, but they should be consistent.

All the above notations should be made during the test. However, it is neither necessary nor desirable to calculate the penetrations until later. The operator should pay full attention to running the equipment and noting the subject's actions during the test.

The cyclic nature of the recorder trace is a function of the subject's breathing cycle. As this example shows, in an air-purifying respirator with a half-mask, negative air pressure created in the facepiece during inhalation increases the leakage. Exhalation creates slightly positive air pressure, reducing the leakage. Also, the lungs absorb some of the test agent, especially if it is an aerosol, thus reducing the quantity of test agent in the exhaled breath. Consequently, the maximum penetration during inhalation indicates the fraction of ambient concentration which has penetrated the facepiece. Therefore respirator performance is based on the average of the peak penetrations.

After the test, the operator may analyze the recording. This is done, treating each exercise separately, by drawing a line through the inhalation peaks to approximate their average. The midpoint of each line is the "average peak penetration" for the exercise. This number should be entered on the chart for each exercise. Where the penetration changes abruptly, it is usually advantageous to split the data into more than one section and treat each separately.

For example, if five chart divisions under UD show a penetration of 2.55% and three show 3.75%, the average peak penetration for the entire exercise is calculated as follows:

5 divisions x 2.55 =	12.75
3 divisions x 3.75 =	11.25
8 divisions	24.00

24.00/8 = 3.00% peak average penetration.

After the average peak penetration has been calculated for each exercise, the data may be entered on a fitting test record. The record should include the information from the recorder chart which uniquely identifies the test. The record should indicate results of the qualitative pretest, the average peak penetrations calculated for each exercise, the test criterion expressed as the maximum allowable average peak penetration, the test average peak penetration obtained by averaging the average peak penetrations for each exercise, and whether the overall performance was satisfactory or not. This determination is based on the qualitative fit, compatibility with safety glasses, and average penetration.

The subject evaluation of the comfort of the particular respirator is based on the following criteria:

1. VERY COMFORTABLE

   Mask can be worn for an indefinite period without becoming unbearably bothersome or painful. No pain points: mask feels comfortable.

2. COMFORTABLE

   Mask can be worn for 2 to 4 hours without undue discomfort. Some pressure points with slight discomfort.

3. BARELY COMFORTABLE

   Mask can be worn for approximately 1/2 to 1 hour without intolerable discomfort. Some discomfort from pressure.

4. UNCOMFORTABLE

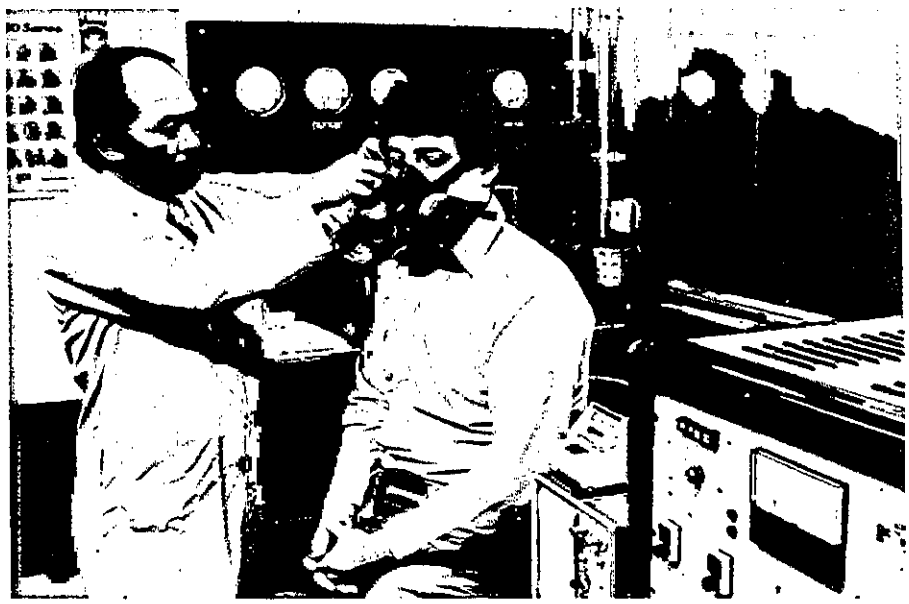
   Mask can be tolerated for the period of the test only.

5. INTOLERABLE

   Mask cannot be worn at all without discomfort.

All other factors being equal, final choice of a respirator should be based on comfort. A worker should not be required to wear a device he considers "uncomfortable" or "intolerable." He may wear a "barely comfortable" respirator if the proposed usage is intermittent for short periods.

In summary, the above is a suggested procedure for conducting a quantitative respirator fitting test, evaluating the results, and recording the data meaningfully, without laborious record keeping. Moreover, the data will be compatible with those from other work.



Photograph Courtesy of North Safety Products

FIGURE B-4. **Checking fit prior to doing quantitative fit testing**

Photograph Courtesy of Gerson Co., Inc.

FIGURE B-5. **Quantitative fit testing of a single-use respirator**

APPENDIX C

SELECTED NIOSH RESPIRATOR USER NOTICES

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
National Institute for Occupational
Safety and Health – ALOSH
944 Chestnut Ridge Road
Morgantown, WV 26505

January 15, 1982

NIOSH EMERGENCY INFORMATION BULLETIN ON THE USE OF SELF-CONTAINED BREATHING APPARATUS IN LOW TEMPERATURES

Extreme caution should be exercised by all persons using open circuit self-contained breathing apparatus (SCBA) in hazardous environments during sub-freezing weather. SCBAs are widely used by fire fighters combatting winter fires. All users who wear SCBAs in cold temperatures should take particular note of the following important precautions:

1. Moisture in the air cylinders must be kept at an absolute minimum since small amounts of moisture in the air supply may freeze and result in failure of the breathing apparatus.

2. Always use a nosecup in the SCBA facepiece when temperatures are below freezing. Failure to use a nosecup under such circumstances can result in facepiece fogging and severely impaired vision. Chemical anti-fog agents may not perform adequately in low temperatures.

3. Carefully read the approval label on the respirator to determine if it is necessary to install special accessories prior to use of the SCBA in sub-freezing weather. Certain older U.S. Bureau of Mines approved SCBAs require such low temperature accessories (SCBAs approved prior to March 25, 1972).

4. When leaving an extremely hot environment, such as a fire scene, and entering cold air (below or near freezing), always place the SCBA facepiece in your turnout coat to keep it warm if it is to be quickly reused. SCBAs when not being actively breathed can freeze-up very quickly.

5. Use special care after washing SCBA facepieces and breathing tubes to remove all moisture to prevent water drainage and freeze-up of the regulator.

6. SCBA alarms can fail in low temperatures; therefore, visual checks of remaining service time should be made when SCBAs are used in sub-freezing conditions.

7. Be familiar with procedures on how to cope with exhalation valves which can freeze open or closed in low temperatures. (Contact the manufacturer or the State Fire Training Officer for specific instructions.)

8. SCBAs are NIOSH laboratory approved for use in temperatures down to -25° F. Therefore, if SCBAs are to be used in temperatures below -25° F, extreme caution should be used.

9. Also observe the following general precautions:

   a. Use G-7.1, Type I, Grade D air or air of equivalent specification.

   b. Follow all information listed on the NIOSH/MSHA or BOM approval label for the specific SCBA in use.

   c. Follow the manufacturer's recommendations included in their instruction and maintenance manual accompanying the SCBA.

   d. Follow all applicable Federal, State, and Local regulations concerned with the use of SCBAs.

   e. Keep SCBAs in a warm location between uses.

James A. Oppold, Ph.D., PE
Director
Division of Safety Research

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
National Institute for Occupational
Safety and Health – ALOSH
944 Chestnut Ridge Road
Morgantown, WV 26505–2888

November 15, 1982

RESPIRATOR INFORMATION NOTICE
ON
MSA Powered Air Purifying Respirator
Mine Safety Appliance Company, Pittsburgh, PA
Model Numbers: 463354, 466607, 466608
Approval Number: TC-21C-186

On April 24, 1981, NIOSH issued a Respirator Information Notice which described the results of a NIOSH study of the MSA high efficiency powered air purifying respirator (PAPR) during use in a silica flour mill. The observed workplace protection factors (defined as the ratio of the concentration of contaminant outside the facepiece to the concentration of contaminant inside the facepiece measured while the respirator is worn) were significantly below the anticipated workplace protection factor of 1000. As a result, NIOSH stated that workers wearing the MSA PAPR may not receive the protection they anticipated. NIOSH stated further than the Institute had no evidence that the problem discovered in that study existed in other industries or situations of use. NIOSH also stated that the Institute would conduct further studies to evaluate the performance of the MSA PAPR against substances physically and chemically different from silica flour to determine whether results with silica flour were indicative of a problem associated with conditions of exposure or related to the malfunction of equipment.

Staff of NIOSH subsequently conducted a field evaluation of the half-mask MSA high efficiency PAPR at a primary lead smelter. The challenge aerosols contained predominantly lead dust and or lead fume. From this and other NIOSH studies, additional information has been developed and this Notice supersedes the Notice of April 24, 1981.

This field evaluation of the MSA PAPR produced the following preliminary results. The workplace protection factors associated with the respirator was found to be approximately lognormally distributed. The MSA PAPR produced a geometric mean workplace protection factor of 376 with a geometric standard deviation of 2.64 against lead fume and lead dust. Approximately 95% of the observed workplace protection factors for the MSA PAPR exceeded 77 while 84% of the observed workplace protection factors were below 1000. During this study no wearer of the MSA PAPR was exposed to concentrations of lead exceeding the permissible exposure limit (PEL).

Subsequent to issuance of the Respirator Information Notice of April 24, 1981, NIOSH and MSHA commenced proceedings to withdraw the certification of the MSA PAPR. That action was predicated upon the determination by

NIOSH that the MSA PAPR, during use in a silica flour mill, apparently did not provide the anticipated level of protection, i.e., a workplace protection factor of 1000. That action was subsequently voluntarily dismissed by the agencies pending the results of further studies. This study and additional studies of the PAPR class conducted by NIOSH indicate that the previously anticipated protection factor of 1000 expected of the entire class of PAPRs is inappropriately high. In view of this, the certification withdrawal proceedings against the MSA PAPR, which were previously dismissed will not be reinstituted. However, NIOSH recommends that users of PAPRs not rely upon them to consistently provide a workplace protection factor of 1000.

The results of the additional PAPR studies will be addressed in a subsequent Respirator Information Notice. For more information on this subject, contact the Testing and Certification Branch, Division of Safety Research, NIOSH, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505, (304) 291-4331.

James A. Oppold, Ph.D., PE, CSP
Director
Division of Safety Research

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
National Institute for Occupational
Safety and Health – ALOSH
944 Chestnut Ridge Road
Morgantown, WV 26505–2888

March 3, 1983

RESPIRATOR INFORMATION NOTICE

ON

3M Powered Air Purifying Respirator
3M, St. Paul, Minnesota
Model Number: W-344
Approval Number: TC-21C-246

Racal Powered Air Purifying Respirator
Racal Airstream, Inc., Frederick, Maryland
Model Number: AH3
Approval Number: TC-21C-212

In a Respirator Information Notice dated November 15, 1982, NIOSH recommended that powered air purifying respirators (PAPRs) with high efficiency filters not be relied upon to consistently provide a workplace protection factor of 1000. That recommendation was based upon the results of the two studies of PAPRs with tight fitting facepieces described in that Notice as well as the additional NIOSH study of helmeted PAPRs described in this Notice.

The NIOSH study of helmeted PAPRs with high efficiency filters was conducted by NIOSH on the 3M W-344 PAPR and the Racal AH3 PAPR at a secondary lead smelter. In this study the challenge aerosols contained lead dust and/or lead fume.

This study produced the following preliminary results. The workplace protection factors associated with both respirator models were found to be approximately lognormally distributed. The results of the t-tests indicate that there is no significant difference ($P < .05$) between the mean workplace protection factors of the 3M and Racal PAPRs under the particular circumstances of these studies. For both the 3M and Racal PAPRs, approximately 98% of the observed workplace protection factors were below 1000. Approximately 95% of the observed workplace protection factors for both the 3M and Racal PAPRs exceeded 33. The geometric mean workplace protection factor for 3M and Racal PAPRs was 182 with a geometric standard deviation of 3.2.

As stated in the November 15, 1982, Respirator Information Notice, the preliminary results of the NIOSH studies of the MSA, 3M and Racal PAPRs indicate that the protection factor expected from this class of respirators is inappropriately high.

For more information on this subject, contact Glendel J. Provost, Division of Safety Research, NIOSH, 944 Chestnut Ridge Road, Morgantown, West Virginia 26505. Commercial telephone number is (304) 291-4595 and the FTS number is 923-4595.

James A. Oppold, Ph.D., PE, CSP
Director
Division of Safety Research

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
National Institute for Occupational
Safety and Health – ALOSH
944 Chestnut Ridge Road
Morgantown, WV 26505–2888

December 16, 1983

RESPIRATOR USER'S NOTICE

Effects of Chemicals on Rubber and Plastic Parts of Self-contained Breathing Apparatus

The National Institute for Occupational Safety and Health (NIOSH) has received several reports of damage to parts of self-contained breathing apparatus that have apparently been exposed to concentrations of chemicals. These exposures have occurred during emergency response activities after accidental chemical vapor release and/or chemical discharge. The most recent report concerned a leak of dimethyl amine in Benicia, California, on August 12 and 13, 1983. Self-contained breathing apparatus and other equipment used during control of this leak were reportedly rendered unserviceable after exposure.

In view of these reports, fire fighting personnel who are engaged in emergency response activities should be equipped with proper chemical protective clothing in addition to respiratory protection. Information on the protective capabilities of such clothing should be obtained from the clothing manufacturer.

NIOSH is conducting a study of permeation of protective clothing materials by chemicals. Part of this study involves preparation of a data base of information on that subject. As part of this data base, NIOSH would appreciate receiving information on further cases of reported damage to self-contained breathing apparatus by chemicals. Reports should be addressed to the Testing and Certification Branch, Division of Safety Research, NIOSH, 944 Chestnut Ridge Road, Morgantown, WV 26505-2888. Reports should include the name of the chemical, Chemical Abstracts Service (CAS) Registry number, if known, identification and/or type of material damaged, extent of damage, and either the approximate concentration of the chemical or details of the exposure (e.g., exposure to liquid and/or vapor, temperature, wind conditions, and degree of enclosure of exposure).

Thomas C. Purcell

Thomas C. Purcell, Ph.D.
Acting Director,
Division of Safety Research

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
National Institute for Occupational
Safety and Health – ALOSH
944 Chestnut Ridge Road
Morgantown, WV 26505–2888

December 16, 1983

RESPIRATOR USER'S NOTICE

Effects of Heat and Flames on Rubber and Plastic Parts of Self-contained Breathing Apparatus

The National Institute for Occupational Safety and Health (NIOSH) has received several reports of damage to parts of self-contained breathing apparatus that have apparently been exposed to excessive heat and/or flames during fire fighting activities. A preliminary investigation of these reports indicates that development of new turnout gear for fire fighters permits them to enter and remain in higher temperatures and flame exposures. These higher temperatures and flame exposures can apparently damage some presently-used rubber and plastic parts of self-contained breathing apparatus.

NIOSH is proposing to include requirements for high-temperature performance of self-contained breathing apparatus in Title 30, Code of Federal Regulations, Part 11 (30 CFR 11), the regulations governing approval of respirators. NIOSH has been advised by self-contained breathing apparatus manufacturers that they are developing new materials with greater resistance to heat and flames. NIOSH recommends that fire fighters avoid overexposure of breathing apparatus parts to high heat and/or flames, where possible.

NIOSH requests that fire fighting personnel and others report further incidents of heat and flame damage of self-contained breathing apparatus. Such reports should be sent to the Testing and Certification Branch, Division of Safety Research, NIOSH, 944 Chestnut Ridge Road, Morgantown, WV 26505-2888.

Thomas C. Purcell, Ph.D.
Acting Director,
Division of Safety Research

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
National Institute for Occupational
Safety and Health – ALOSH
944 Chestnut Ridge Road
Morgantown, WV 26505–2888

November 6, 1984

RESPIRATOR USERS' NOTICE

USE OF UNAPPROVED SUBASSEMBLIES

The National Institute for Occupational Safety and Health (NIOSH) has received many questions and complaints in regard to interchangeability of respirator subassemblies and unapproved modifications to MSHA/NIOSH certified respirators. Further, some problems reported to NIOSH have, upon investigation, been found to have been caused by user's modifying certified respirators which have resulted in the modified respirator failing to perform as anticipated, thus jeopardizing the respirator user.

MSHA/NIOSH respirator certification regulations, Title 30 Code of Federal Regulations Part 11 (30 CFR 11), state that approved respirators are ones that "are maintained in an approved condition and are the same in all respects as those respirators for which a certificate has been issued." [30 CFR 11, 11.2(b)] In addition, the regulations permit NIOSH/MSHA to only approve complete respirator assemblies and prohibit the approval of respirator subassemblies such as cylinders or air supply hoses. These requirements are intended to insure that one manufacturer has overall control and responsibility for the integrity of the approved respirator.

In some cases even minor modifications to respirators may make significant changes in the performance of the respirator. Manufacturers who modify certified respirators must test the modification to determine if the respirator continues to meet the minimum requirements of 30 CFR 11, and must submit the modifications to NIOSH. A user who modifies a certified respirator may not be able to determine whether a change will decrease respiratory protection. Several cases have been reported to NIOSH where unapproved modifications or use of an unapproved subassembly have resulted in respirator failures. Therefore, users of NIOSH/MSHA approved respirators are cautioned against interchanging subassemblies or making unapproved modifications to their respiratory protective devices.

John B. Moran
Director
Division of Safety Research

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
National Institute for Occupational
Safety and Health – ALOSH
944 Chestnut Ridge Road
Morgantown, WV 26505–2888

June 28, 1985

RESPIRATOR USERS NOTICE

Use and Maintenance of Pressure-demand
Self-contained Breathing Apparatus

Since July 1, 1983, the Occupational Safety and Health Administration (OSHA) Fire Brigade Standard, Title 29, Code of Federal Regulations, Part 1910.156, has required that pressure-demand or other positive pressure self-contained breathing apparatus be worn by fire brigade members performing interior structural fire fighting. Although this standard is only applicable to all industrial fire brigades and to municipal fire departments in states with state-OSHA plans, other fire service organizations and industrial users of self-contained breathing apparatus (SCBA) have also recognized the superior protective capabilities of positive-pressure SCBA. As a result, there has been a steady change from demand to pressure-demand SCBA in the United States.

To provide the increased respiratory protection afforded by pressure-demand SCBA, it is generally necessary to increase the static pressure within the facepiece. The complex mechanics necessary to maintain this increased pressure and to control air flow when the facepiece is removed, together with the wearer's physiological response to the pressure-demand system, have presented problems to SCBA users.

Pressure demand SCBA requires more careful maintenance and different training, than is required for demand SCBA. Manufacturers have been providing maintenance and use instructions and training for purchasers of pressure-demand SCBA. The National Institute for Occupational Safety and Health (NIOSH) recommends that users of pressure-demand SCBA read those instructions, follow them carefully in apparatus use and maintenance, and take advantage of the manufacturer's training assistance. In addition to the manufacturers, training courses are offered by Fire Service organizations and by private organizations.

In the area of pressure-demand SCBA maintenance and repair, NIOSH strongly recommends that users have this service performed by a manufacturer-trained representative. This service is required to assure continued safe performance of pressure-demand SCBA.

Please advise NIOSH of any problems encountered in maintenance and use of pressure-demand self-contained breathing apparatus. Call the NIOSH Respirator Problem Coordinator, (304) 291-4595 (FTS 923-4595).

To assist you, NIOSH has prepared the following list of manufacturer's and fire service organization personnel who can provide further information on pressure-demand breathing apparatus training:

Clifton Precision
5100 State Road
Drexel Hill, PA 19026
Mr. Robert Gray (215) 622-1718

Globe Safety Equipment, Inc.
P.O. Box 7248
Dayton, OH 45407
Mr. Steven Bates (513) 224-7468

International Safety Instruments, Inc.
P.O. Box 846
Lawrenceville, GA 30246
Mr. Donald Dawson (404) 962-2552

MSA
600 Penn Center Boulevard
Pittsburgh, PA 15235
Mr. Jay Mears (412) 273-5145

North Safety Equipment
2000 Plainfield Pike
Cranston, RI 02920
Mr. Richard T. Flynn (401) 943-4400

Rexnord
45 Great Valley Parkway
Malvern, PA 19355
Mr. Justin Mills (215) 647-7200 *

Scott Aviation
225 Erie Street
Lancaster, NY 14086
Mr. Dennis Browner (716) 683-5100

U.S.D.
3323 West Warner Avenue
Santa Ana, CA 92702
Mr. Brian Miller (714) 241-4601

National Draeger, Inc.
P.O. Box 120
Pittsburgh, PA 15230
Mr. Les Boord/Ms. Karen Cox/Mr. Richard Weaver (412) 787-8383

International Association of Fire Chiefs
1329 18th Street, NW
Washington, DC 20036
Mr. Jan Thomas (202) 833-3420

International Association of Fire Fighters
1750 New York Avenue, NW
Washington, DC 20006
Mr. Richard Duffy (202) 737-8484

International Society of Fire Service Instructors
20 Main Street
Ashland, MA 01721
Mr. Ed McCormack (617) 881-5800

John B. Moran
Director
Division of Safety Research

* New contact for reporting respirator problems (replaced Mr. John Moffa)

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Centers for Disease Control
National Institute for Occupational
Safety and Health – ALOSH
944 Chestnut Ridge Road
Morgantown, WV 26505–2888

January 17, 1986

RESPIRATOR USERS NOTICE

Inspection of Certain Aluminum Cylinders for Breathing-gas Pressure

The light weight and high charging pressure of aluminum cylinders have resulted in their widespread acceptance and use with self-contained breathing apparatus (SCBA). The National Institute for Occupational Safety and Health (NIOSH) estimates that more than half of the SCBA of 30- and 60-minute duration in regular use today are equipped with aluminum cylinders.

Since first receiving reports of defective fiber-glass wrapped aluminum cylinders in 1983, NIOSH has advised users of potential hazards associated with use of certain fiber-glass wrapped aluminum cylinders. At this time, NIOSH believes there is sufficient evidence to warrant issuance of this NOTICE regarding inspection of fiber-glass wrapped aluminum cylinders.

The presently available evidence indicates that fiber-glass wrapped aluminum cylinders manufactured under Department of Transportation (DOT) exemptions DOT-E 7235 and DOT-E 8059 (including 2216 and 4500 psi) may, upon aging, develop neck cracks and may leak breathing gas during storage and use. This may result in significant loss of breathing gas from an unattended cylinder. If undetected, this loss of breathing gas could be dangerous to the user.

Based on this, NIOSH recommends that where SCBA are equipped with fiber-glass wrapped aluminum cylinders, inspection for cylinder pressure should be made at least weekly, for stored units. When used on a daily basis, as in fire fighting, cylinder pressure should be checked daily and immediately before use.

If a leak is suspected, the cylinder and cylinder valve should be tested as prescribed in American National Standard, Z88.5-1981, Practices for Respiratory Protection for the Fire Service, Section 6.2.4.2.

Leaks in cylinders should be reported to the SCBA manufacturer who will, in turn report them to the cylinder manufacturer. The numbers and charging pressures of leaking cylinders should also be reported to DOT (Mr. Art Mallen, DOT Office of Hazardous Materials, 400 7th St. SW, Washington, DC 20590) and to NIOSH (Mr. John Moran at the address shown at the top of this letter).

Aluminum cylinders used with SCBA, with exemption numbers other than DOT-E 7235 and DOT-E 8059 are not covered in this notice. Self-contained self rescuers used in mines are also not included.

MORE

R E M I N D E R

January 17, 1986

Manufacturers of MSHA/NIOSH-approved SCBA Incorporating DOT-E 7235 4500 Fiber-glass Wrapped Aluminum Cylinders

The following manufacturers incorporate DOT-E 7235 4500 cylinders in their MSHA/NIOSH-approved SCBA:

- Bendix
- Clifton Precision
- Draeger
- Siebe Gorman
- Scott
- U.S.D. (SurvivAir)

DOT-E 7235 4500 cylinders must be retrofitted by Luxfer (Telephone: 714-684-5110) with steel neck rings, to prevent explosive rupture. DOT regulations prohibit charging of any DOT-E 7235 4500 cylinder that has not been fitted with a steel neck ring. Any apparatus utilizing a DOT-E 7235 4500 cylinder without a neck ring, is considered unapproved by MSHA/NIOSH.

Change in Address of Manufacturer's Contact

The following address change has been reported to NIOSH for manufacturer's personnel who are responsible for handling reports of problems with MSHA/NIOSH-approved respirators:

Clifton Precision:	New Address:	750 West Sproul Road, Springfield, PA 19064-4084
	Contact:	Mr. Martin Ziegler

John B. Moran
Director, Division of Safety Research

APPENDIX D

SAMPLE MSHA/NIOSH APPROVAL LABELS

Figure 1. Sample MSHA/NIOSH Approval Label for Pressure Demand SCBA.

PERMISSIBLE

30 Minute
Self Contained Pressure Demand
Compressed Air Breathing Apparatus

United States Department of Labor
MSHA
Mine Safety and Health Administration

U.S. Department of Health and Human Services
Centers for Disease Control
NIOSH
National Institute
for Occupational Safety and Health

MINE SAFETY AND HEALTH ADMINISTRATION
NATIONAL INSTITUTE FOR OCCUPATIONAL
SAFETY AND HEALTH

APPROVAL NO. TC-13F-000

ISSUED TO

ABC Company
Anywhere, USA

SAMPLE

LIMITATIONS

Approved for respiratory protection during the entry into or escape from oxygen deficient atmospheres, gases and vapors at temperatures above -22°F. Approved only when compressed air reservoir is fully charged with air meeting the requirements of the Compressed Gas Association Specification G-7-1 for Type 1, Grade D air or equivalent specifications. The container shall meet applicable DOT specifications. Demand mode shall be used only when donning aparatus. At temperatures above 32°F use without nosecup is permitted.

CAUTION

Use adequate skin protection when worn in gases or vapors that poison by skin absorption (for example, hydrocyanic adic gas). In making renewals and repairs, part identical with those furnished by the manufacturer under the pertinent approval shall be maintained. This respirator shall be selected, fitted, used, and maintained in accordance with Mine Safety and Health Administration, and other applicable regulations.

SAMPLE

MSHA — NIOSH Approval TC-13F-000

Issued to ABC Co., February 31, 2000

The approved assembly consists of the following part numbers:

000-000
000-000
etc.

Figure 2. Sample MSHA/NIOSH Approval Label for Pressure-Demand SAR

PERMISSIBLE

Combination Ten Minute Self-Contained Compressed Air Breathing Apparatus for Escape Only Pressure Demand Type C Supplied Air Respirator

United States Department of Labor
MSHA
Mine Safety and Health Administration

NIOSH

MINE SAFETY AND HEALTH ADMINISTRATION
NATIONAL INSTITUTE FOR OCCUPATIONAL
SAFETY AND HEALTH

APPROVAL NO. TC-13F-000

ISSUED TO

ABC Company
Anywhere, U.S.A.

SAMPLE

LIMITATIONS

Approved for respiratory protection during entry and escape from oxygen deficient atmospheres, gas, and vapors, when using air-line air supply. Approved for escape only, when using self-contained air supply. Approved for use at temperatures above -25°F.

Approved only when compressed air reservoir is fully changed with air meeting the requirements of the Compressed Air Gas Association Specifications G-7-1 for type 1, Grade D air, or equivalent specifications. The containers shall meet applicable DOT specifications.

This approval applies only when the device is supplied with respirable breathing air through 12.5 to 300 feet of hose at air pressures between 78 and 80 pounds per square inch gage or from self-contained air supply. If the supplied-air fails, open cylinder valve and proceed to fresh air immediately.

CAUTION

Use with adequate skin protection when worn in gases and vapors that poison by skin absorption (for example: hydrocyanic-acid gas). In making renewals and repairs, parts identical with those furnished by the manufacturer under the pertinent approval shall be maintained. This respirator shall be selected, fitted, used, and maintained in accordance with Mine Safety and Health Administration, and other applicable regulations.

SAMPLE

MSHA — NIOSH Approval TC-13F-000

Issued to ABC Company, February 31, 2000

The approval assembly consists of the following part numbers:

000-000
000-000
etc.