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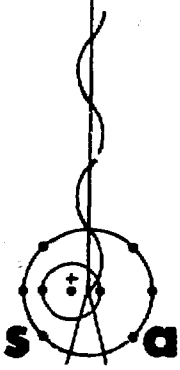
A Guide to Industrial Respiratory Protection

by

John A. Pritchard



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A GUIDE TO INDUSTRIAL RESPIRATORY PROTECTION

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ABSTRACT

The Occupational Safety and Health Act of 1970 has increased the emphasis on proper selection and use of respirators in situations where engineering controls are not feasible or are being implemented. Although a great deal of information on respiratory protection has been published, most of it is more technical than necessary for the average user faced with day-to-day problems of respiratory protection in industrial environments.

This Guide is to provide the industrial user a single reference source containing enough information for establishing and maintaining a respirator program that meets the OSHA requirements outlined in 29 CFR Part 1910.134. It includes chapters on respirator selection, use, maintenance, and inspection, a complete description of all types of respirators and their advantages and limitations, and chapters on respirator fitting and wearer training, respiratory physiology, respiratory hazards, and physiological and psychological limitations. Also included are samples of the decision logic used in respirator selection, guidance on setting up an adequate respirator program through formulation of written standard operating procedures, and discussion of the meaning of the "approved" respirator.

CHAPTER ONE

INTRODUCTION

Until the enactment of the Williams and Steiger Occupational Safety and Health Act (OSHA) in 1970, most guidance on respiratory protective device (respirator) use in hazardous environments was advisory rather than mandatory. Now, OSHA Part 1910.134 (presented as Appendix A of this guide) sets forth specific legal requirements for selection, use, and maintenance of respirators, and gives guidelines for establishing a respirator program to meet those requirements. This guide is written to describe methods for meeting the OSHA requirements, especially for those whose knowledge of respirators is limited. It is meant to complement, not replace, other publications such as the American Industrial Hygiene Association and American Conference of Governmental Industrial Hygienists (ACGIH) Respiratory Protective Devices Manual.

BACKGROUND

American National Standard Institute (ANSI) Standard Z88.2-1969, "Practices for Respiratory Protection," is the origin of the first six sections of OSHA Part 1910.134, "Respiratory Protection." The seventh section is a direct, complete inclusion of ANSI Standard K13.1-1969, "Identification of Gas Mask Canisters."

Certain aspects of ANSI Z88.2 deserve comment. Each ANSI standard is the consensus of the Standards Committee that created it. The Z88.2 committee consisted of 30 members and 17 alternates representing government, industry, and respirator manufacturers. The document they produced, a spin-off from the older ANSI Z2.1-1959, "American National Standard Safety Code for Head, Eye, and Respiratory Protection," like all ANSI standards, is to be revised every five years. At present, Z88.2 can be used to further explain points in the OSHA standards, but it is an advisory document only, not a legal one. However, because insight into the OSHA standards may be gained by reading the corresponding parts of Z88.2, the reader is strongly urged to use a copy as a companion to this guide. It may be obtained from:

American National Standards Institute, Inc.
1430 Broadway
New York, NY 10018.

The OSHA standards state that "approved or accepted respirators shall be used when they are available." That one sentence is the basis for much of this guide. Legally, the Occupational Safety and Health Administration may recognize a respirator evaluated by any competent authority as "approved." However, it has chosen to recognize only those approved by the National Institute for Occupational Safety and Health (NIOSH) and/or the Mine Enforcement and Safety Administration (MESA), the former obtaining its authority from the OSHA provisions and the latter from those of the 1969 Coal Mine Health and Safety Act. The NIOSH and MESA respirator performance requirements are given in Title 30, Code of Federal Regulations, Part 11, commonly known as "Part 11." A copy is presented as Appendix B.

The Bureau of Mines (BOM) began approving self-contained breathing apparatus and gas masks for mine rescue work in 1919 and has added approval schedules for other types of respirators over the years until NIOSH and MESA (which assumed the BOM mine health and safety responsibilities) started the present approval program in 1971. NIOSH performs the respirator approval tests under Part 11, and the results are reviewed by NIOSH and MESA, who grant an approval. The reader should become familiar with Part 11. Understanding of the approval process may provide better understanding of the conditions in which approved devices should, and, more important, should not, be used.

Contributing further to the confusion about respirator standards is the fact that still other Federal Regulations, Military Standards, advisory standards, etc., are made part of the OSHA requirements by reference. Figure 1-1 shows the interrelationship of all these standards.

THE GUIDE

To be effective, a respirator guide must be almost all-encompassing because:

- Respirator users' needs vary greatly. A small manufacturing concern may have to protect only one or two employees from a single hazardous atmosphere, perhaps only infrequently. A large chemical company may have hundreds of workers who must wear respirators more or less regularly in many different hazardous atmospheres. Unfortunately, the OSHA requirements do not differentiate between such large and small users.
- Users' knowledge of respiratory protection varies. A small firm may have only one, poorly trained, employee. Large concerns with extensive respirator programs to cope with many hazards usually hire industrial hygienists and safety engineers who have detailed knowledge of respiratory protection.

This guide is designed to provide adequately detailed information for the least knowledgeable respirator user. There is a chapter on the basic concepts of the pulmonary system and respiration, one that describes and classifies respiratory hazards, and one on basic types of approved respirators. These should provide adequate background for a satisfactory respirator program.

Other chapters, useful to both experienced and inexperienced users, discuss detailed methods for providing OSHA's "minimal acceptable respirator program." The program requirements often can be met in more than one way, and an attempt is made to show how both large and small users can do so. Respirator wearers' physiological and psychological limitations are treated separately because of their importance.

To conform to the OSHA usage, "shall" is used here only to indicate an OSHA requirement. "Should" indicates that an action is "strongly advised," but not legally required. "May" indicates that there is a choice of actions.

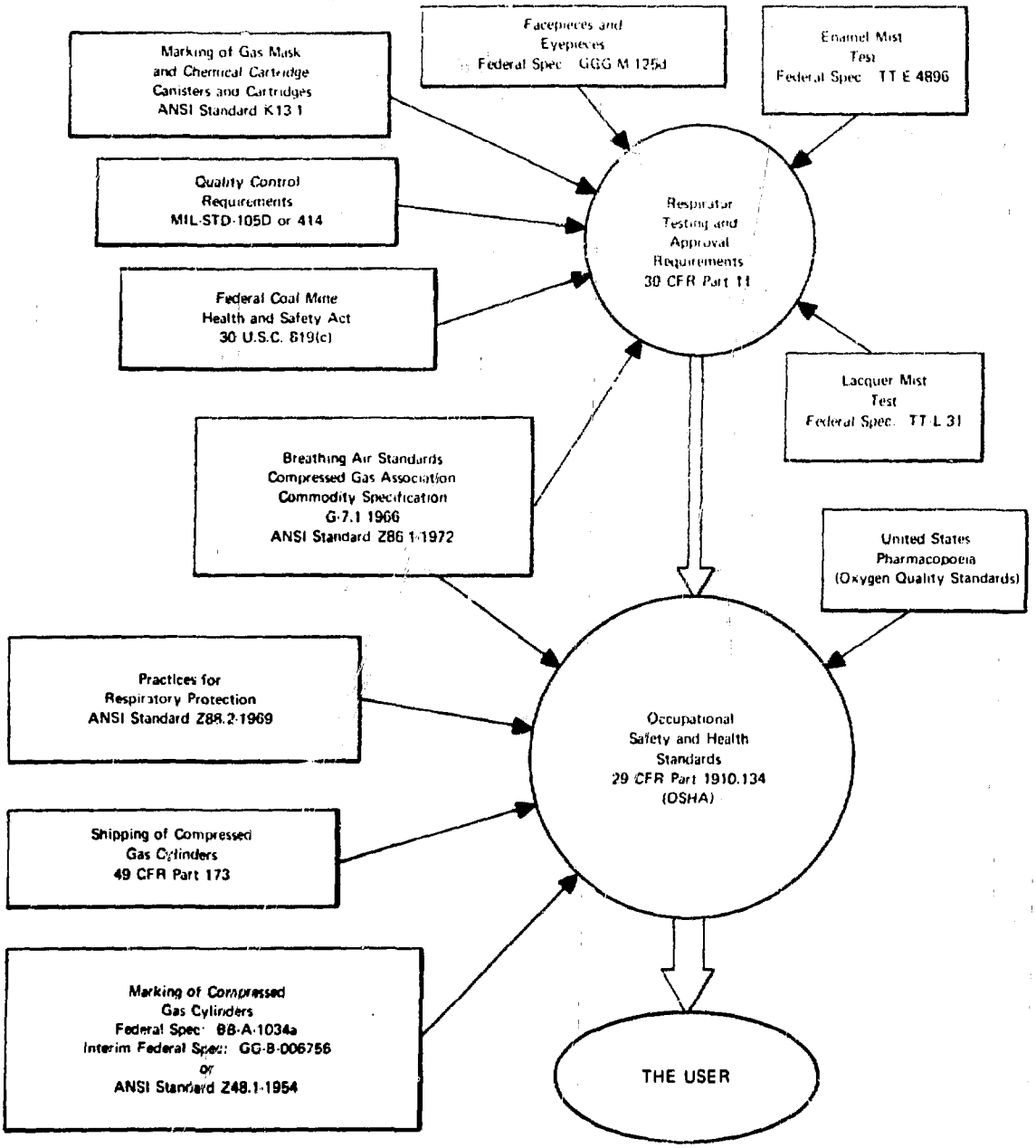


Fig. 1-1.
Sources of the OSHA standards.

CHAPTER TWO

HISTORY OF RESPIRATORY PROTECTION

Recognition of the need to protect the respiratory system is very old. Pliny (ca A.D. 23-79) mentioned use of a loose fitting animal bladder in the Roman mines to protect against inhalation of red oxide of lead. The Greek writer Dioscorides (A.D. 50) described the same hazard and other dangers of mining. A century later, Julius Pollox (A.D. 124-192) described a respirator made from an animal bladder with an attached sackcloth filter for protection against the dust in mines. It is interesting that all the surviving early references involve the hazards of mining, an occupation that is still the subject of a significant share of the effort to improve respiratory protection.

Not surprisingly, Leonardo da Vinci (1452-1519) considered the problems of respiratory protection. As usual, he anticipated history by a few centuries in recommending use of a wet cloth as protection against chemical warfare agents. He also devised two types of underwater breathing devices. One used a mysterious substance he called "Alito" which when fastened to the chest with iron rings allowed the wearer to breathe without an outside air source. The other, really quite practical, was a "snorkel," consisting of a breathing tube with an attached float. Later, Bernadino Ramazzin, (1633-1714) wrote a critical review of the inadequate respiratory protection prevalent in his time. He mentioned the hazards faced by such diverse people as arsenic miners; gypsum, lime, and tobacco workers; bakers and millers; sifters and measurers of grain; and stone cutters. Any good work on occupational diseases will show that we now have named diseases incurred in each of these occupations.

In the 1700's appeared the first description of the ancestors of today's atmosphere-supplying devices, such as open and closed-circuit self-contained breathing apparatus and hose masks.

With the coming of the industrial revolution in the early 1800's, respirators rapidly became more sophisticated. One of the greatest advances was realization of the separate natures of particulates and gases or vapors. Until then, the only recognized hazard had been industrial dusts.

John Roberts in 1825 developed a "smoke filter" for firemen, a leather hood and a hose strapped to the leg, the theory being (correctly) that the best air during a fire would be near the floor. At the lower end of the hose was an inverted funnel containing a coarse woolen cloth to trap particulates and a moist sponge to remove water-soluble gases and vapors. This device is shown in Fig. 2-1.

In 1814 came development of a particulate-removing filter encased in a rigid container, the

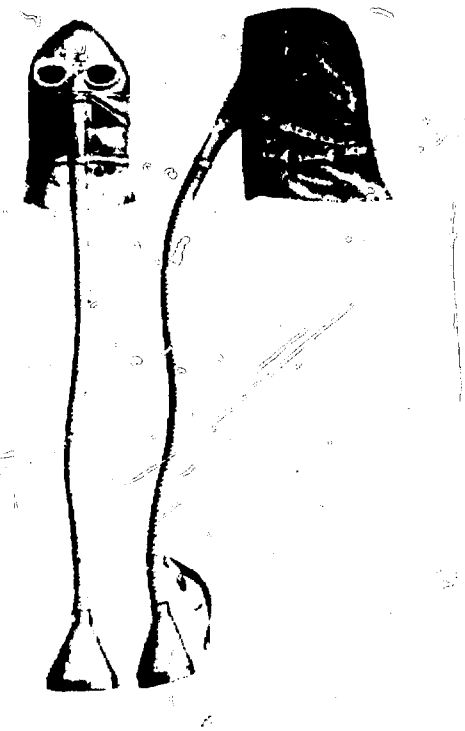


Fig. 2-1.
John Roberts "smoke filter," ca 1825.

predecessor of modern filters for air-purifying respirators. In 1823, C. A. Deane developed a "smoke jacket" for firemen which had a breathing hose with a bellows that supplied clean air under pressure. This was the early equivalent of today's hose mask with blower.

Discovery of the phenomenon of Brownian motion by Robert Brown in 1827 explained the zig-zag motion of very small airborne particles caused by their bombardment by rapidly moving gas molecules in the air. This quickly led to improvement in design of particulate-removing filters through understanding of the principle involved in filtration. Efficient filters had been produced earlier, but their resistance to breathing was usually intolerably high.

Probably the most significant development during the last century was discovery in 1854 of the properties of activated charcoal in removing organic vapors and gases from air. This discovery was almost immediately put to use in respirators. An example, shown in Figs. 2-2 and 2-3 was a fire-fighting "smoke cap" developed by Sir E. M. Shaw and the famous physicist John Tyndall. Its significant feature was clear recognition of the need to protect against particulates (with dry cotton wool), carbon dioxide gas (with lime), and other gases and vapors (with charcoal).

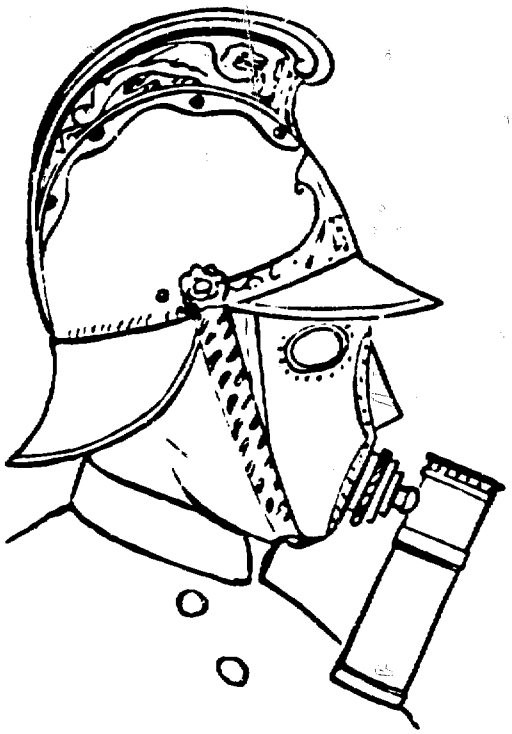


Fig. 2-2.
Tyndall and Shaw "smoke cap."

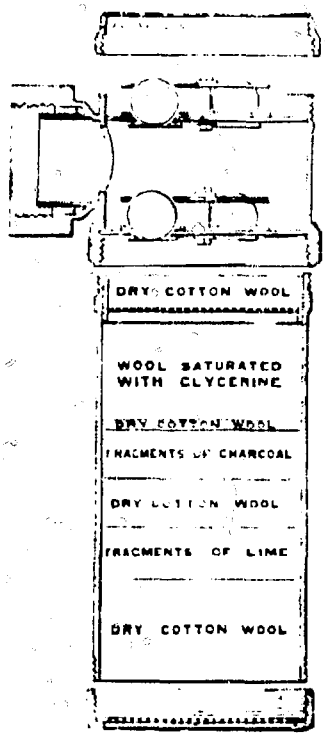


Fig. 2-3.
Tyndall and Shaw smoke cap filter.

The most rapid advances in respiratory protection grew out of the use of chemical warfare in World War I. German use of poison gas brought about almost immediate improvement in gas sorbents used in military masks. This was countered by the German attempt to disperse highly toxic particulate matter on the battlefield, which led to development of still more efficient filters. Although crude by today's standards, the WW I military respirators are definitely recognizable as close relatives of devices manufactured now.

Since WW I, there have been few major breakthroughs in respirator design, with the possible exception of N. L. Hansen's development of the resin-impregnated dust filter in 1930. This material

uses electrostatic force fields to remove dust particles from air. Almost all present respirator use is for protection against moderately toxic dusts, and most dust filters are resin-impregnated. This development has made available efficient, inexpensive filters that have good dust-loading characteristics and low breathing resistance. Another, more recent, development is the ultrahigh-efficiency filter made from paper that contains very fine glass fibers. These extremely efficient filters for very small airborne particles also have low breathing resistance and are commonly used where high dust concentrations are not a problem.

Figures 2-4 through 2-7 show early respirators whose basic designs are still represented in those marketed today.

Fig. 2-4.
Magirus, Germany, ca 1840. Early positive pressure self-contained breathing apparatus.

Fig. 2-5.
Magirus, Germany, ca 1820. Supplied air suit for firemen, similar to today's hose mask or air line respirator.

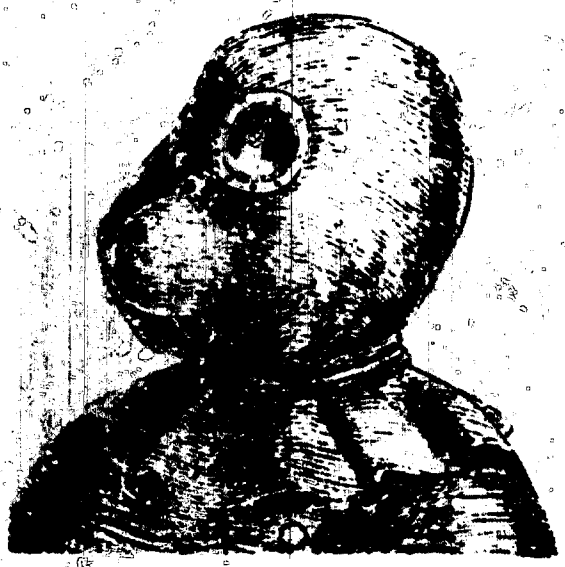


Fig. 2-6.
Magirus, Germany, ca 1830. Reusable full face protection. Sponge placed inside flap over nose.

Fig. 2-7.
Pulmosan dust mask, ca 1920. Very similar to today's single use dust respirator

CHAPTER THREE

THE RESPIRATORY SYSTEM AND RESPIRATION

METABOLISM

To understand the respiratory system's role, we must consider how the body uses the oxygen that the respiratory system supplies. Figure 3-1 is greatly simplified diagram of this use, called metabolism. At its simplest, the body is a "furnace," or ordered arrangement of countless tiny "furnaces" called cells. As a "furnace," the body takes food into the digestive tract where it is converted into a fuel suitable for use by the individual cells. This fuel, in the form of a sugar—glucose—is transported to the cells by the blood stream. The oxygen needed to burn the fuel originates in the air surrounding the body. The air is drawn into the respiratory system, and the needed oxygen is transferred to the blood stream, to travel with the glucose fuel to the cells.

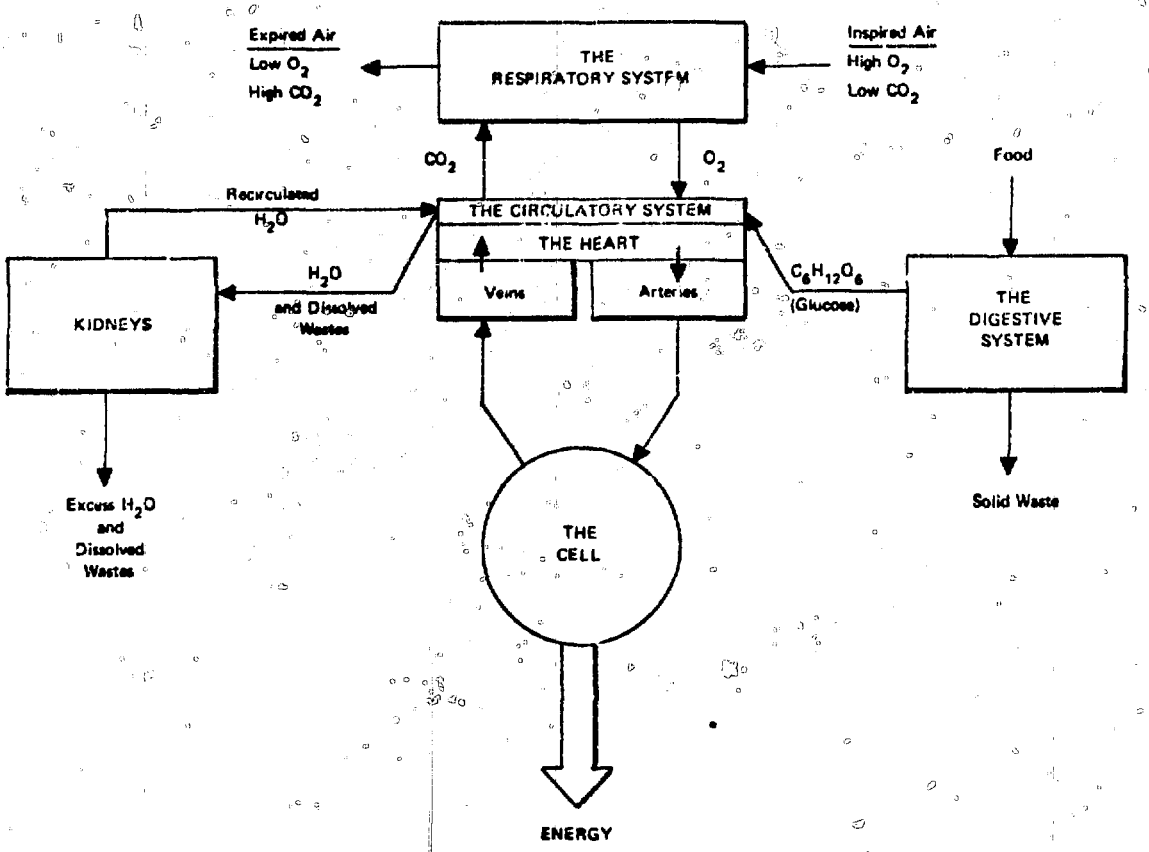


Fig. 3-1.
The metabolic process.

In the cells, the glucose and oxygen combine in a combustion process to produce energy. The energy is used in many ways, ranging from muscle action (mechanical) and control of body temperature (thermal) to maintenance of the body systems. The combustion products, as in all such processes, are primarily carbon dioxide and water, which are carried away in the blood stream for elimination from the body.

Because the body contains a lot of water, that produced by metabolism cannot be called a waste product, but it does contain dissolved wastes that must be removed. This is done primarily by the kidneys which remove the dissolved wastes from the blood stream. These wastes are flushed out in the urine along with water that must be replaced through the digestive tract. There is, however, a quantity of water which circulates throughout the system in the blood stream or is contained in the body tissues.

The system that carries fuel to the cells and removes waste products is unidirectional, as the material enters and leaves the body at separate locations. On the other hand, the system that supplies oxygen and removes carbon dioxide is bidirectional. Although the oxygen gets to the cells through the arteries and carbon dioxide is removed by the veins, transfer to and from the surrounding air takes place at a common location, the lungs. The effect and importance of the lungs' dual role will become apparent when gas transport and exchange are discussed.

THE STRUCTURE OF THE RESPIRATORY SYSTEM

The metabolic aspect of greatest concern here is the structure and workings of the respiratory system, shown much simplified in Fig. 3-2. The respiratory system is a single airway that branches into many smaller passages that end in the lungs. The upper, or conducting, part consists of the nasal passages and pharynx in the head and the larynx and trachea in the neck. Below the trachea, the conducting part branches into two airways called bronchi that lead into the lobes of the lungs. The bronchi subdivide into smaller and smaller pathways, called bronchioles, ending in very small

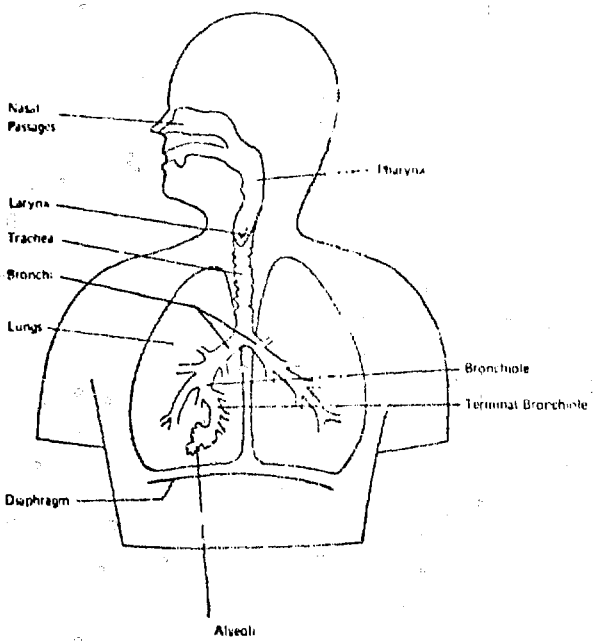


Fig. 3-2.
The respiratory system.

passages, the terminal bronchioles. No gas transfer takes place in the pathways up to this point.

It is at the respiratory surfaces, shown in Fig. 3-3, that the major function of the lungs takes place. Branching from the terminal bronchioles are the respiratory bronchioles, to each of which are attached three to six clusters of extremely small sacs called alveoli. Each of the approximately 300 million alveoli is separated from the blood stream only by an extremely thin membrane, about 0.2 micrometer (μm) thick.* This membrane, which forms the alveolar wall, is permeable to gas molecules. It is here that most of the oxygen passes into the blood stream and that carbon dioxide is removed.

This barrier is so large that it provides almost instantaneous exchange between the gases in the alveolar spaces and the blood stream on the other side. This membrane is approximately 70-100 square meters in surface area and is two cells thick.

*Human hair is 5-500 μm in diameter.

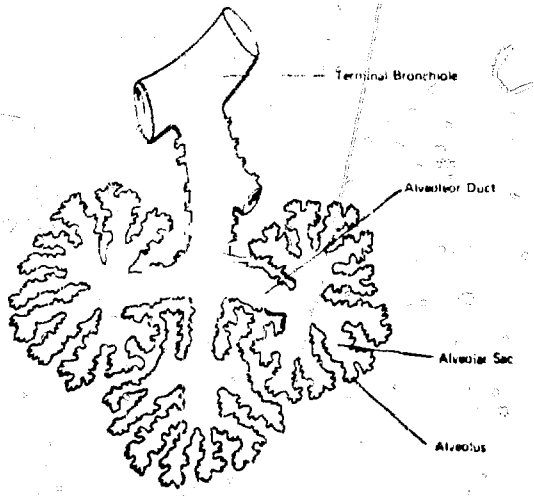


Fig. 3-3.
The respiratory surfaces.

This large lung surface area is necessary because the body cannot store oxygen and, therefore, must be able to absorb a lot of it quickly from the air when necessary. The body has far more storage capacity for water (throughout) and fuel (in the fatty tissues). Man can live for weeks without food and for days without water, but only for minutes without oxygen. The brain is particularly susceptible, as only four minutes without oxygen causes permanent damage, and six to eight minutes kills. Because of its critical relationship to the immediate functioning of the body, the respiratory system demands the utmost protection and care.

THE MECHANICS OF RESPIRATION

Respiration, or breathing, involves inhalation during which fresh air, rich in oxygen and low in carbon dioxide, is drawn into the lungs. This is followed by exhalation in which the air, containing less oxygen and more carbon dioxide owing to gas exchange at the respiratory surfaces, is expelled. One combined inhalation and exhalation is called a breathing cycle. Lung action during a breathing cycle is like the operation of a bellows. The thoracic (chest) cavity, formed by the rib cage around the lungs, expands during inhalation because of contraction of the intercostal muscles attached to the ribs. This contraction enlarges the chest, and the lungs expand to fill the additional space. The chest cavity enlarges further as the diaphragm, a domed muscular partition between it and the abdominal cavity, moves downward.

Expansion of the chest and lungs varies with the body's needs. Under sedentary (inactive) conditions, there is very little expansion because the need for oxygen is slight. Heavy work, however, greatly increases the need for oxygen, causing increased respiration rate and volume. As the chest and lungs expand, a greater surface for transfer of oxygen and carbon dioxide is exposed as the alveoli are ventilated more effectively. The individual alveoli also expand, further increasing the surface area available for gas exchange. This is a mechanism by which the body compensates for its inability to store oxygen; it has a reserve capacity for transferring oxygen by increasing both the size and number of alveoli in use.

During inhalation, the muscles involved are contracted. During exhalation, most of them are relaxed. At the end of inhalation, the intercostal muscles are in a contracted state, and the diaphragm has been pulled down. During exhalation, these muscles and the diaphragm return to their original relaxed state, reducing the volume enclosed by the thoracic cavity (chest) and forcing the air out of the lungs. Almost no physical energy is expended during normal exhalation, analogous to releasing a stretched rubber band.

There are some muscles located in the lower abdomen which can be contracted during forced exhalation, as during heavy work or blowing up a balloon. Because these relatively weak muscles are not used routinely, most people find their sustained use tiring. This is one reason why exhalation resistance in respirators is kept as low as practicable.

The Concept of Partial Pressures

Air is a mixture of several gases, including nitrogen (N_2), oxygen (O_2), carbon dioxide (CO_2), and water vapor (H_2O). At sea level, this mixture has a normal atmospheric pressure of 14.7 pounds/square inch (psi), 29.92 inches of mercury (in. Hg), or 760 millimeters of mercury (mm Hg), all

equivalent values. Here, pressures are expressed in millimeters of mercury.

The concept of partial pressures is that in any mixture of gases, the total gas pressure is the sum of the partial pressures of all the gases. An analogy is a stack of blocks weighing an amount that is the sum of the weights of the individual blocks. Because normal air at sea level contains about 20.9% O_2 at a total pressure of 760 mm Hg, the partial pressure of O_2 (PO_2) must be about 159 mm Hg (760 mm Hg x 20.9% = 159 mm Hg). Similarly, the partial pressure of CO_2 (PCO_2) makes up about 0.04% of the normal atmosphere, or about 0.3 mm Hg. Nitrogen, although it makes up about 80% of the atmosphere, plays only a minor role in respiration, and then only in special circumstances, such as deep sea diving.

NOTE: It is not the percentage of O_2 in the air, but its partial pressure, which is important. As one ascends, the percentage of O_2 and the other gases stays about the same but the partial pressure of each drops owing to the lower total atmospheric pressure. The importance of this fact will become apparent when we discuss gas exchange in the lungs.

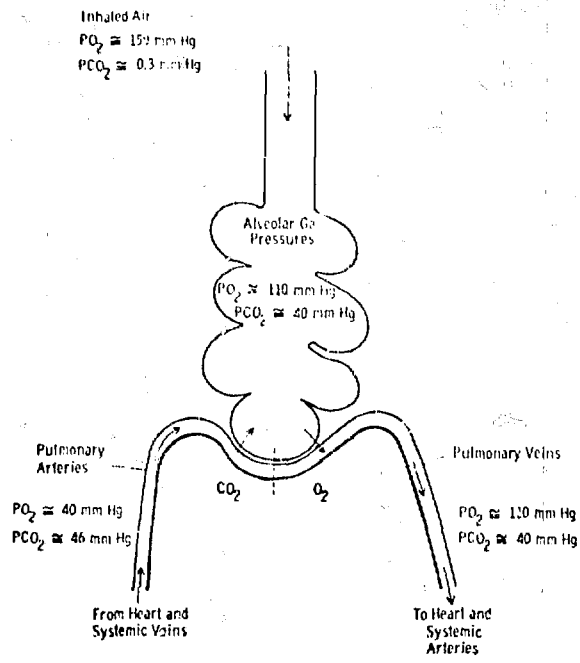


Fig. 3-4.
Gas exchange in the lungs.

Gas Exchange in the Lungs

During the time the air travels to the alveolar space, mixing takes place, reducing the PO_2 to about 110 mm and then increasing the PCO_2 to about 40 mm. At the end of each exhalation, the lungs and upper part of the airway are filled with exhaled air that contains less O_2 and more CO_2 than the atmospheric air, owing to gas transfer. Inhalation draws approximately 500 milliliters (ml) of air into the lungs. However, only about 350 ml of the fresh air reaches the alveoli because the first air that reaches them is the old air left in the upper respiratory tract at the end of the previous exhalation. This 150 ml of air, called the anatomic dead space volume, mixes with the incoming fresh air to give the PO_2 and PCO_2 shown in the alveoli in Fig. 3-4.

Increasing the dead space volume, as by wearing a respirator, may have important consequences. For example, consider the following.

- Without a respirator

Dead space = 150 ml,
Volume inhaled per breath = 500 ml,
Breaths per minute = 10.
The volume reaching the alveoli per minute would be 10 x (500 - 150) = 3500 ml

- Wearing a respirator whose volume (dead space) is 100 ml

Dead space = 100 + 150 = 250 ml,
Volume inhaled per breath = 500 ml,
Breaths per minute = 10,
The volume reaching the alveoli per minute would be 10 x (500 - 250) = 2500 ml.

If there is a pressure difference across a permeable membrane like that separating the alveoli from the pulmonary capillaries, gas molecules pass from the high- to the low-pressure region until the pressures are equalized. The 40-mm-Hg PCO_2 in the alveoli (Fig. 3-4) is lower than the 46-mm PCO_2 in the pulmonary arteries carrying the CO_2-rich blood from the cells, so CO_2 molecules pass from the bloodstream into the alveoli. Conversely, the 110-mm-Hg PO_2 in the alveoli is greater than the 40-mm PO_2 in the pulmonary arteries, so O_2 passes from the alveoli into the bloodstream where the pulmonary veins, heart, and systemic arteries carry it to the cells to be metabolized. PO_2 and PCO_2 in the pulmonary veins are the same as those in the alveoli

because the O_2 and CO_2 pressures are equalized almost instantaneously in a healthy person at rest. However, when one works hard or has impaired breathing, the concentration of oxygen in the blood may be considerably less than that in the alveoli.

Oxygen is carried in the blood physically dissolved in the blood water and chemically combined with the iron atoms in the hemoglobin molecules that are part of the red blood cells. Because O_2 is relatively insoluble in water, 98% of it is carried by the red blood cells. Only about 3 ml of O_2 can be *dissolved* in 100 ml of blood, but about 197 ml can be carried *chemically attached* to the hemoglobin molecules in the red blood cells.

Carbon dioxide is carried similarly to O_2, about 8% of it being physically dissolved in the blood plasma and red cells. Sixty seven per cent of it combines with the water in the blood, is converted to carbonic acid (H_2CO_3), and is carried in ionized form ($HCO_3 + H^+$). (The remaining 25% reacts with the hemoglobin molecules as does O_2.) Ionized CO_2 is extremely soluble, in contrast to gaseous CO_2. The concentration of hydrogen ions (H^+) in the blood is crucial in control of respiration, as is discussed in the next section.

Some airborne contaminants hurt the red blood cells' ability to combine chemically with O_2 molecules. For example, carbon monoxide (CO) combines preferentially with the hemoglobin molecules, thereby preventing their combination with O_2 molecules. P-nitroaniline, an organic vapor, changes the chemical state of the iron atoms, abolishing their capacity to combine with O_2.

Respiration Control

Respiration control is very complex, and can be treated only superficially here. Furthermore, respiration control as a reaction to increased work rate is not fully understood. Briefly, however the major task of the nervous system in regulating respiration rate and depth is to ensure that O_2 is delivered to the cells and CO_2 is removed at exactly the rate needed to meet the body's demands. (Remember, the body cannot store oxygen.) Intuitively, one could guess that this has something to do with maintaining proper PO_2 and PCO_2 levels in the blood, and, indeed, this is true. Generally speaking the PO_2 and PCO_2 balance remains relatively constant, no matter what the level of work. This fact implies that there must be a mechanism that can react quickly to changes in this balance to bring the PO_2 and PCO_2 back into proper proportion, and this is also true, but not completely understood.

The body is sensitive to changes in both PO_2 and PCO_2. The PO_2 sensors are located in the carotid artery that supplies blood to the head, near the aorta leading from the heart. These sensors send their signals to the respiratory control center in the lower part of the brain, the medulla. If the PO_2 is reduced by about half, the control center increases lung ventilation. Although this seems an insensitive mechanism, recent studies indicate that the body is much more sensitive to lowered O_2 levels than was thought. What happens is that response to the high PCO_2 is much stronger than response to the lowered PO_2. Therefore, the PCO_2 response overrides the PO_2 response until the PO_2 becomes very low.

This fact implies that the PCO_2 level influences respiration much more than does the PO_2 level. This is most emphatically true; however, the full answer lies not in the CO_2 molecule itself, but in its ionized form in the blood, HCO_3 and H^+. The latest information indicates that the H^+ concentration in the cerebrospinal fluid surrounding the brain and spinal column is the controlling factor. Extremely sensitive sensors detect slight changes in the H^+ concentration and send signals to the respiratory control center, which brings the system back into balance almost immediately by reducing or increasing the breathing rate.

Such roundabout regulation of respiration may seem strange until one remembers that the brain is most easily damaged by lack of oxygen. It makes perfectly good sense that the regulatory mechanism is in the most critical area. In summary, control of respiration is related primarily to the PCO_2, not the PO_2, concentration in the blood.

Voluntary and Involuntary Control. The respiratory control system's response to changing gas concentrations in the blood is something over which we have no conscious control; it is an involuntary response. Obviously, we do have a great deal of voluntary control, for we can hold our breath, adjust our breathing rate, and cough almost at will. However, this voluntary control has definite limits. For example, we can hold our breath only so long

before the involuntary drive to breathe overrides our intention not to.

Involuntary reactions of other parts of the nervous system sometimes affect the respiration rate. Emotional states, such as fear, joy, or sorrow can change it. Pain increases the respiration rate, and irritation of the respiratory passages causes explosive exhalation, or sneezing.

Effect of Increased Work Rate. As physical activity increases, the respiration rate and volume increase almost immediately as the body compensates for increased metabolic demands through the mechanism just described. Therefore, a greater volume of air per unit of time is taken into and expelled from the lungs. This volumetric flow rate is usually measured as the volume of air inhaled or exhaled per minute, called the minute volume and expressed in liters per minute (lpm). Instantaneous volumetric flow rates at any time during the breathing cycle are measured in the same units.

Air Minute Volume Requirements. The typical worker breathes about 10 cubic meters (m^3) of air in 8 hours. (A cubic meter is approximately a cubic yard.) On a minute volume basis, the flow rates may vary widely with the type of work, as Table 3-1 shows. The minute volumes may range from approximately 9.3 lpm during rest periods to 132 lpm during the heaviest work. An 8-hour work day might involve total inhaled air volumes of 4.5 - 63.4 m^3. Ten cubic meters in eight hours is about 20.8 lpm, or just slightly above the rate for light work. When one considers the situation if these volumes were laden with harmful respirable particulates or gases and vapors, the need for proper respiratory protection becomes apparent.

TABLE 3-1

MINUTE VOLUME AIR FLOW RATES

Activity	Minute Volume (lpm)
Sleep	6.0
Rest	9.3
Light work	19.7
Medium work	29.2
Med heavy work	40
Heavy work	59.5
Maximum work	132.0

Instantaneous Air Flow Rates. With increased physical activity, breathing volume and rate both increase as shown in Fig. 3-5. During rest, breathing is shallow and each cycle takes several seconds. As activity increases, the instantaneous flow rates increase and each cycle becomes shorter as indicated

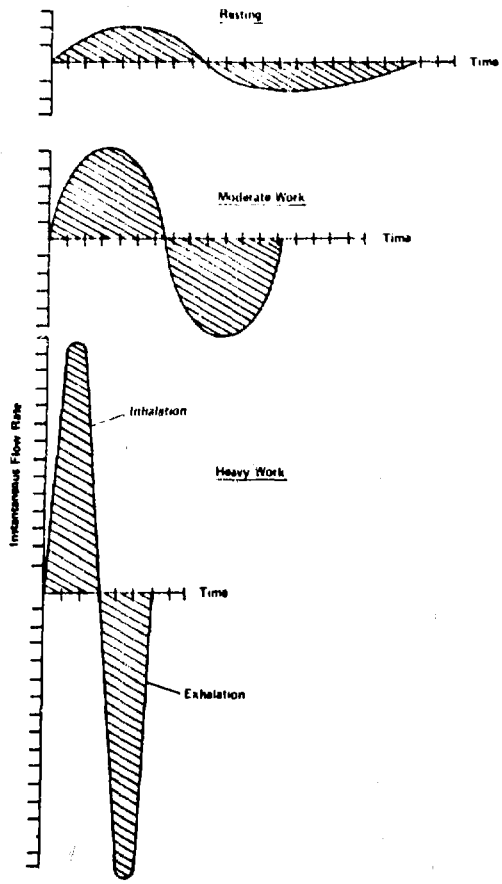


Fig. 3-5.
Breathing rate and volume vs activity level.

by the curves for moderate and heavy work. The area under the inhalation cycles (totaled over 1 min) constitutes the minute volume.

The high instantaneous flow rates required at high work rates become significant when one considers the resistance to inhalation presented by most airpurifying respirators. As the flow rate through a filter or bed of granular sorbent in a respirator increases, (see Chap. 5) the resistance to air flow also increases. Therefore 30 CFR Part 11 keeps the allowable inhalation resistance offered by respirators at specified flow rates as low as possible. If the resistance is too great, the wearer expends extra energy in overcoming it, and the situation worsens as the work level increases.

CHAPTER FOUR

RESPIRATORY HAZARDS*

RESPIRATORY HAZARDS

In choosing the proper respirator for use against a specific hazard, one obviously must assess the type and extent of the hazard. Here, we will discuss the various classes of respiratory hazards, their effects on the body, and methods for evaluating them.

Respiratory hazards are either:

Oxygen deficiency or

Air contamination by

Particulates,

Vapor and gases, or a

Combination of particulates, vapors, and gases.

Respiratory hazards in the work environment must be assessed to determine the effectiveness of engineering and administrative controls and to permit selection of proper respirators.

A hazardous or harmful atmosphere is one that is oxygen deficient or contains a toxic or disease-producing particulate, vapor, or gas in a concentration immediately or ultimately dangerous to life or health.

An atmosphere immediately dangerous to life or health poses an immediate threat to life or health or an immediate threat of exposure that will probably cause delayed harm. Whether there is an immediate threat depends partly on the physical configuration of the workplace. Can the worker, if his respirator fails, escape unharmed? The joint OSHA and NIOSH Standards Completion Program defines an atmosphere immediately dangerous to life and health as one from which a person cannot escape unprotected within a half hour without irreversible health effects or one that has the potential for "obvious severe eye or respiratory irritation which would inhibit escape without injury."

An atmosphere not immediately hazardous to life or health may cause immediate physical discomfort or irritation, produce harm after prolonged exposure, or cause chronic poisoning after repeated short exposures, but it does not cause irreversible damage during a single exposure.

THE NORMAL ATMOSPHERE

Earth's atmosphere has an essentially fixed composition of the following gases in the dry state.

Gas	Vol%	Partial Pressure (mm Hg at sea level)
Nitrogen	78.09	594
Oxygen	20.95	159
Argon	0.93	7
Carbon dioxide	0.04	0.3

Normal air always contains small amounts of other gases such as neon, helium, and krypton. Water vapor, an important constituent of the normal atmosphere, may be up to 5% of the total volume. Note that the per cent by volume of these gases does not vary with altitude, but that the partial pressures decrease with increasing altitude because the total pressure decreases.

OXYGEN DEFICIENCY

An atmosphere that does not contain enough oxygen to support metabolism for an unlimited period

*With the kind permission of the American Optical Corporation, Southbridge, MA, this chapter is adapted in part from a "Refresher Course in Respiratory Protection," presented by W. H. Revoir at the 1974 Conference of the American Industrial Hygiene Association in Miami Beach, Florida.

is called "oxygen deficient." The precise description of an oxygen deficient atmosphere is important for strictly physiological reasons and also for proper respirator selection. If an atmosphere is oxygen deficient, only atmosphere-supplying, not air-purifying respirators may be used (see Chap. Five). Making this distinction would seem a simple matter of applying the description of an oxygen deficient atmosphere. Unfortunately, no one definition (value) is universally accepted. The range of definitions listed in government regulations and other documents can leave the respirator user in a quandary. Table 4-1 is a partial listing of definitions, based primarily on the volume per cent (vol%) of oxygen in the atmosphere at sea level. With a range of 16.0-19.5 vol% to choose from, *the respirator user's only practical course is to use the definition listed in the regulation by which his work is governed.*

It is instructive to consider oxygen deficiency (or, in medical terminology, anoxia and asphyxia) from a strictly physiological standpoint. *Anoxia* is defined as diminished availability of oxygen to the cells of the body, and *asphyxia* is the condition of the body due to anoxia. (If the reader has not yet read Chap. Three, he should do so.) Table 4-2 lists the outward indications of oxygen deficiency, or

TABLE 4-1

DEFINITIONS OF OXYGEN DEFICIENT ATMOSPHERE

Source	Oxygen Content (vol%)	Conditions for Determination	Sea Level PO_2 (mm Hg)
ACGIH Threshold Limit Values For 1973	18.0	"...under normal atmosphere pressure..."	135
Federal Regulations			
29 CFR Part 1915.81 (Maritime Standards)	16.5	(not specified)	125.4
29 CFR Part 1910.94 (Ventilation Standards)	19.5	(not specified)	148
29CFR Part 1910.134 (Respirator Standards)	16.0	(not specified)	122
30 CFR Part 11 (Respirator Approval Tests)	19.5	"...by volume at sea level..."	148
ANSI Standards			
Z88.2-1969 (Respirator Practices)	16.0	"...normal air..."	122
Z88.5-1973 (Firefighting)	19.5	"...where oxygen partial pressure is less than 148 mm Hg at sea level..."	148
K13.1-1973 (Marketing of air-purifying canisters and cartridges)	19.5	"...at sea level..."	148

Note: ANSI Standard Z86.1-1972, "Commodity Specification for Air," as revised in October 1974, specified 19.5-23.5 vol% O_2 for all grades of breathing air.

TABLE 4-2

EFFECTS OF OXYGEN DEFICIENCY

O_2 Vol % At Sea Level	Physiological Effect
16-12	Increased breathing volume, Accelerated heartbeat, Impaired attention and thinking, Impaired coordination.
14-10	Very faulty judgment, Very poor muscular coordination Muscular exertion causes rapid fatigue that may cause permanent heart damage, Intermittent respiration.
10-6	Nausea, Vomiting, Inability to perform vigorous movement, or loss of all movement, Unconsciousness, followed by death.
Less than 6	Spasmatic breathing, Convulsive movements, Death in minutes.

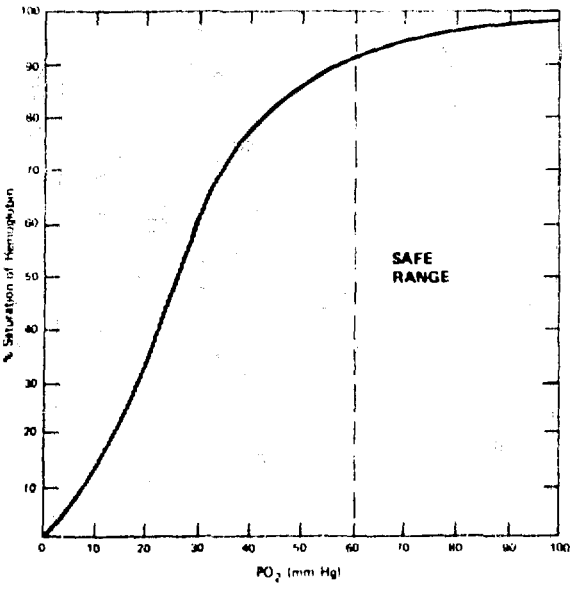


Fig. 4-1.
Hemoglobin saturation curve.

asphyxia, and shows that in atmospheres containing less than 19 vol% oxygen some adverse physiological effects occur but they are unnoticeable. In atmospheres containing less than 16 vol% oxygen, some impairment may be noticed. In those containing less than 6 vol% oxygen, death occurs quickly.

Obviously, there are various opinions as to what constitutes an oxygen deficient atmosphere. Although we cannot change the legal definitions, we can place them in a physiological context. As described in Chap. Three, normal ambient air at sea level contains about 20.9 vol% oxygen, or 160-mm-Hg PO_2, which is reduced to 110-mm PO_2 in the alveolar space. As Fig. 4-1 shows, the hemoglobin is about 95% saturated with oxygen at this PO_2 level. As the oxygen content in the ambient air and, consequently, the alveolar PO_2, are reduced, the saturation of the hemoglobin drops, but at an alveolar PO_2 of 60 mm, the hemoglobin is still 90% saturated. It is at this point that most physiologists agree that oxygen deficiency symptoms become evident. In the following discussion, 60-mm-Hg alveolar PO_2 is taken to be the physiological limit that establishes an oxygen deficient atmosphere.

This 60-mm-Hg PO_2 limit can be approached in two ways. The first is through reduction of the O_2 content of the ambient air at a given altitude. At sea level, this means that the O_2 content could drop to about 14.5 vol% before the PO_2 in the alveolar space dropped to 60 mm Hg. The lowest defined value, 16%, in Table 4-1 therefore provides a margin of safety.

The second way to approach a PO_2 of 60-mm Hg is through increasing altitude. Because the total atmospheric pressure decreases with altitude, the PO_2 also decreases, until at about 10 000 ft the PO_2 in the alveolar space is about 60-mm Hg. (Remember that even at this high altitude the air still contains 20.9% oxygen, but it is 20.9% of a much lower total pressure.) The physiological significance is that altitudes over 10 000 ft are normally oxygen deficient and workers theoretically should be prohibited from wearing air-purifying respirators. There are isolated locations, primarily in Colorado, where air-purifying respirators are being used at about 10 000 ft, apparently without difficulty, so even this statement cannot be taken as absolute.

As the altitude increases, the PO_2 in the alveolar space comes closer to the 60-mm-Hg level. Therefore, a higher minimum volume per cent of O_2 must be maintained to keep the alveolar PO_2 from dropping below 60. Figure 4-2 shows the *minimum* volume per cent of O_2 in the air which must be maintained. Note that this does not provide any safety factor, as do the listed sea level definitions of oxygen deficiency.

To understand Fig. 4-2, let us consider Denver, Colorado, at an elevation of 5280 ft. The solid line indicates that an atmosphere in Denver must contain approximately 17.9 vol% oxygen to avoid being oxygen deficient, assuming no safety factor. To calculate the same safety factor as the lowest sea level definition of oxygen deficiency—16 vol% provides, we can draw a line parallel to the solid line, starting at 16% at sea level. This dashed line indicates that we would need about 19.4 vol% O_2 in Denver to provide the same margin of safety that 16% provides at sea level.

What should the respirator user do with information that seems to disagree with the legal requirements? The important thing is the respirator wearer's safety. If the legal definition of O_2 deficiency is above the O_2 level you can consider safe for humans, you are justified in following the legal definition. If the O_2 deficiency level as legally defined is less than the O_2 concentration you believe safe for human exposure, you must consider raising your minimum O_2 level above the legal limit.

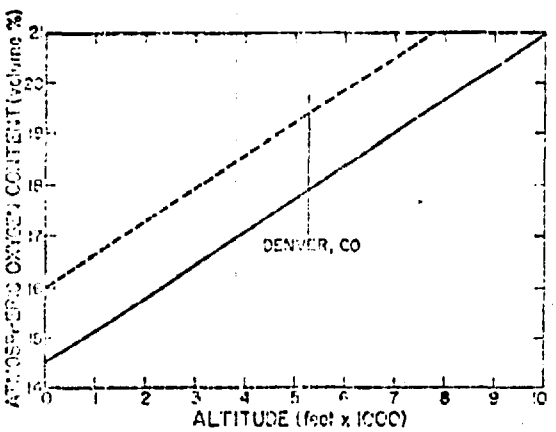


Fig. 4-2.
The effect of altitude on the definition of oxygen deficient atmospheres.

Although not infallible, the PO_2 limit of 60 mm Hg in the alveolar space should be the absolute minimum to which the O_2 level should be allowed to drop. This means that the PO_2 in the ambient air should not drop below about 120 mm Hg. This problem is under study, and eventually "oxygen deficient atmosphere" will be redefined to eliminate the present discrepancies and account for the effect of altitude.

ENTRY OF TOXIC MATERIALS INTO THE BODY

Toxic materials can enter the body through the skin, the digestive tract, or the respiratory tract.

Through the Skin

When a toxic substance touches the skin, four things can happen.

- The skin may act as a barrier that the substance cannot enter or penetrate.
- The substance may injure the skin surface.
- The substance may penetrate the skin surface and injure the skin tissues.
- The substance may penetrate the skin, enter the blood stream, and be disseminated throughout the body to injure various parts of it.

Generally the skin is an effective barrier, and few substances enter the body through it. However, serious injury and even death may result from short exposures of skin to high concentrations of certain very toxic substances, pesticides for example. Lacerations and open wounds obviously increase the possibility of their entering the body.

By the Digestive System

The body may absorb toxic substances through the digestive system. A harmful amount of toxic material can be swallowed accidentally, but ingestion of toxic substances is uncommon in industry. Particles in inspired air which are insoluble in the mucous of the respiratory tract may be carried to the mouth where they are either spit out or swallowed so that they enter the digestive system.

The fact that a substance has been swallowed does not necessarily mean that it will be absorbed, as a certain selectivity in absorption through the walls of the digestive tract tends to prevent absorption of unnatural substances or to limit the amount absorbed. Materials not absorbed are eliminated in the feces. Food and liquid in the digestive tract dilute the toxic substance and may react with it to produce a harmless or insoluble substance. Also, the toxic substance, if absorbed by the blood stream, will pass to the liver which may alter and detoxify it, but possibly be damaged in the process.

By the Respiratory Tract

The respiratory tract is the most important route by which toxic substances enter the body. (Most industrial poisonings result from inhalation of toxic substances.) One reason why the respiratory tract is the most important route of entry is that it has a much larger surface area than the skin or digestive tract. The surface area of the adult respiratory tract, about 70 - 100 m^2 during inhalation, is large compared to the total skin area, which is not over 2 m^2, or the total surface area of the digestive tract, which is not more than 10 m^2. The huge quantity of air inhaled, the continuous flow of blood through the pulmonary capillaries surrounding the alveoli (see Chap. Three), and the fact that the air in the alveoli and the blood in the pulmonary capillaries are separated by membranes whose total thickness is only two cells also help make the respiratory tract the most important route.

PARTICULATE CONTAMINANTS (AEROSOLS)

Particles of solid or liquid matter suspended in air may be classified according to their physical state and properties or according to their effects on the body. The term aerosol is often applied to particles in air. An aerosol is a system in which air is the continuous phase or dispersing medium and the particles are the dispersed phase or dispersoid.

Physical Classification

Mechanical Dispersoid. A mechanical dispersoid consists of particles of solid or liquid matter, formed and dispersed into air by mechanical means such as grinding, crushing, drilling, blasting, and spraying.

Condensation Dispersoid. A condensation dispersoid consists of particles of solid or liquid matter formed and dispersed into air by reactions such as combustion.

Dust. A dust's dispersed phase is a solid mechanical dispersoid. Dust particles range from submicroscopic to visible.

Spray. A spray's dispersed phase is a liquid mechanical dispersoid. The particles are generally visible.

Fume. A fume's dispersed phase is a solid condensation dispersoid. The particles are extremely small, generally less than 1 μm in diameter.

Mist. A mist's dispersed phase is a liquid condensation dispersoid. The particles vary from submicroscopic to visible.

Fog. A fog is a mist dense enough to obscure vision.

Smoke. Smoke generally is defined as the products of incomplete combustion of organic substances in the form of solid and liquid particles suspended in air and gaseous products mixed with air. It is usually visible or obscures vision.

Smog. Smog may consist of any combination of dispersoids, solid and/or liquid, suspended in air and gas or vapor contaminants dispersed in air. Smog sometimes is referred to as a mixture of fog and smoke. It is generally visible or obscures vision.

Physiological Classification

Nuisance and/or Inert. These aerosols produce no known injuries when inhaled but may cause discomfort and minor irritation. However, large quantities of nuisance and/or inert particulate may overwhelm the lungs' capacity to dispose of them and large deposits in the lungs may, in the long run, produce injury. Examples of nuisance and/or inert aerosols are dusts containing particulate clay, limestone, gypsum, or aluminum oxide.

Inert Pulmonary Reaction Producing. These aerosols produce nonspecific reactions in the lungs. Examples are dusts containing particulate silicates or aluminum.

Minimal Pulmonary Fibrosis Producing. These aerosols produce nodulation (discrete deposits of particulate) and a slight diffuse fibrosis (growth of scattered nonelastic tissue) in the lungs. Examples are dusts containing particulate barium sulfate, iron, or iron oxide, and fumes containing particles of iron oxide or tin oxide.

Extensive Pulmonary Fibrosis Producing. These aerosols produce extensive nodulation and fibrosis in the lungs. Examples are dusts containing particulate silica and asbestos. Silicosis and asbestosis are the occupational diseases that result from breathing air containing these contaminants.

Chemical Irritant. These aerosols irritate, inflame, and ulcerate the respiratory tract. Examples are dusts, sprays, fumes, and mists containing particulate acids, alkalies, peroxides, or chromates.

Systemic Poison. These aerosols when inhaled and absorbed produce toxic pathological reactions, including cancer in various body systems. Examples are dusts, sprays, fumes, and mists containing particulate lead, manganese, cadmium, pesticides, or radioactive materials.

Allergy-Producing. These aerosols produce allergic, hypersensitivity reactions such as itching, swollen membranes, and increased liquid secretion in the nose; sneezing; labored breathing; and reduced ventilating capacity of the lungs. Examples are dusts containing particulate pollen, plastic resins, gums, spices, fur fibers, tobacco, or vegetable fibers such as cotton jute, and soft hemp.

Febrile-Reaction Producing. These aerosols produce chills followed by intense fever. Examples are dusts containing particulate bagasse (sugar cane residue) and fumes containing particulate metals such as zinc and copper.

GASEOUS CONTAMINANTS

Vapors or gases mixed with air also may be classified according to their chemical properties and composition or their physiological effects.

Chemical Classification

Gaseous air contaminants cannot be classified perfectly according to chemical composition and properties, because there are a multitude of chemical compositions and the chemical properties within each can vary widely. The following is a meaningful classification system for air contaminants. Some of the classes depend on chemical composition only; others involve chemical properties only. Some contaminants could belong to more than one chemical class.

Acidic. Gaseous air contaminants that are acids or react with water to become acid are called acid vapors and gases. Acids contain hydrogen and produce positively charged hydrogen ions when dissolved in water. Acids taste sour, are corrosive, react with metals to produce hydrogen gas and salts, and react with alkaline substances to produce salts. Acids that readily release hydrogen ions in water solution and react rapidly with other substances are called strong; those that do not are called weak. Strong acid gaseous contaminants include hydrogen chloride, sulfur dioxide, chlorine, and fluorine; weak ones are carbon dioxide, hydrogen sulfide, and hydrogen cyanide. The toxicity does not depend upon the strength; some of the most toxic gaseous air contaminants are weak acids.

Alkaline. Gaseous air contaminants that are alkalies or react with water to become alkaline are called alkaline (or basic) vapors and gases. Alkalies (or bases) produce negatively charged hydroxyl ions when dissolved in water. (A hydroxyl ion consists of an oxygen and a hydrogen atom, but acts like a single entity. It always has a negative charge.) Alkalies taste bitter, may be corrosive, cause organic materials to disintegrate, and react with acids to produce salts. Alkalies that readily produce hydroxyl ions in water solution and react readily with other substances are called strong; those that do not are called weak. No really strong alkaline substances exist in the gaseous state. The toxicity does not depend upon the strength; some of the most toxic gaseous air contaminants are very weak alkalies. Examples of gaseous air contaminants that can be considered moderate to weak alkalies are ammonia and amines; very weak ones include phosphine, arsine, and stibine.

Organic. Gaseous air contaminants that are organic compounds are classified as organic vapors and gases. Organic compounds are compounds of carbon, which can form many compounds because its atoms can share electrons with many other kinds of atoms and with many other carbon atoms. There are thousands of known organic compounds and more are discovered or synthesized constantly.

Organic compounds are classified by molecular structure. Some of the more common and important organic gaseous air contaminants are vapors and gases of saturated hydrocarbons such as methane, ethane, and propane; unsaturated hydrocarbons such as ethylene and acetylene; methyl and ethyl alcohol; methyl and ethyl ether; formaldehyde and acetaldehyde; dimethyl and methyl-ether ketone; formic and acetic acid; halides such as chloroform, carbon tetrachloride, and trichlorethylene; formamide and acetamide; toluene diisocyanate; methylamine and ethylamine; epoxies such as epoxyethene, epichlorohydrin, and propylene oxide; and aromatics such as benzene, toluene, and xylene.

Organometallic. Organometallic compounds are those in which metals are chemically bonded to organic groups. Some are volatile and can become gaseous air contaminants. One example is tetraethyl lead.

Hydride. Hydrides are compounds in which hydrogen is chemically bonded to metals and metalloids (elements intermediate between metals and nonmetals). Examples of gaseous hydride air contaminants are diborane, pentaborane, and decaborane.

Inert. Substances that seldom react chemically with other substances are called inert. Inert gases include helium, neon, argon, krypton, and xenon.

Physiological Classification

Gaseous air contaminants can be classified by their effect on the body. Such classification is imperfect because the effects of many vapors and gases depend on their concentrations and some have more than one effect.

Irritant. Gaseous irritants are corrosive. They injure the respiratory tract by producing painful inflammation and increased mucus secretion. Severe inflammation and a large accumulation of mucus may close the respiratory tract and cause suffocation. Inflammation of the lungs' terminal air sacs, the alveoli, may cause pulmonary edema, increased secretion of fluids into the alveoli and the spaces between them. This edema may interfere severely with gas exchange between the air in the alveoli and the blood in the pulmonary capillaries and obstruct blood flow through the pulmonary capillaries, thus straining the heart. Pulmonary edema can kill by suffocation or heart failure. Gaseous irritants that affect the upper respiratory tract include ammonia, hydrogen chloride, hydrogen fluoride, sulfur trioxide, formaldehyde, acetaldehyde, and vinegar. Those that affect both the upper and lower respiratory tract include sulfur dioxide, iodine, bromine, chlorine, fluorine, ozone, phosphorus trichloride, and phosphorus pentachloride. Those that affect chiefly the lower and terminal parts are nitrogen dioxide, phosgene, and arsenic trichloride.

Asphyxiant. Gaseous asphyxiants interfere with the supply or use of oxygen in the body. They act without directly interfering with breathing. They may be subdivided into two groups, simple and chemical. Simple asphyxiants are inert gases that

dilute the oxygen in the air below the concentration required for body function. They must be present in quantity to have appreciable effect. Chemical asphyxiants, even in very low concentrations, by diluting the ambient atmosphere, interfere with the supply of oxygen or its use in the body. They prevent the blood from transporting oxygen from the lungs to the body tissue cells or prevent the tissue cells from using oxygen to release the energy needed for life. Asphyxiation may kill or it may injure various organs, particularly the nervous system. Simple asphyiants include nitrogen, hydrogen, helium, methane, and ethane. Chemical asphyxiants include carbon monoxide which combines with hemoglobin, thus interfering with the blood's oxygen-carrying capacity, and hydrogen cyanide which inhibits utilization of oxygen in tissue cells by interfering with the catalytic action of enzymes that regulate the reactions of oxygen with substances in the cells.

Anesthetic. Anesthesia is partial or complete loss of sensation. Local anethesia is loss of sensation in a particular area, whereas general anesthesia is total loss of sensation and unconsciousness. Gas or vapor anesthetics depress the central nervous system. The initial effect is mild intoxication with dizziness and loss of coordination. Continued exposure causes unconsciousness, and severe or long exposure may cause respiratory paralysis and death. All organic vapors and gases are anesthetics. Some are also systemic poisons, as mentioned below. Anesthetics are sometimes called narcotics. Anesthetics that generally have no serious effects are nitrous oxide, hydrocarbons (such as propane, butane, ethylene, and acetylene), and ethyl and isopropyl ether.

Systemic Poison. Gaseous systemic poisons injure specific organs and body systems. They include mercury, a protoplasmic poison (a substance that destroys the vitality of any living matter it contacts) that damages mainly the nervous system, the kidneys, and various glands and undermines the general health; phosphorus that makes bones fragile; hydrogen sulfide that paralyzes the respiratory control center and stops breathing; hydrogen selenide that severely injures the liver and spleen; and arsine that destroys red blood cells; and severely injures the liver.

Carbon tetrachloride injures the liver and kidneys; methyl chloride severely injures the kidneys, heart, and nervous system; ethylene dichloride severely injures the liver and kidneys; benzene damages bone marrow where the red blood cells are formed and thus interferes with production of red blood cells; and methyl alcohol seriously damages the nervous system, especially the optic nerve.

EXPRESSING AIR CONTAMINANT CONCENTRATIONS

The concentration of particles suspended in air may be expressed as the number of particles or as the mass of particles in a given volume of air. When concentration is expressed as the number of particles, it generally is given in terms of millions of particles in one cubic foot (abbreviated mppcf) or as the number of particles in one cubic centimeter (ppcc). When concentration is expressed as the mass of particles, it usually is given in terms of milligrams of particulate in one cubic meter (mg/m^3), milligrams in one liter (mg/ℓ), or micrograms in one liter ($\mu g/\ell$).

The concentration of vapor or gas in air may be expressed as the per cent by volume or as the number of volumes per million volumes of air (ppm). Sometimes, extremely small quantities are given as the number of volumes per billion volumes of air (ppb). When the concentration is expressed as the mass of vapor or gas in a given volume of air, it generally is given as the number of milligrams per cubic meter (mg/m^3) or per liter (mg/ℓ).

HAZARD EVALUATION

Normally, respiratory hazards are evaluated by a safety engineer who understands the concepts of industrial hygiene. The industrial hygienist or safety engineer often calls upon other specialists such as the industrial physician, toxicologist, and chemist. The evaluator must have the cooperation of others in obtaining information on the industrial process, the work area, and work activities and materials.

Small firms that do not have their own industrial hygienist or safety engineer may have respiratory

hazards assessed by qualified personnel from outside. Casualty insurance companies employ industrial hygienists to make occupational health surveys of insured firms. There are also many private industrial hygiene consultants and consulting firms. Most states have an industrial hygiene division in their department of labor or health which will make studies without charge. The OSHA requires the U.S. Department of Health, Education, and Welfare (HEW) to evaluate hazards on written request by any employer or group of employees. Such evaluations are free. (If HEW finds a violation of OSHA standards, there will not automatically be an OSHA inspection.) The NIOSH Health Hazard Evaluation Program is given in the code of Federal Regulations (42 CFR 85, Federal Register, Nov. 7, 1972).

Procedure

Proper assessment of industrial respiratory hazards involves a systematic procedure such as:

Learning about the industrial process, including
- Construction of equipment,
- Operation of equipment,
- Physical conditions during equipment operation.

Learning about the work area, including
- Size,
- Equipment layout,
- Ventilation,
- Temperature and humidity.

Learning about personnel activity in the work area, including
- Job routines,
- Work locations,
- Time spent in work area, both continuously and intermittently,
- Work rates.

Learning about the materials involved in the process, including
- Raw materials,
- End-products,
- Actual and potential by-products.

Listing known and potential respiratory hazards, including their
- Chemical composition,
- Type (oxygen deficiency or air contamination)
- Acute and chronic toxicity at various concentrations.
- Established concentration limits for breathing.

Using the above information to select the proper instrument(s) and procedure(s) for determining the degree of workers' exposure to respiratory hazards.

Using the instruments to measure
- Time-weighted average exposure concentrations,
- Peak exposure concentrations.

If possible, having a biochemist test body tissues and wastes to determine worker exposure to respiratory hazards.

Having a physician determine how the hazards affect exposed workers.

Studying and evaluating the measured time-weighted average and peak exposure levels. Comparing them with the biochemical and physiological test results and with established concentration limits for breathing, to determine whether and how to improve engineering and administrative controls to eliminate or reduce the hazards and to determine what types of respirators, if any, are needed in the meantime.

The above procedure is only one of many approaches, and some parts may not be applicable in a given situation, whereas other conditions may require additional considerations. Industrial hygiene experience and professional judgment should play an important part in any hazard evaluation procedure.

Identification of Potential Hazards

Detailed information about the physical and chemical characteristics of raw materials, end-products, and by-products of the industrial process should be available from the manufacturing or engineering departments. If they provide insufficient information, it may be necessary to consult the purchasing department or the material suppliers. If data on end-products are inadequate, it may be necessary to consult a chemist or engineer. Determination of what by-products are produced may require considering all chemical reactions that could occur. Consultation with a chemist or

engineer who will consider the raw materials and the conditions under which they are processed may be helpful.

Identifying potential respiratory hazards in an industrial work area requires thorough knowledge of the raw materials, end-products, and by-products, the industrial process, the means by which substances could escape from the processing equipment into the work area, and chemical reactions that could take place between escaped substances and the atmosphere in the work area or other materials present there. Many relatively inert, nontoxic materials, when machined, heated, dissolved in liquids, or placed in contact with other materials, decompose or react to form highly toxic substances.

The type and form of a hazard are determined by the materials and conditions. Dust may be generated by crushing, grinding, abrading, or polishing solids. Spray particles may be produced by atomizing a liquid. Heating and vaporizing a solid may form a solid fume particulate when the vapor condenses. Liquid mist particles can be produced when a vapor condenses. Often, fume and mist particles are formed through oxidation of finely divided condensation particles by the oxygen in the air. Two gases may react chemically to produce solid fume or liquid mist particles, and the hazard then may consist of both particulate and gas. Heating some solids and liquids decomposes them and releases gas.

Some vapors and gases react with water vapor in the air to generate new vapors, gases, or liquid particles. Certain gases have a great affinity for water, and their molecules act as nuclei for condensation of water vapor that will cause development of a liquid mist particulate.

Certain solid particles also act as nuclei for water vapor condensation to form liquid mist particles. High temperatures like those in welding and cutting flames cause nitrogen and oxygen in the air to form toxic gaseous nitrogen oxides. Radiant energy from sources such as gas-shielded welding arcs may decompose chlorinated hydrocarbon vapors to produce new substances including highly toxic phosgene gas.

In an enclosed space, some substances slowly combine with the oxygen in the air to produce an oxygen-deficient atmosphere. Release of a large quantity of gas, although it is inert or nontoxic, can dilute the oxygen in a work space and cause oxygen deficiency.

Toxicity

Toxicity and hazard are not the same. Toxicity is a material's ability to hurt the body. A hazard is toxic material in a condition in which it can cause bodily harm. Almost any substance can be toxic if enough of it is absorbed. Toxicity depends on the *quantity* of material absorbed and the *rate, method,* and *site* of absorption. In assessing respirator hazards, toxicities should be considered.

Information on toxicity is given in industrial hygiene and occupational medicine journals and books, product bulletins, and product labels. It also can be obtained from Industrial Safety Data Sheets, published by the National Safety Council (NSC); Hygiene Guides, published by the American Industrial Hygiene Association; and Chemical Safety Data Sheets, published by the Manufacturing Chemists Association. Toxicity information also is available from casualty insurance firms, the industrial hygiene division of state labor or medical departments, and the manufacturers of chemical products. Also, consulting toxicologists are available for a fee. Any regional NIOSH or HEW office will provide free toxicity data. These offices have access to NIOSH computerized technical information.

The OSHA requires HEW to publish, at least annually, a list of all known toxic substances and the concentrations at which they become toxic. The OSHA also requires HEW to determine, upon written request by an employer or authorized employee representative, whether any substance in the work area atmosphere is potentially toxic in the concentrations used or found.

Concentration Limits

Recently enacted federal occupational safety and health laws require that workers be provided a safe, healthful work environment. They specify atmospheric quality standards for work areas and list time-weighted average concentrations and, in some cases, ceiling concentrations of air contaminants.

These laws and standards necessitate use of engineering and administrative controls to reduce respiratory hazards in work areas to levels that will not cause bodily harm, and if these controls are inadequate or not feasible, workers must wear suitable respirators.

Determining Degree of Exposure

The degree of exposure to respiratory hazards is determined by measuring the concentration of airborne contaminant in the worker's breathing zone. This testing must be adequate to define the time-weighted average concentration and the peak concentration. The volume of air sampled must contain enough of the substance for accurate analysis. The volume to be sampled, or the duration of sampling, depends on:

Estimated concentration of the substance,
Sensitivity of instrument and test procedures,
Established concentration limit for the substance.

Concentrations of a substance in the worker's breathing zone should be measured during the time he spends in the work area to define the time-weighted average concentration and peak concentration accurately. The concentrations are affected by changes in process operation, changes in rate and direction of air movement and temperature, changes from day to night operations, and seasonal changes.

Instruments and Procedures

There are many instruments and procedures for measuring concentrations of airborne substances. There is no single, universal instrument for all such measurements, and there probably never will be. In fact, the trend is toward development of a greater number of specialized instruments.

Instruments and procedures may be classified as follows:

Those that give a direct reading,
Those that remove the substance from a measured volume of air for later analysis,
Those that collect and retain a measured volume of air for later analysis.

Choice of instrument and procedure depends on many factors, including:

Portability of instrument and ease of operation,
Sensitivity and accuracy of instrument or procedure,
Reliability of instrument,
Availability of instrument,
Type of information desired,
Personal experience.

Grab, or instantaneous direct reading, tests require only a few seconds to a few minutes. They indicate fluctuations in concentration of airborne substances and are useful in determining maximum and minimum concentrations. Many grab tests or samples are needed to determine a time-weighted average concentration.

A continuous test or collected sample requires from several minutes to an entire work shift. Such tests give information on the average concentration of the airborne substance. There is a definite need for both grab and continuous methods, as both give useful information. Instruments and procedures for measuring air contaminant concentrations are specified in some federal standards. Both NIOSH and OSHA have published such lists.

CHAPTER FIVE

RESPIRATORS

Several hu ared different respirators have been approved under various BOM schedules and 30 CFR Part 11. To select the correct respirator for protection against a particular hazard as the OSHA requires, one must have a thorough knowledge of those available. Choosing among the hundreds of devices as individual items would be a formidable task.

Unfortunately, there has been a tendency to think of respirators as individual items rather than as part of a system. The 30 CFR Part 11 approval tests, as well as the old BOM tests, cultivated this attitude by approving respirators for protection against specific hazards or groups of hazards, for example, only dust, fumes, and mists, or a specific gas or vapor.

Here, we take a different approach and present respirators by classes. There are two major classes each of which has many subclasses of the basic respirator modified for particular purposes. Study of this chapter, especially Figs. 5-1 and 5-2, will make selection and use of the proper device easier.

GENERAL RESPIRATOR CLASSIFICATIONS

The basic purpose of any respirator is, very simply, to protect the respiratory system from harmful airborne physical or chemical agents. It provides this protection by removing the contaminant from the air *before it is inhaled* or by supplying an independent source of respirable air.

Basically, a respirator is an enclosure (in 30 CFR 11 terms, a respiratory inlet covering) that covers the nose and mouth or the entire face or head. They are of two general types, tight fitting and loose fitting. Tight-fitting ones are generally a molded, impervious rubber or plastic facepiece that covers the nose and mouth or the entire face. In the latter case, the facepiece has a lens or eyepieces. Sometimes these coverings are called "masks" or, more technically, "oronasal masks." A mouthpiece, held in the wearer's mouth and a clamp that closes his nostrils sometimes make up the respirator.

Loose-fitting respirators include hoods, helmets, blouses, or full suits, all of which cover the head completely. Their configuration varies widely depending on the use for which they are designed.

Attached to the coverings are the elements for removing contaminants from the air (in tight-fitting facepieces only), or hoses to supply respira e air (in both tight- and loose-fitting coverings). It is these accessories that divide respirators into two major classes. If the device removes contaminants, it is an *air-purifying respirator* (see Fig. 5-1). *These devices do not supply oxygen, so they cannot be used in oxygen-deficient atmospheres. This point must never be forgotten.* A wide variety of air-purifying elements are available to tailor respirators for protection against specific contaminants. These also fall into two subclasses; particulate-removing elements that intercept particles before they enter the facepiece, and vapor- and gas-removing elements that entrap gas and vapor molecules. Here we call particulate-removing elements "filters" and vapor- and gas-removing elements either "chemical cartridges" or "canisters." Combination elements for protection against both particulates and vapors and gases are also available.

If, instead of cleaning the air, the accessory attached to the respirator provides respirable air from a source other than the surrounding atmosphere, the respirator is called *atmosphere-supplying* (see Fig. 5-2). These respirators are generally complex and come in many configurations. Because they supply breathable air, they may be used in oxygen-deficient atmospheres (subject to some limitations) as well as against particulates, vapors, and gases.

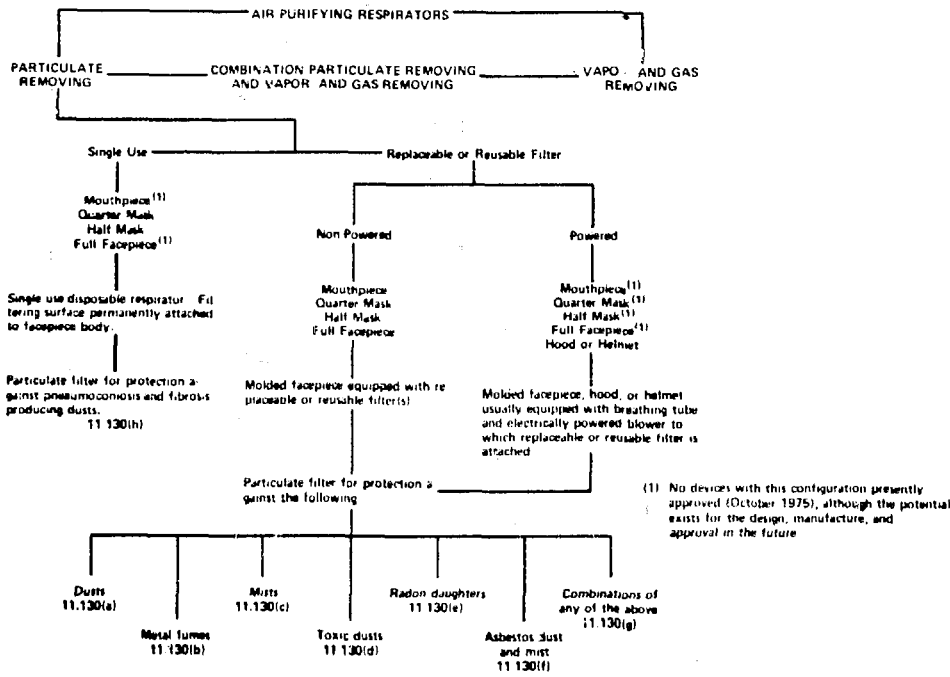


Fig. 5-1(a).
Particulate-removing respirators.

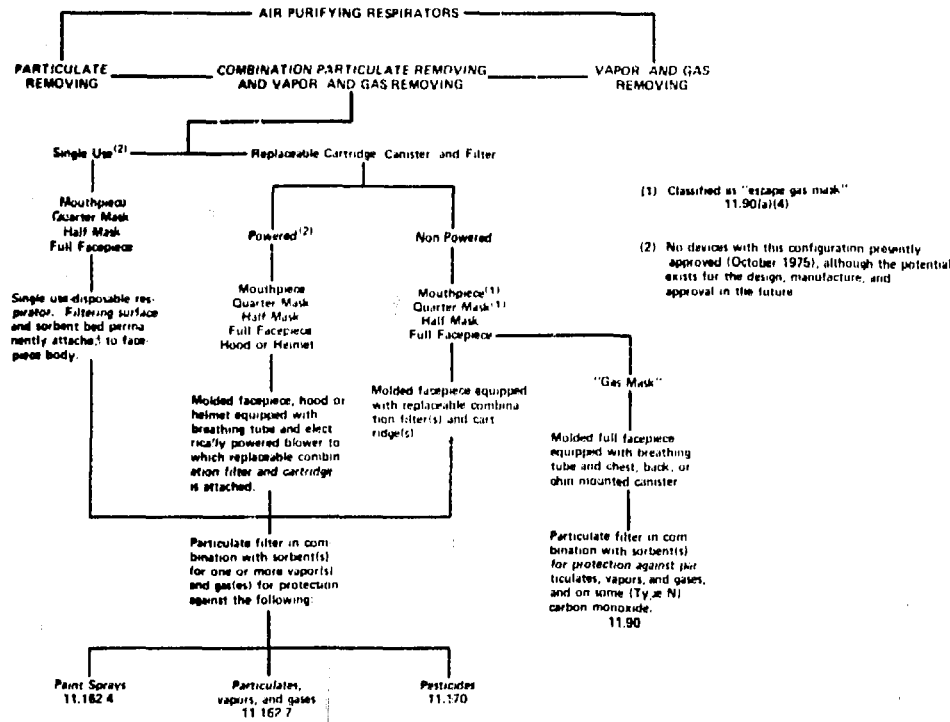


Fig. 5-1(b).
Combination particulate- and vapor- and gas-removing respirators.

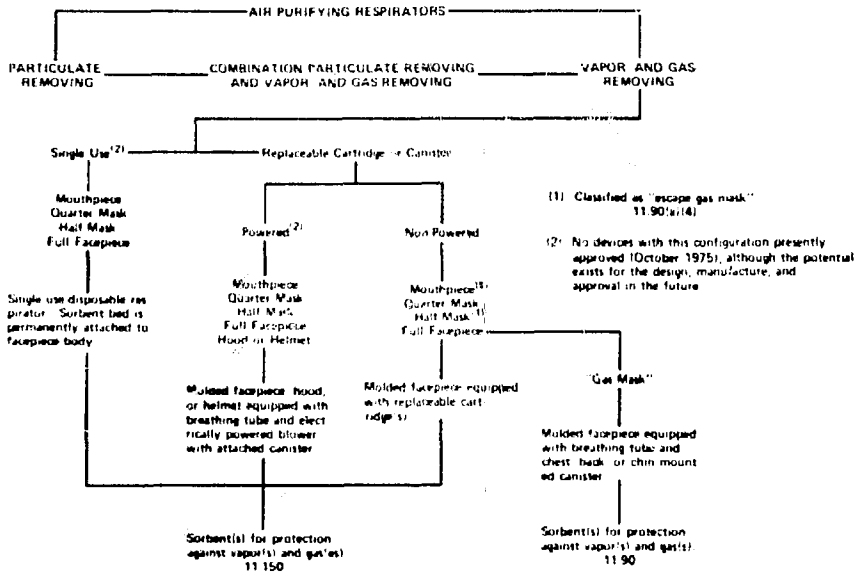


Fig. 5-1(c).
Vapor- and gas-removing respirators.

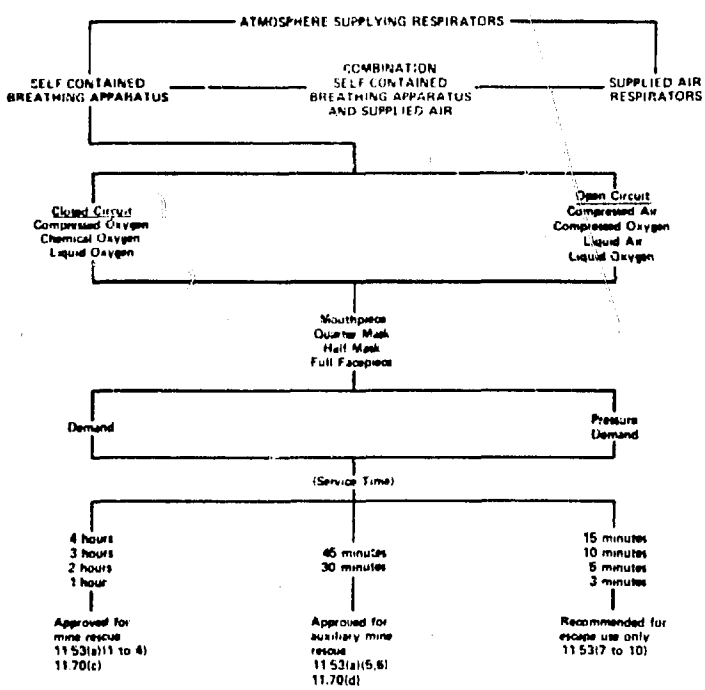


Fig. 5-2(a).
Self-contained breathing apparatus.

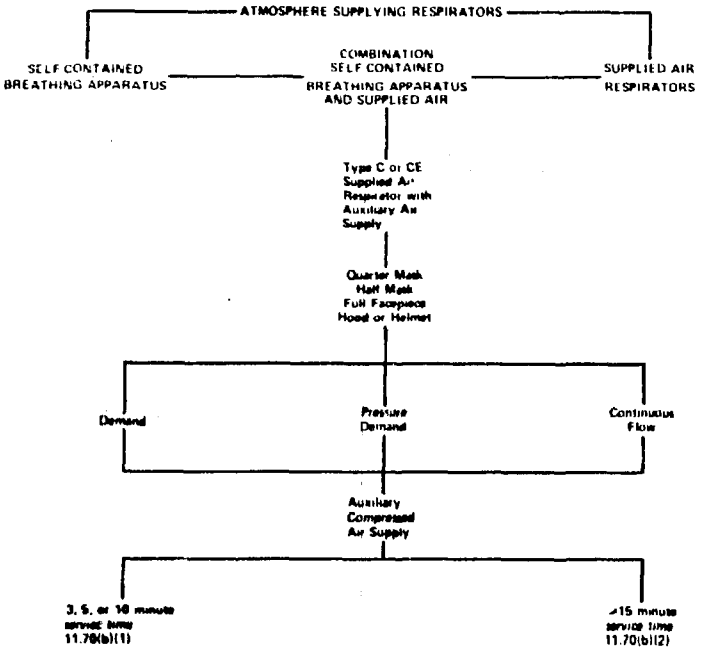
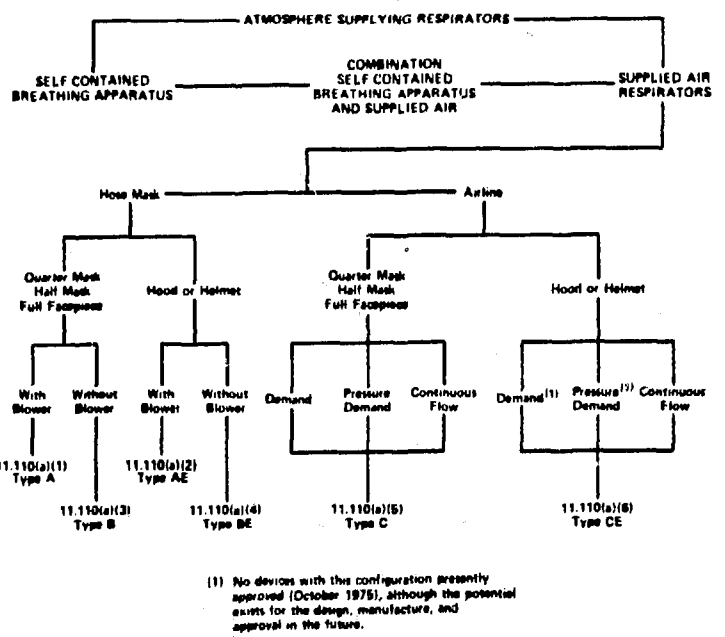


Fig. 5-2(b).
Combination SCBA and supplied air respirators.



(1) No devices with this configuration presently approved (October 1975), although the potential exists for the design, manufacture, and approval in the future.

Fig. 5-2(c).
Supplied air respirators.

Air-Purifying and Atmosphere-Supplying Respirators

Here, we will discuss air-purifying respirators by the types available for use against specific hazards. Atmosphere-supplying devices are more nearly of a single type, so they are subclassified by mode of operation.

Classification of air-purifying respirators is dictated primarily by the NIOSH approval tests in 30 CFR Part 11 (see App. B). This approval is reflected in Figs. 5-1 and 5-2 where the pertinent Part 11 paragraphs are indicated below each type of device. To fully understand this relationship, one might use Figs. 5-1 and 5-2 and the appropriate paragraphs in Part 11 together.

Particulate-removing respirators are generally called "dust," "fume," or "mist" respirators, or combinations thereof. Although the implication is that there are specialized respirators for specialized functions, *all dust, fume, and mist respirators protect in exactly the same way, by removing and retaining the particulate before it can be inhaled.* The types of particulate-removing respirators that may be approved are listed in 30 CFR Part 11 K, "Dust, Fume, and Mist Respirators."

Vapor- and gas-removing respirators for protection against specific hazards are available. Chemical cartridges and canisters are approved under Part 11 for protection against acid gases, such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2), alkaline gases, such as ammonia (NH_3), and organic vapors such as carbon tetrachloride or carbon monoxide (CO). The approvals may be for a single vapor or gas or a combination of several. Further descriptions are given in Part 11, Subparts I, L, and M, "Gas Masks," "Chemical Cartridge Respirators," and "Pesticide Respirators," respectively. These Subparts also describe the combination particulate and gas- and vapor-removing respirators such as paint spray respirators and those for protection against pesticides.

Atmosphere-supplying respirators (Fig. 5-2) are divided into self-contained and supplied-air types. When wearing self-contained apparatus, the user carries a supply of respirable air or oxygen and can move around as he pleases. Supplied-air respirators depend on air supplied through a hose. They use compressed air, never compressed oxygen. See Parts 11 H, "Self-Contained Breathing Apparatus," and J, "Supplied-Air Respirators." The pertinent paragraphs are indicated under each device in Fig. 5-2.

Combination self-contained and supplied-air respirators are covered by Part 11 H. These are generally supplied-air respirators to which a small auxiliary compressed air supply is attached for emergency escape use.

Respiratory Inlet Coverings

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

Tight-Fitting Coverings. Tight-fitting coverings are usually called "facepieces" and made of flexible molded rubber or plastic. Rubber or woven elastic headstraps are attached at two to six points. They buckle together at the back of the head, or sometimes are 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. 5-3). Good protection may be obtained with a quarter-mask, but it is more easily dislodged than other types. Some "dust" respirators have quarter-masks.

A second type, the "half-mask," fits over the nose and under the chin (Fig. 5-4). Half-masks generally

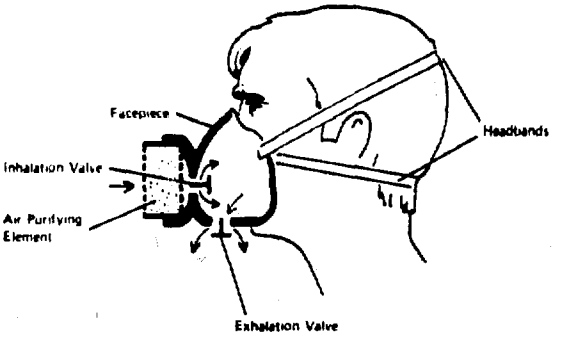


Fig. 5-3.
Typical quarter-mask respirator.

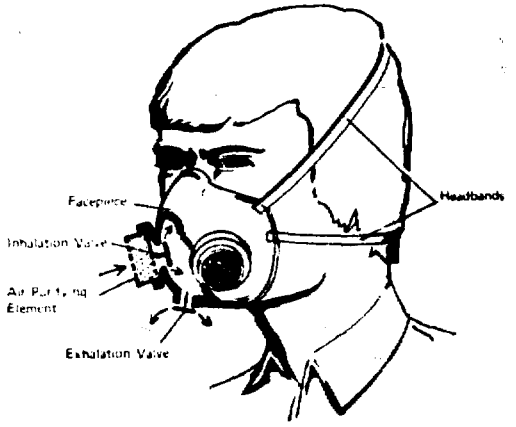


Fig. 5-4.
Typical half-mask respirator.

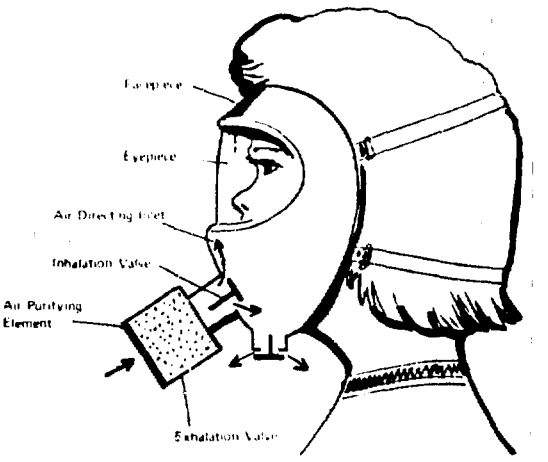


Fig. 5-5.
Typical full-facepiece respirator.

seal more reliably than quarter-masks, so they are preferred for use against more toxic materials.

A third type (Fig. 5-5) is the "full facepiece," which covers from roughly the hair line to below the chin. They provide the greatest protection and usually seal most reliably. Also, the lenses or eyepieces must meet the impact and penetration requirements of Federal Specification GGG-M-125d, October 11, 1965, and thereby provide eye protection 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. They may be used in less toxic atmospheres, but, as they are expensive and difficult to maintain, little is gained by using them in such conditions.

A special tight-fitting respirator that is coming into increasingly extensive use is the "single-use" disposable type. It is shaped much like the half- or quarter-mask, but the air purifier is permanently attached to the facepiece or the entire facepiece is made of filter material. At present, these respirators are approved only for pneumoconiosis- and fibrosis-producing dusts.

Another special type of respirator is the "mouthpiece and nose clamp" shown in Fig. 5-6. It consists of a mouthpiece held in the teeth (the lips seal around it) and a clamp that closes the nostrils. The air-purifying elements are either permanent or replaceable. These small devices are easily carried in a pocket and are designed primarily for emergency escape or intermittent use. They do not provide eye protection.

Loose-Fitting Coverings. Loose-fitting respirators include hoods, helmets, suits, and blouses. The wide variety of designs precludes any simple description, but Fig. 5-7 shows a blouse that illustrates the principles of construction and operation of all such devices.

Generally, loose-fitting respirators enclose at least the head, neck, and shoulders. This enclosure

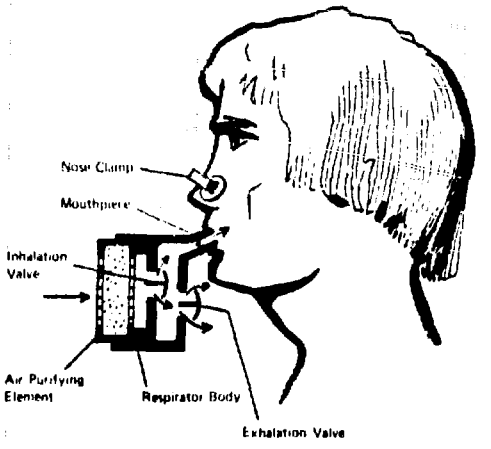


Fig. 5-6.
Typical "mouthpiece" respirator.

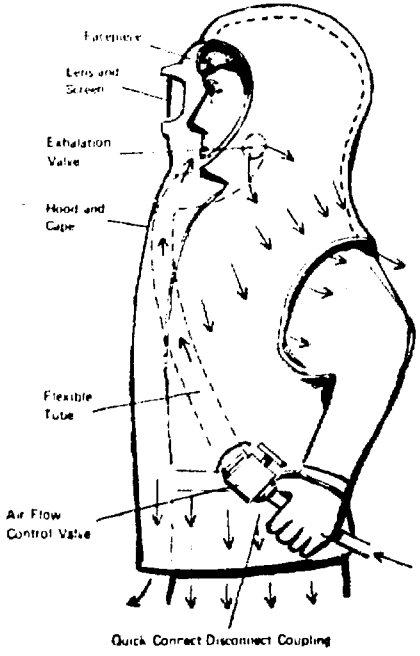


Fig. 5-7.
Typical supplied-air blouse.

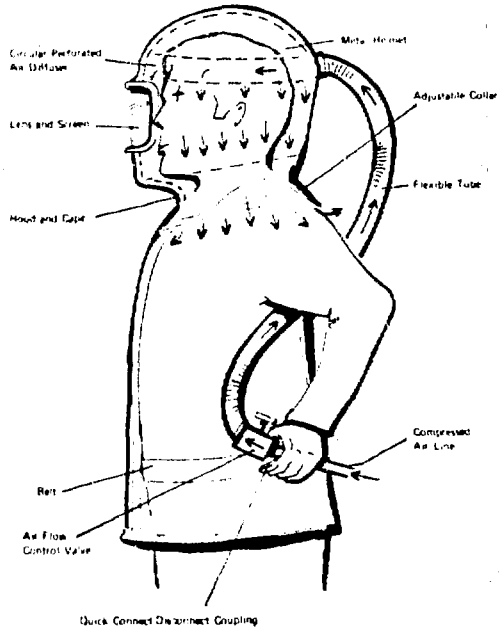


Fig 9.
Typical abrasive blasting hood.

usually contains perforated rigid or flexible tubing through which clean compressed air is distributed around the breathing zone. A light flexible device covering only the 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. Full suits, as the name implies, enclose the whole body, and, in them, additional air is supplied to the extremities for cooling. Generally, full suits are used where skin protection as well as respiratory protection is required.

The permeability of the respirator material by toxic gases and vapors must be considered. Tritium, a radioactive gas, is a good example. The 14 OSHA carcinogen standards specify use of full suits in certain conditions, so permeability by these substances must be considered. At present, there is no NIOSH approval test for supplied-air suits, so no approved suits are available.

A special type of loose-fitting covering in common use is the abrasive-blasting hood (Fig. 5-8). The hood material is designed to withstand rebounding particles of abrasive sand, steel shot, etc. Also, there is usually an impact-resistant glass or plastic viewing lens with plastic, glass, or woven wire shielding that deflects the rebounding particles.

AIR-PURIFYING RESPIRATORS

Particulate-Removing.

All particulate-removing respirators use fibrous material (a filter) to remove the contaminant. As a particle is drawn 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 and shape of both particle and fiber. Here it is enough to say that the particles are retained on the filter fibers.

No filter is 100% efficient in removing particles. An essentially 100% efficient filter could be made, but it would be unacceptably hard to breathe through. Therefore, manufacturers try to produce the most efficient filter with the lowest breathing

resistance. Generally, the higher the efficiency, the greater the breathing resistance.

Another consideration is particle loading. As more and more particulate material collects on the fibers, the openings between them become smaller, so the breathing resistance increases. The filter also becomes more efficient. Filters in general, and dust filters in particular, are designed to remove as much material as possible without excessive breathing resistance.

For the 30 CFR Part 11 approval tests, particulate filters are classified as designed for protection against dust, fumes, mists, and any combination thereof. High-efficiency filters are also dust, fume, and mist filters, but they are designed to protect against particulate contaminants with a threshold limit value (TLV)* less than 0.05 mg/m³. These filters are at least 99.97% efficient against 0.3-μm particles.

Figure 5-9 shows a typical high-efficiency dust, fume, and mist filter. The filter is a flat sheet of material that is pleated and placed in the filter "can." 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. This configuration is common, but other methods of construction also are used.

High-efficiency filters generally have poorer particle-loading characteristics than those designed for protection against the less toxic dusts. Some filters for protection against fumes of various metals, used on the so-called "fume" respirators, look similar. The basic difference is that the fume filter is less efficient (90-99% against 0.6-μm particles) and is approved only for contaminants whose TLV is 0.05 mg/m³ or more.

Less efficient are the so-called "dust" filters used on respirators designed for protection against "pneumoconiosis- and fibrosis-producing dusts" whose TLV is 0.05 mg/m³ or more. Some of these respirators are also approved for mists whose TLV is 0.05 mg/m³ or more, as well as for dusts. This class of respirator accounts for as much as 90% of total

*Threshold limit values are time-weighted concentrations of airborne substances to which nearly all workers may be continuously exposed (during 8-hour workdays and 40-hour workweeks) without adverse effects.
NOTE: ANSI Standard Z88.1-1972, "Commodity Specification for Air," as revised in October 1974, specified 19.5-23.5 vol% O_2 for all grades of breathing air.

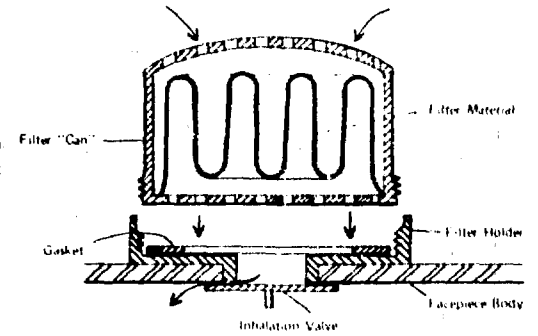


Fig. 5-9.
Typical high-efficiency dust, fume, and mist filter.

sales. Their lower efficiency (80-90% against 0.6-μm particles) results from being designed to withstand heavy dust loadings without unacceptably increasing breathing resistance.

Two types of dust filter predominate. The first and probably most common (Fig. 5-10) 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 are less expensive than the pleated type and protect adequately against most industrial dusts, but one precaution must be observed in their use. Certain agents such as oil mists, extremely small solid particles, and storage in very humid air

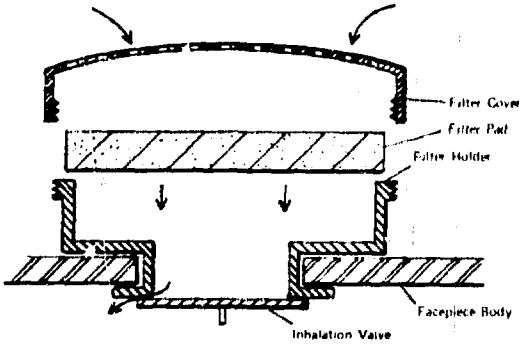


Fig. 5-10.
Typical resin-impregnated felt dust filter.

remove the electrostatic charge. Therefore this type of filter should be used as soon as possible after purchase and should be kept out of oil mists, such as occur around lathes, and high (>80%) humidity.

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

Another type of dust filter is shown in Fig. 5-11. The filtering medium is only loosely packed in the filter "can," so it is much thicker than the compressed type. Such filters are generally made of fiber glass, although nonfelted resin-impregnated natural wool fibers have been used. They are not so common as the felted type. A typical dust respirator is shown in Fig. 5-12.

A major variant is the single-use, or disposable, dust respirator shown in typical use in Fig. 5-13. In these devices, the filter is either an integral part of the facepiece, or it may be the entire facepiece itself. When the filtering surface is permanently attached to the facepiece, the material often is resin-impregnated natural wool fiber or synthetic fiber felt. In some currently approved devices, the entire facepiece is a fabric filtering medium. At present, single-use disposable respirators are approved only for pneumoconiosis- and fibrosis-producing dusts although they could also be approved for such mists. This does not mean that it is impossible or impractical to make more efficient single-use respirators for protection against more toxic dusts and mists and even fumes. It means only that they cannot be

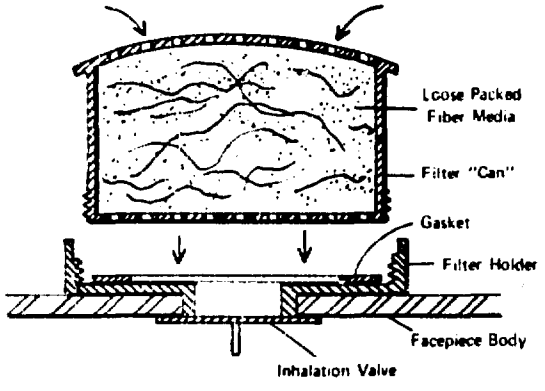


Fig. 5-11.
Typical dust filter with loose-packed medium.

Fig. 5-12.
Typical dust respirator with replaceable filters.

approved as Part 11 is now written. Significant advances probably will be made in single-use respirators, and the user should watch for developments.

Some particulate filters may vary from the designs described. The important thing to recognize is the type of medium rather than the shape.

Fig. 5-13.
Typical single use dust respirators.

Vapor- and Gas-Removing

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, and classes, such as organic vapors or acid gases. 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 more for protection against specific contaminants.

Vapor- and gas-removing respirators all 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.

Adsorption, Absorption, and Catalysis. Three sorptive mechanisms are used in vapor- and gas-removing respirators. The first, adsorption, retains the contaminant molecule on the exposed surface of the sorbent granule by physical or chemical attraction whose intensity varies with the type of sorbent and contaminant.

In physical attraction, the adsorbed molecules are held more or less weakly. These bonds may be broken by heating the sorbent so that the gas and vapor molecules are released into their original state. If chemical forces are involved, the adsorption process is called chemisorption. Then 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 probably 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 adsorbents used in vapor- and gas-removing respirators include molecular sieves, activated alumina, and silica gel.

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 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.

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 relatively nontoxic 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 material and into the facepiece. This is in contrast to 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. Vapor- and gas-removing cartridges must generally be protected from the atmosphere while in storage.

Cartridges and Canisters. 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 occasionally 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.

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 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 and are designed for use in higher concentrations or for prolonged use in lower concentrations of gases and vapors. Front- or back-mounted canisters are used with full facepieces as part of "gas masks." The "gas mask" is not a special, exotic type of respirator. 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. Also, gas masks, except for escape gas masks, are required to have full facepieces.

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 is selecting the proper device? An American National Standard, ANSI K.13.1, established a color code for the various types of sorbent cartridges and canisters which identifies the contaminants they are designed to protect against. The printed approval label also clearly lists these contaminants. Whether the user memorizes the color code or not, he should always **READ THE LABEL!** This is the only foolproof way of ensuring use of the correct cartridge or canister. ANSI K.13.1 has been included verbatim in the OSHA regulations, 29 CFR 1910.134(g).

Construction. Construction of vapor- and gas-removing cartridges and canisters varies little from manufacturer to manufacturer. The type of sorbent for a particular substance may differ with manufacturer, but the basic construction problems are about the same, to provide enough sorbent bed depth and volume to ensure that the contaminant is totally removed in the test times specified in the 30 CFR Part 11 bench tests, and that the sorbent remains mechanically stable in the container.

Figure 5-14 shows a typical chemical cartridge approved for use with a half- or quarter-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. The pads only keep the fines in the sorbent

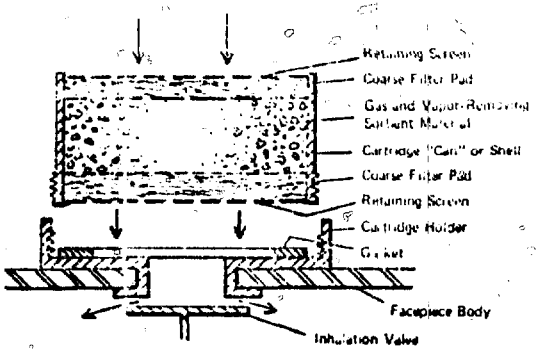


Fig. 5-14.
Typical chemical cartridge.

from escaping from the cartridge; they are not designed for protection against particulate contaminants. Various precautions for use of these cartridges are discussed in Chap. Seven, Respirator Use.

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 also a tendency toward channeling where the irregular sorbent granules touch the smooth canister wall. Sometimes this is prevented by forming ridges in the canister shell like those in Fig. 5-15. The retaining screens and pads hold the granular sorbent bed in place. The spring ensures that the sorbent remains tightly packed.

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 very carefully.

Chemical Cartridge Respirators. Figure 5-16 shows a typical chemical cartridge air-purifying respirator. In 30 CFR Part 11.150 is a listing of the vapors and gases and maximum concentrations for which chemical cartridge respirators are approved.

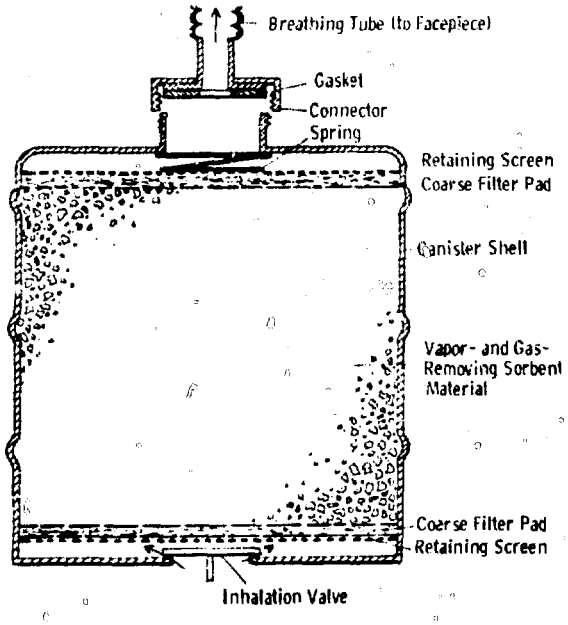


Fig. 5-15.
Typical front- or back-mounted canister.

Note the accompanying restrictions on use and remember that these concentrations pertain to the cartridge only, not to facepiece fit.

Gas Masks. According to Subpart I of Part 11, the following gas masks may be approved.

Front- or back-mounted
Type N, front- or back-mounted, combination gas, vapor, and particulate
Chin-style
Escape

Front- or Back-Mounted. Front- or back-mounted gas masks are usually approved for use with a full facepiece. 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 Fig. 5-15. Note that the construction does not differ markedly from that of the chemical cartridge shown in Fig. 5-14. 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. Figure 5-17 shows typical front- (back)-mounted canister gas masks.

Fig. 5-16.
Typical chemical cartridge respirator being used during weed spraying.

Type N. Type N, front- or back-mounted, combination gas, vapor, and particulate gas masks are approved under Subpart I of Part 11 for protection against acid gases, ammonia, carbon monoxide, organic vapors, and particulates. However, we do not discuss these devices here because the Type N canister contains a high-efficiency particulate filter as well as various sorbents, so it should be classified as part of a combination particulate- and vapor- and gas-removing respirator.

Chin-Style. Chin-style gas masks typically have a medium-sized (250-500 cm^3) canister (Fig. 5-18), rigidly attached to a full facepiece. 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. Figure 5-19 shows a typical chin-style gas mask.

Other types of canisters are designed for protection against more than one vapor or gas. In them, the sorbents are either arranged in layers or intermixed. Figure 5-20 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, with sorbent layering being most common.

Courtesy Mine Safety Appliances Co.

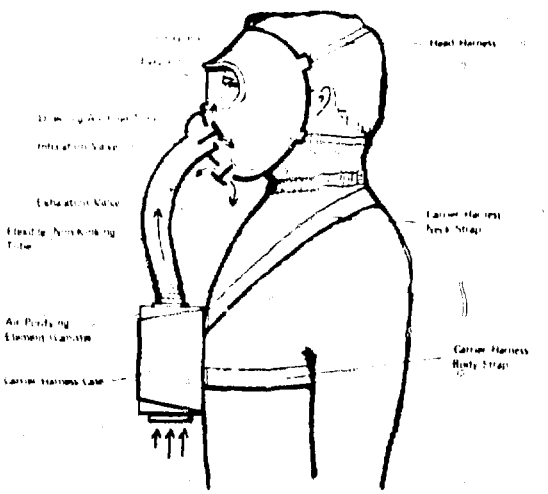


Fig. 5-17.
Typical front- or back-mounted canister gas masks.

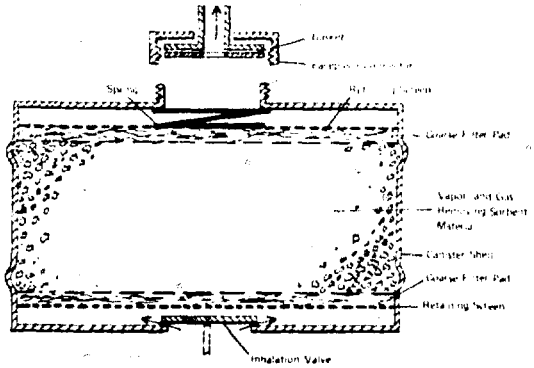


Fig. 5-18.
Typical chin-mounted canister.

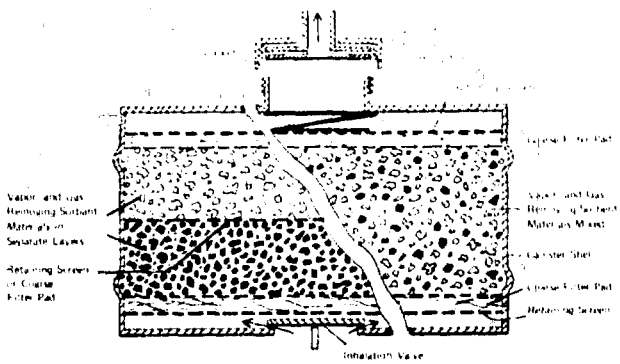


Fig. 5-20.
Methods of packing more than one sorbent.

Maximum use concentrations established in 30 CFR Part 11 for all types of gas masks, are being withdrawn (1975). NIOSH is advising the user to contact the NIOSH Testing and Certification Laboratory, Morgantown, West Virginia, or the Mine Enforcement Safety Administration, Pittsburgh, Pennsylvania, for guidance in use of gas masks in high contaminant concentrations.

Fig. 5-19.
Typical chin-style gas mask in use in a chemical plant.

Escape Masks. Gas masks for use during escape from (not reentry into) atmospheres immediately hazardous to life and health are approved under Subpart I, 30 CFR Part 11. They can be approved only if they have a half-mask facepiece or a mouthpiece. Where eye irritation is a consideration, a full-facepiece gas mask is preferable.

Particulate-, Vapor-, and Gas-Removing

Cartridges and canisters are available to protect against both particulates and vapors and gases. These devices look much like the sorbent cartridge or sorbent canister alone. Figure 5-21 shows the two methods of attaching a particulate filter to a typical cartridge used with half- or quarter-masks. In A, the particulate filter is inside the cartridge "can," in B it is outside the can and held in place by a snap-on cover. Other variations may be found, but the principle is the same. Pesticide and paint spray respirators use combination respirator cartridges, although paint spray respirators are approved under Subpart I, of 30 CFR 11 (Chemical Cartridge Respirators), and pesticide respirators under Subpart M. A typical combination particulate- and vapor- and gas removing respirator is shown in Fig. 5-22, being used in paint spraying.

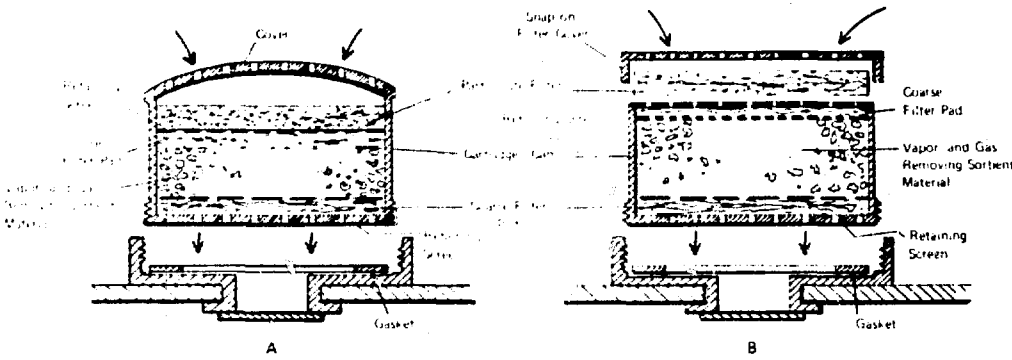


Fig. 5-21.
Typical combination particulate- and vapor- and gas-removing cartridges.

High-efficiency particulate filters are included on some types of combination canisters like the chin-mounted canister shown in Fig. 5-23.

A very specialized type of combination particulate- and vapor- and gas-removing canister is the so-called, "Type N," or "Universal" canister. Fig. 5-24. It looks much like a front- or back- mounted canister, being about the same size and held on the body in the same way. Internally, however, there is a great deal of difference. The distinguishing feature is that it contains several different sorbents for various vapors and gases; a catalyst, hopcalite, to convert carbon monoxide to carbon dioxide; and fibrous filters for particulates.

The multiple protection the Type N canister provides has led to unfortunate, sometimes tragic, misuse. Usually the user assumed that he could get the same useful service life from a Type N canister as from an industrial canister of about the same size. Obviously, this is not so, for as Fig. 5-24 shows,

Fig. 5-22.
Typical combination particulate- and gas- and vapor-removing cartridge respirator being used in paint spraying.

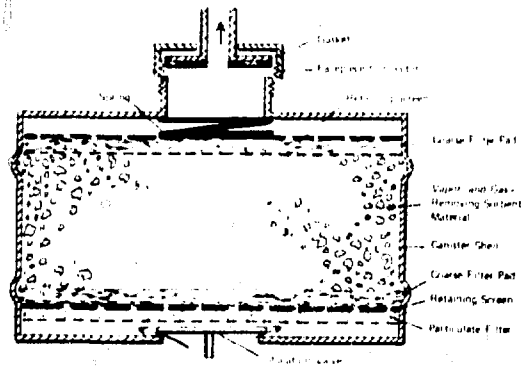


Fig. 5-23.
Typical chin-mounted combination particulate-removing and gas- and vapor-removing canister.

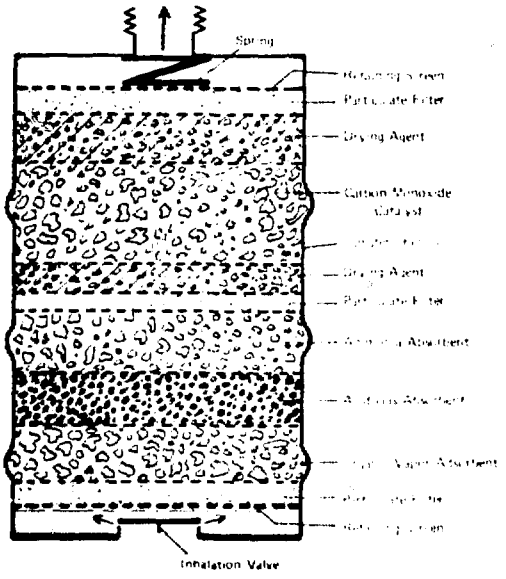


Fig. 5-24.
Typical Type N canister.

sorbents for several different vapor and gas contaminants, two layers of drying agent to protect the catalyst from water vapor, and fibrous particulate filters are packed into the equivalent space. Therefore, the sorptive capacity of any single layer of sorbent in the Type N canister must be less than that of the large sorbent bed in the industrial size canister for use against a single contaminant. Consequently, the useful service life of the Type N canister is short.

All Type N canisters have an indicator, usually behind a small window, that supposedly shows when the canister is exhausted. Actually, it indicates the condition of the drying agent upstream of the catalyst. The CO sorbent, hopcalite, is rendered useless by moisture, and this indicator tells only the condition of this critical layer, not that of the acid gas, ammonia gas, or organic vapor sorbent. Therefore, it cannot be used as an indication of the overall canister condition.

Because of the difficulties in use of Type N canisters, they are being withdrawn from the market. These canisters were originally designed for emergency use, a purpose being met increasingly by atmosphere-supplying devices. However, even with its drawbacks, the Type N canister is useful if the user is well aware of its limitations. Figure 5-25 shows a typical Type N canister attached to a full facepiece.

Powered Air-Purifying Respirators

The powered air-purifying respirator uses a blower to pass contaminated air through an element that removes the contaminants and to supply 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. The covering may be a facepiece, helmet, or hood. These respirators are approved under 30 CFR, Part 11, Subparts K, L, and M.

One type of powered air-purifying respirator consists of an air-purifying element attached to the housing of a small battery-powered blower that is

Fig. 5-25.
Typical Type N canister attached to a full facepiece. (Courtesy Mine Safety Appliances Co.)

connected by flexible tubing to the respiratory inlet covering. The wearer carries this entire assembly. Another type consists of an air-purifying element attached to a stationary blower, powered by a battery or externally supplied electricity and connected by a long flexible tube to the respiratory inlet covering. The respirator aproval document requires that the blower deliver at least 4 cfm of air to a tight-fitting facepiece and at least 6 cfm to a loose-fitting helmet or hood. A battery-powered air-purifying respirator should supply air for at least 4 hours without recharging of the battery.

The great advantage of the powered air-purifying respirator is that it usually supplies air at positive pressure so that any leakage is outward from the facepiece. Thus, even if the fit is poor, contaminated air cannot enter. The type and degree of protection depend on the air-purifying element whose protection level and useful service time depend, in turn, on its material, size, and shape and on the nature and concentration of the contaminant.

Also affecting the degree of protection is the wearer's work rate. At high work rates, it is possible, through rapid breathing to create a negative pressure in the facepiece, thereby potentially increasing facepiece leakage. Furthermore, because there is a constant air flow through the air-purifying element, instead of flow only during inhalation, the useful lifetimes of sorbent canisters and cartridges attached to the blower assemblies are much shorter than when the same elements are attached to the *common air purifying respirator.*

Advantages and Limitations of Air-Purifying Respirators

It is important that the user be thoroughly familiar with the following information. Many instances of misuse arise because the user is unaware of the performance limits of a particular device.

Advantages. Air-purifying devices are small, relatively inexpensive, and easily maintained. They restrict the wearer's movement least. Many combinations of facepieces, mouthpieces, filters, cartridges, and canisters allow the user to match the device to the particular situation.

Disadvantages.

General. Air-purifying respirators cannot be used in atmospheres immediately hazardous to life and health or when the contaminant has poor warning properties, except for escape.

Quarter-Mask, Half-Mask, and Mouthpiece Respirators. Maximum use concentrations may be restricted because of unreliable sealing. These respirators do not protect the eyes or skin. Further restrictions should be placed on their use owing to small sorbent or filter capacity.

Full Facepiece Respirators. Eye protection is provided, but use may be restricted by limited sorbent capacity. They are more expensive than other facepieces.

ATMOSPHERE-SUPPLYING RESPIRATORS

The class of respirators which provide air from a source independent of the surrounding atmosphere instead of purifying the atmosphere is shown in Fig. 5-2. The basic types of atmosphere-supplying respirators vary less than the air-purifying types, but there is greater variation among devices designed for a given purpose. It may be difficult to recognize a particular type of device by appearance alone. The different types may be recognized in two ways, by the method by which air is supplied and the way in which the air supply is regulated.

Self-Contained Breathing Apparatus

The distinguishing feature of all types of self-contained breathing apparatus (SCBA) is that the wearer need not be connected to a stationary air source, such as a compressor. Instead, enough air or oxygen for up to 4 hours, depending on the design, is carried on the person. As Fig. 5-2 shows, SCBAs are classified as "closed-circuit" or "open-circuit."

Closed-Circuit. Another name for closed-circuit SCBAs is "rebreathing" device, indicative of the mode of operation. The air 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 approval tests for the closed-circuit apparatus are given in Subpart H of 30 CFR Part 11.

These devices are designed primarily for 1- to 4-hour use in oxygen-deficient atmospheres such as might be encountered during mine rescues. They have been used thus since the early 1900's when the Gibbs and McCaa devices were developed. The designs have not changed much since then, a significant commentary on their acceptance and good performance. ***NOTE: 30 CFR Part 11 approves for mine rescue only devices that give 1 hour or more performance. Devices that give 30-min or longer performance may be approved for auxiliary mine rescue service.***

Closed-circuit devices are not a cure-all; there are design features that restrict their use. Because negative pressure is created in the facepiece during inhalation, there is increased leakage potential. Therefore, the devices should be used in atmospheres immediately hazardous to life and health only when their long-term use capability is necessary, as in mine rescue. They should not be used in preference to pressure demand SCBAs for short times in immediately hazardous atmospheres. For use in oxygen-deficient atmospheres over a long period, these devices are ideal. For 1/2 hour or less, in highly toxic atmospheres immediately hazardous to life, a positive pressure open-circuit SCBA is recommended.

Two basic types of closed-circuit SCBA are available, distinguished by whether they use a tank of compressed oxygen or a solid oxygen-generating substance. Figure 5-26 shows a typical closed-circuit SCBA with a small cylinder of compressed oxygen. Available from several manufacturers, these devices are all based on the old McCaa device. 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 made up. The advantage of the rebreathing process is that only the oxygen supply need be

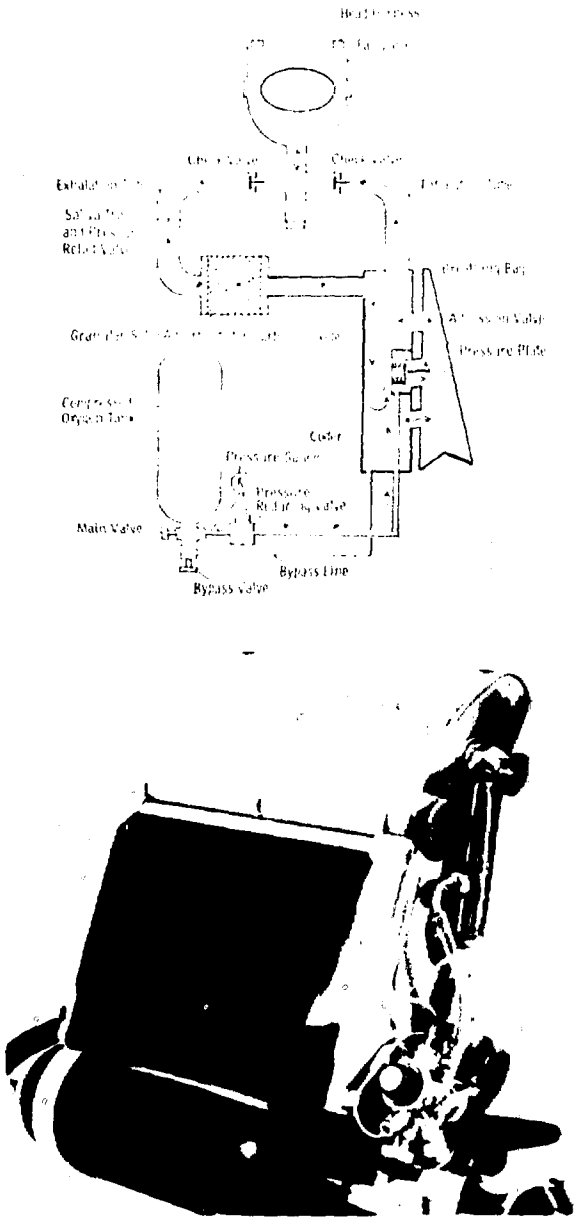


Fig. 5-26.
Closed-circuit SCBA.

carried, 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. However, it is bulky and does not provide the ultimate in protection because negative

pressure is created in the facepiece during inhalation. Figure 5-27 shows a closed-circuit SCBA in use.

The second type of closed-circuit SCBA (Fig. 5-28) 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.

$$2KO_2 + CO_2 + H_2O \cdot K_2CO_3 + 1.5O_2 + H_2O \ ,$$
$$2KO_2 + 2CO_2 + H_2O \cdot KHCO_3 + 1.5O_2.$$

As the O_2 is released when the wearer's exhaled breath reaches the canister, there is a short time lag after the canister is initiated before O_2 flow begins. This has been overcome in some devices by providing a "quick start" feature, a canister section filled with mixed sodium chlorate and iron. Oxygen flow is started by striking the device, somewhat like lighting a match. This provides enough oxygen until the potassium superoxide in the canister begins to function.

Fig. 5-27.
Typical oxygen-supplying closed circuit SCBA as used for mine rescue.

Oxygen is continually released 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 by nitrogen buildup in the facepiece.

This closed-circuit apparatus is lighter, simpler, and cheaper than the tank type. However, it is useful for only about 1 hour and, once initiated, cannot be turned off. The precautions mentioned for the type containing a cylinder of compressed oxygen apply. Figure 5-29 shows a typical oxygen-generating closed-circuit SCBA being worn.

Open-Circuit. An open-circuit SCBA exhausts the exhaled air to the atmosphere instead of recirculating it. 30 CFR Part 11 does not specify what breathing gas may be approved for these devices, but it is almost always compressed air. Compressed oxygen could be used in a device designed for compressed air, but it must not be, because minute amounts of oil or other foreign matter in the device components can cause an explosion. In fact, 30 CFR Part 11 prohibits approval of any device designed to permit interchangeable use of oxygen and air. *IN*

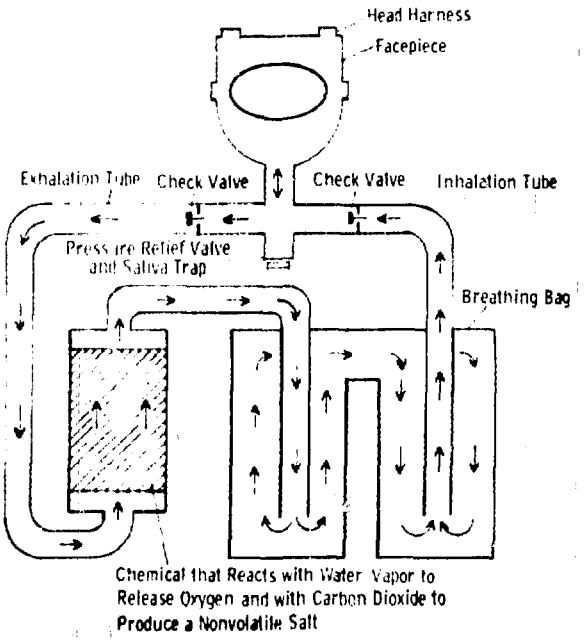


Fig. 5-28.
Oxygen-generating closed circuit SCBA.

Fig. 5-29.
Typical oxygen-generating closed circuit SCBA. (Courtesy Mine Safety Appliances Co.)

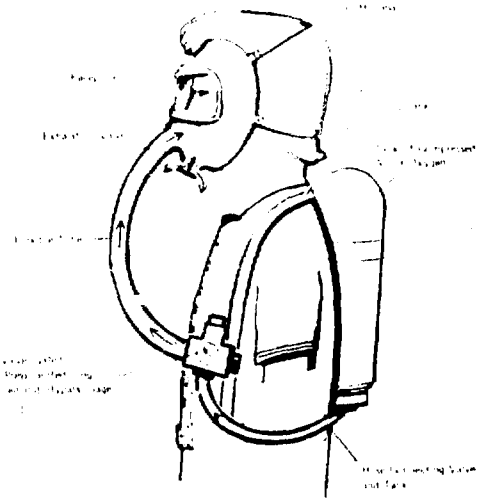


Fig. 5-30.
Open-circuit SCBA.

GENERAL. OXYGEN SHALL NEVER BE USED IN A DEVICE UNLESS IT IS SPECIFICALLY DESIGNED FOR THAT PURPOSE. Figure 5-30 shows a typical open-circuit SCBA. A tank of high-pressure (~2000-psi) compressed air, carried on the back, supplies air to a two-stage regulator that reduces the pressure for delivery to the facepiece. This regulator also serves as a flow regulator by passing air to the facepiece only on demand. A flexible corrugated hose connects the regulator to the respiratory-inlet covering, usually a full facepiece.

Because it has to provide the total breathing requirements, not just the oxygen requirements as in the closed-circuit SCBA, the service life of the open-circuit SCBA is usually shorter. Most open-circuit devices have a service life of 30 min. NIOSH approves units with less than 1-hour, but not less than 30-min, service time, for auxiliary mine rescue. Therefore open-circuit devices are very seldom used for this purpose, but they are widely used in fire fighting and industrial emergencies. They are less expensive than the closed-circuit SCBAs. SCBAs with less than 30-min service time are approved but only for escape use in combination with a supplied-air air line respirator.

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, shown in Fig. 5-31. This is a "demand-"type regulator. Air at approximately 2000 psi is supplied to the regulator through the main valve. 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) presses 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.

A pressure-demand regulator is very similar except that there is usually a spring between the diaphragm and the outside case of the regulator.

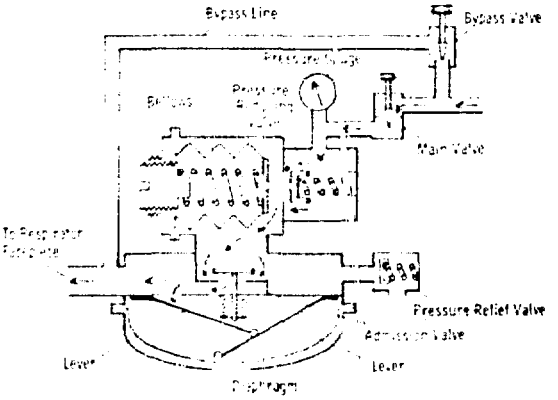


Fig. 5-31.
Open-circuit SCBA regulator.

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 in. 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 maintains positive pressure in the facepiece at all times, and the regulator still supplies additional air on "demand." Because of the positive pressure, any leakage is outward so 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.***

In a demand-type SCBA, negative pressure in the facepiece during inhalation opens the demand valve. This negative pressure is approximately the same as that created in an air-purifying respirator. Therefore, leakage is inward and of the same magnitude as that in an air-purifying respirator. Recent studies showed that a demand-type SCBA is no more efficient than an air-purifying respirator with the same facepiece. Therefore, ***a demand type open-circuit SCBA should not be used in atmospheres immediately hazardous to life or health.*** Like closed-circuit SCBAs, they are, however, adequate against oxygen-deficient atmospheres.

Some open-circuit SCBAs can be switched from demand to pressure-demand operation; others are available only in one configuration or the other. There is certainly an advantage in being able to change from demand to pressure-demand at will, but there is also a good argument against it. Because these devices are primarily for emergency use, the user should not have the choice, as a demand device is no more efficient than an air-purifying respirator with the same facepiece. In short, if the ultimate in protection is required for emergency use, a pressure-demand SCBA should be purchased.

Because of the high instantaneous flow rates that may be required during inhalation (see Chap. Three), both demand and pressure-demand regulators can deliver flows of 350-400 lpm. This ensures that the wearer will obtain adequate air and generally not be able to "overbreathe" a device. Overbreathing creates extreme negative pressure in the facepiece of a demand SCBA, potentially increasing facepiece leakage. This also can happen in a pressure-demand SCBA, but is less likely because the wearer must overcome the 1.5- to 3-in. H_2O positive pressure.

Several required safety features on all approved closed- and open-circuit SCBAs 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 show when only 20-25% remains.
- 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 device is best left to the user, and should be based on thorough evaluation of the respiratory hazards. If there is any potential atmosphere immediately hazardous to life, a pressure-demand SCBA should most certainly be used. Typical demand or pressure-demand SCBAs are shown in Fig. 5-32.

Fig. 5-32.
Typical open-circuit SCBAs.

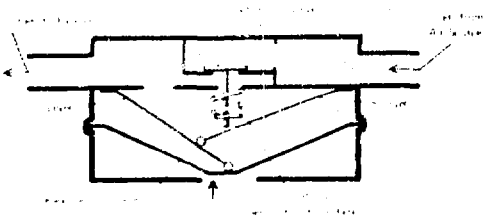
Supplied-Air Respirators

Air line respirators are categorized in 30 CFR Part 11 as one of the types of supplied-air respirators, along with hose masks which will be described later. The distinction of air line devices is that they all use a stationary source of compressed air delivered through a high-pressure hose. 30 CFR Part 11 specifies that the pressure shall not exceed 125 psi at the point where the hose attaches to the air supply. When the manufacturer submits an air line respirator for approval, he must specify the operating pressure and the hose length, from 25 to 300 ft. At the lowest pressure and greatest hose length, the device must deliver at least 6 cfm to a helmet or hood. The flow rate must not exceed 15 cfm.

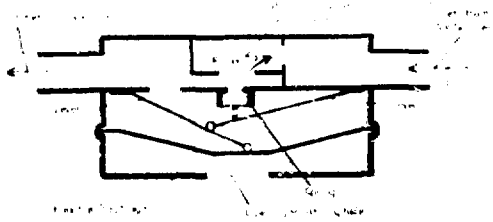
Air line respirators are available in demand, pressure-demand, and continuous flow configurations (see Fig. 5-2). They are called Type "C" supplied-air-respirators. The respiratory-inlet covering may be a facepiece, helmet, hood, or complete suit, although there are presently no approval tests for suits. When a full facepiece, helmet, or hood provides special protection against impact and abrasion from rebounding abrasive material, it is called a Type "CE" supplied-air respirator.

A demand or pressure-demand air line respirator is very similar 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 high-pressure air source. Because the air pressure is limited to 125 psi, regulators for air line respirators have only single-stage reduction. Figure 5-33 shows a typical demand-type regulator. Its operation is self-explanatory and identical to that of a demand-type open-circuit SCBA regulator. Like the pressure-demand open circuit SCBA regulator, the pressure-demand air line regulator has a spring between the diaphragm and the outer case. In combination with a special exhalation valve on the facepiece, it provides positive pressure in the facepiece at all times. Fig. 5-34 shows typical demand or pressure-demand air line respirators with tight fitting facepieces. Note that the regulator sometimes is mounted on the facepiece.

Continuous-flow air line 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 Part 11, a flow of at



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.

Fig. 5-33.
Typical demand-type air flow regulator.

least 4 cfm to a tight fitting respiratory-inlet covering and 6 cfm to a loose-fitting one must be maintained at the lowest air pressure and longest hose length specified. This means that, by design, 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.

Never replace an air flow control valve with another type of valve, even one from another manufacturer's air line respirator. Besides possibly creating a hazard owing to improper air flow rates, substitution of another component negates NIOSH and MESA approval of the device. Furthermore, only the air supply hose furnished by the respirator manufacturer may be used with a supplied-air respirator. Substitution of another type of hose, even though equivalent, negates approval of the device.

Figure 5-35 depicts a typical continuous flow air line respirator with a tight fitting facepiece. Notice the air-purifying element on the air supply line. Figure 5-36 shows typical such devices, which also may be obtained with half-masks.

Although addition of an air-purifying element in the supply line just upstream of the air supply hose attachment is a good idea, other precautions also must be taken to ensure breathing air quality. The air supply to air line 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 Chap. Six).

Air line 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 air line respirators or Type "CE" supplied-air respirators.

Figures 5-7 and 5-8 showed two types of continuous flow air line abrasive blasting hoods, although it might be preferable to call them "blouses" as they extend to the waist. The figures indicate the design variations within the Type "CE" device category. Figure 5-37 shows a typical abrasive blasting hood, and Fig. 5-38 shows a variation designed specifically for lead grinding. Note the protective screen over the lens and the heavy apron on the abrasive blasting hood.

Full-suit air line respirators are available. They provide purified 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 skin and enter the blood stream to produce toxic effects. At present, 30 CFR Part 11 does not provide for approval of air line suits. Typical full suits are shown in Figs. 5-39 and 5-40.

Air line respirators provide a high degree of protection, but their use is limited to atmospheres not immediately hazardous to life. The reasoning is

Fig. 5-34.
Typical demand or pressure demand air line respirators.

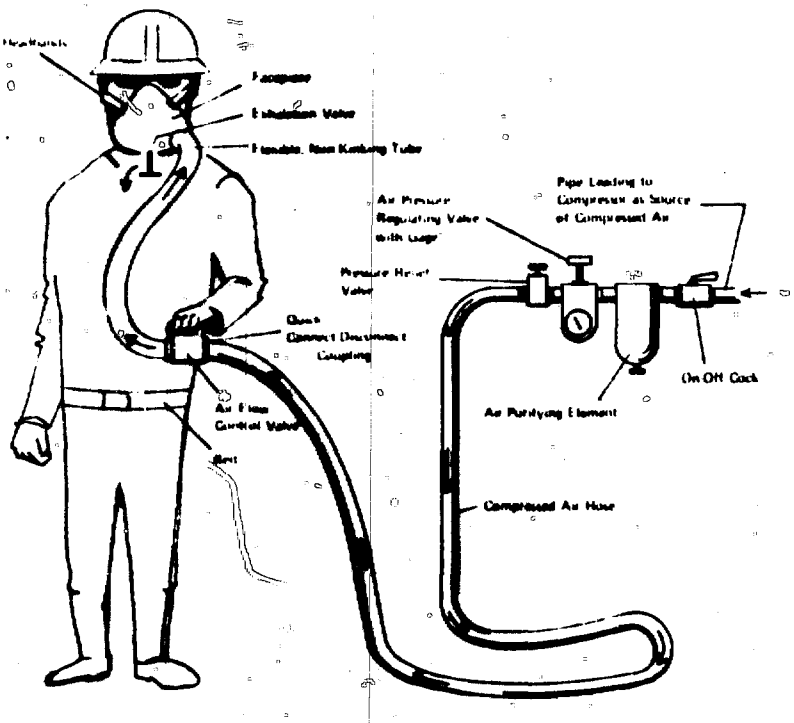


Fig. 5-35.
Continuous flow air line respirator.

that the wearer is totally dependent upon the integrity of the air supply hose. Therefore, he must be able to escape from the contaminated area without endangering his life.

Combination SCBA and Supplied Air Respirators

To be usable in an atmosphere immediately hazardous to life, an air line respirator must have an auxiliary air supply to protect against potential failure of the primary supply. This is provided by adding a self-contained tank of high-pressure compressed air to a Type "C" or "CE" air line respirator. The auxiliary air supply may be approved for 3-, 5-, or 10-min service time, or for 15 min or longer (see Fig. 5-2). The approval tests for these combination devices are found in 30 CFR Part 11, Subpart H, "Self-Contained Breathing Apparatus."

The combination air line and SCBA respirator is essentially the same as the air line respirator itself, with an added small compressed air cylinder that may be carried on one's back or at one's side in a sling. The device shown in Fig. 5-41 is only representative of this general class; designs vary widely.

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 atmospheres immediately hazardous to life. The self-contained part of the device is used only when the air line part fails and the wearer must escape, or when it may be necessary to disconnect the air line temporarily while changing locations. A combination air line and SCBA may be used for *emergency* entry into a hazardous atmosphere (to connect the air line), if the SCBA part is classified for 15-min 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.

Fig. 5-36.
Typical air line continuous flow respirators with full facepieces. (Courtesy Mine Safety Appliances Co. and Scott Aviation.)

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 Part 11 Subpart J, as a Type "A" supplied-air respirator and is approved for use in atmospheres immediately dangerous to life or health. The hose mask without a blower is categorized as Type "B" and is approved for use only in atmospheres not immediately hazardous to life or health. The hose mask with a blower may have a facepiece, helmet, or hood, but the one without a 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 a blower is classified as a Type "AE" supplied-air respirator, and the one without a blower is classified as Type "BE."

An approved hose mask with a blower may have up to 300 ft of air supply hose in multiples of 25 ft, but one without a blower may have only up to 75 ft in multiples of 25 ft. 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 ft of hose must deliver no more than 145 lpm. However, no maximum air flow rate is specified for the hand-operated blower. Figure 5-42 shows a typical hose mask with a hand-operated blower. Notice that a harness and attached lifeline are necessary for use in atmospheres immediately dangerous to life or health.

Fig. 5-37.
Typical abrasive blasting hood. (Courtesy Mine Safety Appliances Co. and Scott Aviation.)

Fig. 5-38.
Supplied air hood for lead grinding. (Courtesy Mine Safety Appliances Co. and Scott Aviation.)

Fig. 5-39.
Simple flexible plastic full suit.

Fig. 5-40.
Complex full suit for protection in demanding conditions.

The wearer's mobility and area of movement are restricted by the large hose that requires him to leave a contaminated area by the way he entered. He must be careful not to damage the hose and to prevent it from becoming caught on objects.

NOTE: Although the hose mask with blower is approved at present for use in atmospheres immediately dangerous to life or health, it is not permitted for such use in the standards that NIOSH is developing for OSHA.

A hose mask with blower should not be used in an atmosphere immediately hazardous to life or health because air flow as low as 50 lpm will result in negative air pressure during inhalation, permitting contaminated air to leak into the covering. Also, if the air supply hose is cut or flattened, the wearer will be unprotected. Figure 5-43 shows a typical hose mask with hand operated blower in use in a tank entry operation.

Fig. 5-41.
Typical combination air line and SCBA respirator. (Courtesy Mine Safety Appliances Co.)

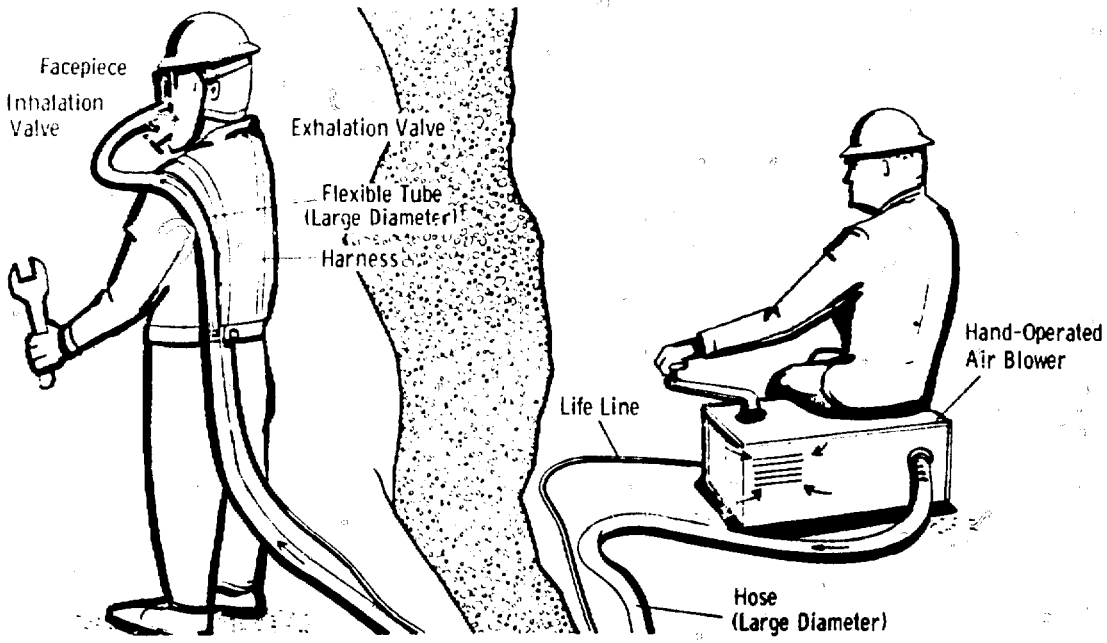


Fig. 5-42.
Hose mask respirator with hand-operated blower.

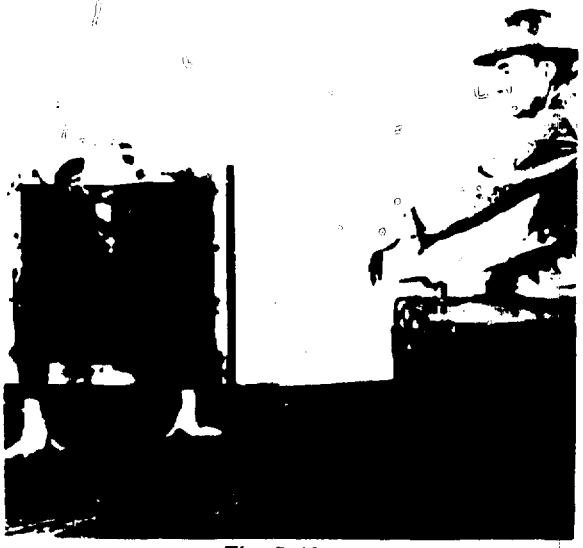


Fig. 5-43.
Typical hose mask with hand-operated blower being used for tank entry. (Courtesy Mine Enforcement Safety Administration.)

CHAPTER SIX

RESPIRATOR SELECTION

OSHA STANDARDS

OSHA 1910.134 states that respirators shall be selected on the basis of the hazards to which workers are exposed and that ANSI Z88.2-1969 shall be used for guidance in their selection. OSHA also requires that approved or accepted respirators be used when available. For certain respiratory hazards, specific instructions about respirator use are given in other OSHA regulations. The trend seems to be toward regulations that specify the conditions of respirator use for each task. OSHA 1910.134 is then consulted for general instructions. Regardless of the regulations, respirators must be selected with the environment in which they will be used in mind. To do so requires certain basic information, so one should always ask the following questions before selecting a respirator.

1. What is the estimated contaminant concentration where the respirator will be used?
2. What is the permissible limit of exposure to the contaminant?
3. Is the contaminant a gas, vapor, mist, dust, or fume?
4. Could the contaminant concentration be termed immediately hazardous to life or health?
5. If the contaminant is flammable, does the estimated concentration approach the lower explosive limit?
6. Does the contaminant have adequate warning properties?
7. Will the contaminant irritate the eyes at the estimated concentration?
8. If the contaminant is a gas or vapor, is there an available sorbent that traps it efficiently?
9. Can the contaminant be absorbed through the skin as a vapor or liquid? If so, will it cause serious injury?

The answers to these questions can provide enough information for choosing a respirator for routine use. There is nothing strange or unique about these questions. They represent the factors that a good industrial hygiene program would incorporate for respirator selection or any other type of control and form the basis for the Respirator Decision Logic (incorporated verbatim as Appendix F) used in the Joint NIOSH and OSHA Standards Completion Program.

You should review the Decision Logic when considering respirator selection because it incorporates the above questions in an orderly sequence. By following this logic, you will be able to choose a respirator that is satisfactory for the situation at hand and be assured that you have not overlooked any important factor.

The Decision Logic is being used (in 1975) in development of detailed work practices for the material listed in 29CFR Part 1910.1000, Tables Z-1, 2, and 3. It will be useful to you in developing your own respirator program until standards are listed for the particular materials in which you are interested. Before proceeding to examples of how to use the Decision Logic, we would like to point out four criteria of particular interest.

- When respirators are used for protection against gases and vapor, it is commonly recommended that cartridges be changed when the wearer smells the vapor. This indicates that there must be some smell or irritation to alert the wearer. Section IV B of the Decision Logic states that a substance should be considered to have warning properties if the odor or irritation threshold is not more than three times the exposure limit, and there is no ceiling limit. Consideration is given to whether undetected exposure in this concentration range could cause serious or irreversible health effects. If not, the substance is considered to have adequate warning properties.
- Section IV C states that where there is supporting evidence of vapor breakthrough in less than three minutes at concentrations immediately dangerous to life or health or below, a cartridge or canister sorbent air-purifying device should not be

allowed for any use. The principal sources of information on sorbent efficiencies are Lawrence Livermore Laboratory and 30 CFR-11 on certain specific materials on which cartridge tests are run. Users should be alert to any future information on sorbent efficiency, as it will definitely affect choice of air-purifying respirators.

• Section IV D states that for routine operations any perceptible eye irritation is considered unacceptable. No definition of perceptible eye irritation is given.

• Section IV E concerns atmospheres immediately dangerous to life or health, (IDLH). Opinions on the correct definition of IDLH differ, but this section gives several guidelines to assist you in defining it. Although not everyone will agree with all the conservative guidelines given, this is the best information available for assessing IDLH problems.

ANSI Z88.2-1969 STANDARDS

Before development of the NIOSH and OSHA Decision Logic, the ANSI 288.2-1969 Standards were the main source of information on respirator selection. Section 3.5.2, Requirements for a Minimal Acceptable Respirator Program, states that "respirators shall be selected on the basis of the hazards to which workers are exposed." Section 3.8 states that "approved or accepted respirators shall be used when available." Section 6 is devoted exclusively to respirator selection; however, new technology has made much of that information obsolete. The Standard is being revised, and when it is reissued it should contain useful details on respirator selection.

SELECTION

OSHA 1910.134 requires that approved or accepted respirators be used when available. What does "available" mean? If at least one brand of approved or accepted respirator suitable for the specific application exists, it is available. Therefore, those who must provide respirators to workers must select and use approved or accepted respirators.

An approved respirator is one that has been tested, found to meet established performance criteria, and listed as approved by an authority such as the Mining Enforcement and Safety Administration (MESA) of the US Department of the Interior, or the National Institute for Occupational Health, (NIOSH) of the US Department of Health, Education, and Welfare.

The Bureau of Mines (BOM) no longer tests and approves respirators; however, BOM-approved respirators now in the possesssion of industrial firms who must provide them to workers will be recognized as approved for various periods depending upon their type. Approval will continue until March 31, 1976, for particulate-filter and chemical cartridge respirators, until March 31,1979, for self-contained breathing apparatus, and until March 31, 1980, for supplied-air respirators. An expiration date for gas masks had not been established at the time of printing. MESA and NIOSH now test and approve respirators jointly under the provisions of a respirator test and approval document, 30 CFR Part 11.

There are some respirators, full suits, for example, for which there are no approval criteria. Such a special respirator is said to be "accepted" if it has been tested and found satisfactory for its specific application by some recognized organization.

SELECTION OF RESPIRATORS FOR ROUTINE USE

Routine use of a respirator is daily or frequent use on a regular basis. For such use, a respirator of low initial cost, simple maintenance to keep operating costs down, minimal wearing discomfort, low resistance to breathing, light weight, and compact construction should be considered. Nonpowered air-purifying respirators and air line and hose mask supplied-air respirators are suitable.

SELECTION OF RESPIRATORS FOR NONROUTINE AND EMERGENCY USE

A respirator used nonroutinely is used for hazardous situations that occur only occasionally. For such applications, initial costs and maintenance costs are less important than for routine applications. The degree of protection and the useful service time provided are important.

Any respirator that protects adequately against a hazardous atmosphere that occurs suddenly may be used for escape purposes. If the hazardous atmosphere causes eye irritation, the respirator should have a full facepiece. Compact air-purifying respirators with mouthpieces and nose clamps have been used successfully for escape from some hazardous atmospheres.

If an area containing an unknown air contaminant concentration must be entered, a pressure demand SCBA or a combination SCBA and air line supplied-air respirator, either of which is specifically designed to maintain positive air pressure inside the facepiece, should be used.

A pressure demand SCBA should be used in fire fighting. All the questions that should be answered in selecting respirators for routine use should also be answered in selecting respirators for emergency use. In the NIOSH Decision Logic, emergency use is mentioned under respirator protection factors.

RESPIRATOR PROTECTION FACTORS

Definition

The respirator protection factor indicates how much protection a respirator provides. It is the ratio of the contaminant concentrations outside and inside the respirator. Determination of the protection factor requires quantitative performance tests of the respirator worn in a test atmosphere during exercise simulating motions made by workers, or worn by workers carrying out tasks in contaminated work areas (see Chap. Eight).

Assignment

Much research has been done recently on assigning protection factors to various types of respirators. Table 6-1, reproduced verbatim from the LASL protection factor document, lists assigned respirator protection factors resulting from this research. When using Table 6-1, pay strict attention to its footnotes as they are essential in interpreting the table and assist in application of protection factors. The protection factors listed in the Decision Logic are taken from Table 6-1.

Application

To apply an assigned protection factor for a particular type of respirator, one must know both the actual contaminant concentration in the work area and the established time-weighted average concentration. Multiplying the time-weighted average concentration by the respirator protection factor gives the maximum concentration of the contaminant against which the particular type of respirator may be used. If the actual concentration is less than the calculated maximum use concentration, the respirator may be used.

In describing use of protection factors in respirator selection, it is assumed that a complete respirator program is in force. A protection factor is not applicable if the wearer cannot satisfactorily seal the respirator to his face or head. Anything such as facial hair or spectacles that prevents satisfactory sealing of a respirator nullifies application of a respirator protection factor. A protection factor can be used only if the respirator is in good operating condition, so the respirator must be properly maintained. Other limitations of various types of respirators discussed in Chap. Eight must also be considered in applying protection factors.

EXAMPLES OF RESPIRATOR SELECTION

The following are hypothetical but typical examples of the respirator selection process. They should not be used as cookbook models, but as guides to the rationale for selecting particular respirators, and, equally important, to the industrial hygiene aspects of the hazards. In these examples, we assume that regular use of respirators is permissible.

1. A muller operator in a foundry complains of dust in the air, and the superintendent supplies him a single-use, disposable respirator. The steward tells the superintendent that this is a violation of the OSHA Regulations as the particular respirator does not have NIOSH and MESA approval. Who is right, and what should be done?

Answer: Nothing bans the sale or use of unapproved devices in areas where respirators are not required. Before deciding about use of this respirator, we need information about the dust concentration in the air. Samples were taken in the muller's

TABLE G-1

RESPIRATOR PROTECTION FACTORS[1]

Type Respirator	Facepiece[2] Pressure	Protection Factor
I. Air Purifying		
A. Particulate[3] removing		
Single use,[4] dust[5]		5
Quarter-mask, dust[6]		5
Half mask, dust[6]		10
Half- or Quarter mask, fume[7]		10
Half- or Quarter mask, High Efficiency[8]		10
Full Facepiece, High Efficiency		50
Powered, High Efficiency, all enclosures	+	1000
Powered, dust or fume, all enclosures	+	X[9]
B. Gas and Vapor-Removing[10]		
Half-Mask		10
Full Facepiece		50
II. Atmosphere-Supplying		
A. Supplied-Air		
Demand, Half-mask		10
Demand, Full Facepiece		50
Hose Mask Without Blower, Full Facepiece		50
Pressure-Demand, Half-Mask[11]	+	1000
Pressure-Demand, Full Facepiece[12]	+	2000
Hose Mask With Blower, Full Facepiece		50
Continuous Flow, Half-Mask[11]	+	1000
Continuous Flow, Full Facepiece[12]	+	2000
Continuous Flow, Hood, Helmet, or Suit[13]	+	2000
B. Self Contained Breathing Apparatus (SCBA)		
Open Circuit, Demand, Full Facepiece	–	50
Open Circuit, Pressure-demand Full Facepiece	+	10,000[14]
Closed-Circuit Oxygen Tank-type, Full Facepiece	–	50
III. Combination Respirator		
A. Any combination of air-purifying and atmosphere-supplying respirator.	Use minimum protection factor listed above for type of mode of operation.	
B. Any combination of supplied-air respirator and an SCBA		

Exception: Combination supplied-air respirators, in pressure-demand or other positive pressure mode with an auxiliary self-contained air supply, and a full facepiece, should use the PF for pressure demand SCBA.

NOTE: Table is not to be reproduced without the accompanying footnotes.

[1] The overall protection afforded by a given respirator design (and mode of operation) may be defined in terms of its protection factor (PF). The PF is a measure of the degree of protection afforded by a respirator, defined as the ratio of the concentration of contaminant in the ambient atmosphere to that inside the enclosure (usually inside the facepiece) under conditions of use. Respirators should be selected so that the concentration inhaled by the wearer will not exceed the appropriate limit. The recommended respirator PF's are selection and use guides, and should only be used when the employer has established a minimal acceptable respirator program as defined in Section 3 of the ANSI Z88.2-1969 Standard.

[2] In addition to facepieces, this includes any type of enclosure or covering of the wearer's breathing zone, such as supplied-air hoods, helmets, or suits.

[3] Includes dusts, mists, and fumes only. Does not apply when gases or vapors are absorbed on particulates and may be volatilized or for particulates volatile at room temperature. Example: Coke oven emissions.

[4] Any single-use dust respirator (with or without valve) not specifically tested against a specified contaminant.

[5] Single-use dust respirators have been tested against asbestos and cotton dust and could be assigned a PF of 10 for these particulates.

[6] Dust filter refers to a dust respirator approved by the silica dust test, and includes all types of media, that is, both nondegradable mechanical type media and degradable resin-impregnated wool felt or combination wool-synthetic felt media.

[7] Fume filter refers to a fume respirator approved by the lead fume test. All types of media are included.

[8] High-efficiency filter refers to a high-efficiency particulate respirator. The filter must be at least 99.97% efficient against 0.3 μm DOP to be approved.

[9] To be assigned, based on dust or fume filter efficiency for specific contaminant.

[10] For gases and vapors, a PF should only be assigned when published test data indicate the cartridge or canister has adequate sorbent efficiency and service life for a specific gas or vapor. In addition, the PF should not be applied in gas or vapor concentrations that are: 1) immediately dangerous to life, 2) above the lower explosive limit, and 3) cause eye irritation when using a half-mask.

[11] A positive pressure supplied-air respirator equipped with a half-mask facepiece may not be as stable on the face as a full facepiece. Therefore, the PF recommended is half that for a similar device equipped with a full facepiece.

[12] A positive pressure supplied-air respirator equipped with a full facepiece provides eye protection but is not approved for use in atmospheres immediately dangerous to life. It is recognized that the facepiece leakage, when a positive pressure is maintained, should be the same as an SCBA operated in the positive pressure mode. However, to emphasize that it basically is not for emergency use, the PF is limited to 2,000.

[13]The design of the supplied-air hood, suit, or helmet (with a minimum of 6 cfm of air) may determine its overall efficiency and protection. For example, when working with the arms over the head, some hoods draw the contaminant into the hood breathing zone. This may be overcome by wearing a short hood under a coat or overalls. Other limitations specified by the approval agency must be considered before using in certain types of atmospheres.

[14]The SCBA operated in the positive pressure mode has been tested on a selected 31-man panel and the facepiece leakage recorded as less than 0.01% penetration. Therefore, a PF of 10,000+ is recommended. At this time, the lower limit of detection 0.01% does not warrant listing a higher number. A positive pressure SCBA for an unknown concentration is recommended. This is consistent with the 10,000+ that is listed. It is essential to have an emergency device for use in unknown concentrations. A combination supplied-air respirator in pressure-demand or other positive pressure mode, with auxiliary self-contained air supply is also recommended for use in unknown concentrations of contaminants immediately dangerous to life. Other limitations, such as skin absorption of HCN or tritium, must be considered.

breathing zone, and the dust concentration was found to be 5 mg/m³. The amount of crystalline silica (quartz) in the dust was 48%. The permissible quartz dust exposure limit in such conditions is 1.5 mg/m³.

Now refer to Section II of the Respirator Decision Logic, Appendix F. Because the material is a particulate, statements 2, 4, and 6 are not pertinent. As to the other statements: (3) Silica is not known to be an eye irritant, (5) the IDLH concentration is far above the 5-mg/m³ dust level found in this case, and (7) to date, there is no evidence of injury from silica through skin absorption. As the material is a particulate, we can proceed to Section III B, the specific decision logic chart for respiratory protection against particulates. The restrictions under Routine Use do not apply, so we can proceed to Appendix I, Section A, "Protection Factors for Particulate Filter Respirators." As the dust concentration is less than five times the permissible limit, we can choose any respirator from this list. A single-use respirator with a protection factor of 5 or a half-mask respirator with a protection factor of 10 probably would be chosen.

2. A woman doing silk screening without any local exhaust ventilation complained of headaches and nausea from the vapors and fumes. She was given a dust respirator customarily used by a sandblaster's helper. (Obviously a dust respirator for use against an organic vapor is a completely wrong choice.) The woman's continued complaints of headaches and nausea led to an OSHA inspection. Air sampling revealed 40 ppm of isophorone in her breathing zone. It was pointed out that this was above the permissible 25-ppm limit for isophorone. A local exhaust system was suggested. Management agreed, and while the local exhaust system was being installed supplied the employee with what type of respirator if any?

Answer: The measured 40-ppm concentration is 1.6 times the 25-ppm permissible limit. In the Decision Logic, Section II, note that questions 2-6 and 7 are unanswered. A review of the literature on isophorone will show that it can be detected well below the 25-ppm level and that 40 ppm presents a definite sensation to the eyes. This, using the Decision Logic interpretation, would be interpreted as eye irritation. The lower explosive limit and the concentration immediately hazardous to life are well above 40 ppm. Finally, there is no evidence of poor sorbent efficiencies or problems of skin absorption with this material.

Proceed to Section III A, the Chart for Respiratory Protection Against Gases or Vapors, Item C, Eye Irritation, eliminates use of half-mask respirators. Protection factors for chemical cartridges and gas masks are listed in Appendix I B. Although the protection factor necessary is only 3, chemical cartridge half-mask respirators with protection factors of 10 are eliminated because of the eye irritation problem. A minimum of a chemical cartridge respirator with a full facepiece must be provided.

3. A sandblaster and his helper are working outdoors on a 50-foot scaffold. Are respirators necessary? If so, what type of respirators?

Answer: To fully answer these questions, we must ask what abrasive is being used and what surface is being treated. Let's assume that the abrasive is silica sand and the surface is granite. These create a silica dust problem, and the OSHA ventilation standards 1910.94 require that the employer furnish respiratory protection whenever silica sand is used as an abrasive. Furthermore, even if a different abrasive were used, silica dust would be produced from the granite. Therefore the operator must be furnished an approved abrasive blasting respirator, a Type AE, BE, or CE device.

Another aspect of this problem which must be considered closely is the workplace geometry. The sandblaster and his helper are working on the scaffold. We have specified protection for the sandblaster, but how about his helper? He is in the immediate vicinity of the blasting, so he should have the same degree of protection. However, he will probably have to leave the scaffold occasionally to perform some task. Then, having to remove the abrasive blasting hood will be a nuisance, and trying to climb down from the scaffold while wearing it will be dangerous.

There are several solutions to this problem. The best would be to arrange that the helper stay on the ground, ascending to the scaffold only when absolutely necessary. Then, a half-mask dust respirator would be adequate. If the helper must be on the scaffold with the sandblaster most of the time, work practices should specify that he must stay as far away from the sandblaster as the scaffolding allows. If this is done in conjunction with periodic air sampling to ensure that the airborne silica concentrations do not exceed the OSHA limits by more than 10 times, a half-mask dust respirator can be used. It this is impossible, the only recourse is to provide the helper the same protection as the sandblaster. Remember, the air supply system must meet the requirements for Grade D or better compressed air.

The point illustrated in this example is that it is not enough to abide only by the requirements of 29 CFR Part 1910.134 which is concerned with general use of respirators. There are other requirements within the OSHA regulations which may also affect respirator selection and use.

Use of the Decision Logic was not mentioned in this example. The regulations requiring use of a supplied air hood were made before assembly of the Decision Logic. You will note that the Decision Logic Protection Factor Table lists a PF of 2000 for the supplied air hood. Considering the unknown concentration of silica dust to which the sandblaster can be exposed, the protection required is consistent with the Decision Logic.

4. A man assigned to clean a large degreaser must occasionally go into the degreaser pit. He complains that the odor of trichloroethylene (trichlor) is so strong that it comes through his respirator cartridges after only a short time. Should he be assigned another type of respirator?

Answer: The fact that the worker complains about the short lifetime of the sorbent cartridges warns that the trichlor concentrations may be high. This brings up the dual hazards of toxicity and oxygen deficiency. Degreaser pits are places where vapors may collect and, unless ventilated, actually reduce the oxygen below safe levels. Unless the pit is ventilated to prevent oxygen depletion, a positive pressure SCBA must be used. If the pit is ventilated, it will not be necessary to wear a respirator if tests show that the trichlor concentration is below the exposure limit and that the oxygen has not been depleted.

Again, the Decision Logic Section III A shows that for entry into and escape from unknown concentrations, the only type of device that can be used is positive pressure self-contained breathing apparatus.

5. A flagman for an aerial crop duster using Phosdrin dust is supplied a single-use disposable dust respirator. Is this adequate?

Answer: Several points listed in the Decision Logic flow chart are pertinent here. Pesticides such as Phosdrin are noted for their ability to kill by absorbtion through the skin. The single-use respirator certainly does not provide complete skin protection. In such cases, protective clothing is as important as a proper respirator.

The pesticide is mixed with the dust; however, some of it may vaporize from dust. This is one reason why the only respirators approved for pesticide use have organic charcoal in back of the dust filter.

The Phosdrin concentration to which the flagman is exposed is not stated. Before a respirator can be

assigned, we must know the approximate concentration expected. If the concentration cannot be estimated, the flagman will have to be provided with a self-contained breathing apparatus.

6. Hydrocyanic acid is used in a fumigation chamber. By state regulation, a full-face respirator or gas mask with a hydrocyanic acid canister is required. Is such protection satisfactory?

Answer: To decide whether the respirator is adequate, one must have some knowledge of the toxicity and potential concentration of the hydrocyanic acid. The TLV for hydrocyanic acid is listed as 10 ppm, with a warning that skin absorption is a problem. Regardless of the respiratory protection provided, there must be some protection for the skin in such an atmosphere.

A review of the toxicity of hydrocyanic acid will show that a concentration of 270 ppm is immediately fatal and concentrations of 110 ppm are fatal within half an hour. Concentrations of hydrocyanic acid in fumigation chambers usually exceed 1% (10,000 ppm). The full-face gas mask is accorded a protection factor of only 50 in Table 6-1. Therefore, it would not be useful in concentrations above 500 ppm. Such a mask would not be satisfactory in this case. The Decision Logic offers a quicker solution. Section III A notes that when the contaminant concentration exceeds that immediately dangerous to life or health, only positive pressure self-contained breathing apparatus is acceptable respiratory protection.

7. A salvage company is to demolish a large open-framework steel structure built in 1910 in a southern city. The job will require extensive use of cutting torches. Will respirators be required, and if so, of what type?

Answer: Respirators definitely must be used. As the structure was built in 1910, it undoubtedly has many coats of lead-base paint, which when heated by the cutting torches will create a severe airborne lead problem. Therefore a respirator approved for protection against metal fumes can be used. Whether this will be a quarter- or half-mask or full-facepiece respirator can be determined only after air samples are taken in the wearers' breathing zones. Because this is an outdoor operation, the concentrations will vary widely. However, similar operations have shown that concentrations of 2 mg/m^3 are not unusual. Considering the low protection factors for air-purifying respirators, the high temperatures in this climate, and the added heat loss from the cutting torches, a continuous flow air line respirator should be considered. The trailing air hoses should not present much of a problem, as the workers will already be encumbered with the gas supply lines to the cutting torches. When equipped with a half-mask facepiece to allow wearing of the necessary goggles, the air line respirator will provide a more than adequate protection factor of 2000.

Providing this protection involves the expense and maintenance of the air supply system, plus the cost of the expensive air line respirator itself. However, in this example, these complications seem more than justified.

8. A large packing firm in Washington state stores apples in warehouses containing a nitrogen atmosphere with less than 3% oxygen. Inspectors must enter the storage areas periodically to examine the apples. What type of protection do they need?

Answer: Obviously with only 3% oxygen, the atmosphere inside the warehouse must be considered immediately hazardous to life. This fact seems to dictate use of a positive pressure supplied air device. This is not entirely true, as we are dealing only with reduced oxygen content of the air, not toxic materials in it. As discussed in Chapters Three and Four, the sea level oxygen content can be reduced, on a physiological basis—not a legal one, to about 14.5% without significant physiological effects. This amounts to reducing the partial pressure of oxygen in the air from a normal 160 mm Hg to about 110 mm. This 50-mm reduction is about 30% of the total normal oxygen (50/160 x 100 = 31%). Translated into respirator leakage, this means that the wearer could tolerate about 30% leakage of air containing no oxygen into the facepiece. On the basis of facepiece leakage alone, a half-mask with a protection factor of 10 would allow up to 10% leakage, and a full facepiece would allow up to 2% leakage with a protection factor of 50. Atmosphere-supplying devices with either of these facepieces would provide adequate protection and a reasonable margin of safety. Many choices could be made. If the inspectors must remain inside for more than 30 minutes, an air line respirator with escape cylinder or a closed circuit SCBA should be used. The choice will depend on whether the inspector can tolerate the trailing air line or prefers to carry 35 pounds of breathing apparatus on his back. An oxygen-generating closed circuit SCBA could be used, but its useful lifetime is

only one hour and once started it cannot be shut off. For less than a half hour, an open circuit SCBA could be used, as well as the device just mentioned.

This example illustrates that a simple oxygen deficiency hazard is relatively easy to deal with. However, it must be classified as being immediately hazardous to life and the OSHA requirements for communications, standby men, lifelines, etc. during respirator use in such atmospheres must be met.

Although the rationale for use of demand type atmosphere supplying units is reviewed, they would not be allowed. Section III A states specifically that in concentrations immediately dangerous to life or health you must eliminate all but the positive pressure self contained breathing apparatus.

We hope that these examples of respirator selection indicate the fundamental thought processes involved. Without a knowledge of the degree and extent of the respiratory hazard and other possible physiological hazards, choosing the proper respirator can deteriorate into a potentially dangerous guessing game. The fact that the person selecting the respirator may not be an industrial hygienist or other knowledgeable individual is no excuse. The OSHA requirements state that the respirator "shall be selected on the basis of hazards to which the worker is exposed," which, freely translated, means by hazard evaluation.

CHAPTER SEVEN

RESPIRATOR USE

LEGAL REQUIREMENTS

OSHA 1910.134 states that the correct respirator shall be specified for each job and that a qualified individual supervising the respirator program usually specifies the respirator. Also, the person who issues respirators shall be adequately instructed to ensure he issues the correct respirator.

PRACTICALITIES OF RESPIRATOR USE

Issuance of respirators seems simple, but issue of an incorrect respirator may injure or even kill a worker, so the matter cannot be treated lightly. The person responsible for issuing respirators must be adequately trained to make sure that he issues the correct respirator for each job. Some firms have developed an elaborate system wherein each worker is issued a card that specifies what type of respirator he can be issued for protection against a particular hazard. He 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 his exclusive use, and should be permanently marked to indicate to whom it is assigned. Care must be taken to ensure that the marking does not hurt the respirator performance. If possible, records should be kept on the issuance and use of each respirator. To do so, each must be permanently identified. Records should include the date of brand issue, the dates of reissue, and a listing of repairs.

SUPERVISION OF RESPIRATOR USE

Random Inspection

Respirators in use shall 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:

- Determination that the proper respirators are being used.
- Determination that respirators are being worn properly.
- 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

Problems discovered during the random inspections must be rectified.

Employee Responsibility

Proper supervision of respirator use should ensure that each worker understands that he has the following responsibilities.

- He shall use the respirator as instructed.
- He shall guard against damaging the respirator.
- He shall go immediately to an area having respirable air if the respirator fails to provide proper protection.
- He shall report any respirator malfunction to a person responsible for the respirator program.

Determination of Worker's Exposure to Hazards

Appropriate surveillance of work area conditions and of worker exposure to respiratory hazards shall be carried out. This means that the concentration of the respiratory hazard to which workers are exposed

shall be determined periodically and records shall be kept. The monitoring must 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 must be determined. Preferably, the air in the work area should be sampled in the workers' breathing zones.

Fit Testing Before Use

Respirator facepieces shall be checked for fit each time they are worn. The wearer can make either the positive- or the negative-pressure test, discussed in Chap. Eight, before entering a hazardous atmosphere, but a qualitative check using either isoamyl acetate or irritant smoke is much preferred.

FUNCTIONAL AND PHYSICAL CHARACTERISTICS AND USE LIMITATIONS OF RESPIRATORS

The various types of respirators and their functional and physical characteristics and use limitations are discussed in Chap. Five. As these factors are most important in respirator use, additional information is given here.

Limitations of Particulate-Filter Elements

As discussed in Chap. Five, 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 must be replaced frequently. Elements should be replaced at least daily or more often if necessary. Filter elements designed to be cleaned and reused also should be cleaned at least daily.

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 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 materials efficiency in removing particles from air, it also increases resistance to air flow.

Limitations of Vapor- and Gas-Removing Cartridges and Canisters

It has been stated that if a vapor or gas lacks adequate warning properties (odor, taste, irritation) in a concentration above the established breathing time-weighted average concentration, a vapor- and gas-removing air-purifying respirator should not be used. Another limitation is limited capacity of the cartridges and canisters in these respirators to remove vapors and gases from air, or to catalyze a reaction that converts 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 respirator. If the wearer detects an odor or taste of gas in the inspired air, or feels eye or throat irritation, he should leave the hazardous area immediately and go to a safe area that contains respirable air. Then, he 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.

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.

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, never use an unsealed one and remember that if the hazardous atmosphere is very moist or dry, the useful service time may be markedly reduced.

Advantages and Limitations of Nonpowered Air-Purifying Respirators

In addition to those limitations imposed by respiratory-inlet coverings (see Chap. Five), 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 him. This can best be accomplished by individual fittings.

Other disadvantages of nonpowered air-purifying respirators include resistance to breathing, need for frequent replacement of air-purifying elements, and need for continual maintenance (except for single-use respirators).

Advantages and Limitations of Powered Air-Purifying Respirators

In addition to those imposed by respiratory inlet coverings, particulate-filter elements, and cartridges containing sorbents, other limitations of powered air-purifying respirators should be considered.

A powered respirator's battery must 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 whose parts eventually wear out. Therefore, the blower will have to be replaced periodically. If the blower fails, the wearer of a powered respirator must go to the nearest safe area immediately.

Other disadvantages include weight, bulk, complex design, the need for continual maintenance, high initial cost, cost of at least daily replacement of air-purifying elements, and cost of periodic replacement of batteries and blowers.

The great advantage of the powered air-purifying respirator is that the air inside the respiratory-inlet covering is normally at positive pressure which reduces the possibility of contaminated air entering, and that the wearer is continually being supplied with fresh air with no breathing resistance.

Advantages and Limitations of Airline Supplied-Air Respirators

Loss of the source of respirable air supplied to the respiratory-inlet covering of the air line supplied-air respirator 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 prohibits air line respirator use in atmospheres immediately dangerous to life or health. However, an air line respirator with an auxiliary self-contained air supply can 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 air line respirator severely restricts the wearer's mobility. This may make the air line respirator unsuitable for those who must move frequently between widely separated work stations. A combination air line and self-contained breathing respirator may be suitable if the supply of self-contained breathing air is adequate for the time required to move from place to place.

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, air line respirators that operate in the continuous-flow or pressure-demand mode always have positive air pressure inside the respiratory-inlet covering which keeps contaminated air from leaking in. Thus, an air line respirator operating in

the continuous-flow or pressure-demand mode provides much better protection than one that operates in the demand mode.

A great advantage of the air line respirator is that it can 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.

Advantages and Limitations of Hose Mask Type Supplied-Air Respirators

Obviously, air pressure inside the respiratory-inlet covering of the hose mask with no blower is negative during inhalation, so contaminated air can leak in if the covering fits poorly. At present, 30 CFR Part 11 allows a hose mask with a blower that supplies respirable air at a relatively low (50-lpm) flow rate to be approved for atmospheres immediately dangerous to life and health. Hose mask type supplied-air respirators, with and without blower, are not recommended in atmospheres immediately dangerous to life or health.

The trailing air supply hose of the hose mask also severely limits mobility, so it may be unsuitable for those who must 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.

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

Advantages and Limitations of Self-Contained Breathing Apparatus

The bulk and weight of most SCBAs make them unsuitable for strenuous work or use in a very confined space. The limited service life makes them unsuitable for routine use for long continuous periods. The especially 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.

The demand type open-circuit SCBA and most closed-circuit SCBAs 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 SCBAs that are positive-pressure devices provide very good protection because the air inside the respiratory-inlet covering is always at positive pressure which keeps the contaminated atmosphere from leaking in.

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.

RESPIRATOR USE UNDER SPECIAL CONDITIONS

In Dangerous Atmospheres

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

In Confined Spaces

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 atmosphere 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 must be force-ventilated to keep the concentration of a flammable substance at a safe level. No one shall enter if a flammable substance exceeds the lower explosive limit. No one shall enter without wearing the proper type of respirator if any air contaminant exceeds the established breathing time-weighted average 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.

Air-purifying respirators and air line and hose mask type supplied-air respirators may be worn in a confined space only if tests show that the atmosphere contains adequate oxygen and that air contaminants are well below levels immediately dangerous to life or health. While people wearing these types of respirators are in a confined space, its atmosphere must 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 shall wear a SCBA or a combination air line and self-contained breathing respirator 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 man with proper rescue equipment, including a SCBA, must be present outside for emergency rescue. He must maintain communications (visual, voice, signal line, telephone, radio, or other suitable type) with those inside. Also, those inside the space must be equipped with safety harnesses and safety lines to allow their removal in case they are overcome.

In Low and High Temperatures

Low temperatures will fog respirator lenses. Coating the inner surface of the lens with an anti-fogging compound will 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 termperatures, exhalation valves may freeze owing to moisture. Dry respirable air should be used with air line respirators and with the type of SCBA that has an air tank when they are used in low temperatures.

A person working in high-temperature air is under stress. Wearing a respirator causes additional strain which should be minimized by using a light-weight respirator with low breathing resistance. The air line 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.

SPECIAL PROBLEMS IN RESPIRATOR USE

Facial Hair

Facial hair lying between the sealing surface of a respirator facepiece and the wearer's skin will prevent a good seal. If the respirator permits negative air pressure inside the facepiece during inhalation, there will be excessive penetration by an air contaminant. Even a few days growth of stubble will permit excessive contaminant penetration.

Respirators shall not be worn when conditions prevent a good seal of the facepiece to the face. Items such as beards and sideburns prevent satisfactory sealing. Therefore, anyone who has stubble, a moustache, sideburns, or a beard that passes between his face and the sealing surface shall not wear a respirator that allows negative pressure inside the facepiece during inhalation.

Corrective Lenses

Those who must wear spectacles present a problem in respiratory protection. Spectacle temple bars or straps that pass between the sealing surface of a full facepiece and the wearer's face prevent a good seal. Therefore, spectacles that have temple bars or straps shall not be used when a full-facepiece respirator must be worn. Spectacles with short temple bars that do not protrude between the sealing surface and the wearer's face, or spectacles without temple bars which are taped to the wearer's face may be used temporarily. Special corrective lenses to be mounted inside full facepieces are available and should be used by those who need them. These lenses shall be mounted in the full facepiece only by qualified persons to ensure good vision, comfort, and proper sealing of the facepiece.

Spectacles or goggles may also interfere with quarter- or half-masks. They shall be worn so as not to interfere with the seal of the facepiece. If there is interference, a full facepiece respirator should be worn to avoid sealing problems.

Contact lenses shall not be worn while wearing a respirator in a contaminated atmosphere. Contaminants that penetrate the respirator may get into the eyes and cause severe discomfort because of the contact lenses.

Miscellaneous Sealing Problems

Scars, hollow temples, very prominent cheekbones, deep skin creases, and lack of teeth or dentures may cause respirator facepiece sealing problems. Dentures or missing teeth may cause problems in sealing a mouthpiece in a person's mouth. Full dentures should be retained when wearing a respirator, but partial dentures may or may not have to be removed, depending upon the possibility of swallowing them. With full lower dentures, problems in fitting quarter-masks can be expected, as the lower part of the mask tends to unseat the denture.

CHAPTER EIGHT

TRAINING AND FITTING

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 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,

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. These requirements originated in ANSI Standard Z88.2-1969. Section 7.4 of that Standard gives more details.

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,
- Discussion of how to recognize and handle emergencies.

Unfortunately, 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. It must be emphasized again, however, that the OSHA requirements apply to large and small users alike.

Supervisor Training

Supervisors, 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.

- Basic respiratory protection practices,
- Selection and use of respirators to protect each worker against every respiratory hazard to which he 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. The supervisor should understand his responsibility to facilitate functioning of the program, including maintenance that the worker may be expected to do himself, issuance of respirators, control of their use, and evaluation of the program's effectiveness.
- The legal requirements pertinent to use of respirators in his situation.

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.

Worker Instruction and Training

The extent and frequency of the workers' training depends primarily on the nature and extent of the hazard. If the hazard is a nuisance particulate, for example, the danger from misuse of the respirator is not likely to be serious. However, against highly toxic particulates, 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 shall be given some instruction and training 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 respirator selected for his 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, Sec. 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 should include recognition that every reasonable effort is being made to reduce or eliminate the need for respirators.
>
> (3) Discussion of why this is the proper type of respirator for the particular purpose.
>
> (4) Discussion of the respirator's capabilities and limitations.
>
> (5) Instruction and training in actual use of the respirator (especially one for emergency use) and close, frequent supervision to ensure that it continues to be used properly.
>
> (6) Classroom and field training in recognizing and coping with emergencies.
>
> (7) Other special training as needed."

A major thrust is toward explaining as much as possible about the reasons for wearing a respirator. This, of course, is to motivate the user to accept the fact that protection is necessary, and to instill in him the desire to wear and maintain his respirator properly. Just throwing a respirator at a worker with orders that he 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. Recent field studies have pointed this out. Much of this natural resistance can be overcome by taking the time and effort to inform the wearer as thoroughly as possible why he needs the respirator. This effort will create easier acceptance of respirators and contribute to subsequent correct use.

RESPIRATOR FITTING METHODS

All the care that went into design and manufacture of a respirator to give 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.

Respirator Fitting Tests

Determination of facepiece fit could 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 are as follows.

Qualitative Tests

Advantages

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

Disadvantages

Qualitative tests rely on the wearer's subjective response, so they are not entirely reliable.

Quantitative Tests

Advantages

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

Disadvantages

Quantitative fitting tests require expensive (up to $10 000) equipment that can be operated only by highly trained personnel and is unsuitable for field use because of its complexity and bulk. 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.

Selection of a qualitative 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 fitting 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.

As mentioned in Chap. Five, quarter- and half-masks, and full facepieces have inherently different fitting characteristics. Moreover, several brands of each are marketed, each brand manufactured in only one size and style and each having slightly different fitting characteristics. Although every manufacturer designs his facepieces to fit as broad a section of the working population as possible, no respirator marketed will fit everyone. Therefore it is strongly suggested that many brands of a given type of respirator be purchased to take advantage of the different fitting characteristics of each. In this way, the chances of properly fitting all workers are increased. Equally important is the fact that having more than one facepiece to choose from 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 qualitative test, has the greatest impact.

Respirator Fitting Procedures

One point must be kept in mind throughout the following discussions. The OSHA regulations require that workers be allowed to test the facepiece-to-face seal of the respirator and to wear it in a test atmosphere.

NOTE: During any fitting test, the respirator headstraps must be as comfortable as possible. Tightening the straps will sometimes reduce facepiece leakage, but the wearer may be unable to tolerate the respirator for any length of time.

Qualitative Fitting Tests

Negative Pressure Test. The wearer can perform this test by himself in the field. 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.

Although this test is simple, it has severe drawbacks, primarily that the wearer must handle the respirator after it has supposedly been positioned on his face. This handling can modify the facepiece seal. It is strongly recommended that this test be used only as a very gross determination of fit when the respirator is to be used in relatively toxic atmospheres. The wearer should use this test (Fig. 8-1) just before entering any toxic atmosphere.

Fig. 8-1.
Negative pressure test.

Fig. 8-2.
Positive 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 most 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 (Fig. 8-2) just before entering any hazardous atmosphere.

Isoamyl Acetate Vapor (Banana Oil) Test. Anyone who has ever built flying model airplanes has smelled banana oil, widely used in the dope for coating their fabric coverings. This chemical, isoamyl acetate, has a pleasant, easily detectable odor, so it also is used widely in qualitatively checking respirator fit.

This is the first test mentioned that gives the user the required opportunity to wear the respirator in a test atmosphere. Generally it consists of creating an atmosphere containing banana oil around the wearer of an atmosphere-supplying or air-purifying respirator with an organic vapor-removing cartridge(s) or canister. If the hazard is particulate matter or a nonorganic vapor or gas, the organic vapor cartridge(s) or canister must be replaced with a particulate filter(s) or proper cartridge(s) or canister after this test.

There are several versions of the banana oil test. The simplest is to saturate a piece of cotton or cloth with the liquid and pass it close to the respirator near the sealing surface, taking care to avoid the skin. A second method is to use a stencil brush (Fig.

s 50 filled with isoamyl acetate in the same manner as the cotton or cloth.

A more complex, and better, version of the test uses a room or small booth or a hood that covers the respirator wearer's head and shoulders. In this enclosure is generated a known concentration of vapor, usually 100 ppm, created by vaporizing 17.3 ml of isoamyl acetate liquid for each 1000 ft³ (or about 28 m³) of enclosure volume. Use of a fixed enclosure decreases the test's flexibility but provides a known vapor concentration that reduces the number of variables involved. Most people can smell 1-10 ppm of isoamyl acetate; the permissible exposure limit is 100 ppm.

In general, the isoamyl acetate fitting test should be performed as follows.

- The wearer puts on the respirator in a normal manner. If it is an air-purifying device, it must be equipped with a cartridge(s) or canister specifically designed for protection against organic vapors.
- The wearer enters the test enclosure, or the saturated cloth or stencil brush is passed close to the respirator sealing surfaces.

Fig. 8-3.
Banana oil test.

- If the wearer smells banana oil, he returns to clean air and readjusts the facepiece and/or adjusts the headstraps without unduly tightening them.
- The wearer repeats the second step. If he does not smell banana oil, he is assumed to have obtained a satisfactory fit. If he smells the vapor, an attempt should be made to find the leakage point. If the leak cannot be located, another respirator of the same type and brand should be tried. If this leaks, another brand of respirator with a facepiece of the same type should be tried.
- After a fit is obtained, if the respirator is an air-purifying device it must be equipped with the correct filter(s), cartridge(s), or canister for the anticipated hazard.

During the test, the subject should make movements that approximate a normal working situation. These may include, but not necessarily be limited to, the following.

- Normal breathing.
- Deep breathing, as during heavy exertion. This should not be done long enough to cause hyperventilation.
- Side-to-side and up-and-down head movements. These movements should be exaggerated, but should approximate those that take place on the job.
- Talking. This is most easily accomplished by reading a prepared text loudly enough to be understood by someone standing nearby.
- Other exercises may be added depending upon the situation. For example, if the wearer is going to spend a significant part of his time bent over at some task, it may be desirable to include an exercise approximating this bending.

If the test is used in training the worker and selecting the respirator that fits him best, he should perform the complete set of exercises. However, the number of exercises may be reduced when the test is used as a quick field check before routine entry into a contaminated atmosphere.

The major drawback of the isoamyl acetate test is that the odor threshold varies widely among individuals. Furthermore, the sense of smell is easily dulled and may deteriorate during the test so that the wearer can detect only high vapor concentrations. Another disadvantage is that isoamyl acetate smells pleasant, even in high concentrations. Therefore, a wearer may say that the respirator fits although it has a large leak. This is usually because

he likes the comfort of the particular respirator or is following the lead of someone else and selecting the same respirator. Conversely, a wearer may claim that a particular respirator leaks if it is uncomfortable, etc. Therefore, unless the worker is highly motivated toward wearing respirators, the results of this test must sometimes be suspect.

Irritant Smoke Test. This qualitative test is similar to the isoamyl test in concept. It usually involves exposing the respirator wearer to an irritating aerosol produced by commercially available smoke tubes normally used to check the quality of ventilation systems. These are sealed glass tubes, approximately 12 cm long by 1 cm in diameter (Fig. 8-4), filled with pumice impregnated with stannic chloride or titanium tetrachloride. When the tube ends are broken and air is passed through it, the material inside reacts with the moisture in the air to produce a dense, highly irritating smoke, consisting of hydrochloric acid adsorbed on small solid particles.

As a qualitative means of determining respirator fit, this test has a distinct advantage in that the wearer usually reacts involuntarily to leakage, by coughing or sneezing. The likelihood of his giving a false indication of proper fit is reduced. On the other hand, the aerosol is very irritating and must be used carefully to avoid injury. Also, it is advisable to have exhaust ventilation behind the subject to protect the person doing the testing.

This test can be used for both air-purifying and atmosphere-supplying respirators, but an air-purifying respirator must have a high-efficiency filter(s). After the test, it may be necessary to replace the high-efficiency filter(s) on the air-purifying respirator with another type of air-purifying element(s), depending upon the hazard to which the respirator wearer is to be exposed. This test can be used for worker training or respirator selection.

The irritant smoke test must be performed with proper safeguards because the aerosol is highly irritating. A suggested procedure is as follows.

- The wearer puts on the respirator normally, taking care not to tighten the headstraps uncomfortably. He stands with his back to a source of exhaust ventilation, such as a chemical fume hood.

Fig. 8-4.
Irritant smoke test.

- The tester tells the wearer to close his eyes, even if he is wearing a full facepiece respirator, and to keep them closed until told to open them.
- The tester lightly puffs smoke over the respirator, holding the smoke tube at least 2 ft from it. At this time, he should keep the amount of smoke minimal and pause between puffs to note the wearer's reaction.
- If the wearer detects no leakage, the tester may increase the smoke density and move the smoke tube progressively closer to the subject, still remaining alert to his reactions.
- When the smoke tube has been brought to within about 6 in. of the respirator with no leakage detected, the tester may start to direct smoke specifically at the potential sources of leakage, around the sealing surface and exhalation valve, while the subject holds his head still.

• At this point, if no leakage has been detected, the wearer may cautiously begin the head movements mentioned in the isoamyl acetate test. The tester should remain especially alert and be prepared to stop producing smoke immediately.

• If leakage is detected at any time, the tester should stop the smoke and let the wearer readjust the facepiece or headstrap tension. The tester should then start the test at the second step.

In all fairness, this test is not so time-consuming as it sounds. Also, because of its greater sensitivity and lesser reliance on subjective response, it is considered more reliable than the isoamyl acetate vapor test. If the wearer keeps his eyes closed and the smoke is increased gradually, there is little danger or discomfort.

Other Quatitative Tests. Other qualitative fitting tests have been used, although not so extensively as those just described. Among these are tests in which a stream of talcum powder or coal dust is directed around the respirator sealing surface. The wearer then removes the respirator and any leakage is revealed by telltale streaks of the powder or dust. These tests have been used almost exclusively for investigative purposes rather than routine fitting.

Another similar test, used very infrequently, involves spraying fluorescein dye (uranine) around the sealing surface. The respirator is then removed, and the sources of leakage are detected with ultraviolet light. Obviously, this test is more for research than for routine fitting.

In summary, qualitative fitting tests are quick, easily performed with a minimum of special equipment and generally adequate for checking respirator fit before entering a contaminated area. However, they have limitations that make them less useful than quantitative tests for initial selection of a brand of respirator that fits best. For that purpose, the following tests are preferred.

Quantitative Fitting Tests.

All quantitative respirator performance tests involve placing the wearer in an atmosphere containing an easily detectable, relatively nontoxic gas, vapor, or aerosol. The atmosphere inside the respirator is sampled continuously through a probe in the respiratory-inlet covering. The leakage is expressed as a percentage of the challenge atmosphere outside the respirator, called "per cent of penetration," or simply "penetration."

The procedures are relatively independent of the type of aerosol or gas. Appendix D details standardized test procedures and shows a typical strip-chart recording of a quantitative fitting test and a suggested format for recording and evaluating the data.

Sodium Chloride (NaCl) Test. In the NaCl aerosol quantitative respirator fitting test, a liquid aerosol is generated continuously from an aqueous solution (salt water) by use of a nebulizer, dried to produce discrete submicron salt particles, and dispersed into a test chamber or hood. The resultant NaCl aerosol is called polydisperse because the particles vary in size. A means is provided for sampling the atmosphere in the chamber or hood and that inside the respirator. These samples are fed to the analyzing section where the aerosol's penetration inside the respirator is determined. The amount of penetration is displayed on a meter or recorder. Figure 8-5 shows a NaCl quantitative respirator fitting test system. See Appendix E for details of the test system. Appendix D gives the procedures for conducting the NaCl quantitative test.

Dioctyl Phthalate (DOP) Test. The dioctyl phthalate (DOP) quantitative fitting test made using an air-generated DOP aerosol differs from the NaCl test only in that the aerosol particle is liquid (see Appendix D). The aerosol is generated using a nozzle-type atomizer, but, being an oil, DOP does not dry into solid particles when injected into a diluting air stream. Figure 8-6 shows a DOP test system, and Appendix D gives a more detailed description.

A second type of DOP system uses a thermally generated liquid aerosol. Liquid DOP is heated to boiling, and the vapor is passed to a cooling chamber where it condenses at a very closely controlled temperature, to produce a 0.3-μm monodisperse aerosol. That is, all the particles are 0.3 μm in diameter. This aerosol has been used widely for quality control of high-efficiency respirator filters and for basic research on aerosol filtration. It was also used for quantitative fitting tests but has fallen into disfavor because the boiling produces aerosol particles that have a disagreeable odor and an unknown toxicity.

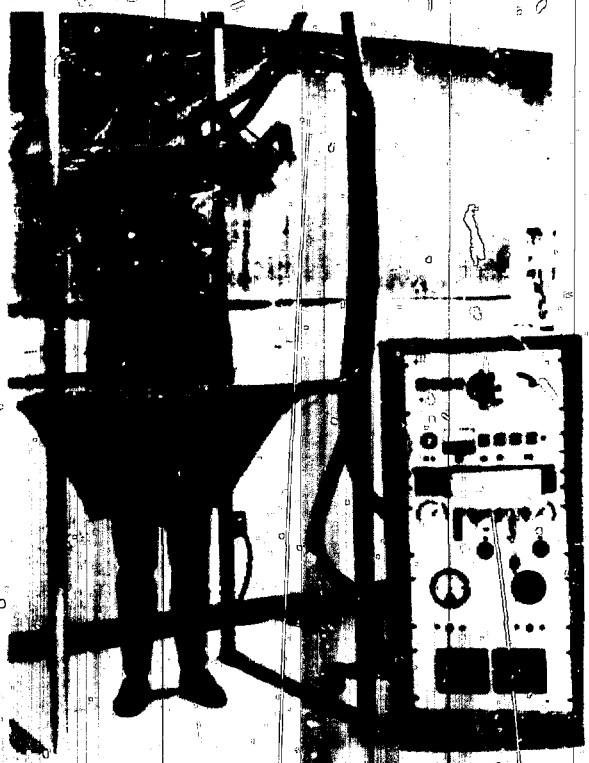


Fig. 8-5.
NaCl quantitative respirator-fitting test system.

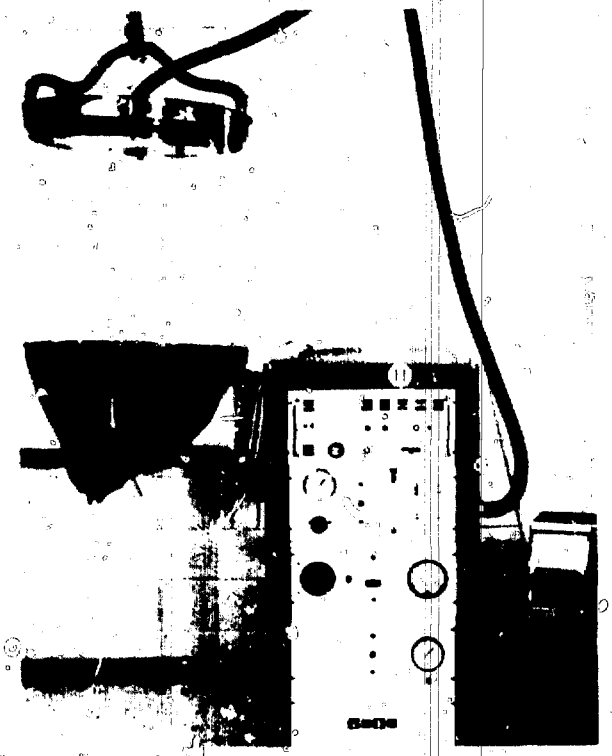


Fig. 8-6.
DOP quantitative respirator-fitting test system.

Freon 12 Test. Freon 12, [illegible] a refrigerant gas, has been used in quantitative respirator fitting tests. It is not so useful as NaCl [illegible] DOP because the slow response time of the analyzing instrumentation prevents following the fluctuations in concentration of the gas that penetrates the respirator.

CHAPTER NINE

RESPIRATOR INSPECTION, CLEANING, MAINTENANCE, AND STORAGE

ELEMENTS OF AN ADEQUATE RESPIRATOR INSPECTION, CLEANING, MAINTENANCE, AND STORAGE PROGRAM

Scrupulous respirator maintenance must be made an integral part of the overall respirator program. Wearing poorly maintained or malfunctioning respirators is, in one sense, more dangerous than not wearing a respirator at all. The worker wearing a defective device thinks he is protected when, in reality, he is not. Emergency escape and rescue devices are particularly vulnerable to poor maintenance as 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 [illegible] importance of an adequate [illegible] permit its tailoring to the [illegible] of plant [illegible] ditions, and hazards [illegible]. [illegible] programs are required [illegible]

- Inspection for defects [illegible]
- Cleaning and disinfect[illegible]
- Repair.
- Storage.

A proper [illegible] worker's re[illegible] was new.

INSPECTION [illegible]

[illegible]

cleaned. In a small operation where the worker probably maintains his own respirator, the two types of inspection become essentially one and the same. In a large organization with a central respirator maintenance facility, the inspections differ.

Frequency of Inspection

OSHA requires that "all respirators be inspected before and after each use," and that those not used [illegible], i.e., emergency escape and rescue devices, "[illegible] inspected after each use and at least [illegible]." In one case, the respirator is to be in[illegible] both before and after each use. However, it is [illegible]likely that anyone needing a respirator [illegible] as during an emergency, is going to in[illegible] fact, it could be dangerous to take time to [illegible]

[illegible]

FIELD INSPECTION

Air-Purifying Respirators

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

(a) Examine the facepiece for:

Excessive dirt.

Cracks, tears, holes, or distortion from improper storage.

Inflexibility (stretch and massage to restore flexibility).

Cracked or badly scratched lenses in full facepieces.

Incorrectly mounted full facepiece lens or broken or missing mounting clips.

Cracked or broken air-purifying element holder(s), badly worn threads, or missing gasket(s) (if required).

(b) Examine the headstraps of head harness for:

Breaks.

Loss of elasticity.

Broken or malfunctioning buckles and attachments.

(Full facepieces only). Excessively worn serrations on the head harness which might permit slippage.

(c) Examine the exhalation valve for the following after removing its cover:

Foreign material, such as detergent residue, dust particles, or human hair under the valve seat.

Cracks, tears, or distortion in the valve material.

Improper insertion of the valve body in the facepiece.

Cracks, breaks, or chips in the valve body, particularly in the sealing surface.

Missing or defective valve cover.

Improper installation of the valve in the valve body.

(d) Examine the air-purifying elements for:

Incorrect cartridge, canister, or filter for the hazard.

Incorrect installation, loose connections, missing or worn gaskets, or cross-threading in holder.

Expired shelf-life date on cartridge or canister.

Cracks or dents in outside case of filter, cartridge, or canister.

Evidence of prior use of sorbent cartridge or canister, indicated by absence of sealing material, tape, foil, etc., over inlet.

(e) If the device has a corrugated breathing tube, examine it for:

Broken or missing end connectors.

Missing or loose hose clamps.

Deterioration, determined by stretching the tube and looking for cracks.

(f) Examine the harness of a front- or back-mounted gas mask for:

Damage or wear to the canister holder which may prevent its being held securely in place.

Broken harness straps or fastenings.

Atmosphere-Supplying Respirators

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

(a) 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.

(b) 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.

(c) Examine the air supply system for:

Integrity and good condition of air supply lines and hoses, including attachments and end fittings.

Correct operation and condition of all regulators, valves, or other air-flow regulators.

On SCBAs, 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 SCBAs, make sure that a fresh canister of CO sorbent is installed before use, or that the total use time on the canister is known. On open-circuit SCBAs, recharge the cylinder if less than 25% of the useful service time remains. All these

SCBAs are required to have a warning device that indicates when this point is reached. 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."

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. 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.*

Inspection During Cleaning

Because respirator cleaning usually involves some disassembly, it presents a good opportunity to examine each respirator thoroughly. The procedures outlined above for a field inspection should be used, but a precleaning check would not normally include an operational check, which obviously should be done just before the device is returned to service. Therefore, it is suggested that the inspection be made *after* the respirator is cleaned.

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 extensive respirator programs. It involves use of a machined metal head form with an inflated sealing surface over which a full facepiece may be placed. The respirator facepiece is placed over the headform, the straps are fastened down, and the inflatable seal built into the headform is pressurized to provide a gastight seal between the headform and the facepiece. A continuous air sample is withdrawn from inside the facepiece through the headform and passed through an aerosol detector like that described in Chap. Eight. 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.

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 installations have built a small test chamber around the headform. Instead of the aerosol's 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 a difficult position as he cannot afford this sophisticated equipment but is bound by the same requirements as the large user. The best advice for the small user, which is of little help, is to use his ingenuity and devise a method that will satisfy the basic purpose of the leak check, assurance that the reassembled respirator is leak-free.

CLEANING AND DISINFECTING

The OSHA requirements 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. If each worker is to maintain his own respirator, he should be thoroughly briefed on its cleaning and disinfecting. Although a worker may not be required to maintain his own respirator, briefings on the cleaning procedure will encourage his acceptance of the respirator by providing assurance that he always receives a clean, disinfected, properly maintained device. This is particularly important where

respirators are not individually assigned. Where respirators are individually assigned, a practice to be encouraged, they should be durably identified to ensure that the worker always receives the same device. Identification markers must not penetrate the facepiece or block filter or cartridge ports or exhalation valves.

In a small respirator program, or where each worker cleans his own respirator, 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.

In a large program, there may be a centralized cleaning and maintenance facility with specialized equipment and personnel trained in respirator maintenance. Figure 9-1 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 ft².

In the following discussion of cleaning and maintenance procedures, *reference to Fig. 9-1* should help in understanding the overall process. The following procedure may be used:

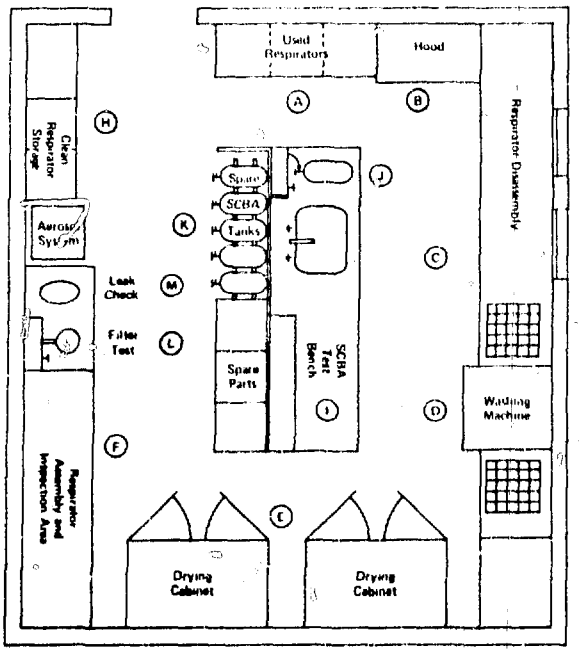


Fig. 9-1.
Typical large respirator maintenance facility.

Disassembly

The used respirators are collected and deposited in a central location, (A) of Fig. 9-1. They are taken to an area (C) where the filters, cartridges, or canisters are removed and discarded. Canisters should be damaged to prevent accidental 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 SCBAs 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 in. 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, particularly neglecting to punch holes in the canister, can cause a violent explosion.

Cleaning and Sanitizing

The actual cleaning may be done in a variety of ways. In Fig. 9-1, it is assumed that a commercial dishwasher (D) is used. Figure 9-2 shows a unit of this type. 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

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 mandatory. 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 Clorox to 1 liter of water or, in kitchen language, 2 tablespoons per gallon. A 2-min 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. An equivalent expression is approximately 1 teaspoon of tincture of iodine per gallon of water. Again, a 2-min 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 must 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.*

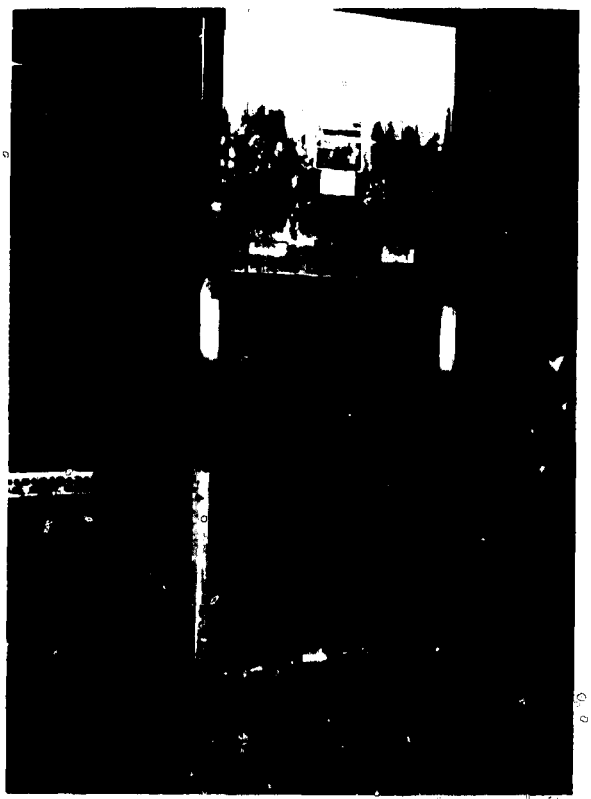


Fig. 9-2.
Commercial dishwasher used for respirator cleaning.

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.

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 equip a standard steel storage cabinet, Fig. 9-1 (E), with an electric heater that has a built-in circulating fan, and to replace the solid shelves with steel mesh. Appendix C gives instructions for these modifications.

Reassembly and Inspection

The clean dry respirator facepieces should be reassembled and inspected in an area, Fig. 9-1 (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, Fig. 9-1 (M).

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

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 approval of the device.* Therefore, the user would be wearing an unapproved device, in violation of the OSHA requirement.

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

These restrictions apply primarily to maintenance of the more complicated devices, especially closed- and open-circuit SCBAs, 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." The words "trained technician" permit on-site repair if the maintenance personnel are trained. 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 quantitites must be kept in stock. It is desirable to have some sort of record-keeping system to indicate spare parts usage and the inventory on hand.

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,
- 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."

Air-purifying respirators kept ready for non-routine or emergency use should be stored in a cabinet in individual compartments. A steel wall-mounted cabinet, with six compartments is shown in Fig. 9-3. 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

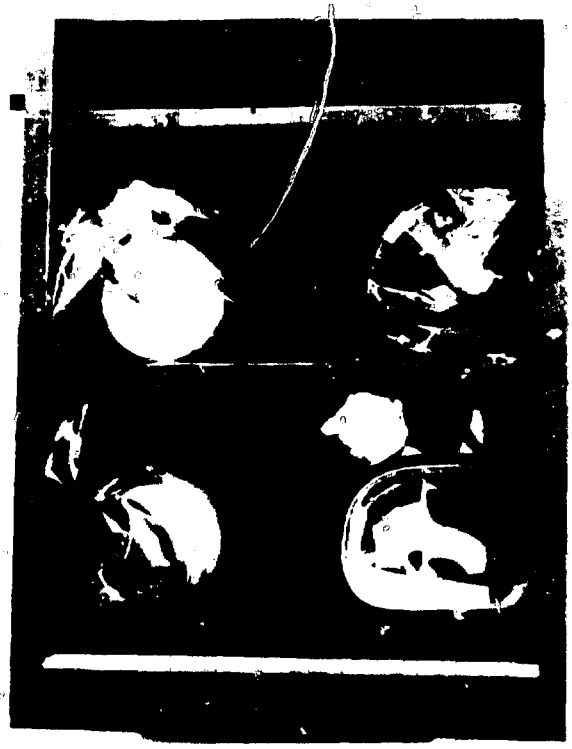


Fig. 9-3.
Air-purifying respirator storage.

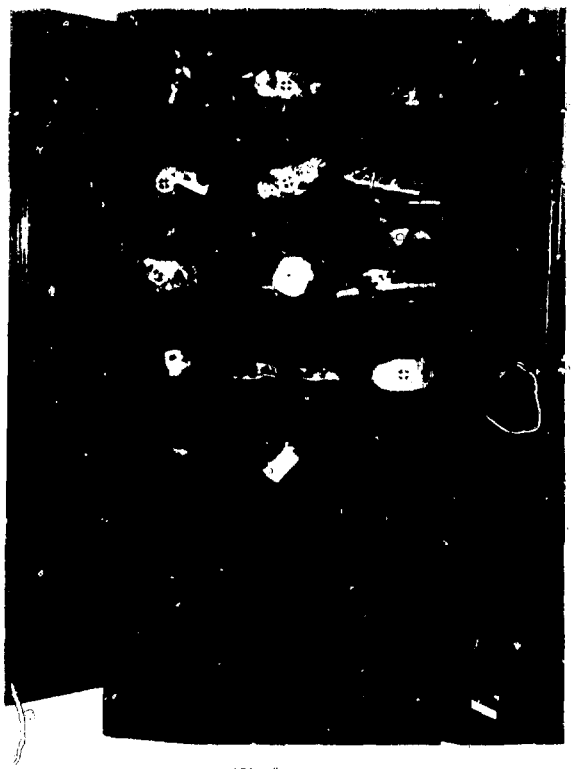


Fig. 9-4.
Standard storage cabinet used for respirator storage.

improperly. Another acceptable method of storage in a standard steel storage cabinet is shown in Fig. 9-4. 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, Fig. 9-5, or wall-mounted case, Fig. 9-6, may be purchased from the respirator manufacturer for storing a SCBA for use in emergencies. Again, the locations of SCBAs 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

Fig. 9-5.
Storage chest for a SCBA.

Fig. 9-6.
Wall-mounted storage cabinet for a SCBA.

workers take 30 seconds to 1 min 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 would provide only minimal protection from mechanical damage.

If the worker is trained adequately, he should develop a respect for his respirator which will automatically give him incentive to protect it from damage. Besides providing better assurance of adequate protection, this training will lower maintenance costs because of decreased damage.

CHAPTER TEN

PHYSIOLOGICAL AND PSYCHOLOGICAL LIMITATIONS ON RESPIRATOR USE

PHYSIOLOGICAL LIMITATIONS

Wearing any type of respirator imposes some physiological stress on the wearer. Air-purifying respirators resist inhalation because the filter or cartridge restricts free air flow, and also resist exhalation because the expired air must force open a valve. The special exhalation valve on an open-circuit pressure-demand SCBA, designed to ensure that the air pressure inside the facepiece is always positive, requires the wearer to exhale against significant resistance. The bulk and weight (up to 35 lb) of some SCBAs are a significant burden. Wearers of air line respirators and hose masks must drag around up to 300 ft of air supply hose.

Any or all of these factors significantly increase the work load. If the worker's cardiovascular or pulmonary function is significantly impaired, wearing a respirator could constitute an unacceptable risk. The OSHA standards suggest that the local physician determine whether a worker can wear a respirator and perform useful work safely. As there is so little information on the physiological effects, it may be difficult for the local physician to determine whether or not a worker should wear a specific type of respirator.

How is the person responsible for overseeing the physical well-being of those who must wear respirators supposed to make decisions? The only practical approach is to treat each case individually, using the best medical advice available, and to consider the physical burdens imposed by the various types of respirators.

Pulmonary

The individual should be examined for evidence of respiratory impairment such as emphysema, chronic pulmonary obstructive disease, or bronchial asthma. Historical and x-ray evidence of significant pulmonary disease, if substantiated by reduced vital capacity or reduced forced expiratory volume may justify forbidding a person to wear a respirator that restricts inhalation and exhalation, and limiting him to powered air-purifying or continuous flow air line respirators. Breathing difficulties should not necessarily prohibit a worker from wearing air-purifying respirators, if he is reasonably comfortable, because such prohibition might deprive him of his livelihood.

Workers in occupations, such as installing asbestos insulation, coal mining, and sand blasting, which cause high incidence of pulmonary diseases, should be given particular attention. In any case, if difficulties are experienced, the local physician shall make the final determination.

Cardiovascular

Cardiovascular impairment must be treated with much more concern than pulmonary impairment because of its potentially catastrophic consequences. Workers who have indications of coronary artery disease or angina pectoris, probably should not wear nonpowered air-purifying respirators or the heavy (35-lb) SCBAs. The same restrictions are recommended for those who have myocardial infarction or progressive or severe hypertension.

Those whose duty is to respond to emergencies should not wear any type of respirator if they have any cardiovascular deficiency. Or, if emergency response duty absolutely requires use of respirators, those wearing them should be completely free of cardiovascular impairment. Such people include firemen and mine rescue team members, who might have to rescue an unconscious 200-lb man from an extremely hazardous environment while wearing 35 lb of self-contained breathing apparatus.

Other Physiological Considerations

Other physical conditions such as diabetes, or grand mal epilepsy may limit wearing of respirators. Skin sensitivity to certain organic compounds may prevent some workers from entering certain environments at all, let alone wearing respirators in them. A perforated eardrum, allowing air passage through the eustachian tube into the respiratory tract, may keep a person from working in a toxic environment unless he wears a respirator with a full head enclosure, such as a supplied-air hood, helmet, or suit.

Deep facial scars or blemishes, hollow temples, or an abnormally receding chin may spoil the seal of certain types of respirator facepieces. Also, full or partial dentures may prohibit wearing of certain types of facepieces or mouthpieces.

In summary, physiological conditions that may determine whether an individual should wear a respirator or not are varied. Pending more research on this problem, specific guidelines cannot be stated, and one must rely on the best judgement of the local physician.

PSYCHOLOGICAL LIMITATIONS

Psychological conditions that may prevent a worker from wearing a respirator are, if anything, less clearly defined than physical limitations. However, those who experience claustrophobia or anxiety when confined in a small space should not be given jobs that require respirators. In this category are firefighting, which frequently requires entering smoke-filled rooms with poor visibility, and mine rescue, which necessitates crawling through small passages containing highly toxic gases.

A more subtle psychological consideration is comfort. Obviously, if a respirator with an ill-fitting or irritating facepiece causes continual discomfort, it is bound to have an adverse psychological effect.

CHAPTER ELEVEN

PROGRAM ADMINISTRATION

Unfortunately, respirators generally are 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. This chapter presents detailed methods for ensuring that a respirator program remains effective.

WRITTEN STANDARD OPERATING PROCEDURES

The importance of written standard operating procedures is emphasized in OSHA 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 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 can be established, and from that information, any user, large or small, can formulate procedures for his own circumstances.

General Content

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 himself, 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) must have been assessed thoroughly; otherwise the written procedures will have only limited validity. Generally, the procedures should contain the following.

- Guidance for selection of the approved respirator(s) for protection against particular hazard(s).
- Detailed instructions for training workers in proper use of the respirator(s), including respirator fitting.
- Detailed maintenance procedures for:
  - Cleaning and disinfecting,
  - Drying,
  - Inspection,
  - Repair or replacement of worn or defective components,
  - Storage.
- 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.
- Instructions for respirator use during emergencies, including fire, which can create an atmosphere immediately hazardous to life and health.
- Guidelines for medical surveillance of workers, including preemployment 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.

- 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 must be written down.

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 hazards(s) increases, demanding better and more reliable protection. It is better to be overly detailed in developing written operating procedures than not detailed enough.

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 must be considered in advance and prepared for in the written procedures because in the stress of an emergency memories may be faulty. Furthermore, these emergency procedures should be used in training emergency response teams.

THE PROGRAM ADMINISTRATOR

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 as shown in Fig. 11-1. 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. She or he may be a safety engineer, industrial hygienist, health physicist, or physician. He or she should have the full support of higher level management, without it, an effective respirator program is difficult to initiate and maintain.

It may seem strange that respirator purchasing should be controlled by the program administrator. There are good reasons related to respirator fitting and selection. Several respirator manufacturers produce a wide variety of devices for protection against specific hazards. Unfortunately, the facepiece of each device generally is made in only one size that may fit only 50-75% of a group of workers. However, if more than one brand of respirator is purchased, thus providing a variety of facepiece sizes, it is possible to fit over 95% 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 considers to be the best types of devices and ensure that they are purchased. As the price spread among the various brands of respirators for a particular type of hazard is not great, it is foolish to select a respirator on the basis of price alone. The program administrator, with his comprehensive knowledge, should have a strong influence on, if not absolute control over, respirator purchases.

What about the small user who cannot afford (and may not need) to involve several people specifically in a respirator program? Does he not have to meet the same requirements that the program administrator does for the large user? Because the OSHA regulations do not differentiate between large and small users, the answer is yes! In a small firm, where only a few workers must 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 himself, if he is the only person who must wear a respirator.

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

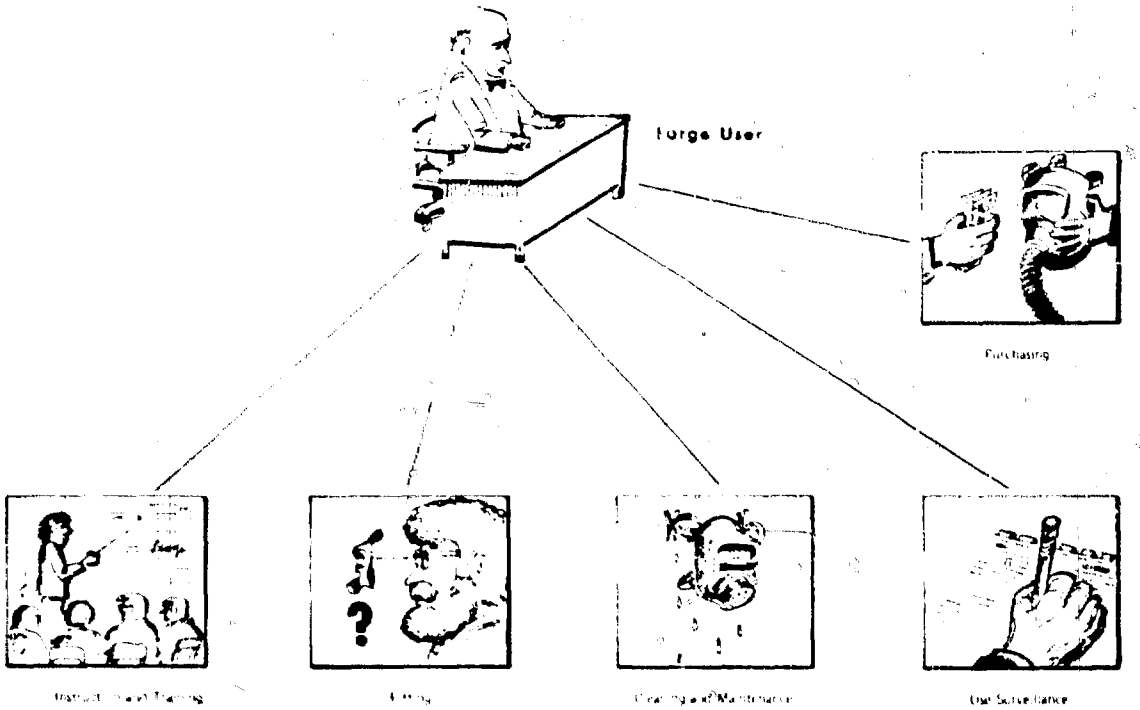


Fig. 11-1.
Respirator program administration.

for his own respirator. Like the written operating procedures, the exact administration of the respirator program must be tailored to the individual situation.

THE DUTIES OF THE PROGRAM ADMINISTRATOR

The program administrator is generally a supervisor and coordinator. He receives workplace hazard evaluations, medical information, reports on worker acceptance of particular devices, etc., which he uses for guidance.

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 must stay abreast of these changes by subscribing to pertinent publications, and must not hesitate to modify his program to meet changing conditions.

Thus, the administrator, of a large or small program, must 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.

CHAPTER TWELVE

SURVEILLANCE AND PROGRAM EVALUATION

SURVEILLANCE

Surveillance of Work Area Conditions and Worker Exposure

OSHA 1910.134 and Sec. 3.5.8 of ANSI Z88.2 state that surveillance of conditions in the work area and of worker exposure to respiratory hazards 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.

Medical Surveillance

OSHA 1910.134 and Sec. 3.7 of ANSI Z88.2 state that no one should be assigned to tasks requiring use of respirators unless he has been found physically able to do the work while wearing the respirator. Both standards declare that a physician shall determine what health and physical conditions are pertinent, and that respirator wearers' medical status should be reviewed periodically.

Pre-employment 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.

Periodic routine medical examinations shall be made to determine whether respirator wearers have been exposed to harmful levels of respiratory hazards. Examination frequency should be tailored to particular situations. 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 of body tissues and wastes should be made to measure respirator wearers' exposures to respiratory hazards.

EVALUATION OF RESPIRATOR PROGRAM EFFECTIVENESS

OSHA 1910.134 and Sec. 3.5.9 of ANSI Z88.2 state that respirator program effectiveness shall be inspected and evaluated regularly. 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.

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 should list plans to correct faults and the target dates for their implementation.

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Special thanks must be given to the Zia Company, Los Alamos, New Mexico, for their time and assistance in obtaining photographs of various types of respirators being used in typical work situations. The respirator manufacturers were also of great assistance in providing photographs of respirators.

APPENDIX A

29 CFR PART 1910.134

§ 1910.134 Respiratory protection.

(a) *Permissible practice.* (1) In the control of those occupational diseases caused by breathing air contaminated with harmful dusts, fogs, fumes, mists, gases, smokes, sprays, or vapors, the primary objective shall be to prevent atmospheric contamination. This shall be accomplished as far as feasible by accepted engineering control measures (for example, enclosure or confinement of the operation, general and local ventilation, and substitution of less toxic materials). When effective engineering controls are not feasible, or while they are being instituted, appropriate respirators shall be used pursuant to the following requirements.

(2) Respirators shall be provided by the employer when such equipment is necessary to protect the health of the employee. The employer shall provide the respirators which are applicable and suitable for the purpose intended. The employer shall be responsible for the establishment and maintenance of a respiratory protective program which shall include the requirements outlined in paragraph (b) of this section.

(3) The employee shall use the provided respiratory protection in accordance with instructions and training received.

(b) *Requirements for a minimal acceptable program.* (1) Written standard operating procedures governing the selection and use of respirators shall be established.

(2) Respirators shall be selected on the basis of hazards to which the worker is exposed.

(3) The user shall be instructed and trained in the proper use of respirators and their limitations.

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

(5) Respirators shall be regularly cleaned and disinfected. Those issued for the exclusive use of one worker should be cleaned after each day's use, or more often if necessary. Those used by more than one worker shall be thoroughly cleaned and disinfected after each use.

(6) Respirators shall be stored in a convenient, clean, and sanitary location.

(7) Respirators used routinely shall be inspected during cleaning. Worn or deteriorated parts shall be replaced. Respirators for emergency use such as self-contained devices shall be thoroughly inspected at least once a month and after each use.

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

(9) There shall be regular inspection and evaluation to determine the continued effectiveness of the program.

(10) Persons should 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 local physician shall determine what health and physical conditions are pertinent. The respirator user's medical status should be reviewed periodically (for instance, annually).

(11) Approved or accepted respirators shall be used when they are available. The respirator furnished shall provide adequate respiratory protection against the particular hazard for which it is designed in accordance with standards established by competent authorities. The U.S. Department of Interior, Bureau of Mines, and the U.S. Department of Agriculture are recognized as such authorities. Although respirators listed by the U.S. Department of Agriculture continue to be acceptable for protection against specified pesticides, the U.S. Department of the Interior, Bureau of Mines, is the agency now responsible for testing and approving pesticide respirators.

(c) *Selection of respirators.* Proper selection of respirators shall be made according to the guidance of American National Standard Practices for Respiratory Protection Z88.2-1969.

(d) *Air quality.* (1) Compressed air, compressed oxygen, liquid air, and liquid oxygen used for respiration shall be of high purity. Oxygen shall meet the requirements of the United States Pharmacopoeia for medical or breathing oxygen. Breathing air shall meet at least the requirements of the specification for Grade D breathing air as described in Compressed Gas Association Commodity Specification G-7.1-1966. Compressed oxygen shall not be used in supplied-air respirators or in open circuit self-contained breathing apparatus that have previously used compressed air. Oxygen must never be used with air line respirators.

(2) Breathing air may be supplied to respirators from cylinders or air compressors.

(i) Cylinders shall be tested and maintained as prescribed in the Shipping Container Specification Regulations of the Department of Transportation (49 CFR Part 178).

(ii) The compressor for supplying air shall be equipped with necessary safety and standby devices. A breathing air-type compressor shall be used. Compressors shall be constructed and situated so as to avoid entry of contaminated air

into the system and suitable in-line air purifying sorbent beds and filters installed to further assure breathing air quality. A receiver of sufficient capacity to enable the respirator wearer to escape from a contaminated atmosphere in event of compressor failure, and alarms to indicate compressor failure and overheating shall be installed in the system. If an oil-lubricated compressor is used, it shall have a high-temperature or carbon monoxide alarm, or both. If only a high-temperature alarm is used, the air from the compressor shall be frequently tested for carbon monoxide to insure that it meets the specifications in subparagraph (1) of this paragraph.

(3) Air line couplings shall be incompatible with outlets for other gas systems to prevent inadvertent servicing of air line respirators with nonrespirable gases or oxygen.

(4) Breathing gas containers shall be marked in accordance with American National Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained, Z48.1-1954; Federal Specification RR-A-1034, June 21, 1963, Air, Compressed for Breathing Purposes; or Interim Federal Specification GG-B-00675b, April 27 1988, Breathing Apparatus, Self-Contained.

(e) *Use of respirators.* (1) Standard procedures shall be developed for respirator use. These should include all information and guidance necessary for their proper selection, use, and care. Possible emergency and routine uses of respirators should be anticipated and planned for.

(2) The correct respirator shall be specified for each job. The respirator type is usually specified in the work procedures by a qualified individual supervising the respiratory protective program. The individual issuing them shall be adequately instructed to insure that the correct respirator is issued. Each respirator permanently assigned to an individual should be durably marked to indicate to whom it was assigned. This mark shall not affect the respirator performance in any way. The date of issuance should be recorded.

(3) Written procedures shall be prepared covering safe use of respirators in dangerous atmospheres that might be encountered in normal operations or in emergencies. Personnel shall be familiar with these procedures and the available respirators.

(i) In areas where the wearer, with failure of the respirator, could be overcome by a toxic or oxygen-deficient atmosphere, at least one additional man shall be present. Communications (visual, voice, or signal line) shall be maintained between both or all individuals present. Planning shall be such that only individual will be unaffected by any likely incident and have the proper rescue equipment to be able to assist the other(s) in case of emergency.

(ii) When self-contained breathing apparatus or hose masks with blowers are used in atmospheres immediately dangerous to life or health, standby men must be present with suitable rescue equipment.

(iii) Persons using air line respirators in atmospheres immediately hazardous to life or health shall be equipped with safety harnesses and safety lines for lifting or removing persons from hazardous atmospheres or other and equivalent provisions for the rescue of persons from hazardous atmospheres shall be used. A standby man or men with suitable self-contained breathing apparatus shall be at the nearest fresh air base for emergency rescue.

(4) Respiratory protection is no better than the respirator in use, even though it is worn conscientiously. Frequent random inspections shall be conducted by a qualified individual to assure that respirators are properly selected, used, cleaned, and maintained.

(5) For safe use of any respirator, it is essential that the user be properly instructed in its selection, use, and maintenance. Both supervisors and workers shall be so instructed by competent persons. Training shall provide the man an opportunity to handle the respirator, have it fitted properly, test its face-piece-to-face seal, wear it in normal air for a long familiarity period, and, finally, to wear it in a test atmosphere.

(i) Every respirator wearer shall 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 shall 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. Also, the absence of one or both dentures can seriously affect the fit of a facepiece. The worker's diligence in observing these factors shall be evaluated by periodic check. To assure proper protection, the facepiece fit shall be checked by the wearer each time he puts on the respirator. This may be done by following the manufacturer's facepiece fitting instructions.

(ii) Providing respiratory protection for individuals wearing corrective glasses is a serious problem. A proper seal cannot be established if the temple bars of eye glasses extend through the sealing edge of the full facepiece. As a temporary measure, glasses with short temple bars or without temple bars may be taped to the wearer's head. Wearing of contact lenses in contaminated atmospheres with a respirator shall not be allowed. Systems have been developed for mounting corrective lenses inside full facepieces. When a workman must wear corrective lenses as part of the facepiece, the facepiece and lenses shall be fitted by qualified individuals to provide good vision, comfort, and a gas-tight seal.

corrective spectacles or goggles are required, they shall be worn in a manner not to affect the fit of the facepiece. Proper selection of equipment will minimize or avoid this problem.

(f) *Maintenance and care of respirators.* (1) A program for maintenance and care of respirators shall be adjusted to the type of plant, working conditions, and hazards involved, and shall include the following basic services:

(i) Inspection for defects (including a leak check),

(ii) Cleaning and disinfecting,

(iii) Repair,

(iv) Storage.

Equipment shall be properly maintained to retain its original effectiveness.

(2) (i) All respirators shall be inspected routinely before and after each use. A respirator that is not routinely used but is kept ready for emergency use shall be inspected after each use and at least monthly to assure that it is in satisfactory working condition.

(ii) Self-contained breathing apparatus shall be inspected monthly. Air and oxygen cylinders shall be fully charged according to the manufacturer's instructions. It shall be determined that the regulator and warning devices function properly.

(iii) Respirator inspection shall include a check of the tightness of connections and the condition of the facepiece, headbands, valves, connecting tube, and canisters. Rubber or elastomer parts shall be inspected for pliability and signs of deterioration. Stretching and manipulating rubber or elastomer parts with a massaging action will keep them pliable and flexible and prevent them from taking a set during storage.

(iv) A record shall be kept of inspection dates and findings for respirators maintained for emergency use.

(3) Routinely used respirators shall be collected, cleaned, and disinfected as frequently as necessary to insure that proper protection is provided for the wearer. Each worker should be briefed on the cleaning procedure and be assured that he will always receive a clean and disinfected respirator. Such assurances are of greatest significance when respirators are not individually assigned to workers. Respirators maintained for emergency use shall be cleaned and disinfected after each use.

(4) Replacement or repairs shall be done only by experienced persons with parts designed for the respirator. No attempts shall be made to replace components or to make adjustment or repairs beyond the manufacturer's recommendations. Reducing or admission valves or regulators shall be returned to the manufacturer or to a trained technician for adjustment or repair.

(5) (i) After inspection, cleaning, and necessary repair, respirators shall be stored to protect against dust, sunlight, heat, extreme cold, excessive moisture, or damaging chemicals. Respirators placed at stations and work areas for emergency use should be quickly accessible at all times and should be stored in compartments built for the purpose. The compartments should be clearly marked. Routinely used respirators, such as dust respirators, may be placed in plastic bags. Respirators should not be stored in such places as lockers or tool boxes unless they are in carrying cases or cartons.

(ii) Respirators should be packed or stored so that the facepiece and exhalation valve will rest in a normal position and function will not be impaired by the elastomer setting in an abnormal position.

(iii) Instructions for proper storage of emergency respirators, such as gas masks and self-contained breathing apparatus, are found in "use and care" instructions usually mounted inside the carrying case lid.

(g) *Identification of gas mask canisters.* (1) The primary means of identifying a gas mask canister shall be by means of properly worded labels. The secondary means of identifying a gas mask canister shall be by a color code.

(2) All who issue or use gas masks falling within the scope of this section shall see that all gas mask canisters purchased or used by them are properly labeled and colored in accordance with these requirements before they are placed in service and that the labels and colors are properly maintained at all times thereafter until the canisters have completely served their purpose.

(3) On each canister shall appear in bold letters the following:

(i)—

Canister for _____
(Name for atmospheric contaminant)
or
Type N Gas Mask Canister

(ii) In addition, essentially the following wording shall appear beneath the appropriate phrase on the canister label: "For respiratory protection in atmospheres containing not more than _____ percent by volume of _____
_____"
(Name of atmospheric contaminant)

(iii) All of the markings specified above should be placed on the most conspicuous surface or surfaces of the canister.

(4) Canisters having a special high-efficiency filter for protection against radionuclides and other highly toxic particulates shall be labeled with a statement of the type and degree of protection afforded by the filter. The label shall be affixed to the neck end of, or to the gray stripe which is around and near the top of, the canister. The degree of protection shall be marked as the percent of penetration of the canister by a 0.3-micron-diameter dioctyl phthalate (DOP) smoke at a flow rate of 85 liters per minute.

(5) Each canister shall have a label warning that gas masks should be used only in atmospheres containing sufficient oxygen to support life (at least 16 percent by volume), since gas mask canisters are only designed to neutralize or remove contaminants from the air.

(6) Each gas mask canister shall be painted a distinctive color or combination of colors indicated in Table I-1. All colors used shall be such that they are clearly identifiable by the user and clearly distinguishable from one another. The color coating used shall offer a high degree of resistance to chipping, scaling, peeling, blistering, fading, and the effects of the ordinary atmospheres to which they may be exposed under normal conditions of storage and use. Appropriately colored pressure sensitive tape may be used for the stripes.

TABLE I-1

Atmospheric contaminants to be protected against	*Colors assigned**
Acid gases	White.
Hydrocyanic acid gas	White with ½-inch green stripe completely around the canister near the bottom.
Chlorine gas	White with ½-inch yellow stripe completely around the canister near the bottom.
Organic vapors	Black.
Ammonia gas	Green.
Acid gases and ammonia gas	Green with ½-inch white stripe completely around the canister near the bottom.
Carbon monoxide	Blue.
Acid gases and organic vapors	Yellow.
Hydrocyanic acid gas and chloropicrin vapor	Yellow with ½-inch blue stripe completely around the canister near the bottom.
Acid gases, organic vapors, and ammonia gases	Brown.
Radioactive materials, excepting tritium and noble gases	Purple (Magenta).
Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors	Canister color for contaminant, as designated above, with ½-inch gray stripe completely around the canister near the top.
All of the above atmospheric contaminants	Red with ½-inch gray stripe completely around the canister near the top.

*Gray shall not be assigned as the main color for a canister designed to remove acids or vapors.

NOTE: Orange shall be used as a complete body, or stripe color for any gases not included in this table. The user will need to refer to the canister label to determine the degree of protection the canister will afford.

Title 30—MINERAL RESOURCES

Chapter I—Bureau of Mines,

SUBCHAPTER B—RESPIRATORY PROTECTIVE APPARATUS; TESTS FOR PERMISSIBILITY; FEES

PART 11—RESPIRATORY PROTECTIVE DEVICES; TESTS FOR PERMISSIBILITY; FEES

PART 12—SUPPLIED-AIR RESPIRATORS

PART 13—GAS MASKS

PART 14—FILTER-TYPE DUST, FUME, AND MIST RESPIRATORS

PART 14a—NONEMERGENCY GAS RESPIRATORS (CHEMICAL CARTRIDGE RESPIRATORS, INCLUDING PAINT SPRAY RESPIRATORS)

Pursuant to the authority vested in the Secretary of the Interior under 37 Stat. 369, as amended 37 Stat. 681 (30 U.S.C. 3, 5, and 7), and the authority vested in the Secretary of the Interior and the Secretary of Health, Education, and Welfare under sections 202(h), 204, and 508 of the Federal Coal Mine Health and Safety Act of 1969 (30 U.S.C. 842(h), 844, and 957), there was published in the FEDERAL REGISTER for March 10, 1971 (36 F.R. 4652) a notice of proposed rule making wherein it was proposed to revoke Parts 11, 12, 13, 14, and 14a of Subchapter B, Chapter I, Title 30, Code of Federal Regulations (Bureau of Mines Schedules 13E, 14F, 19B, 21B, and 23B), and to substitute therefor a new Part 11, prescribing the approval procedures, establishing the fees, and consolidating and extending the requirements for obtaining joint approval of respirators by the Bureau of Mines, Department of the Interior and the National Institute for Occupational Safety and Health, Department of Health, Education, and Welfare.

Interested persons were afforded a period of 45 days from the date of publication of the notice within which to submit written comments, suggestions, or objections to the proposed amendments. Approximately 15 associations, companies, labor organizations, individuals, and State and Federal agencies submitted comments, suggestions, or objections. In addition interested parties informally conferred with officials of the Department of the Interior and the Department of Health, Education, and Welfare in March, April, October, and November 1971 in order to discuss the proposed amendments.

Some of the regulations have been revised as suggested; in other instances revisions have been made in view of the comments received.

The proposed regulations specified that protection factors for certain types of respirators would be determined by the Bureau during the course of testing. A suggestion was received that protection factors be determined for all types of respirators. After thorough consideration of this issue, the Bureau and the Institute have decided that although the concept of protection factors is valid, present technology in this area is insufficient to produce reliable data upon which to base such factors. Therefore, references to protection factors have been deleted from the regulations, with a view toward working to improve relevant technology and data in order to incorporate requirements for protection factors into Part 11 at a later date.

Other significant technical revisions are: (1) Performance requirements have replaced certain design specifications; and (2) tests have been included for powered air-purifying respirators.

Certain procedural revisions have also been made. The arrangement and numbering system of the proposed amendments has been totally redesignated so as to place all procedural requirements at the beginning of Part 11 (Subparts A through F), followed by all technical requirements (Subparts G through M). Expanded and more stringent quality control requirements have been established (Subpart E). Examples of causes which may result in revocation of the certificate of approval have been specified. The time limit for phasing out respirators approved under revoked Parts 11, 12, 13, 14, and 14a of this Title 30 has been clarified (see § 11.2).

A suggestion was received that models submitted for testing and approval be made only on regular production tooling with no operations included which would not be incorporated in regular production processing in order to insure that commercially produced respirators would be identical in all respects to those tested and approved under these regulations. This suggestion was carefully considered. However, it was determined by the Bureau and the Institute that such a requirement might well operate to obstruct advances in respirator technology, since substantial investment would be necessary to build production models with no adequate assurance of ultimate approval. Consequently it was decided to continue the testing of soundly designed and constructed prototype models; however, upon completion of such testing the Bureau and the Institute may require the applicant to resubmit a production model for additional testing prior to issuance of a certificate of approval (see §§ 11.11 (c) and 11.30).

Subchapter B of Chapter I, Title 30, Code of Federal Regulations, amended by revoking Parts 11, 12, 13, 14, and 14a, and substituting therefor a new Part 11—Respiratory Protective Devices; Tests for Permissibility; Fees, as set forth below is herewith promulgated and shall become effective 60 days following publication in the FEDERAL REGISTER.

W. T. PECORA,
Acting Secretary of the Interior.

FEBRUARY 17, 1972.

ELLIOT L. RICHARDSON,
Secretary of Health, Education, and Welfare.

MARCH 10, 1972.

AUTHORITY: The provisions of this Part 11 issued under sections 202(b), 204, and 508 of the Federal Coal Mine Health and Safety Act of 1969 (30 U.S.C. 842(b), 844, and 957) and 38 Stat. 930, as amended 87 Stat. 901 (30 U.S.C. 3, 5, and 7).

Subpart A—General Provisions

§ 11.1 Purpose.

The purpose of the regulations contained in this Part 11 is: (a) To establish procedures and prescribe requirements which must be met in filing applications for joint approval by the Bureau of Mines and the National Institute for Occupational Safety and Health of respirators or changes or modifications of approved respirators; (b) to establish a schedule of fees to be charged each applicant for the inspections, examinations, and testing conducted by the Bureau under the provisions of this part; (c) to provide for the issuance of certificates of approval or modifications of certificates of approval for respirators which have met the applicable construction, performance, and respiratory protection requirements set forth in this part; and (d) to specify minimum requirements and to prescribe methods to be employed by the Bureau and by the applicant in conducting inspections, examinations, and tests to determine the effectiveness of respirators used during entry into or escape from hazardous atmospheres.

§ 11.2 Approved respirators.

(a) Until March 30, 1974, respirators or combinations of respirators shall be considered to be approved for use during entry into hazardous mine atmospheres, escape from hazardous mine atmospheres, or both, where such respirators or combinations of respirators are: (1) The same in all respects as those respirators which have been approved after meeting the minimum requirements for performance and respiratory protection set forth in this Part 11; or (2) fabricated, assembled, or built under any approval, or any modification thereof, issued by the U.S. Bureau of Mines, Department of the Interior, in accordance with the schedules set forth below; and (3) maintained in an approved condition:

(i) Self-contained Breathing Apparatus, Bureau of Mines Schedules 13, March 5, 1919; 13A, January 21, 1930; 13B, August 12, 1935; 13C, July 9, 1946; 13D, September 22, 1956; and 13E, July 19, 1968.

(ii) Gas Masks, Bureau of Mines Schedule 14F, April 23, 1955.

(iii) Supplied-air Respirators, Bureau of Mines Schedule 19B, April 19, 1955.

(iv) Filter-type Dust, Fume, and Mist Respirators, Bureau of Mines Schedule 21B, January 19, 1965.

(v) Nonemergency Gas Respirators, Bureau of Mines Schedule 23B, August 4, 1959.

(b) After March 30, 1974, respirators or combinations of respirators shall be considered to be approved for use during entry into hazardous mine atmospheres, escape from hazardous mine atmospheres, or both, only where such respirators or combinations of such respirators are: (1) The same in all respects as those respirators which have been approved after meeting the minimum requirements for performance and respiratory protection prescribed in this Part 11; and (2) maintained in an approved condition.

§ 11.2–1 Selection, fit, use, and maintenance of approved respirators.

In order to insure the maximum amount of respiratory protection, approved respirators shall be selected,

fitted, used, and maintained in accordance with the provisions of the American National Standard Practices for Respiratory Protection, Z88.2, obtainable from American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

§ 11.3 Definitions.

As used in this part—

(a) "Air Contamination Level" means the standards of contamination levels prescribed by the Secretary of Labor in accordance with the provisions of the Occupational Safety and Health Act of 1970 (Public Law 91-596; 84 Stat. 1590).

(b) "Applicant" means an individual, partnership, company, corporation, association, or other organization that designs, manufactures, assembles, or controls the assembly of a respirator and who seeks to obtain a certificate of approval for such respirator.

(c) "Approval" means a certificate or formal document issued by the Bureau and the Institute stating that an individual respirator or combination of respirators has met the minimum requirements of this Part 11, and that the applicant is authorized to use and attach an approval label to any respirator, respirator container, or instruction card for any respirator manufactured or assembled in conformance with the plans and specifications upon which the approval was based, as evidence of such approval.

(d) "Approved" means conforming to the minimum requirements of this Part 11.

(e) "Auxiliary equipment" means a self-contained breathing apparatus, the use of which is limited in underground mine rescue and recovery operations to situations where the wearer has ready access to fresh air and at least one crew equipped with approved self-contained breathing apparatus of 2 hours or longer rating, is in reserve at a fresh-air base.

(f) "Bureau" means the U.S. Bureau of Mines, Department of the Interior.

(g) "Compressed breathing gas" means oxygen or air stored in a compressed state and supplied to the wearer in gaseous form.

(h) "Concentration limits for radionuclides" means the concentration limits set forth in Appendix B, Table 1, Column I of Title 10 CFR Part 20 by the Atomic Energy Commission.

(i) "dBA" means sound pressure levels in decibels, as measured with the A-weighted network of a standard sound level meter using slow response.

(j) "DOP" means a homogenous liquid aerosol, having a particle diameter of 0.3 micrometer, which is generated by vaporization and condensation of dioctyl phthalate.

(k) "Dust" means a solid mechanically produced particle with a size ranging from submicroscopic to macroscopic.

(l) Respirators "for entry into and escape from" means respiratory devices providing protection during entry into and escape from hazardous atmospheres.

(m) Respirators "for escape only" means respiratory devices providing protection only during escape from hazardous atmospheres.

(n) A "facepiece" or "mouthpiece" is a respirator component designed to provide a gas-tight or dust-tight fit with the face and may include headbands, valves, and connections for canisters, cartridges, filters, or respirable gas source.

(o) "Final inspection" means that activity carried out on a product after all manufacturing and assembly operations are completed to insure completeness and adherence to performance or other specifications, including satisfactory appearance.

(p) "Fume" means a solid condensation particle, generally less than 1 micrometer in diameter.

(q) "Gas" means an aeriform fluid which is in a gaseous state at ordinary temperature and pressure.

(r) "Hazardous atmosphere" means: (1) Any atmosphere containing a toxic or disease producing gas, vapor, dust, fume, mist, or pesticide, either immediately or not immediately dangerous to life or health; or (2) any oxygen-deficient atmosphere.

(s) A "hood" or "helmet" is a respirator component which covers the wearer's head and neck, or head, neck, and shoulders, and is supplied with incoming respirable air for the wearer to breathe. It may include a headharness and connection for a breathing tube.

(t) "Immediately dangerous to life or health" means conditions that pose an immediate threat to life or health or conditions that pose an immediate threat of severe exposure to contaminants, such as radioactive materials, which are likely to have adverse cumulative or delayed effects on health.

(u) "Incoming inspection" means the activity of receiving, examining, and accepting only those materials and parts whose quality conforms to specification requirements.

(v) "In-process inspection" means the control of products at the source of production and at each step of the manufacturing process, so that departures from specifications can be corrected before defective components or materials are assembled into the finished product.

(w) "Institute" means the National Institute for Occupational Safety and Health, Department of Health, Education, and Welfare.

(x) "Liquefied breathing gas" means oxygen or air stored in liquid form and supplied to the wearer in a gaseous form.

(y) "Mist" means a liquid condensation particle with a size ranging from submicroscopic to macroscopic.

(z) "Not immediately dangerous to life or health" means any hazardous atmosphere which may produce physical discomfort immediately, chronic poisoning after repeated exposure, or acute adverse physiological symptoms after prolonged exposure.

(aa) "Oxygen deficient atmosphere" means an atmosphere which contains an oxygen partial pressure of less than 148 millimeters of mercury (19.5 percent by volume at sea level).

(bb) "Pesticide" means (1) any substance or mixture of substances (including solvents and impurities) intended to prevent, destroy, repel, or mitigate any insect, rodent, nematode, fungus, weed, or other form of plant or animal life or virus, and (2) any substance or mixture of substances (including solvents and impurities) intended for use as a plant regulator, defoliant, or desiccant, as defined in the Federal Insecticide, Fungicide, and Rodenticide Act of 1947, as amended (7 U.S.C. 135-135k), excluding fumigants which are applied as gases or vapors or in a solid or liquid form as pellets or poured liquids for subsequent release as gases or vapors.

(cc) "Powered air-purifying respirator" means a device equipped with a facepiece, hood, or helmet, breathing tube, canister, cartridge, filter, canister with filter, or cartridge with filter, and a blower.

(dd) "Radionuclide" means an atom identified by the constitution of its nucleus (specified by the number of protons Z, number of neutrons N, and energy, or, alternatively, by the atomic number Z, mass number A=(N+Z), and atomic mass) which exists for a measurable time; decays or disintegrates spontaneously, emits radiation, and results in the formation of new nuclides.

(ee) "Respirable dust" means a dust particle aerodynamically capable of reaching the terminal airways of the lung.

(ff) "Respirator" means any device designed to provide the wearer with respiratory protection against inhalation of a hazardous atmosphere.

(gg) "Smoke" means the products of incomplete combustion of organic substances in the form of solid and liquid particles and gaseous products in air, usually of sufficient concentration to perceptibility obscure vision.

(hh) "Vapor" means the gaseous state of a substance that is solid or liquid at ordinary temperature and pressure.

§ 11.4 Incorporation by reference.

In accordance with 5 U.S.C. 552(a)(1), the technical publications to which reference is made in this Part 11, and which have been prepared by organizations other than the Bureau of Mines, are hereby incorporated by reference and made a part hereof. The incorporated technical publications are available for examination at Approval and Testing, Health and Safety Technical Support Center, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. In addition, copies of the American National Standard Practices for Respiratory Protection, Z88.2, are available for examination in every Coal Mine Health and Safety District and Subdistrict Office.

Subpart B—Application for Approval

§ 11.10 Application procedures.

(a) Inspection, examination, and testing leading to the approval of the types of respirators classified in Subpart F of this part shall be undertaken by the Bureau only pursuant to written applications which meet the minimum requirements set forth in this Subpart B.

(b) Applications shall be submitted to Approval and Testing, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, PA

15213, and shall be accompanied by a check, bank draft, or money order in the amount specified in Subpart C of this part payable to the order of the U.S. Bureau of Mines.

(c) Except as provided in § 11.64, the examination, inspection, and testing of all respirators shall be conducted by Approval and Testing, Bureau of Mines, Pittsburgh, Pa. 15213.

(d) Applicants, manufacturers, or their representatives may visit or communicate with Approval and Testing in order to discuss the requirements for approval of any respirator or the proposed designs thereof. No charge shall be made for such consultation and no written report shall be issued to applicants manufacturers, or their representatives by the Bureau as a result of such consultation.

§ 11.11 Contents of application.

(a) Each application for approval shall contain a complete written description of the respirator for which approval is requested together with drawings and specifications (and lists thereof) showing full details of construction of the respirator and of the materials used. Drawings and specifications (and lists thereof) shall be submitted in triplicate.

(b) Drawings shall be titled, numbered, and dated; any revision dates shall be shown on the drawings, and the purpose of each revision being sought shall be shown on the drawing or described on an attachment to the drawing to which it applies.

(c) Each application for approval shall contain a proposed plan for quality control which meets the minimum requirements set forth in Subpart E of this part.

(d) Each application shall contain a statement that the respirator has been pretested by the applicant as prescribed in § 11.64, and shall include the results of such tests.

(e) Each application for approval shall contain a statement that the respirator and component parts submitted for approval are either (1) prototypes, or (2) made on regular production tooling, with no operation included which will not be incorporated in regular production processing.

§ 11.12 Delivery of respirators by applicant; requirements.

(a) Each applicant shall, when an application is filed pursuant to § 11.10, be advised by the Bureau of the total number of respirators and component parts required for testing.

(b) The applicant shall deliver, at his own expense, the number of completely assembled respirators and component parts required for testing, to Approval and Testing, Bureau of Mines, Pittsburgh, Pa. 15213.

(c) Respirators and component parts submitted for approval must be made from materials specified in the application.

(d) One completely assembled respirator approved under the provisions of this part may be retained by the Bureau as a laboratory exhibit, the remaining respirators may be returned to the applicant at his own expense, upon written request within 30 days after notice of approval. If no such request is made, the respirators will be disposed of by the Bureau in such manner as it deems appropriate.

(e) Where a respirator fails to meet the requirements for approval set forth in this part, all respirators and components delivered in accordance with this section may be returned to the applicant at his own expense, upon written request within 30 days after notice of disapproval. If no such request is made, the respirators will be disposed of by the Bureau in such manner as it deems appropriate.

Subpart C—Fees

§ 11.20 Examination, inspection and testing of complete respirator assemblies; fees.

Except as provided in § 11.22, the following fees shall be charged by the Bureau for the examination, inspection and testing of complete respirator assemblies:

(a) Self-contained breathing apparatus—	
(1) Entry and escape, 1 hour or more	$3,500
(2) Entry and escape, less than 1 hour	2,750
(3) Escape only	2,000
(b) Gas masks, including pesticide gas masks—	
(1) Single hazard	1,100
(2) Type N	4,100
(c) Supplied-air respirators	750
(d) Dust, fume and mist respirators—	
(1) Single particulate hazard having an Air Contamination Level more than 0.05 mg./m.³ or 2 million particles per cubic foot	500
(2) Combination particulate hazards having an Air Contamination Level more than 0.05 mg./m.³ or 2 million particles per cubic foot	750
(3) Particulate hazards having an Air Contamination Level less than 0.05 mg./m.³ or 2 million particles per cubic foot, radon daughters	1,250
(4) All dusts, fumes and mists	2,000
(e) Chemical cartridge respirators	1,150
(f) Paint spray respirators	1,600
(g) Pesticide respirators	1,600

§ 11.21 Examination, inspection and testing of respirator components or subassemblies; fees.

Except as provided in § 11.22, the following fees shall be charged by the Bureau for the examination, inspection and testing of the individual respirator components or subassemblies:

(a) Facepieces	$450
(b) Canisters	900
(c) Cartridges	500
(d) Filters	650
(e) Hoses	250
(f) Blowers	250
(g) Harnesses	100

§ 11.22 Unlisted fees; additional fees; payment by applicant prior to approval.

(a) Applications for the examination, inspection and testing of complete respirator assemblies which are not listed in § 11.20, or for the examination, inspection, and testing of respirator components or subassemblies which are not listed in § 11.21, shall be accompanied by the following deposits:

(1) Complete respirator assembly	$1,500
(2) Each individual component or subassembly	500

(b) The Bureau reserves the right to conduct any examination, inspection, or test it deems necessary to determine the quality and effectiveness of any listed or unlisted respirator assembly or respirator component or subassembly, and to assess the cost of such examinations, inspections, or tests against the applicant prior to the issuance of any approval for the respiratory equipment examined, inspected, or tested.

(c) The fees charged for the examination, inspection, and testing of unlisted respirator assemblies, unlisted individual respirator components or subassemblies, and for the additional examination, inspection, and testing of listed respirator assemblies and components or subassemblies shall be at the rate of $100 per day for each man-day required to be expended by the Bureau.

(d) Upon completion of all examinations, inspections, and tests of unlisted respirator assemblies or components, or following the completion of any additional examination, inspections, or tests of listed assemblies, or components or subassemblies, including retesting subsequent to disapproval, the Bureau shall advise the applicant in writing of the total cost assessed and the additional amount, if any, which must be paid to the Bureau as a condition of approval.

(e) In the event the amount assessed by the Bureau for unlisted assemblies, or components or subassemblies is less than the amount of the deposit submitted in accordance with paragraph (a) of this section, the Bureau shall refund the overpayment upon the issuance of any approval or notice of disapproval.

Subpart D—Approval and Disapproval

§ 11.30 Certificates of approval; scope of approval.

(a) The Bureau and the Institute shall issue certificates of approval pursuant to the provisions of this subpart only for individual, completely assembled respirators which have been examined, inspected, and tested, and which meet the minimum requirements set forth in Subparts H through M of this part, as applicable.

(b) The Bureau and the Institute will not issue certificates of approval for any respirator component or for any respirator subassembly.

(c) The Bureau and the Institute shall not issue an informal notification of approval. However, if the application for approval, submitted in accordance with § 11.11, states that the submitted respirator and component parts are only prototypes, the Bureau will examine, inspect, and test such respirator and component parts in accordance with the

provisions of this Part 11. If, upon completion of such examinations, inspections and tests, it is found that the prototype meets the minimum requirements set forth in this part, the Bureau and the Institute may inform the applicant, in writing, of the results of the examinations, inspections, and tests, and may require him to resubmit respirators and component parts made on regular production tooling, with no operations included which will not be incorporated in regular production processing, for further examination, inspection, and testing, prior to issuance of the certificate of approval.

(d) Applicants required to resubmit respirators and component parts made on regular production tooling, with no operation included which will not be incorporated in regular production processing, shall be charged fees in accordance with Subpart C of this part.

§ 11.31 Certificates of approval; contents.

(a) The certificate of approval shall contain a classification and a description of the respirator or combination of respirators for which it is issued, as provided in this part.

(b) The certificate of approval shall specifically set forth any restrictions or limitations on the respirator's use in hazardous atmospheres.

(c) Each certificate of approval shall be accompanied by the drawings and specifications (and lists thereof) submitted by the applicant in accordance with § 11.11. These drawings and specifications shall be incorporated by reference in the certificate of approval, and shall be maintained by the applicant. The drawings and specifications listed in each certificate of approval shall set forth in detail the design and construction requirements which shall be met by the applicant during commercial production of the respirator.

(d) Each certificate of approval shall be accompanied by a reproduction of the approval label design to be employed by the applicant with each approved respirator, as provided in § 11.33.

(e) No test data or specific laboratory findings will accompany any certificate of approval, however, the Bureau will release pertinent test data and specific findings upon written request by the applicant, or as required by statute or regulation.

(f) Each certificate of approval shall also contain the approved quality control plan as specified in § 11.42.

§ 11.32 Notice of disapproval.

(a) If, upon the completion of the examinations, inspections, and tests required to be conducted in accordance with the provisions of this part, it is found that the respirator does not meet the minimum requirements set forth in this part, the Bureau and the Institute shall issue a written notice of disapproval to the applicant.

(b) Each notice of disapproval shall be accompanied by all pertinent data or findings with respect to the defects of the respirator for which approval was sought with a view to the possible correction of any such defects.

(c) The Bureau and the Institute shall not disclose, except to the applicant or as required by statute or regulation, any data, findings, or other information with respect to any respirator for which a notice of disapproval is issued.

§ 11.33 Approval labels and markings; approval of contents; use.

(a) Full-scale reproductions of approval labels and markings, and a sketch or description of the method of application and position on the harness, container, canister, cartridge, filter, or other component, together with instructions for the use and maintenance of the respirator shall be submitted to the Bureau and the Institute for approval.

(b) Approval labels shall bear the seals of the U.S. Bureau of Mines and the Department of Health, Education, and Welfare, the applicant's name and address, an approval number assigned by the Bureau, and, where appropriate, restrictions or limitations placed upon the use of the respirator by the Bureau and the Institute.

(c) The Bureau shall, where necessary, notify the applicant when additional labels, markings, or instructions will be required.

(d) Approval labels and markings shall only be used by the applicant to whom they were issued.

(e) Legible reproductions or abbreviated forms of the label approved by the Bureau and the Institute for use on each respirator shall be attached to or printed at the following locations:

Respirator type	Label type	Location
Self-contained breathing apparatus.	Entire	Harness assembly and canister (where applicable).
Gas mask	Entire	Mask container and canister
Supplied air respirator.	Entire	Respirator container or instruction card.
Dust, fume, and mist respirator.	Entire	Respirator container and filter container.
	Abbreviated.	Filters
Chemical-cartridge respirator, including paint spray respirator.	Entire	Respirator container, cartridge container, and filter containers (where applicable).
	Abbreviated.	Cartridges and filters and filter containers.
Pesticide respirator	Entire	Respirator container, and cartridge and filter containers.
	Abbreviated.	Cartridges and filters.

(f) The use of any Bureau and Institute approval label obligates the applicant to whom it is issued to maintain or cause to be maintained the approved quality control sampling schedule and the acceptable quality level for each characteristic tested, and to assure that it is manufactured according to the drawings and specifications upon which the certificate of approval is based.

(g) Each respirator, respirator component, and respirator container shall, as required by the Bureau and the Institute to assure quality control and proper use of the respirator, be labeled distinctly to show the name of the applicant, and the name and letters or numbers by which the respirator or respirator component is designated for trade purposes, and the lot number, serial number, or approximate date of manufacture.

§ 11.34 Revocation of certificates of approval.

The Bureau and the Institute reserve the right to jointly revoke, for cause, any certificate of approval issued pursuant to the provisions of this part. Such causes include, but are not limited to, misuse of approval labels and markings, misleading advertising, violations of section 109(e) of the Federal Coal Mine Health and Safety Act of 1969 (30 U.S.C. 819 (e)), and failure to maintain or cause to be maintained the quality control requirements of the certificate of approval.

§ 11.35 Changes or modification of approved respirators; issuance of modification of certificate of approval.

(a) Each applicant may, if he desires to change any feature of an approved respirator, request a modification of the original certificate of approval issued by the Bureau and the Institute for such respirator by filing an application for such modification in accordance with the provisions of this section.

(b) Applications shall be submitted as for an original certificate of approval, with a request for a modification of the existing certificate to cover any proposed change.

(c) The application shall be accompanied by appropriate drawings and specifications, and by a proposed quality control plan which meets the requirements of Subpart E of this part.

(d) The application for modification, together with the accompanying material, shall be examined by the Bureau to determine whether testing will be required.

(e) The Bureau shall inform the applicant of the fee required for any additional testing and the applicant will be charged for the actual cost of any examination, inspection, or test required, and such fees shall be submitted in accordance with the provisions of Subpart C of this part.

(f) If the proposed change or modification meets the requirements of this part, a formal certificate of modification will be issued, accompanied, where necessary, by a list of new and revised drawings and specifications covering the change(s) and reproductions of revised approval labels.

§ 11.36 Delivery of changed or modified approved respirator.

An approved respirator for which a formal certificate of modification has been issued shall be delivered, with proper markings and containers, by the applicant to the Bureau of Mines, Approval and Testing, 4800 Forbes Avenue, Pittsburgh, PA 15213, as soon as it is commercially produced.

Subpart E—Quality Control

§ 11.40 Quality control plans, filing requirements.

As a part of each application for approval or modification of approval submitted pursuant to this part, each applicant shall file with the Bureau and the Institute a proposed quality control plan which shall be designed to assure the quality of respiratory protection provided by the respirator for which approval is sought.

§ 11.41 Quality control plans; contents.

(a) Each quality control plan shall contain provisions for the management of quality, including: (1) Requirements for the production of quality data and the use of quality control records; (2) control of engineering drawings, documentations, and changes; (3) control and calibration of measuring and test equipment; (4) control of purchased material to include incoming inspection; (5) lot identification, control of processes, manufacturing, fabrication, and assembly work conducted in the applicant's plant; (6) audit of final inspection of the completed product; and, (7) the organizational structure necessary to carry out these provisions.

(b) Each provision for incoming and final inspection in the quality control plan shall include a procedure for the selection of a sample of respirators and the components thereof for testing, in accordance with procedures set forth in Military Standard MIL-STD-105D, "Sampling Procedures and Tables for Inspection by Attributes," or Military Standard MIL-STD-414, "Sampling Procedures and Tables for Inspection by Variables for Percent Defective," or an approved equivalent sampling procedure, or an approved combination of sampling procedures. Incoming bulk raw material inspection or verification of specification, and in-process inspection shall be sufficient to ensure control of product quality through the manufacturing cycle.

(c) The sampling procedure shall include a list of the characteristics to be tested by the applicant or his agent.

(d) The characteristics listed in accordance with paragraph (c) of this section shall be classified according to the potential effect of such defect and grouped into the following classes:

(1) *Critical.* A defect that judgment and experience indicate is likely to result in a condition immediately hazardous to life or health for individuals using or depending upon the respirator;

(2) *Major A.* A defect, other than critical, that is likely to result in failure to the degree that the respirator does not provide any respiratory protection, or a defect that reduces protection and is not detectable by the user;

(3) *Major B.* A defect, other than Major A or critical, that is likely to result in reduced respiratory protection, and is detectable by the user; and

(4) *Minor.* A defect that is not likely to materially reduce the usability of the respirator for its intended purpose, or a defect that is a departure from established standards and has little bearing on the effective use or operation of the respirator.

(e) The quality control inspection test method to be used by the applicant or his agent for each characteristic required to be tested shall be described in detail.

(f) Each item manufactured shall be 100 percent inspected for defects in all critical characteristics and all defective items shall be rejected.

(g) The Acceptable Quality Level (AQL) for each major or minor defect so classified by the applicant shall be:

(1) *Major A.* 1.0 percent;

(2) *Major B.* 2.5 percent; and

(3) *Minor.* 4.0 percent.

(h) Except as provided in paragraph (i) of this section, inspection level II as described in MIL-STD-105D, or inspection level IV as described in MIL-STD-414, shall be used for major and minor characteristics and 100 percent inspection for critical characteristics.

(i) Subject to the approval of the Bureau and the Institute, where the quality control plan provisions for raw material, processes, manufacturing, and fabrication inspection are adequate to insure control of finished article quality, destructive testing of finished articles may be conducted at a lower level of inspection than that specified in paragraph (h) of this section.

§ 11.42 Proposed quality control plans; approval by the Bureau and the Institute.

(a) Each proposed quality control plan submitted in accordance with this subpart shall be reviewed by the Bureau and the Institute to determine its effectiveness in insuring the quality of respiratory protection provided by the respirator for which an approval is sought.

(b) If the Bureau and the Institute determine that the proposed quality control plan submitted by the applicant will not insure adequate quality control, the Bureau and the Institute shall require the applicant to modify the procedures and testing requirements of the plan prior to approval of the plan and issuance of any certificate of approval.

(c) Approved quality control plans shall constitute a part of and be incorporated into any certificate of approval issued by the Bureau and the Institute, and compliance with such plans by the applicant shall be a condition of approval.

§ 11.43 Quality control records; review by the Bureau and the Institute; revocation of approval.

(a) The applicant shall keep quality control inspection records sufficient to carry out the procedures required in MIL-STD-105D or MIL-STD-414, or an approved equivalent sampling procedure.

(b) The Bureau and the Institute reserve the right to have their representatives inspect the applicant's quality control test methods, equipment, and records, and to interview any employee or agent of the applicant in regard to quality control test methods, equipment, and records.

(c) The Bureau and the Institute reserve the right to jointly revoke, for cause, any certificate of approval where it is found that the applicant's quality control test methods, equipment, or records do not insure effective quality control over the respirator for which the approval was issued.

Subpart F—Classification of Approved Respirators; Scope of Approval; Atmospheric Hazards; Service Time

§ 11.50 Types of respirators to be approved; scope of approval.

Approvals shall be issued for the types of respirators which have been classified pursuant to this Subpart F, have been inspected, examined and tested by the Bureau in accordance with the provisions of Subparts G through M of this part, and have been found to provide respiratory protection for fixed periods of time against the hazards specified in such approval.

§ 11.51 Entry and escape, or escape only; classification.

Respirators described in Subparts H through M of this part shall be classified for use as follows:

(a) *Entry and escape.* Respirators designed and approved for use during entry into a hazardous atmosphere, and for escape from a hazardous atmosphere; or,

(b) *Escape only.* Respirators designed and approved for use only during escape from a hazardous atmosphere.

§ 11.52 Respiratory hazards; classification.

Respirators described in Subparts H through M of this part shall be classified as approved for use against any or all of the following respiratory hazards:

(a) Oxygen deficiency;

(b) Gases and vapors;

(c) Particles, including dusts, fumes and mists; and

(d) Pesticides.

§ 11.53 Service time; classification.

(a) Respirators described in Subparts H through M of this part shall be classified, where applicable, as approved for use during the following prescribed service times:

(1) Four hours;

(2) Three hours;

(3) Two hours;

(4) One hour;

(5) Forty five minutes;

(6) Thirty minutes;

(7) Fifteen minutes;

(8) Ten minutes;

(9) Five minutes;

(10) Three minutes.

(b) Other service times may be prescribed by the Bureau and the Institute.

Subpart G—General Construction and Performance Requirements

§ 11.60 Construction and performance requirements; general.

(a) The Bureau and the Institute shall issue approvals for the types of respirators described in Subparts H through M

of this part which have met the minimum requirements set forth for such respirators in this Part 11.

(b) In addition to the types of respirators specified in Subparts H through M, the Bureau and the Institute shall issue approvals for other respiratory protective devices not specifically described in this Part 11 subject to such additional requirements as may be imposed in accordance with § 11.62(c).

§ 11.61 General construction requirements.

(a) Respirators will not be accepted by the Bureau for examination, inspection and testing unless they are designed on sound engineering and scientific principles, constructed of suitable materials and evidence good workmanship.

(b) Respirator components which come into contact with the wearer's skin shall be made of nonirritating materials.

(c) Components replaced during or after use shall be constructed of materials which will not be damaged by normal handling.

(d) Mouthpieces, hoods, helmets, and facepieces, except those employed in single-use respirators, shall be constructed of materials which will withstand repeated disinfection as recommended by the applicant in his instructions for use of the device.

(e) The components of each respirator approved by the Bureau and the Institute, for use where permissibility is required, shall meet the requirements for permissibility and intrinsic safety set forth in Part 18, Subchapter D of this chapter (Bureau of Mines Schedule 2G).

§ 11.62 Component parts; minimum requirements.

(a) The component parts of each respirator shall be:

(1) Designed, constructed, and fitted to insure against creation of any hazard to the wearer;

(2) Assembled to permit easy access for inspection and repair of functional parts; and

(3) Assembled to permit easy access to parts which require periodic cleaning and disinfecting.

(b) Replacement parts shall be designed and constructed to permit easy installation and to maintain the effectiveness of the respirator.

§ 11.63 Test requirements; general.

(a) Each respirator and respirator component shall when tested by the applicant and by the Bureau, meet the applicable requirements set forth in Subparts H through M of this part.

(b) Where a combination respirator is assembled from two or more types of respirators, as described in this part, each of the individual respirator types which have been combined shall, as applicable, meet the minimum requirements for such respirators set forth in Subparts H through M of this part, and such combination respirators, except as specified in § 11.70(b)(2), will be classified by the type of respirator in the combination which provides the least protection to the user.

(c) In addition to the minimum requirements set forth in Subparts H through M of this part, the Bureau and the Institute reserve the right to require as a further condition of approval, any additional requirements deemed necessary to establish the quality, effectiveness, and safety of any respirator used as protection against hazardous atmospheres.

(d) Where it is determined after receipt of an application that additional requirements will be required for approval, the Bureau will notify the applicant in writing of these additional requirements, and necessary examinations, inspections, or tests, stating generally the reasons for such requirements, examinations, inspections, or tests.

§ 11.64 Pretesting by applicant; approval of test methods by the Bureau.

(a) Prior to making or filing any application for approval or modification of approval, the applicant shall conduct, or cause to be conducted, examinations, inspections, and tests of respirator performance which are equal to or exceed the severity of those prescribed in this part.

(b) With the application, the applicant shall provide a statement to the Bureau showing the types and results of the examinations, inspections, and tests required under paragraph (a) of this section and state that the respirator meets the minimum requirements of Subparts H through M of this part, as applicable. Complete examination, inspection, and test data shall be retained on file by the applicant and be submitted, upon request, to the Bureau.

(c) The Bureau may, upon written request by the applicant, provide drawings and descriptions of its test equipment and otherwise assist the applicant in establishing a test laboratory or securing the services of a testing agency.

(d) The Bureau will not issue an approval to the applicant until it has validated the applicant's test results.

§ 11.65 Conduct of examinations, inspections, and tests by the Bureau and the Institute; assistance by applicant; observers; recorded data; public demonstrations.

(a) All examinations, inspections, and tests conducted pursuant to Subparts H through M of this part will be under the sole direction and control of the Bureau and the Institute.

(b) The Bureau and the Institute may, as a condition of approval, require the assistance of the applicant or agents of the applicant during the assembly, disassembly, or preparation of any respirator or respirator component prior to testing or in the operation of such equipment during testing.

(c) Only Bureau and Institute personnel, persons assisting the Bureau pursuant to paragraph (b) of this section, and such other persons as are requested by the Bureau, the Institute, or the applicant to be observers, shall be present during any examination, inspection, or test conducted prior to the issuance of an approval by the Bureau and the Institute for the equipment under consideration.

(d) The Bureau and the Institute shall hold as confidential any analyses, drawings, specifications, or materials submitted by the applicant and shall not disclose any principles or patentable features of such equipment, except as required by statute or regulation.

(e) As a condition of each approval issued for any respirator the Bureau and the Institute reserve the right, following the issuance of such approval, to conduct such public tests and demonstrations of the approved respiratory equipment as is deemed appropriate.

§ 11.66 Withdrawal of applications; refund of fees.

(a) Any applicant may, upon a written request submitted to the Bureau or the Institute, withdraw any application for approval of any respirator.

(b) Upon receipt of a written request for the withdrawal of an application, the Bureau shall determine the total man-days expended and the amount due for services already performed during the course of any examinations, inspections, or tests conducted pursuant to such application. The total amount due shall be determined in accordance with the provisions of § 11.22 and assessed against the fees submitted by the applicant. If the total amount assessed is less than the fees submitted, the Bureau shall refund the balance together with a statement of the charges made for services rendered.

Subpart H—Self-Contained Breathing Apparatus

§ 11.70 Self-contained breathing apparatus; description.

(a) Self-contained breathing apparatus, including all completely assembled, portable, self-contained devices designed for use as respiratory protection during entry into and escape from or escape only from hazardous atmospheres, are described as follows:

(1) *Closed-circuit apparatus.* An apparatus of the type in which the exhalation is rebreathed by the wearer after the carbon dioxide has been effectively removed and a suitable oxygen concentration restored from sources composed of:

(i) Compressed oxygen; or

(ii) Chemical oxygen; or

(iii) Liquid-oxygen.

(2) *Open-circuit apparatus.* An apparatus of the following types from which exhalation is vented to the atmosphere and not rebreathed:

(i) *Demand-type apparatus.* An apparatus in which the pressure inside the facepiece in relation to the immediate environment is positive during exhalation and negative during inhalation.

(ii) *Pressure-demand-type apparatus.* An apparatus in which the pressure inside the facepiece in relation to the immediate environment is positive during both inhalation and exhalation.

(b) The following respirators may be classified as designed and approved for

use during emergency entry into a hazardous atmosphere: A combination respirator which includes a self-contained breathing apparatus and a Type "C" or Type "CE" supplied air respirator, where (1) the self-contained breathing apparatus is classified for 3-, 5-, or 10-minute service time and the air line supply is used during entry, or (2) the self-contained breathing apparatus is classified for 15 minutes or longer service time and not more than 20 percent of the rated capacity of the air supply is used during entry.

(c) Self-contained breathing apparatus classified for less than 1 hour service time will not be approved for use during underground mine rescue and recovery operations except as auxiliary equipment.

(d) Self-contained breathing apparatus classified for less than 30 minutes' service time will not be approved for use as auxiliary equipment during underground mine rescue and recovery operations.

§ 11.71 Self-contained breathing apparatus; required components.

(a) Each self-contained breathing apparatus described in § 11.70 shall, where its design requires, contain the following component parts:

(1) Facepiece or mouthpiece, and noseclip;
(2) Respirable breathing gas container;
(3) Supply of respirable breathing gas;
(4) Gas pressure or liquid level gages;
(5) Timer;
(6) Remaining service life indicator or warning device;
(7) Hand-operated valves;
(8) Breathing bag;
(9) Safety relief valve or safety relief system; and
(10) Harness.

(b) The components of each self-contained breathing apparatus shall meet the minimum construction requirements set forth in Subpart G of this part.

§ 11.72 Breathing tubes; minimum requirements.

(a) Flexible breathing tubes used in conjunction with breathing apparatus shall be designed and constructed to prevent:

(1) Restriction of free head movement;
(2) Disturbance of the fit of facepieces and mouthpieces;
(3) Interference with the wearer's activities; and,
(4) Shutoff of airflow due to kinking, or from chin or arm pressure.

§ 11.73 Harnesses; installation and construction; minimum requirements.

(a) Each apparatus shall, where necessary, be equipped with a suitable harness designed and constructed to hold the components of the apparatus in position against the wearer's body.

(b) Harnesses shall be designed and constructed to permit easy removal and replacement of apparatus parts, and, where applicable, provide for holding a full facepiece in the ready position when not in use.

§ 11.74 Apparatus containers; minimum requirements.

(a) Apparatus may be equipped with a substantial, durable container bearing markings which show the applicant's name, the type and commercial designation of the respirator it contains, and all appropriate approval labels.

(b) Containers supplied by the applicant for carrying or storing self-contained breathing apparatus will be inspected, examined, and tested as components of the respirator for which approval is sought.

(c) Containers for self-contained breathing apparatus shall be designed and constructed to permit easy removal of the apparatus.

§ 11.75 Half-mask facepieces, full facepieces, mouthpieces; fit; minimum requirements.

(a) Half-mask facepieces and full facepieces shall be designed and constructed to fit persons with various facial shapes and sizes, either (1) by providing more than one facepiece size, or (2) by providing one facepiece size which will fit varying facial shapes and sizes.

(b) Full facepieces shall provide for the optional use of corrective spectacles or lenses which shall not reduce the respiratory protective qualities of the apparatus.

(c) Apparatus with mouthpieces shall be equipped with noseclips which are securely attached to the mouthpiece or apparatus and provide an airtight seal.

(d) Facepieces shall be designed to prevent eyepiece, spectacle, and lens fogging.

§ 11.76 Facepieces; eyepieces; minimum requirements.

(a) Facepieces shall be designed and constructed to provide adequate vision which is not distorted by the eyepiece.

(b) All eyepieces shall be designed and constructed to meet the impact and penetration requirements specified in Federal Specification, Mask, Air Line, and Respirator, Air Filtering, Industrial, GGG-M-125d, October 11, 1965. This Federal Specification is available from the Government Printing Office or the General Services Administration.

§ 11.77 Inhalation and exhalation valves; minimum requirements.

(a) Inhalation and exhalation valves shall be provided where necessary and protected against damage and distortion.

(b) Exhalation valves shall be:

(1) Protected against external influence, and
(2) Designed and constructed to prevent inward leakage of contaminated air.

§ 11.78 Head harnesses; minimum requirements.

(a) Facepieces shall be equipped with adjustable and replaceable head harnesses designed and constructed to provide adequate tension during suspension and an even distribution of pressure over the entire area in contact with the face.

(b) Mouthpieces shall be equipped, where applicable, with adjustable and replaceable head straps designed and constructed to hold the mouthpiece in place.

§ 11.79 Breathing gas; minimum requirements.

(a) Breathing gas used to supply apparatus shall be respirable and contain no less than 19.5 (dry atmosphere) volume percent of oxygen.

(b) Oxygen, including liquid oxygen, shall meet the minimum requirements for medical or breathing oxygen set forth in the U.S. Pharmacopeia.

(c) Compressed, gaseous breathing air shall meet the applicable minimum grade requirements for Type I gaseous air set forth in the Compressed Gas Association Commodity Specification for Air, G-7.1 (Grade D or higher quality).

(d) Compressed, liquefied breathing air shall meet the applicable minimum grade requirements for Type II liquid air set forth in the Compressed Gas Association Commodity Specification for Air, G-7.1 (Grade B or higher quality).

§ 11.79-1 Interchangeability of oxygen and air prohibited.

Approvals shall not be issued by the Bureau and the Institute for any apparatus, combination of respirator assemblies, or any apparatus or respirator component which is designed or constructed to permit the interchangeable use of oxygen and air.

§ 11.80 Compressed breathing gas and liquified breathing gas containers; *minimum requirements.*

(a) Compressed breathing gas and liquefied breathing gas containers shall meet the minimum requirements of the Department of Transportation for Interstate shipment of such containers when fully charged.

(b) Such containers shall be permanently and legibly marked to identify their contents, e.g., compressed breathing air, compressed breathing oxygen, liquefied breathing air, or liquefied breathing oxygen.

(c) Containers normally removed from apparatus for refilling shall be equipped with a dial indicating gage which shows the pressure in the container.

(d) Compressed breathing gas contained valves or a separate charging system or adapter provided with each apparatus shall be equipped with outlet threads specified for the service by the American National Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections, B57.1 (1965), obtainable from American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

§ 11.81 Gas pressure gages; minimum requirements.

(a) Gas pressure gages employed on compressed breathing gas containers shall be calibrated in pounds per square inch.

(b) Liquid-level gages shall be calibrated in fractions of total container capacity, or in units of liquid volume.

(c) Gas pressure gages other than those specified in paragraphs (a) and (b) of this section shall be calibrated in:

(1) Pounds per square inch, or

(2) In fractions of total container capacity, or

(3) Both in pounds per square inch inch and fractions of total container capacity.

(d) (1) Dial-indicating gages shall be reliable to within ±5 percent of full scale when tested both up and down the scale at each of 5 equal intervals.

(2) The full scale graduation of dial-indicating gages shall not exceed 150 percent of the maximum rated cylinder pressures specified for the container in applicable Department of Transportation specifications or permits.

(e) (1) Stem-type gages shall be readable by sight and by touch and shall have a stem travel distance of not less than one-fourth inch between each graduation.

(2) A minimum of five graduations shall be engraved on the stem of each gage and these graduations shall include readings for empty, one-quarter, one-half, three-quarters, and full.

(3) Stem gage readings shall not vary from true readings by more than one-sixteenth inch per inch of stem travel.

(f) The loss of gas through a broken gage or severed gage connection shall not exceed 70 liters per minute when the cylinder pressure is 8,900 kN/m.² (1,000 pounds per square inch gage) or when the liquid level is at one-half.

(g) Where gages are connected to the apparatus through a gage line, the gage and line shall be capable of being isolated from the apparatus except where the failure of the gage or line would not impair the performance or service life of the apparatus.

(h) Oxygen pressure gages shall have the words, "Oxygen" and "Use No Oil," marked prominently on the gage.

(i) (1) Apparatus using compressed breathing gas, except apparatus classified for escape only, shall be equipped with gages visible to the wearer which indicate the remaining gas content in the container.

(2) Apparatus using liquefied breathing gas, except apparatus classified for escape only, shall be equipped with gages visible to the wearer which indicate the remaining liquid content in the container; however, where the liquid content cannot be rapidly vented, and the service time of the device begins immediately after filling, a timer shall be provided in place of a visible gage.

§ 11.82 Timers; elapsed time indicators; remaining service life indicator; minimum requirements.

(a) Elapsed time indicators shall be provided for apparatus with a chemical oxygen source, except:

(1) Apparatus used for escape only; or,

(2) Liquefied breathing gas apparatus equipped with gages visible to the wearer which indicate the remaining liquid content in the container.

(b) The timer or other indicator shall be accurately calibrated in minutes of remaining service life.

(c) Timers shall be readable by sight and by touch during use by the wearer.

(d) Timers shall be equipped with automatically preset alarms which will warn the wearer for a period of 7 seconds or more after the preset time has elapsed.

(e) Remaining service-life indicators or warning devices shall be provided in addition to a pressure gage on compressed gas self-contained breathing apparatus, except apparatus used for escape only, and shall operate automatically without preadjustment by the wearer.

(f) Each remaining service-life indicator or warning device shall give an alarm when the remaining service life of the apparatus is reduced within a range of 20 to 25 percent of its rated service time.

§ 11.83 Hand-operated valves; minimum requirements.

(a) Hand-operated valves shall be designed and constructed to prevent removal of the stem from the valve body during normal usage to insure against a sudden release of the full pressure of the container when the valve is opened.

(b) Valves shall be designed or positioned to prevent accidental opening and closing, and damage from external forces.

(c) Valves operated during use of the apparatus shall be installed in locations where they can be readily adjusted by the wearer.

(d) Main-line valves, designed and constructed to conserve gas in the event of a regulator or demand valve failure, shall be provided in addition to gas container valves, except when such failure will not affect performance.

(e) Hand-operated bypass systems designed and constructed to permit the wearer to breathe and to conserve his gas supply in the event of a regulator or demand valve failure, shall be provided where necessary.

(f) Valves installed on apparatus shall be clearly distinguishable from one another by sight and touch.

(g) The bypass system valve control shall be colored red.

(h) A main-line or bypass valve or system will not be required on apparatus for escape only.

(i) Safety relief valves or systems, designed and constructed to release excess pressure in the breathing circuit, shall be provided on closed-circuit apparatus, and shall meet the following requirements:

(1) The relief valve or system shall operate automatically when the pressure in the breathing circuit on the inhalation side of the breathing bag reaches 12 mm. (one-half inch) water-column height or pressure above the minimum pressure required to fill the breathing bag, within the breathing resistance requirements for the apparatus.

(2) The relief valve or system shall be designed to prevent external atmospheres from entering the breathing circuit.

(3) The relief valve or system shall be designed to permit manual overriding for test purposes and in the event of a failure in the valve or system.

§ 11.84 Breathing bags; minimum requirements.

(a) Breathing bags shall have sufficient volume to prevent gas waste during exhalation and to provide an adequate reserve for inhalation.

(b) Breathing bags shall be constructed of materials which are flexible and resistant to gasoline vapors.

(c) Breathing bags shall be installed in a location which will protect them from damage or collapse by external forces, except on apparatus classified for escape only.

§ 11.85 Self-contained breathing apparatus; performance requirements; general.

Self-contained breathing apparatus and the individual components of each such device shall as applicable meet the requirements specified in §§ 11.85–1 through 11.85–19.

§ 11.85–1 Component parts exposed to oxygen pressures; minimum requirements.

Each applicant shall certify that the materials employed in the construction of component parts exposed to oxygen pressures above atmospheric pressure are safe and compatible for their intended use.

§ 11.85–2 Compressed gas filters; minimum requirements.

All self-contained breathing apparatus using compressed gas shall have a filter downstream of the gas source to effectively remove particles from the gas stream.

§ 11.85–3 Breathing bag test.

(a) Breathing bags will be tested in an air atmosphere saturated with gasoline vapor at room temperature (24°–30° C./75°–85° F.) for a continuous period of twice the rated time of the apparatus (except for apparatus for escape only where the test period shall be the rated time of the apparatus).

(b) The bag will be operated during this test by a breathing machine with 24 respirations per minute and a minute-volume of 40 liters.

(c) A breathing machine cam with a work rate of 422 kg.-m./min. will be used.[1]

(d) The air within the bag(s) shall not contain more than 100 parts per million of gasoline vapor at the end of the test.

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[1] Silverman, L., C. Lee, T. Plotkin, J. Amory, and A. B. Tansey, Fundamental Factors in Design of Protective Equipment, O.S.R.D. Report No. 5782, issued Apr. 1, 1945. The dimensions of the breathing machine cam are available from the Bureau upon request.

§ 11.85–4 Weight requirement.

(a) The completely assembled and fully charged apparatus shall not weigh more than 16 kg. (35 pounds); however, where the weight decreases by more than 25 percent of its initial charge weight during its rated service life, the maximum allowable weight of a completely assembled and fully charged apparatus shall be 18 kg. (40 pounds).

(b) Where an apparatus employs equipment which contributes materially to the wearer's comfort, e.g., a cooling system, the completely assembled and fully charged apparatus shall not weigh more than 13 kg. (40 pounds) regardless of the decrease in weight during use.

§ 11.85–5 Breathing resistance test; inhalation.

(a) Resistance to inhalation airflow will be measured in the facepiece or mouthpiece while the apparatus is operated by a breathing machine as described in § 11.85–3.

(b) The inhalation resistance of open-circuit apparatus shall not exceed 32 mm. (1.25 inch) water-column height (at a flow rate of 120 liters per minute).

(c) The inhalation resistance of closed-circuit apparatus shall not exceed the difference between exhalation resistance (§ 11.85–6(e)) and 10 cm. (4 inches) water-column height.

§ 11.85–6 Breathing resistance test; exhalation.

(a) Resistance to exhalation airflow will be measured in the facepiece or mouthpiece of open-circuit apparatus with air flowing at a continuous rate of 85 liters per minute.

(b) The exhalation resistance of demand apparatus shall not exceed 25 mm. (1 inch) water-column height.

(c) The exhalation resistance of pressure-demand apparatus shall not exceed the static pressure in the facepiece by more than 51 mm. (2 inches) water-column height.

(d) The static pressure (at zero flow) in the facepiece shall not exceed 38 mm. (1.5 inches) water-column height.

(e) Resistance to exhalation airflow will be measured in the facepiece or mouthpiece of closed-circuit apparatus with a breathing machine as described in § 11.85–3, and the exhalation resistance shall not exceed 51 mm. (2 inches) water-column height.

§ 11.85–7 Exhalation valve leakage test.

(a) Dry exhalation valves and valve seats will be subjected to a suction of 25 mm. (1 inch) water-column height while in a normal operating position.

(b) Leakage between the valve and the valve seat shall not exceed 30 milliliters per minute.

§ 11.85–8 Gas flow test; open-circuit apparatus.

(a) A static-flow test will be performed on all open-circuit apparatus.

(b) The flow from the apparatus shall be greater than 200 liters per minute when the pressure in the facepiece of demand-apparatus is lowered by 51 mm. (2 inches) water-column height when full container pressure is applied.

(c) Where pressure demand apparatus are tested, the flow will be measured at zero gage pressure in the facepiece.

(d) Where apparatus with compressed-breathing-gas containers are tested, the flow test shall also be made with 3,450 kN/m.² (500 p.s.i.g.) container pressure applied.

§ 11.85–9 Gas flow test; closed-circuit apparatus.

(a) Where oxygen is supplied by a constant-flow device only, the rate of flow shall be at least 3 liters per minute for the entire rated service time of the apparatus.

(b) Where constant flow is used in conjunction with demand flow, the constant flow shall be greater than 1.5 liters per minute for the entire rated service time.

(c) All demand-flow devices shall provide at least 30 liters of oxygen per minute when in the fully open position.

§ 11.85–10 Service time test; open-circuit apparatus.

(a) Service time will be measured with a breathing machine as described in § 11.85–3.

(b) The open-circuit apparatus will be classified according to the length of time it supplies air or oxygen to the breathing machine.

(c) The service time obtained on this test will be used to classify the open-circuit apparatus in accordance with § 11.53.

§ 11.85–11 Service time test; closed-circuit apparatus.

(a) The closed-circuit apparatus will be classified according to the length of time it supplies adequate breathing gas to the wearer during man test No. 4 described in Table 4.

(b) The service time obtained on man test No. 4 will be used to classify the closed-circuit apparatus in accordance with § 11.53.

§ 11.85–12 Test for carbon dioxide in inspired gas; open- and closed-circuit apparatus; maximum allowable limits.

(a) Open-circuit apparatus:

(1) The concentration of carbon dioxide in inspired gas in open-circuit apparatus will be measured at the mouth while the apparatus mounted on a dummy head is operated by a breathing machine.[3]

(2) The breathing rate will be 14.5 respirations per minute with a minute-volume of 10.5 liters.

(3) A sedentary breathing machine cam will be used.

(4) The apparatus will be tested at a temperature of 27° ± 2° C. (80° ± 5° F.).

(5) A concentration of 5 percent carbon dioxide in air will be exhaled into the facepiece.

(b) Closed-circuit apparatus:

(1) The concentration of carbon dioxide in inspired gas in closed-circuit apparatus will be measured at the mouth while the parts of the apparatus contributing to dead-air space are mounted on a dummy head and operated by the breathing machine as in paragraphs (a) (1) through (5) of this section.

(c) During the testing required by paragraphs (a) and (b) of this section, the concentration of carbon dioxide in inspired gas at the mouth will be continuously recorded, and the maximum average concentration during the inhalation portion of the breathing cycle shall not exceed the following limits:

Where the service time is:	*Maximum allowable average concentration of carbon dioxide in inspired air, percent by volume*
Not more than 30 minutes	2.5
1 hour	2.0
2 hours	1.5
3 hours	1.0
4 hours	1.0

(d) In addition to the tests requirements for closed-circuit apparatus set forth in paragraph (b) of this section, gas samples will be taken during the course of the man tests described in Tables 1, 2, 3, and 4. These gas samples will be taken from the closed-circuit apparatus at a point downstream of the carbon dioxide sorbent, and they shall not contain more than 0.5 percent carbon dioxide at any time.

§ 11.85–13 Tests during low temperature operation.

(a) The applicant shall specify the minimum temperature for safe operation and two persons will perform the tests described in paragraphs (c) and (d) of this section, wearing the apparatus according to applicant's directions. At the specified temperature, the apparatus shall meet all the requirements described in paragraph (e) of this section.

(b) The apparatus will be precooled at the specified minimum temperature for 4 hours.

(c) The apparatus will be worn in the low temperature chamber for 30 minutes, or for the service time of the apparatus, whichever is less.

(d) During the test period, alternate 1-minute periods of exercise and rest will be required with the exercise periods consisting of stepping onto and off a box 21.5 cm. (8½ inches) high at a rate of 30 cycles per minute.

(e) (1) The apparatus shall function satisfactorily at the specified minimum temperature on duplicate tests.

(2) The wearer shall have sufficient unobscured vision to perform the work.

(3) The wearer shall not experience undue discomfort because of airflow restriction or other physical or chemical changes in the operation of the apparatus.

[3] Kloce, E. J., and J. Lamonica, A Machine-Test Method for Measuring Carbon Dioxide in the Inspired Air of Self-Contained Breathing Apparatus. Bureau of Mines Report of Investigations 6865, 1966, 11 pp.

(f) Auxiliary low-temperature parts which are commercially available to the user may be used on the apparatus to meet the requirements described in paragraph (e) of this section.

§ 11.85–14 Man tests; testing conditions; general requirements.

(a) The man tests described in Tables 1, 2, 3, and 4 represent the workload performed in the mining, mineral, or allied industries by a person wearing the apparatus tested.

(b) The apparatus tested will be worn by Bureau personnel trained in the use of self-contained breathing apparatus, and the wearer will, before participating in these tests, pass a physical examination conducted by a qualified physician.

(c) All man tests will be conducted by the Bureau.

(d) The apparatus will be examined before each man test to ensure that it is in proper working order.

(e) Breathing resistance will be measured within the facepiece or mouthpiece and the wearer's pulse and respiration rate will be recorded during each 2 minute sample period prescribed in tests 1, 2, 3, and 4.

(f) Man tests 1, 2, 3, 4, 5, and 6 will be conducted in duplicate.

(g) If man tests are not completed through no fault of the apparatus, the test will be repeated.

§ 11.85–15 Man tests 1, 2, 3, and 4; requirements.

(a) Man tests 1, 2, 3, and 4, set forth in Tables 1, 2, 3, and 4 respectively, prescribe the duration and sequence of specific activities. These tests will be conducted to:

(1) Familiarize the wearer with the apparatus during use;

(2) Provide for a gradual increase in activity;

(3) Evaluate the apparatus under different types of work and physical orientation; and

(4) Provide information on the operating and breathing characteristics of the apparatus during actual use.

§ 11.85–16 Man test 5; requirements.

(a) Test 5 will be conducted to determine the maximum length of time the apparatus will supply the respiratory needs of the wearer while he is sitting at rest.

(b) The wearer will manipulate the devices controlling the supply of breathing gas to the advantage of the apparatus.

(c) Samples of inspiration from within the apparatus facepiece or mouthpiece shall be taken once every 15 minutes, and shall meet the minimum requirement for oxygen specified in § 11.79(a) of this part, and the maximum allowable average concentration of carbon dioxide specified in § 11.85–12(c).

(d) One sample of inspiration will be taken in the case of 3-, 5-, and 10-minute apparatus.

§ 11.85–17 Man test 6; requirements.

(a) Man test 6 will be conducted with respect to liquefied breathing gas apparatus only.

(b) This test will be conducted to evaluate operation of the apparatus in other than vertical positions.

(c) The wearer will lie face downward for one-fourth the service life of the apparatus with a full charge of liquefied breathing gas, and then a one-quarter full charge of liquefied breathing gas.

(d) The test will be repeated with the wearer lying on each side and on his back.

(e) The oxygen content of the gas supplied to the wearer by the apparatus will be continuously measured.

§ 11.85–18 Man tests; performance requirements.

(a) The apparatus shall satisfy the respiratory requirements of the wearer for the classified service time.

(b) Fogging of the eyepiece shall not obscure the wearer's vision, and the wearer shall not experience undue discomfort because of fit or other characteristics of the apparatus.

(c) When the ambient temperature during testing is 24° ± 6° C. (75° ± 10° F.), the maximum temperature of inspired air recorded during man tests shall not exceed the following, after correction for deviation from 24° C. (75° F.):

Where service life of apparatus is—	Where percent relative humidity of inspired air is—	Maximum permissible temperature of inspired air shall not exceed—	
		°F.	°C.
¼ hour or less	0–100	135	57
½ hour to ¾ hour	0–80	125	52
	80–100	[1] 110	[1] 43
1 to 2 hours	0–50	115	46
	50–100	[1] 106	[1] 41
3 hours	0–80	110	43
	80–100	[1] 100	[1] 38
4 hours	0–80	106	41
	80–100	[1] 96	[1] 35

[1] Where percent relative humidity is 80–100 and apparatus is designed for escape only, these maximum permissible temperatures will be increased by 4° C. (7° F.).

§ 11.85–19 Gas tightness test; minimum requirements.

(a) Each apparatus will be tested for tightness by persons wearing it in an atmosphere of 1,000 p.p.m. isoamyl acetate.

(b) Six persons will each wear the apparatus in the test concentrations specified in paragraph (a) of this section for 2 minutes and none shall detect the odor or taste of the test vapor.

TABLE 1.—DURATION AND SEQUENCE OF SPECIFIC ACTIVITIES FOR TEST 1, IN MINUTES

(30 CFR Part 11, Subpart H, § 11.85, et seq.)

Activity	Service time—							
	3 minutes	5 minutes	10 minutes	15 minutes	30 minutes	45 minutes	1 hour	2, 3, and 4 hours
Sampling and readings				3	2	2	2	Perform 1 hour test 2, 3, or 4 times respectively.
Walks at 4.8 km. (3 miles) per hour	3	5	3	4	8	12	16	
Sampling and readings			2	2	2	2	2	
Walks at 4.8 km. (3 miles) per hour			5	6	8	12	16	
Sampling and readings			2	2	2	2	2	
Walks at 4.8 km. (3 miles) per hour					6	12	16	
Sampling and readings					2	2	2	

TABLE 2.—DURATION AND SEQUENCE OF SPECIFIC ACTIVITIES FOR TEST 2, IN MINUTES
(30 CFR Part 11, Subpart H, § 11.88, et seq.)

Activity	Service Time—							
	2 minutes	5 minutes	10 minutes	15 minutes	30 minutes	45 minutes	1 hour	2, 3 and 4 hours [1]
Sampling and readings				2	2	2	2	2.
Walks at 4.8 km. (3 miles) per hour			1	1	3	4	6	10.
Carries 20 kg. (40 pound) weight over overcoat.			1 time in 2 minutes.	1 time in 2 minutes.	2 times in 4 minutes.	3 times in 6 minutes.	4 times in 6 minutes.	6 times in 10 minutes.
Walks at 4.8 km. (3 miles) per hour				1	3	3	3	8.
Climbs vertical treadmill [2] (or equivalent).	1	1	1	1	1	1	1	1.
Walks at 4.8 km. (3 miles) per hour		1	1			2	3	8.
Climbs vertical treadmill (or equivalent)		1				1	1	1.
Sampling and readings					2	2	2	3.
Walks at 4.8 km. (3 miles) per hour				2	2	6	6	11.
Climbs vertical treadmill (or equivalent)				1	1	1	1	1.
Carries 20 kg. (40 pound) weight over overcoat.				1 time in 2 minutes.	3 times in 6 minutes.	4 times in 6 minutes.	5 times in 10 minutes.	8 times in 10 minutes.
Sampling and readings			2			2	2	2.
Walks at 4.8 km. (3 miles) per hour				1	3	3	3	
Climbs vertical treadmill (or equivalent)			1		1	1	1	Then repeat above activities once.
Walks at 4.8 km. (3 miles) per hour			2			2	3	
Climbs vertical treadmill (or equivalent)						1	1	
Carries 20 kg. (45 pound) weight and walks at 4.8 km. (3 miles) per hour.	1						2	
Walks at 4.8 km. (3 miles) per hour.	1	2				1	4	
Sampling and readings				2	2	2	2	

[1] Total test time for Test 2 for 2-hour, 3-hour, and 4-hour apparatus is 2 hours.
[2] Treadmill shall be inclined 15° from vertical and operated at a speed of 1 foot per second.

TABLE 3.—DURATION AND SEQUENCE OF SPECIFIC ACTIVITIES FOR TEST 3, IN MINUTES
(30 CFR Part 11, Subpart H, § 11.88, et seq.)

Activity	Service time—							
	3 minutes	5 minutes	10 minutes	15 minutes	30 minutes	45 minutes	1 hour	2, 3 and 4 hours [1]
Sampling and readings				2	2	2	2	Perform test No. 3 for 1 hr. apparatus; then perform test No. 1 for 1 hour apparatus.
Walks at 4.8 km. (3 miles) per hour			1	1	2	2	3	
Runs at 9.7 km. (6 miles) per hour	1	1	1	1	1	1	1	
Pulls 20 kg. (45 pound) weight to 5 feet		15 times in 1 minute.		30 times in 2 minutes.	30 times in 2 minutes.	30 times in 2 minutes.	60 times in 6 minutes.	
Lies on side	½	1	1	2	3	4	5	
Lies on back	½	1	1	2	2	3	3	
Crawls on hands and knees	1	1	1	2	2	2	2	
Sampling and readings			2		2	2	2	
Runs at 9.7 km. (6 miles) per hour				1	1	1	1	
Walks at 4.8 km. (3 miles) per hour					2	8	10	
Pulls 20 kg. (45 pound) weight to 5 feet			30 times in 2 minutes.		60 times in 6 minutes.	60 times in 6 minutes.	60 times in 6 minutes.	
Sampling and readings				2		2	2	
Walks at 4.8 km. (3 miles) per hour			1		3	4	10	
Lies on side						2	4	
Lies on back						2	1	
Sampling and readings					2	2	2	

[1] Total test time for Test 3 for 2-hour, 3-hour, and 4-hour apparatus is 2 hours.

TABLE 4.—DURATION AND SEQUENCE OF SPECIFIC ACTIVITIES FOR TEST 4, IN MINUTES

(30 CFR Part 11, Subpart H, § 11.86, et seq.)

Activity	Service time—									
	5 minutes	5 minutes	10 minutes	15 minutes	30 minutes	45 minutes	1 hour	2 hours	3 hours	4 hours
Sampling and readings				2	2	2	2	Perform test No. 1 for 30-minute apparatus; then perform test No. 4 for 1-hour apparatus; then perform test No. 1 for 30-minute apparatus.	Perform test No. 1 for 1-hour apparatus; then perform test No. 4 for 1-hour apparatus.	Perform test No. 1 for 1-hour apparatus; then perform test No. 4 for 1-hour apparatus; then perform test No. 1 for 1-hour apparatus twice (i.e., two one-hour tests).
Walks at 4.8 km. (3 miles) per hour				1	2	2	2			
Climbs vertical treadmill [1] (or equivalent)		1	1	1	1	1	1			
Walks at 4.8 km. (3 miles) per hour		1	1	1	2	2	2			
Pulls 20 kg. (45 pound) weight to 5 feet		30 times in 2 minutes.	30 times in 2 minutes.	30 times in 2 minutes.	60 times in 5 minutes.	60 times in 5 minutes.	60 times in 5 minutes.			
Walks at 4.8 km. (3 miles) per hour		1		1	1	2	3			
Carries 23 kg. (50 pound) weight over overcast.				1 time in 1 minute.	1 time in 1 minute.	2 times in 3 minutes.	3 times in 4 minutes.			
Sampling and readings			2		2	2	2			
Walks at 4.8 km. (3 miles) per hour			1		3	3	4			
Runs at 9.7 km. (6 miles) per hour		1	1		1	1	1			
Carries 23 kg. (50 pound) weight over overcast.			1 time in 1 minute.	1 time in 1 minute.	2 times in 3 minutes.	4 times in 6 minutes.	6 times in 8 minutes.			
Pulls 20 kg. (45 pound) weight to 5 feet.	15 times in 1 minute.			15 times in 1 minute.	60 times in 5 minutes.	30 times in 2 minutes.	30 times in 2 minutes.			
Sampling and readings			2		2	2	2			
Walks at 4.8 km. (3 miles) per hour		1	1			2	3			
Pulls 20 kg. (45 pound) weight to 5 feet.						60 times in 5 minutes.	60 times in 5 minutes.			
Carries 20 kg. (45 pound) weight and walks at 4.8 km. (3 miles) per hour.						3	3			
Sampling and readings						2	2			

[1] Treadmill shall be inclined 15° from vertical and operated at a speed of 30 cm. (1 foot) per second.

Subpart I—Gas Masks

§ 11.90 Gas masks; description.

(a) **Gas masks** including all completely assembled air purifying masks which are designed for use as respiratory protection during entry into and escape or escape only from hazardous atmospheres containing adequate oxygen to support life are described as follows:

(1) *Front-mounted or back-mounted gas mask.* A gas mask which consists of a full facepiece, a breathing tube, a canister at the front or back, a canister harness, and associated connections.

(2) *Type "N" front-mounted or back-mounted gas mask.* A gas mask specifically designed to protect against acid gases, ammonia, carbon monoxide, organic vapors, and particulate contaminants which consists of a full facepiece, breathing tube, a canister at the front or back, a canister harness, and associated connections.

(3) *Chin-style gas mask.* A gas mask which consists of a full facepiece, a canister which is usually attached to the facepiece, and associated connections.

(4) *Escape gas mask.* A gas mask designed for use during escape only from hazardous atmospheres which consists of a half-mask facepiece or mouthpiece, a canister, and associated connections.

(b) **Gas masks** shall be further described according to the specific gases or vapors against which they are designed to provide respiratory protection, as follows:

	Maximum use concentration, percent by volume
Type of front-mounted or back-mounted gas mask:	
Acid gas [1, 4]	[5] 2
Ammonia [3]	2
Carbon monoxide [3]	2
Organic vapors [3, 4]	[6] 2

	Maximum use concentration, percent by volume
Type of chin-style gas mask:	
Acid gas [1, 4]	[5] 0.5
Ammonia	.5
Organic vapors [3, 4]	[6] .5

	Maximum use concentration, parts per million
Type of escape gas mask:	
Acid gas [1, 4, 6]	[5] 1,000
Ammonia [6]	5,000
Carbon monoxide	10,000
Organic vapors [3, 4, 6]	[5] 5,000

[1] Approval may be for acid gases or organic vapors as a class or for specific acid gases, ammonia, or organic vapors. Approval may also be granted for combinations of acid gases, organic vapors, and other gases and vapors.

[2] Not for use against acid gases or organic vapors with poor warning properties or which generate high heats of reaction with sorbent materials in the canister.

[3] Suggested maximum use concentrations are lower than these for some acid gases and organic vapors.

[4] Eye protection may be required in certain concentrations of acid gases, ammonia, and organic vapors.

(c) **Gas masks** for respiratory protection against gases and vapors other than those specified in paragraph (b) of this section may be approved. The applicant shall submit a request for approval, in writing, to the Bureau of Mines, Approval and Testing, 4800 Forbes Avenue, Pittsburgh, PA 15213, listing the gas or vapor and suggested maximum use concentration for the specific type of gas mask. The Bureau and the Institute will consider the application and accept or reject the application on the basis of effect on the wearer's health and safety and any field experience in use of gas masks for such exposures. If the application is accepted the Bureau will test such gas mask in accordance with the requirements of this subpart.

§ 11.91 Gas masks; required components.

(a) Each gas mask described in § 11.90 shall, where its design requires, contain the following component parts:

(1) Facepiece or mouthpiece and noseclip;

(2) Canister or cartridge;

(3) Canister harness;

(4) External check valve; and

(5) Breathing tube.

(b) The components of each gas mask shall meet the minimum construction requirements set forth in Subpart G of this part.

§ 11.92 Canisters and cartridges in parallel; resistance requirements.

Where two or more canisters or cartridges are used in parallel, their resistance to airflow shall be essentially equal.

§ 11.93 Canisters and cartridges; color and markings; requirements.

The color and markings of all canisters and cartridges or labels shall conform with the requirements of the American National Standard for Identification of Gas Mask Canisters, K13.1, obtainable from American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

§ 11.94 Filters used with canisters and cartridges; location; replacement.

(a) Particulate matter filters used in conjunction with a canister or cartridge shall be located on the inlet side of the canister or cartridge.

(b) Filters shall be incorporated in or firmly attached to the canister or cartridge and each filter assembly shall, where applicable, be designed to permit its easy removal from and replacement in the canister or cartridge.

§ 11.95 Breathing tubes; minimum requirements.

(a) Flexible breathing tubes used in conjunction with gas masks shall be designed and constructed to prevent:

(1) Restriction of free head movement;

(2) Disturbance of the fit of facepieces or mouthpieces;

(3) Interference with the wearer's activities; and,

(4) Shutoff of airflow due to kinking, or from chin or arm pressure.

§ 11.96 Harnesses; installation and construction; minimum requirements.

(a) Each gas mask shall, where necessary, be equipped with a suitable harness designed and constructed to hold the components of the gas mask in position against the wearer's body.

(b) Harnesses shall be designed and constructed to permit easy removal and replacement of gas mask parts, and where applicable, provide for holding a full facepiece in the ready position when not in use.

§ 11.97 Gas mask containers; minimum requirements.

(a) Gas masks shall be equipped with a substantial, durable container bearing markings which show the applicant's name, the type and commercial designation of mask it contains and all appropriate approval labels.

(b) Containers for gas masks shall be designed and constructed to permit easy removal of the mask.

§ 11.98 Half-mask facepieces, full facepieces and mouthpieces; fit; minimum requirements.

(a) Half-mask facepieces and full facepieces shall be designed and constructed to fit persons with various facial shapes and sizes either: (1) By providing more than one facepiece size, or (2) by providing one facepiece size which will fit varying facial shapes and sizes.

(b) Full facepieces shall provide for optional use of corrective spectacles or lenses, which shall not reduce the respiratory protective qualities of the gas mask.

(c) Half-mask facepieces shall not interfere with the fit of common industrial safety spectacles, as determined by the Bureau's facepiece tests in § 11.102–3.

(d) Gas masks with mouthpieces shall be equipped with noseclips which are securely attached to the mouthpiece or gas mask and provide an airtight seal.

(e) Facepieces shall be designed to prevent eyepiece fogging.

§ 11.99 Facepieces; eyepieces; minimum requirements.

(a) Full facepieces shall be designed and constructed to provide adequate vision which is not distorted by the eyepiece.

(b) All eyepieces shall be designed and constructed to meet the impact and penetration requirements specified in Federal Specification, Mask, Air Line: and Respirator, Air Filtering, Industrial, GGG–M–125d, October 11, 1965.

§ 11.100 Inhalation and exhalation valves; minimum requirements.

(a) Inhalation and exhalation valves shall be provided where necessary and protected against damage and distortion.

(b) Inhalation valves shall be designed and constructed to prevent excessive exhaled air from adversely affecting cartridges, canisters, and filters.

(c) Exhalation valves shall be protected against external influence, and designed and constructed to prevent inward leakage of contaminated air.

§ 11.101 Head harnesses; minimum requirements.

(a) Facepieces shall be equipped with adjustable and replaceable head harnesses, designed and constructed to provide adequate tension during use and an even distribution of pressure over the entire area in contact with the face.

(b) Mouthpieces shall be equipped, where applicable, with adjustable and replaceable harnesses designed and constructed to hold the mouthpiece in place.

§ 11.102 Gas masks; performance requirements; general.

Gas masks and the individual components of each such device shall, as appropriate, meet the requirements for performance and protection specified in the tests described in §§ 11.102–1 through 11.102–5.

§ 11.102–1 Breathing resistance test; minimum requirements.

(a) Resistance to airflow will be measured in the facepiece or mouthpiece of a gas mask mounted on a breathing machine both before and after each test conducted in accordance with §§ 11.102–2, 11.102–4, and 11.102–5, with air flowing at a continuous rate of 85 liters per minute.

(b) The maximum allowable resistance requirements for gas masks are as follows:

MAXIMUM RESISTANCE
(mm. water-column height)

Type of gas mask	Inhalation		Exhalation
	Initial	Final[1]	
Front-mounted or back-mounted (without particulate filter)	60	75	20
Front-mounted or back-mounted (with approved particulate filter)	70	85	20
Chin-style (without particulate filter)	60	85	20
Chin-style (with approved particulate filter)	65	80	20
Escape (without particulate filter)	60	75	20
Escape (with approved particulate filter)	70	85	20

[1] Measured at end of the service life specified in Tables 6, 6, and 7.

§ 11.102–2 Exhalation valve leakage test.

(a) Dry exhalation valves and valve seats will be subjected to a suction of 25 mm. water-column height while in a normal operating position.

(b) Leakage between the valve and valve seat shall not exceed 30 milliliters per minute.

§ 11.102–3 Facepiece tests; minimum requirements.

(a) The complete gas mask will be fitted to the faces of persons having varying facial shapes and sizes.

(b) Where the applicant specifies a facepiece size or sizes for the gas mask, together with the approximate measurements of faces they are designed to fit, the Bureau will insure that test subjects suit such facial measurements.

(c) Any gas mask parts which must be removed to perform the facepiece or mouthpiece fit test shall be replaceable without special tools and without disturbing the facepiece or mouthpiece fit.

(d) The facepiece or mouthpiece fit test, using positive or negative pressure recommended by the applicant and described in his instructions will be used before each test specified in paragraph (e) of this section, and in § 11.102–4.

(e) (1) Each wearer will enter a chamber containing 100 p.p.m. isoamyl acetate vapor for a half-mask facepiece and 1,000 p.p.m. isoamyl acetate vapor for a full facepiece or mouthpiece.

(2) The facepiece or mouthpiece may be adjusted, if necessary, in the test chamber before starting the tests.

(3) Each wearer will remain in the chamber for 8 minutes while performing the following activities:

(i) Two minutes, nodding and turning head;

(ii) Two minutes, calisthenic arm movements;

(iii) Two minutes, running in place, and

(iv) Two minutes, pumping with a tire pump into a 28 liter (1 cubic foot) container.

(4) Each wearer shall not detect the odor of isoamyl acetate during the test.

§ 11.102–4 Dust, fume, mist, and smoke tests; canisters containing filters; minimum requirements.

(a) Gas mask canisters containing filters for protection against dusts, fumes, mists, and smokes in combination with gases, vapors, or gases and vapors, will be tested as prescribed in § 11.140.

(b) Gas mask canisters designed for protection against smokes will be tested in an atmospheric concentration of 100 micrograms of dioctyl phthalate per liter of air at continuous flow rates of (1) 32 liters per minute, and (2) 85 liters per minute for a period of 5 to 10 seconds, and the DOP leakage through the canister shall not exceed 0.03 percent of the test concentration.

§ 11.102–5 Canister bench tests; minimum requirements.

(a) (1) Bench tests, except for carbon monoxide tests, will be made on an apparatus that allows the test atmosphere at 50±5 percent relative humidity and room temperature (25°±2.5° C.) to enter the canister continuously at concentrations and rates of flow specified in Tables 5, 6, and 7.

(2) Three canisters will be removed from containers and tested as received from the applicant.

(3) Two canisters, other than those described in paragraph (a)(2) of this section, will be equilibrated at room temperature by passing 25 percent relative humidity air through them at 64 liters per minute for 6 hours.

(4) Two canisters, other than those described in paragraphs (a) (2) and (3) of this section, will be equilibrated at room temperature by passing 85 percent relative humidity air through them at 64 liters per minute for 6 hours.

(5) The equilibrated canisters will be resealed, kept in an upright position at room temperature, and tested within 18 hours.

(b) Front-mounted and back-mounted gas mask canisters will be tested and shall meet the minimum requirements set forth in Table 5.

(c) (1) Front-mounted and back-mounted canisters designated as Type N canisters shall have a window or other indicator to warn the gas mask wearer when the canister will no longer satisfactorily remove carbon monoxide from the inhaled air.

(2) Other types of front- and back-mounted canisters may also be equipped with a window or other indicator to warn of imminent leakage of other gases or vapors.

(3) The window indicator canisters will be tested as regular canisters, but shall show a satisfactory indicator change or other warning before the allowable canister penetration has occurred.

(d) Chin-style gas mask canisters shall meet the minimum requirements set forth in Table 6.

(e) Escape gas mask canisters shall meet the minimum requirements set forth in Table 7.

TABLE 5.—CANISTER BENCH TESTS AND REQUIREMENTS FOR FRONT AND BACK-MOUNTED GAS MASK CANISTERS

(30 CFR Part 11, Subpart I, § 11.102–5)

Canister type	Test condition	Test atmosphere: Gas or vapor	Concentration, p.p.m.	Flow rate, l.p.m.	Number of tests	Maximum allowable penetration, p.p.m.	Minimum service life, minutes [1]
Acid gas	As received	SO_2	20,000	64	3	5	12
		Cl_2	20,000	64	3	5	12
		NO_2	20,000	64	3	5	12
	Equilibrated	SO_2	20,000	32	4	5	12
		Cl_2	20,000	32	4	5	12
		NO_2	20,000	32	4	5	12
Organic vapors	As received	CCl_4	20,000	64	3	5	12
	Equilibrated	CCl_4	20,000	32	4	5	12
Ammonia	As received	NH_3	30,000	64	3	50	12
	Equilibrated	NH_3	30,000	32	4	50	12
Carbon monoxide	As received	CO	20,000	[2] 64	2	[3] 333	60
		CO	5,000	[4] 32	3		60
		CO	5,000	[2] 32	3		60
Type N	As received	SO_2	20,000	64	3	5	6
		Cl_2	20,000	64	3	5	6
		NO_2	20,000	64	3	5	6
		CCl_4	20,000	64	3	5	6
		NH_3	30,000	64	3	50	6
		CO	20,000	[2] 64	2	[3] 333	60
		CO	5,000	[4] 32	3		60
		CO	5,000	[2] 32	3		60
	Equilibrated	SO_2	20,000	32	4	5	6
		Cl_2	20,000	32	4	5	6
		NO_2	20,000	32	4	5	6
		CCl_4	20,000	32	4	5	6
		NH_3	30,000	32	4	50	6

[1] Minimum life will be determined at the indicated penetration.
[2] Relative humidity of test atmosphere will be 90±3 percent; temperature of test atmosphere will be 25±2.5° C.
[3] Maximum allowable CO penetration will be 365 cc. during the minimum life. The penetration shall not exceed 500 p.p.m. during this time.
[4] Relative humidity of test atmosphere will be 90±3 percent; temperature of test atmosphere entering the test fixture will be 0–2.5° C.–0° C.

TABLE 6.—CANISTER BENCH TESTS AND REQUIREMENTS FOR CHIN-STYLE GAS MASK CANISTERS

(30 CFR Part 11, Subpart I, § 11.102–5)

Canister type	Test condition	Test atmosphere: Gas or vapor	Concentration, p.p.m.	Flow rate, l.p.m.	Number of tests	Maximum allowable penetration, p.p.m.	Minimum service life, minutes [1]
Acid gas	As received	SO_2	5,000	64	3	5	12
		Cl_2	5,000	64	3	5	12
		NO_2	5,000	64	3	5	12
	Equilibrated	SO_2	5,000	32	4	5	12
		Cl_2	5,000	32	4	5	12
		NO_2	5,000	32	4	5	12
Organic vapors	As received	CCl_4	5,000	64	3	5	12
	Equilibrated	CCl_4	5,000	32	4	5	12
Ammonia	As received	NH_3	5,000	64	3	50	12
	Equilibrated	NH_3	5,000	32	4	50	12

[1] Minimum life will be determined at the indicated penetration.

TABLE 7.—CANISTER BENCH TESTS AND REQUIREMENTS FOR ESCAPE GAS MASK CANISTERS

(30 CFR Part 11, Subpart I, § 11.102–5)

Canister type	Test condition	Test atmosphere: Gas or vapor	Concentration, p.p.m.	Flow rate, l.p.m.	Number of tests	Maximum allowable penetration, p.p.m.	Minimum service life, minutes [1]
Acid gas	As received	SO_2	5,000	64	3	5	12
		Cl_2	5,000	64	3	5	12
		NO_2	5,000	64	3	5	12
	Equilibrated	SO_2	5,000	32	4	5	12
		Cl_2	5,000	32	4	5	12
		NO_2	5,000	32	4	5	12
Organic vapors	As received	CCl_4	5,000	64	3	5	12
	Equilibrated	CCl_4	5,000	32	4	5	12
Ammonia	As received	NH_3	5,000	64	3	50	12
	Equilibrated	NH_3	5,000	32	4	50	12
Carbon monoxide	As received	CO	10,000	[2] 32	2	[3]	[4] 60
		CO	5,000	[2] 32	3	[3]	60
		CO	5,000	[2] 32	3	[3]	60

[1] Minimum life will be determined at the indicated penetration.
[2] Relative humidity of test atmosphere will be 90±3 percent; temperature of test atmosphere will be 25±2.5° C.
[3] Maximum allowable CO penetration will be 365 cc. during the minimum life. The penetration shall not exceed 500 p.p.m. during this time.
[4] If effluent temperature exceeds 109° C. during this test, the escape gas mask shall be equipped with an effective heat exchanger.
[5] Relative humidity of test atmosphere will be 90±3 percent; temperature of test atmosphere entering the test fixture will be 0–2.5° C.–0° C.

Subpart J—Supplied-Air Respirators

§ 11.110 Supplied-air respirators; description.

(a) Supplied-air respirators, including all completely assembled respirators designed for use as respiratory protection during entry into and escape from hazardous atmospheres are described as follows:

(1) *Type "A" supplied-air respirators.* A hose mask respirator, for entry into and escape from hazardous atmospheres, which consists of a motor-driven or hand-operated blower that permits the free entrance of air when the blower is not operating, a strong large-diameter hose having a low resistance to airflow, a harness to which the hose and the lifeline are attached and a tight-fitting facepiece.

(2) *Type "AE" supplied-air respirators.* A Type "A" supplied-air respirator equipped with additional devices designed to protect the wearer's head and neck against impact and abrasion from rebounding abrasive material, and with shielding material such as plastic, glass, woven wire, sheet metal, or other suitable material to protect the window(s) of facepieces, hoods, and helmets which do not unduly interfere with the wearer's vision and permit easy access to the external surface of such window(s) for cleaning.

(3) *Type "B" supplied-air respirators.* A hose mask respirator, for entry into and escape from atmospheres not immediately dangerous to life or health, which consists of a strong large-diameter hose with low resistance to airflow through which the user draws inspired air by means of his lungs alone, a harness to which the hose is attached, and a tight-fitting facepiece.

(4) *Type "BE" supplied-air respirators.* A type "B" supplied-air respirator equipped with additional devices designed to protect the wearer's head and neck against impact and abrasion from rebounding abrasive material, and with shielding material such as plastic, glass, woven wire, sheet metal, or other suitable material to protect the window(s) of facepieces, hoods, and helmets which do not unduly interfere with the wearer's vision and permit easy access to the external surface of such window(s) for cleaning.

(5) *Type "C" supplied-air respirators.* An airline respirator, for entry into and escape from atmospheres not immediately dangerous to life or health, which consists of a source of respirable breathing air, a hose, a detachable coupling, a control valve, orifice, a demand valve or pressure demand valve, an arrangement for attaching the hose to the wearer, and a facepiece, hood, or helmet.

(6) *Type "CE" supplied-air respirators.* A type "C" supplied-air respirator equipped with additional devices designed to protect the wearer's head and neck against impact and abrasion from rebounding abrasive material, and with shielding material such as plastic, glass, woven wire, sheet metal, or other suitable material to protect the window(s) of facepieces, hoods, and helmets which do not unduly interfere with the wearer's vision and permit easy access to the external surface of such window(s) for cleaning.

§ 11.111 Supplied-air respirators; required components.

(a) Each supplied-air respirator described in § 11.110 shall, where its design requires, contain the following component parts:

(1) Facepiece, hood, or helmet;
(2) Air supply valve, orifice, demand or pressure-demand regulator;
(3) Hand operated or motor driven air blower;
(4) Air supply hose;
(5) Detachable couplings;
(6) Flexible breathing tube; and
(7) Respirator harness.

(b) The component parts of each supplied-air respirator shall meet the minimum construction requirements set forth in Subpart G of this part.

§ 11.112 Breathing tubes; minimum requirements.

(a) Flexible breathing tubes used in conjunction with supplied-air respirators shall be designed and constructed to prevent:

(1) Restriction of free head movement;
(2) Disturbance of the fit of facepieces, mouthpieces, hoods, or helmets;
(3) Interference with the wearer's activities; and
(4) Shutoff of airflow due to kinking, or from chin or arm pressure.

§ 11.113 Harnesses; installation and construction; minimum requirements.

(a) Each supplied-air respirator shall, where necessary, be equipped with a suitable harness designed and constructed to hold the components of the respirator in position against the wearer's body.

(b) Harnesses shall be designed and constructed to permit easy removal and replacement of respirator parts, and where applicable, provide for holding a full facepiece in the ready position when not in use.

§ 11.114 Respirator containers; minimum requirements.

Supplied-air respirators shall be equipped with a substantial, durable container bearing markings which show the applicant's name, the type and commercial designation of the respirator it contains, and all appropriate approval labels.

§ 11.115 Half-mask facepieces, full facepieces, hoods, and helmets; fit; minimum requirements.

(a) Half-mask facepieces and full facepieces shall be designed and constructed to fit persons with various facial shapes and sizes either (1) by providing more than one facepiece size, or (2) by providing one facepiece size which will fit varying facial shapes and sizes.

(b) Full facepieces shall provide for optional use of corrective spectacles or lenses, which shall not reduce the respiratory protective qualities of the respirator.

(c) Hoods and helmets shall be designed and constructed to fit persons with various head sizes, provide for the optional use of corrective spectacles or lenses, and insure against any restriction of movement by the wearer.

(d) Facepieces, hoods, and helmets shall be designed to prevent eyepiece fogging.

§ 11.116 Facepieces, hoods, and helmets; eyepieces; minimum requirements.

(a) Facepieces, hoods, and helmets shall be designed and constructed to provide adequate vision which is not distorted by the eyepiece.

(b) All eyepieces except those on Types B, BE, C, and CE supplied-air respirators shall be designed and constructed to meet the impact and penetration requirements specified in Federal Specification, Mask, Air Line, and Respirator, Air Filtering, Industrial GGG-M-126d, October 11, 1965.

(c) (1) The eyepieces of AE, BE, and CE type supplied-air respirators shall be shielded by plastic, glass, woven wire, sheet metal, or other suitable material which does not interfere with the vision of the wearer.

(2) Shields shall be mounted and attached to the facepiece to provide easy access to the external surface of the eyepiece for cleaning.

§ 11.117 Inhalation and exhalation valves; check valves; minimum requirements.

(a) Inhalation and exhalation valves shall be provided where necessary and protected against distortion.

(b) Exhalation valves shall be:

(1) Protected against damage and external influence; and
(2) Designed and constructed to prevent inward leakage of contaminated air.

(c) Check valves designed and constructed to allow airflow toward the facepiece only shall be provided in the connections to the facepiece or in the hose fitting near the facepiece of all Type A, AE, B, and BE supplied-air respirators.

§ 11.118 Head harnesses; minimum requirements.

Facepieces shall be equipped with adjustable and replaceable head harnesses which are designed and constructed to provide adequate tension during use, and an even distribution of pressure over the entire area in contact with the face.

§ 11.119 Head and neck protection; supplied-air respirators; minimum requirements.

Type AE, BE, and CE supplied-air respirators shall be designed and constructed to provide protection against impact and abrasion from rebounding abrasive materials to the wearer's head and neck.

§ 11.120 Air velocity and noise levels; hoods and helmets; minimum requirements.

Noise levels generated by the respirator will be measured inside the hood or helmet at maximum airflow obtainable

within pressure and hose length requirements and shall not exceed 80 dBA.

§ 11.121 Breathing gas; minimum requirements.

(a) Breathing gas used to supply supplied-air respirators shall be respirable breathing air and contain no less than 19.5 volume-percent of oxygen.

(b) Compressed, gaseous breathing air shall meet the applicable minimum grade requirements for Type I gaseous air set forth in the Compressed Gas Association Commodity Specification for Air, G–7.1 (Grade D or higher quality).

(c) Compressed, liquefied breathing air shall meet the applicable minimum grade requirements for Type II liquid air set forth in the Compressed Gas Association Commodity Specification for Air, G–7.1 (Grade B or higher quality).

§ 11.122 Air supply source; hand-operated or motor driven air blowers; Type A supplied-air respirators; minimum requirements.

(a) Blowers shall be designed and constructed to deliver an adequate amount of air to the wearer with either direction of rotation, unless constructed to permit rotation in one direction only, and to permit the free entrance of air to the hose when the blower is not operated.

(b) No multiple systems, whereby more than one user is supplied by one blower, will be approved, unless each hose line is connected directly to a manifold at the blower.

§ 11.123 Terminal fittings or chambers; Type B supplied-air respirators; minimum requirements.

(a) Blowers or connections to air supplies providing positive pressures shall not be approved for use on Type B supplied-air respirators.

(b) Terminal fittings or chambers employed in Type B supplied-air respirators, shall be:

(1) Installed in the inlet of the hose;

(2) Designed and constructed to provide for the drawing of air through corrosion resistant material arranged so as to be capable of removing material larger than 0.149 mm. in diameter (149 micrometers, 100-mesh, U.S. Standard sieve).

(3) Installed to provide a means for fastening or anchoring the fitting or chamber in a fixed position in a zone of respirable air.

§ 11.124 Supplied-air respirators; performance requirements; general.

Supplied-air respirators and the individual components of each such device shall, as appropriate, meet the requirements for performance and protection specified in the tests described in §§ 11.124–1 through 11.124–24.

§ 11.124–1 Hand-operated blower test; minimum requirements.

(a) Hand-operated blowers shall be tested by attaching them to a mechanical drive and operating them 6 to 8 hours daily for a period of 100 hours at a speed necessary to deliver 50 liters of air per minute through each completely assembled respirator. Each respirator shall be equipped with the maximum length of hose with which the device is to be approved and the hose shall be connected to each blower or manifold outlet designed for hose connections.

(b) The crank speed of the hand-operated blower shall not exceed 50 revolutions per minute in order to deliver the required 50 liters of air per minute to each facepiece.

(c) The power required to deliver 50 liters of air per minute to each wearer through the maximum length of hose shall not exceed one-fiftieth horsepower, and the torque shall not exceed a force of 2.3 kg. (5 pounds) on a 20 cm. (8-inch) crank, as defined in § 11.124–3.

(d) The blower shall operate throughout the period without failure or indication of excessive wear of bearings or other working parts.

§ 11.124–2 Motor-operated blower test; minimum requirements.

(a) Motor-operated blowers shall be tested by operating them at their specified running speed 6 to 8 hours daily for a period of 100 hours when assembled with the kind and maximum length of hose for which the device is to be approved and when connected to each blower or manifold outlet designed for hose connections.

(b) The connection between the motor and the blower shall be so constructed that the motor may be disengaged from the blower when the blower is operated by hand.

(c) The blower shall operate throughout the period without failure or indication of excessive wear of bearings or other working parts.

(d) Where a blower, which is ordinarily motor driven, is operated by hand, the power required to deliver 50 liters of air per minute to each wearer through the maximum length of hose shall not exceed one-fiftieth horsepower, and the torque shall not exceed a force of 2.3 kg. (5 pounds) on a 20 cm. (8-inch) crank, as defined in § 11.124–3.

(e) Where the respirator is assembled with the facepiece and 15 m. (50 feet) of the hose for which it is to be approved, and when connected to one outlet with all other outlets closed and operated at a speed not exceeding 50 revolutions of the crank per minute, the amount of air delivered into the respiratory-inlet covering shall not exceed 150 liters per minute.

§ 11.124–3 Method of measuring the power and torque required to operate blowers.

As shown in Figure 1, the blower crank is replaced by a wooden drum, *a* (13 cm. (5 inches) in diameter is convenient). This drum is wound with about 12 m. (40 feet) of No. 2 picture cord, *b*. A weight, *c*, of sufficient mass to rotate the blower at the desired speed is suspended from this wire cord. A mark is made on the cord about 3 to 4.5 m. (10 to 15 feet) from the weight, *c*. Another mark is placed at a measured distance (6–9 m./20–30 feet is convenient) from the first. These are used to facilitate timing. To determine the torque or horsepower required to operate the blower, the drum is started in rotation manually at or slightly above the speed at which the power measurement is to be made. The blower is then permitted to assume constant speed, and then as the first mark on the wire leaves the drum, a stopwatch is started. The watch is stopped when the second mark leaves the drum. From these data the foot-pounds per minute and the torque may be calculated.

§ 11.124–4 Type B supplied-air respirator; minimum requirements.

No Type B supplied-air respirator shall be approved for use with a blower or with connection to an air supply device at positive pressures.

§ 11.124–5 Type C supplied-air respirator, continuous flow class; minimum requirements.

(a) Respirators tested under this section shall be approved only when they supply respirable air at the pressures and quantities required.

(b) The pressure at the inlet of the hose connection shall not exceed 863 kN/m². (125 pounds per square inch gage).

(c) Where the pressure at any point in the supply system exceeds 863 kN/m.² (125 pounds per square inch gage), the respirator shall be equipped with a pressure-release mechanism that will prevent the pressure at the hose connection from exceeding 863 kN/m.² (125 pounds per square inch gage) under any conditions.

§ 11.124–6 Type C supplied-air respirator, demand and pressure demand class; minimum requirements.

(a) Respirators tested under this section shall be approved only when used to supply respirable air at the pressures and quantities required.

(b) The manufacturer shall specify the range of air pressure at the point of attachment of the air-supply hose to the air-supply system, and the range of hose length for the respirator. For example, he might specify that the respirator be used with compressed air at pressures ranging from 280–550 kN/m.² (40 to 80 pounds per square inch) with from 6 to 76 m. (15 to 250 feet) of air-supply hose.

(c) The specified air pressure at the point of attachment of the hose to the air-supply system shall not exceed 863 kN/m.² (125 pounds per square inch gage).

(d) (1) Where the pressure in the air-supply system exceeds 863 kN/m.² (125 pounds per square inch gage), the respirator shall be equipped with a pressure-release mechanism that will prevent the pressure at the point of attachment of the hose to the air-supply system from exceeding 863 kN/m.² (125 pounds per square inch gage).

(2) The pressure-release mechanism shall be set to operate at a pressure not more than 20 percent above the manufacturer's highest specified pressure. For example, if the highest specified pressure is 863 kN/m.² (125 pounds per square inch), the pressure-release mechanism

would be set to operate at a maximum of 1,035 kN/m.² (150 pounds per square inch).

§ 11.124–7 Air-supply line tests; minimum requirements.

Air supply lines employed on Type A, Type B, and Type C supplied-air respirators shall meet the minimum test requirements set forth in Table 8.

§ 11.124–8 Harness test; minimum requirements.

(a) (1) Shoulder straps employed on Type A supplied-air respirators shall be tested for strength of material, joints, and seams and must separately withstand a pull of 113 kg. (250 pounds) for 30 minutes without failure.

(2) Belts, rings, and attachments for life lines must withstand a pull of 136 kg. (300 pounds) for 30 minutes without failure.

(3) The hose shall be firmly attached to the harness so as to withstand a pull of 113 kg. (250 pounds) for 30 minutes without separating, and the hose attachments shall be arranged so that the pull or drag of the hose behind an advancing wearer does not disarrange the harness or exert pull upon the facepiece.

(4) The arrangement and suitability of all harness accessories and fittings will be considered.

(b) (1) The harness employed on Type B supplied-air respirators shall not be uncomfortable, disturbing, or interfere with the movements of the wearer.

(2) The harness shall be easily adjustable to various sizes.

(3) The hose shall be attached to the harness in a manner that will withstand a pull of 45 kg. (100 pounds) for 30 minutes without separating or showing signs of failure.

(4) The design of the harness and attachment of the line shall permit dragging the maximum length of hose considered for approval over a concrete floor without disarranging the harness or exerting a pull on the facepiece.

(5) The arrangement and suitability of all harness accessories and fittings will be considered.

(c) The harness employed on Type C respirators shall be similar to that required on the Type B respirator, or, it may consist of a simple arrangement for attaching the hose to a part of the wearer's clothing in a practical manner that prevents a pull equivalent to dragging the maximum length of the hose over a concrete floor from exerting pull upon the respiratory-inlet covering.

(d) Where supplied-air respirators have a rigid or partly rigid head covering, a suitable harness shall be required to assist in holding this covering in place.

§ 11.124–9 Breathing tube test; minimum requirements.

(a) (1) Type A and Type B supplied-air respirators shall employ one or two flexible breathing tubes of the nonkinking type which extend from the facepiece to a connecting hose coupling attached to the belt or harness.

(2) The breathing tubes employed shall permit free head movement, insure against closing off by kinking or by chin or arm pressure, and they shall not create a pull that will loosen the facepiece or disturb the wearer.

(b) Breathing tubes employed on Type C supplied-air respirators of the continuous flow class shall meet the minimum requirements set forth in paragraph (a) of this section, however, an extension of the connecting hose may be employed in lieu of the breathing tubes required.

(c) (1) A flexible, nonkinking type breathing tube shall: (i) Be employed on Type C supplied-air respirators of the demand and pressure-demand class; and (ii) extend from the facepiece to the demand or pressure-demand valve, except where the valve is attached directly to the facepiece.

(2) The breathing tube shall permit free head movement, insure against closing off by kinking or by chin or arm pressure, and shall not create a pull that will loosen the facepiece or disturb the wearer.

§ 11.124–10 Airflow resistance test, Type A and Type AE supplied-air respirators; minimum requirements.

(a) Airflow resistance will be determined when the respirator is completely assembled with the respiratory-inlet covering, the air-supply device, and the maximum length of air-supply hose coiled for one-half its length in loops 1.5 to 2.1 m. (5 to 7 feet) in diameter.

(b) The inhalation resistance, drawn at the rate of 85 liters (3 cubic feet) per minute when the blower is not operating or under any practical condition of blower operation shall not exceed the following amounts:

Maximum length of hose for which respirator is approved		Maximum resistance, water column height	
Feet	Meters	Inches	Millimeters
75	23	1.5	38
150	46	2.5	64
200	70	3.5	89
300	91	4.0	102

(c) The exhalation resistance shall not exceed 25 mm. (1 inch) of water-column height at a flow rate of 85 liters (3 cubic feet) per minute when the blower is not operating or under any practical condition of blower operation.

§ 11.124–11 Airflow resistance test; Type B and Type BE supplied-air respirators; minimum requirements.

(a) Airflow resistance shall be determined when the respirator is completely assembled with the respiratory-inlet covering and the hose in the maximum length to be considered for approval, coiled in loops 1.5 to 2.1 m. (5 to 7 feet) in diameter.

(b) Airflow resistance shall not exceed 38 mm. (1.5 inches) of water-column height to air drawn at the flow rate of 85 liters (3 cubic feet) per minute.

(c) The exhalation resistance shall not exceed 26 mm. (1 inch) of water-column height at this flow rate.

§ 11.124–12 Airflow resistance test; Type C supplied-air respirator, continuous flow class and Type CE supplied-air respirator; minimum requirements.

The resistance to air flowing from the respirator shall not exceed 25 mm. (1 inch) of water-column height when the air flow into the respiratory-inlet covering is 115 liters (4 cubic feet) per minute.

§ 11.124–13 Airflow resistance test; Type C supplied-air respirator, demand class; minimum requirements.

(a) Inhalation resistance shall not exceed 50 millimeters (2 inches) of water at an air flow of 115 liters (4 cubic feet) per minute.

(b) The exhalation resistance to a flow of air at a rate of 85 liters (3 cubic feet) per minute shall not exceed 25 millimeters (1 inch) of water.

§ 11.124–14 Airflow resistance test; Type C supplied-air respirator, pressure-demand class; minimum requirements.

(a) The static pressure in the facepiece shall not exceed 38 mm. (1.5 inches) of water-column height.

(b) The pressure in the facepiece shall not fall below atmospheric at inhalation airflows less than 115 liters (4 cubic feet) per minute.

(c) The exhalation resistance to a flow of air at a rate of 85 liters (3 cubic feet) per minute shall not exceed the static pressure in the facepiece by more than 51 mm. (2 inches) of water-column height.

§ 11.124–15 Exhalation valve leakage test.

(a) Dry exhalation valves and valve seats will be subjected to a suction of 25 mm. water-column height while in a normal operating position.

(b) Leakage between the valve and valve seat shall not exceed 30 milliliters per minute.

§ 11.124–16 Man tests for gases and vapors; supplied-air respirators; general performance requirements.

(a) Wearers will enter a chamber containing a gas or vapor as prescribed in §§ 11.124–17, 11.124–18, 11.124.19, and 11.124–20.

(b) Each wearer will spend 10 minutes in work to provide observations on freedom of the device from leakage. The freedom and comfort allowed the wearer will also be considered.

(c) Time during the test period will be divided as follows:

(1) *Five minutes.* Walking, turning head, dipping chin; and

(2) *Five minutes.* Pumping air with a tire pump into a 28-liter (1 cubic foot) container, or equivalent work.

(d) No odor of the test gas or vapor shall be detected by the wearer in the air breathed during any such test, and the wearer shall not be subjected to any undue discomfort or encumbrance because of the fit, air delivery, or other features of the respirator during the testing period.

§ 11.124–17 Man test for gases and vapors; Type A and Type AE respirators; test requirements.

(a) The completely assembled respirator will be worn in a chamber containing 0.1 ±0.025 percent isoamyl acetate vapor, and the blower, the intake of the hose, and not more than 25 percent of the hose length will be located in isoamyl acetate-free air.

(b) The man in the isoamyl acetate atmosphere will draw his inspired air through the hose, connections, and all parts of the air device by means of his lungs alone (blower not operating).

(c) The 10-minute work test will be repeated with the blower in operation at any practical speed up to 50 revolutions of the crank per minute.

§ 11.124–18 Man test for gases and vapors; Type B and Type BE respirators; test requirements.

(a) The completely assembled respirator will be worn in a chamber containing 0.1±0.025 percent isoamyl acetate vapor, and the intake of the hose, and not more than 25 percent of the hose length will be located in isoamyl acetate-free air.

(b) The man in the isoamyl acetate atmosphere will draw his inspired air through the hose and connections by means of his lungs alone.

§ 11.124–19 Man test for gases and vapors; Type C respirators, continuous-flow class and Type CE supplied-air respirators; test requirements.

(a) The completely assembled respirator will be worn in a chamber containing 0.1±0.025 percent isoamyl acetate vapor, the intake of the hose will be connected to a suitable source of respirable air, and not more than 25 percent of the hose length will be located in isoamyl acetate-free air.

(b) The minimum flow of air required to maintain a positive pressure in the respiratory-inlet covering throughout the entire breathing cycle will be supplied to the wearer, provided however, that airflow shall not be less than 115 liters per minute for tight-fitting and not less than 170 liters per minute for loose-fitting respiratory inlet-coverings.

(c) The test will be repeated with the maximum rate of flow attainable within specified operating pressures.

§ 11.124–20 Man test for gases and vapors; Type C supplied-air respirators, demand and pressure-demand classes; test requirements.

(a) The completely assembled respirator will be worn in a chamber containing 0.1±0.025 percent isoamyl acetate vapor, the intake of the hose will be connected to a suitable source of respirable air, and not more than 25 percent of the hose length will be located in isoamyl acetate free air.

(b) The test will be conducted at the minimum pressure with the maximum hose length and will be repeated at the maximum pressure with the minimum hose length.

§ 11.124–21 Tests for protection during abrasive blasting; Type AE, Type BE, and Type CE supplied-air respirators; general performance requirements.

(a) Tests will be made under conditions of typical abrasive blasting operation.

(b) The tests prescribed in §§ 11.124–22, 11.124–23, and 11.124–24 will be conducted under the following conditions:

(1) A suction-feed abrasive blasting outfit will be used by the wearer;

(2) The diameter of the air jet shall be 5 mm. ($\frac{3}{16}$ inch);

(3) Air pressure will be 276–483 kN/m.² (40–70 pounds per square inch);

(4) The abrasive used will contain a composition of 99+ percent free silica (SiO_2);

(5) The size properties of the abrasive used will be a mixture of 90 percent by weight of essentially No. 1 sandblast sand and 10 percent air-floated fines; and

(6) The No. 1 sand used will meet a size specification of not more than 10 percent on a 20-mesh sieve and not more than 10 percent through a 35-mesh sieve; 99+ percent of the fines will be able to pass through a 270-mesh sieve. All size determinations will be made by standard-mesh sieves.

(c) Tests will be conducted for 30 minutes continuously.

(d) (1) The person wearing the respirator will sandblast the inside surface of a common iron kettle of approximate hemispherical shape (about 76 cm. (30 inches) in diameter, and 113.6 liters (30 gallons) capacity).

(2) The kettle will be placed with the plane of the opening inclined 45° from a vertical position and with the lowest point of the rim at about the height of the person's hips.

(3) The wearer will stand at one position in front of the kettle and lean over until the upper part of the body is inclined to parallel the face of the kettle.

(4) The wearer will blast the entire inner surface of the kettle with the blast at all times directed approximately at right angles to the surface with the nozzle of the gun approximately 15 cm. (6 inches) from the surface, and with his head approximately 46 cm. (18 inches) from the nozzle.

(5) The wearer will move his head forward, backward, and sideways during each blasting operation.

(e) (1) Air will be withdrawn continuously during the test at the rate of 32 liters (1.13 cubic feet) per minute from the respiratory-inlet covering at a point as near as convenient to the wearer's nostrils.

(2) Simultaneously air will be drawn at the same rate from the source of intake air to the respirator.

(f) Respirators tested in accordance with §§ 11.124–22, 11.124–23, and 11.124–24 shall meet the following minimum requirements:

(1) The amount of particulate matter in the air withdrawn from the respiratory-inlet covering shall not exceed the amount of particulate matter supplied to the respirator by more than 0.5 mg. for the 30-minute test period;

(2) The wearer of the respirator in this test shall not experience undue encumbrance and discomfort because of the fit, air delivery, or other features of the respirator; and.

(3) The head and shoulder covering shall adequately protect the wearer from discomfort or injury due to impact or abrasion from the rebounding material during the test.

§ 11.124–22 Test for protection during abrasive blasting; Type AE supplied-air respirator; test requirements.

(a) The respirator will be arranged as prescribed in § 11.124–17(a), and the tests prescribed in § 11.124–21 will be performed.

(b) The wearer will draw his inspired air through the hose, connections, and all parts of the air device by means of his lungs alone (blower not operating).

(c) The test will be repeated with the blower in operation at any practical speed up to 50 revolutions per minute of the crank.

§ 11.124–23 Test for protection during abrasive blasting; Type BE supplied-air respirator; test requirements.

(a) The respirator will be arranged as prescribed in § 11.124–18(a), and the tests prescribing in § 11.124–21 will be performed.

(b) The wearer will draw his inspired air through the hose, connections, and all parts of the air device by means of his lungs alone.

§ 11.124–24 Test for protection during abrasive blasting; Type CE supplied-air respirator; test requirements.

(a) The respirator will be arranged as prescribed in § 11.124–19(a), and the tests prescribed in § 11.124–21 will be performed.

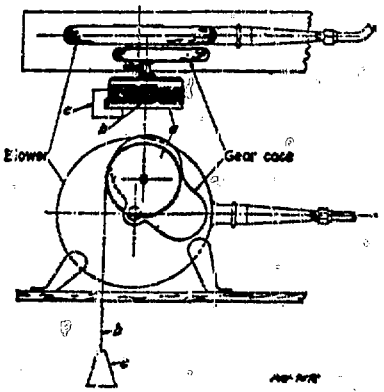

Figure 1.—Apparatus for measuring power required to operate blower. (30 CFR Part 11, Subpart J, § 11.124-3)

TABLE 8.—AIR-SUPPLY-LINE REQUIREMENTS AND TESTS

(30 CFR Part 11, Subpart J, § 11.134-7)

Specific requirements	Requirements for the air-supply lines of the indicated type of supplied-air respirator		
	Type A	Type B	Type C
Length of hose	Maximum of 91 m. (300 feet), in multiples of 7.6 m. (25 feet).	Maximum of 23 m. (75 feet) in multiples of 7.6 m. (25 feet).	Maximum of 91 m. (300 feet) in multiples of 7.6 m. (25 feet). It will be permissible for the applicant to supply hose of the approved type of shorter length than 7.6 m. (25 feet) provided it meets the requirements of the part.
Air flow	None	None	The air-supply hose with air regulating valve or orifice shall permit a flow of not less than 115 liters (4 cubic feet) per minute to tight-fitting and 170 liters (6 cubic feet) per minute to loose-fitting respiratory-inlet coverings through the maximum length of hose for which approval is granted and at the minimum specified air-supply pressure. The maximum flow shall not exceed 425 liters (15 cubic feet) per minute at the maximum specified air-supply pressure with the minimum length of hose for which approval is granted. The air-supply hose, detachable coupling, and demand valve of the demand class or pressure-demand valve of the pressure-demand class for Type C supplied-air respirators, demand and pressure-demand classes, shall be capable of delivering respirable air at a rate of not less than 115 liters (4 cubic feet) per minute to the respiratory-inlet covering at an inhalation resistance not exceeding 50 millimeters (2 inches) of water-column height measured in the respiratory-inlet covering with any combination of air-supply pressure and length of hose within the applicant's specified range of pressure and hose length. The air-flow rate and resistance to inhalation shall be measured while the demand or pressure-demand valve is actuated 20 times per minute by a source of intermittent suction. The maximum rate of flow to the respiratory-inlet covering shall not exceed 425 liters (15 cubic feet) per minute under the specified operating conditions.
Air-regulating valve.	None	None	If an air-regulating valve is provided, it shall be so designed that it will remain at a specific adjustment, which will not be affected by the ordinary movement of the wearer. The valve must be so constructed that the air supply with the maximum length of hose and at the minimum specified air-supply pressure will not be less than 115 liters (4 cubic feet) of air per minute to tight-fitting and 170 liters (6 cubic feet) of air per minute of loose-fitting respiratory inlet coverings for any adjustment of the valve. If a demand or pressure-demand valve replaces the air-regulating valve, it shall be connected to the air-supply at the maximum air pressure for which approval is sought by means of the minimum length of air-supply hose for which approval is sought. The outlet of the demand or pressure-demand valve shall be connected to a source of intermittent suction so that the demand or pressure-demand valve is actuated approximately 20 times per minute for a total of 100,000 inhalations. To expedite this test, the rate of actuation may be increased if mutually agreeable to the applicant and the Bureau. During this test the valve shall function without failure and without excessive wear of the moving parts. The demand or pressure-demand valve shall not be damaged in any way when subjected at the outlet to a pressure or suction of 25 cm. (10 inches) of water gage for 2 minutes.

TABLE 8.—AIR-SUPPLY-LINE REQUIREMENTS AND TESTS—Continued

(30 CFR Part 11, Subpart J, § 11.134-7)

Specific requirements	Requirements for the air-supply lines of the indicated types of supplied-air respirators		
	Type A	Type B	Type C
Noncollapsibility.	The hose shall not collapse or exhibit permanent deformation when a force of 90 kg. (200 pounds) is applied for 5 minutes between 2 planes 7.6 cm. (3 inches) wide on opposite sides of the hose.	Same as Type A.	None.
Nonkinkability.	None.	None.	A 7.6 m. (25 foot) section of the hose will be placed on a horizontal-plane surface and shaped into a one-loop coil with one end of the hose connected to an airflow meter and the other end of the hose supplied with air at the minimum specified supply pressure. The connection shall be in the plane of the loop. The other end of the hose will be pulled tangentially to the loop and in the plane of the loop until the hose straightens. To meet the requirements of this test the loop shall maintain a uniform near-circular shape and ultimately unfold as a spiral, without any localized deformation that decreases the flow of air to less than 90 percent of the flow when the hose is tested while remaining in a straight line.
Strength of hose and couplings.	Hose and couplings shall not separate or fail when tested with a pull of 113 kg. (250 pounds) for 5 minutes.	Same as Type A.	Hose and couplings shall not exhibit any separation or failure when tested with a pull of 45 kg. (100 pounds) for 5 minutes and when tested by subjecting them to an internal air pressure of 2 times the maximum respirator-supply pressure that is specified by the applicant or at 173 kN/m.² (25 pounds per square inch) gage, whichever is higher.
Tightness.	No air leakage shall occur when the hose and couplings are joined and the joint(s) are immersed in water and subjected to an internal air pressure of 35 kN/m.² (5 pounds per square inch) gage.	None.	Leakage of air exceeding 50 cc. per minute at each coupling shall not be permitted when the hose and couplings are joined and are immersed in water, with air flowing through the respirator under a pressure of 173 kN/m.² (25 pounds per square inch) gage applied to the inlet end of the air-supply hose, or at twice the maximum respirator-supply pressure that is specified by the applicant, whichever is higher.
Permeation of hose by gasoline.	The permeation of the hose by gasoline will be tested by immersing 7.6 m. (25 feet) of hose and one coupling in gasoline, with air flowing through the hose at the rate of 8 liters per minute for 5 hours. The air from the hose shall not contain more than 0.01 percent by volume of gasoline vapor at the end of the test.	Same as for Type A.	Same as for Type A, except the test period shall be 1 hour.
Detachable coupling.	None.	None.	A hand-operated detachable coupling by which the wearer can readily attach or detach the connecting hose shall be provided at a convenient location. This coupling shall be durable, remain connected under all conditions of normal respirator use, and meet the prescribed tests for strength and tightness of hose and couplings.

Subpart K—Dust, Fume, and Mist Respirators

§ 11.130 Dust, fume, and mist respirators; description.

Dust, fume, and mist respirators, including all completely assembled respirators designed for use as respiratory protection during entry into and escape from hazardous particulate atmospheres which contain adequate oxygen to support life, are described as follows:

(a) Respirators, either with replaceable or reusable filters, designed as respiratory protection against dusts (1) having an air contamination level not less than 0.05 milligram per cubic meter of air, including but not limited to coal, arsenic, cadmium, chromium, lead, and manganese; or (2) dusts having an air contamination level not less than 2 million particles per cubic foot of air, including but not limited to aluminum, flour, iron ore, and free silica, resulting principally from the disintegration of a solid, e.g., dust clouds produced in mining, quarrying, and tunneling, and in dusts produced during industrial operations, such as grinding, crushing, and the general processing of minerals and other materials.

(b) Respirators, with replaceable filters, designed as respiratory protection against fumes of various metals having an air contamination level not less than 0.05 milligram per cubic meter, including but not limited to aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury (except mercury vapor), and zinc, which result from the sublimation or condensation of their respective vapors, or from the chemical reaction between their respective vapors and gases.

(c) Respirators, with replaceable filters, designed as respiratory protection against mists of materials having an air contamination level not less than 0.05 milligram per cubic meter or 2 million particles per cubic foot, e.g., mists produced by spray coating with vitreous enamels, chromic acid mist produced during chromium plating, and other mists of materials whose liquid vehicle does not produce harmful gases or vapors.

(d) Respirators, with replaceable filters, designed as respiratory protection against dusts, fumes, and mists having an air contamination level less than 0.05 milligram per cubic meter, including but not limited to lithium hydride and beryllium, and against radionuclides.

(e) Respirators, with replaceable filters, designed as respiratory protection against radon daughters, and radon daughters attached to dusts, fumes, and mists.

(f) Respirators, with replaceable filters, designed as respiratory protection against asbestos-containing dusts and mists.

(g) Respirators, with replaceable filters, designed as protection against various combinations of particulate matter.

(h) Single-use dust respirators designed as respiratory protection against pneumoconiosis- and fibrosis-producing dusts, or dusts and mists, including but not limited to aluminum, asbestos, coal, flour, iron ore, and free silica.

(i) The types of dust, fume, and mist respirators in paragraphs (a) through (g) of this section may also be classified according to their design as follows:

(1) Air-purifying respirators; and

(2) Powered air-purifying respirators.

§ 11.131 Dust, fume and mist respirators; required components.

(a) Each dust, fume, and mis respirator described in § 11.130 shall, where its design requires, contain the following component parts:

(1) Facepiece, mouthpiece with noseclip, hood, or helmet;

(2) Filter unit;

(3) Harness;

(4) Attached blower; and

(5) Breathing tube.

(b) The components of each dust, fume, and mist respirator shall meet the minimum construction requirements set forth in Subpart G of this part.

§ 11.132 Breathing tubes; minimum requirements.

(a) Flexible breathing tubes used in conjunction with respirators shall be designed and constructed to prevent:

(1) Restriction of free head movement;

(2) Disturbance of the fit of facepieces, mouthpieces, hoods, or helmets;

(3) Interference with the wearer's activities; and

(4) Shutoff of airflow due to kinking, or from chin or arm pressure.

§ 11.133 Harnesses; installation and construction; minimum requirements.

(a) Each respirator shall, where necessary, be equipped with a suitable harness designed and constructed to hold the components of the respirator in position against the wearer's body.

(b) Harnesses shall be designed and constructed to permit easy removal and replacement of respirator parts, and, where applicable, provide for holding a full facepiece in the ready position when not in use.

§ 11.134 Respirator containers; minimum requirements.

(a) Except as provided in paragraph (b) of this section each respirator shall be equipped with a substantial, durable container bearing markings which show the applicant's name, the type of respirator is contains, and all appropriate approval labels.

(b) Containers for single-use respirators may provide for storage of more than one respirator, however, such containers shall be designed and constructed to prevent contamination of respirators which are not removed, and to prevent damage to respirators during transit.

§ 11.135 Half-mask facepieces, full facepieces, hoods, helmets, and mouthpieces; fit; minimum requirements.

(a) Half-mask facepieces and full facepieces shall be designed and constructed to fit persons with various facial shapes and sizes either: (1) By providing more than one facepiece size, or (2) by providing one facepiece size which will fit varying facial shapes and sizes.

(b) Full facepieces shall provide for optional use of corrective spectacles or lenses, which shall not reduce the respiratory protective qualities of the respirator.

(c) Hoods and helmets shall be designed and constructed to fit persons with various head sizes, provide for the optional use of corrective spectacles or lenses, and insure against any restriction of movement by the wearer.

(d) Mouthpieces shall be equipped with noseclips which are securely attached to the mouthpiece or respirator and provide an airtight seal.

(e) Facepieces, hoods, and helmets shall be designed to prevent eyepiece fogging.

(f) Half-mask facepieces shall not interfere with the fit of common industrial safety corrective spectacles, as determined by the Bureau's facepiece tests in §§ 11.140–1 and 11.140–2.

§ 11.136 Facepieces, hoods, and helmets; eyepieces; minimum requirements.

Facepieces, hoods, and helmets shall be designed and constructed to provide adequate vision which is not distorted by the eyepieces.

§ 11.137 Inhalation and exhalation valves; minimum requirements.

(a) Inhalation and exhalation valves shall be protected against distortion.

(b) Inhalation valves shall be designed and constructed and provided where necessary to prevent excessive exhaled air from adversely affecting filters, except where filters are specifically designed to resist moisture as prescribed in § 11.140–5.

(c) Exhalation valves shall be: (1) Provided where necessary; (2) protected against damage and external influence; and (3) designed and constructed to prevent inward leakage of contaminated air.

§ 11.138 Head harnesses; minimum requirements.

(a) All facepieces shall be equipped with head harnesses designed and constructed to provide adequate tension during use and an even distribution of pressure over the entire area in contact with the face.

(b) Facepiece head harnesses, except those employed on single-use respirators, shall be adjustable and replaceable.

(c) Mouthpieces shall be equipped, where applicable, with adjustable and replaceable harnesses, designed and constructed to hold the mouthpiece in place.

§ 11.139 Air velocity and noise levels; hoods and helmets; minimum requirements.

Noise levels generated by the respirator will be measured inside the hood or helmet at maximum airflow obtainable and shall not exceed 80 dBA.

§ 11.140 Dust, fume, and mist respirators; performance requirements; general.

Dust, fume, and mist respirators and the individual components of each such device shall, as appropriate, meet the requirements for performance and protection specified in the tests described in §§ 11.140–1 through 11.140–12 and prescribed in Tables 9 and 10.

§ 11.140–1 Isoamyl acetate tightness test; dust, fume, and mist respirators designed for respiratory protection against fumes of various metals having an air contamination level not less than 0.05 milligram per cubic meter; minimum requirements.

(a) The respirator will be modified in such a manner that all of the air that normally would be inhaled through the inhalation port(s) is drawn through an efficient activated charcoal-filled canister, or cartridge(s), without interference with the face-contacting portion of the facepiece.

(b) The modified respirator will be worn by persons for at least 2 minutes each in a test chamber containing 100 parts (by volume) of isoamyl-acetate vapor per million parts of air.

(c) The odor of isoamyl-acetate shall not be detected by the wearers of the modified respirator while in the test atmosphere.

§ 11.140–2 Isoamyl acetate tightness test; respirators designed for respiratory protection against dusts, fumes, and mists having an air contamination level less than 0.05 milligram per cubic meter, or against radionuclides; minimum requirements.

(a) The applicant shall provide a charcoal-filled canister or cartridge of a size and resistance similar to the filter unit with connectors which can be attached to the facepiece in the same manner as the filter unit.

(b) (1) The canister or cartridge will be used in place of the filter unit, and persons will each wear a modified half-mask facepiece for 5 minutes in a test chamber containing 100 parts (by volume) of isoamyl-acetate vapor per million parts of air.

(2) The following work schedule will be performed by each wearer in the test chamber:

(i) Two minutes walking, nodding, and shaking head in normal movements; and

(ii) Three minutes exercising and running in place.

(3) The facepiece shall be capable of adjustment, according to the applicant's instructions, to each wearer's face, and the odor of isoamyl-acetate shall not be detectable by any wearer during the test.

(c) Where the respirator is equipped with a full facepiece, hood, helmet, or mouthpiece, the canister or cartridge will be used in place of the filter unit, and persons will each wear the modified respiratory-inlet covering for 5 minutes in a test chamber containing 1,000 parts (by volume) of isoamyl-acetate vapor per million parts of air, performing the work schedule specified in paragraph (b) (2) of this section.

§ 11.140–3 Air-purifying filter tests; performance requirements; general.

Dust, fume, and mist respirators will be tested in accordance with the schedule set forth in Table 10 to determine their effectiveness as protection against the particulate hazards specified therein.

§ 11.140–4 Silica dust test; single-use or reuseable filters; minimum requirements.

(a) Three respirators with single-use filters will be tested for periods of 90 minutes each at a continuous airflow rate of 32 liters per minute for air-purifying respirators, and for periods of 4 hours each at a flowrate not less than 115 liters per minute to tight-fitting facepieces, and not less than 170 liters per minute to loose-fitting hoods and helmets for powered air-purifying respirators.

(b) The relative humidity in the test chamber will be 20–80 percent, and the room temperature approximately 25° C.

(c) The test suspension in the chamber will not be less than 50 nor more than 60 milligrams of flint (99+ percent free silica) per cubic meter of air.

(d) The flint in suspension will be ground to pass 99+ percent through a 270-mesh sieve.

(e) The particle-size distribution of the test suspension will have a geometric mean of 0.4 to 0.6 micrometer, and the standard geometric deviation will not exceed 2.

(f) The total amount of unretained test suspension in samples taken during testing shall not exceed 1.5 milligrams for an air-purifying respirator, 14.4 milligrams for a powered air-purifying respirator with tight-fitting facepiece, and 21.3 milligrams for a powered air-purifying respirator with loose-fitting hood or helmet.

(g) Three respirators with reusable filters will be tested and shall meet the requirements specified in paragraphs (a) through (f) of this section; each filter shall be tested three times: Once as received; once after cleaning; and once after recleaning. The applicant's instructions shall be followed for each cleaning.

§ 11.140–5 Silica-dust test; single-use dust respirators; minimum requirements.

(a) Three respirators will be tested

(b) As described in § 11.140–4, airflow will be cycled through the respirator by a breathing machine at the rate of 24 respirations per minute with a minute volume of 40 liters; a breathing machine cam with a work rate of 622 kg.-m.^{2}/minute shall be used.

(c) Air exhaled through the respirator will be 35° ±2° C. (95° ±3° F.) with 94 ±3 percent relative humidity.

(d) Air inhaled through the respirator will be sampled and analyzed for respirator leakage.

(e) The total amount of unretained test suspension, after drying, in samples taken during testing, shall not exceed 1.8 milligrams for any single test.

§ 11.140–6 Lead fume test; minimum requirements.

(a) Three respirators will be tested for a period of 312 minutes each at a continuous airflow rate of 32 liters per minute for air-purifying respirators, and for periods of 4 hours each at a flow rate not less than 115 liters per minute to tight-fitting facepieces, and not less than 170 liters per minute to loose-fitting hoods and helmets for powered air-purifying respirators.

(b) The relative humidity in the test chamber will be 20–80 percent, and the room temperature approximately 25° C.

(c) The test suspension in the test chamber will not be less than 15 nor more than 20 milligrams of freshly generated lead-oxide fume, calculated as lead (Pb), per cubic meter of air.

(d) The fume will be generated by impinging an oxygen-gas flame on molten lead.

(e) Samples of the test suspension will be taken during each test period for analysis.

(f) The total amount of unretained test suspension in the samples taken during testing, which is analyzed and calculated as lead (Pb), shall not exceed 1.5 milligrams of lead for an air-purifying respirator, 4.2 milligrams of lead for a powered air-purifying respirator with tight-fitting facepiece, and 6.2 milligrams of lead for a powered air-purifying respirator with loose-fitting hood or helmet.

§ 11.140–7 Silica mist test; minimum requirements.

(a) Three respirators will be tested for a period of 312 minutes each at a continuous airflow rate of 32 liters per minute for air-purifying respirators, and for periods of 4 hours each at a flow rate not less than 115 liters per minute to tight-fitting facepieces, and not less than 170 liters per minute to loose-fitting hoods and helmets for powered air-purifying respirators.

(b) The room temperature in the test chamber will be approximately 25° C.

(c) The test suspension in the test chamber will not be less than 20 nor more than 25 milligrams of silica mist, weighed as silica dust, per cubic meter of air.

(d) Mist will be produced by spraying an aqueous suspension of flint (99+ percent free silica), and the flint shall be ground to pass 99+ percent through a 270-mesh sieve.

(e) Samples of the test suspension will be taken during each test period for analysis.

(f) The total amount of silica mist unretained in the samples taken during testing, weighed as silica dust, shall not exceed 2.5 milligrams for an air-purifying respirator, 6.9 milligrams for a powered air-purifying respirator with tight-fitting facepiece, and 10.2 milligrams for a powered air-purifying respirator with loose-fitting hood or helmet.

§ 11.140–8 Tests for respirators designed for respiratory protection against more than one type of dispersoid; minimum requirements.

Respirators designed as respiratory protection against more than one particulate hazard (dust, fume, or mist) shall comply with all the requirements of this part, with respect to each of the specific hazards involved.

§ 11.140–9 Airflow resistance tests; all dust, fume, and mist respirators; minimum requirements.

(a) Resistance to airflow will be measured in the facepiece, mouthpiece, hood, or helmet of a dust, fume, or mist respirator mounted on a test fixture with air flowing at a continuous rate of 85 liters per minute, both before and after each test conducted in accordance with §§ 11.140–4 through 11.140–7.

(b) The maximum allowable resistance requirements for dust, fume, and mist respirators are as follows:

MAXIMUM RESISTANCE
(mm. water-column height)

Type of respirator	Initial inhalation	Final inhalation	Exhalation
Single-use	12	15	
Dust, fume, and mist, with single-use filter	30	50	20
Dust, fume, and mist, with reusable filter	20	40	20
Radon daughter	15	25	15
Asbestos dust and mist	15	25	15

[1] Measured after silica dust test described in § 11.140–4.

§ 11.140–10 Exhalation valve leakage test; minimum requirements.

(a) Dry exhalation valves and valve seats will be subjected to a suction of 25 mm. water-column height while in a normal operating position.

(b) Leakage between the valve and valve seat shall not exceed 30 milliliters per minute.

§ 11.140–11 DOP filter test; respirators designed as respiratory protection against dusts, fumes, and mists having an air contamination level less than 0.05 milligram per cubic meter and against radionuclides; minimum requirements.

(a) All single air-purifying respirator filter units will be tested in an atmosphere concentration of 100 micrograms of DOP per liter of air at continuous flow rates of 32 and 85 liters per minute for a period of 5 to 10 seconds.

(b) Where filters are to be used in pairs, the flow rates will be 16 and 42.5 liters per minute, respectively, through each filter.

(c) The filter will be mounted on a connector in the same manner as used on the respirator, and the total leakage for the connector and filter shall not exceed 0.03 percent of the ambient DOP concentration at either flow rate.

§ 11.140–12 Silica dust loading test; respirators designed as protection against dusts, fumes, and mists having an air contamination level less than 0.05 milligram per cubic meter and against radionuclides; minimum requirements.

Three respirators will be tested in accordance with the provisions of § 11.140–4 and shall meet the minimum requirements of §§ 11.140–4 and 11.140.9.

TABLE 9.—FACEPIECE TEST REQUIREMENTS
(30 CFR Part 11, Subpart K, § 11.140–1, et seq.)

Respirator types	Pressure tightness test [1]	Isoamyl acetate test	
		11.140–1	11.140–2
Dusts: Air Contamination Level not less than 0.05 mg/M³ or 2 mppcf	X		
Fumes: Air Contamination Level not less than 0.05 mg/M³	X	X	
Mists: Air Contamination Level not less than 0.05 mg/M³ or 2 mppcf	X		
Dusts, Fumes, and Mists: Air Contamination Level less than 0.05 mg/M³ or 2 mppcf, and radionuclides	X		X
Radon daughters	X	X	
Asbestos-containing dusts and mists	X		

[1] Test is required only where applicable.

TABLE 10—AIR-PURIFYING AND POWERED AIR-PURIFYING RESPIRATOR FILTER TESTS REQUIRED FOR APPROVAL
(30 CFR Part 11, Subpart K, § 11.140–4, et seq.)

Respirator types	Silica dust tests			Lead fume test	Silica mist test	DOP test
	11.140–4	11.140–5	11.140–12	11.140–6	11.140–7	11.140–11
Dusts: Air Contamination Level not less than 0.05 mg/M³ or 2 mppcf	X					
Fumes: Air Contamination Level not less than 0.05 mg/M³				X		
Mists: Air Contamination Level not less than 0.05 mg/M³ or 2 mppcf					X	
Dusts, Fumes, and Mists: Air Contamination Level less than 0.05 mg/M³ or 2 mppcf, and radionuclides		X				X
Radon daughters	X[1]			X[1]		
Asbestos-containing dusts and mists	X[2]				X[2]	
Single-use dust and mist respirators		X[3]				

[1] For resistance only.
[2] For penetration only.
[3] Test required only where applicable.

Subpart L—Chemical Cartridge Respirators

§ 11.150 Chemical cartridge respirators; description.

Chemical cartridge respirators including all completely assembled respirators which are designed for use as respiratory protection during entry into or escape from atmospheres not immediately dangerous to life and health, are described according to the specific gases or vapors against which they are designed to provide respiratory protection, as follows:

Type of chemical cartridge respirator:	Maximum use concentration, parts per million
Ammonia	300
Chlorine	10
Hydrogen chloride	50
Methyl amine	100
Organic vapor [1]	[2] 1,000
Sulfur dioxide	50

[1] Not for use against organic vapors with poor warning properties or those which generate high heats of reaction with sorbent material in the cartridge.

[2] Maximum use concentrations are lower for organic vapors which produce atmospheres immediately hazardous to life or health at concentrations equal to or lower than this concentration.

NOTE: Chemical cartridge respirators for respiratory protection against gases or vapors, which are not specifically listed with their maximum use concentration except pesticides, may be approved if the applicant submits a request for such approval, in writing, to the Bureau. The Bureau and the Institute shall consider each such application and accept or reject the application after a review of the effects on the wearer's health and safety and in the light of any field experience in use of chemical cartridge respirators as protection against such hazards.

§ 11.151 Chemical cartridge respirators; required components.

(a) Each chemical cartridge respirator described in § 11.150 shall, where its design requires, contain the following component parts:

(1) Facepiece, mouthpiece, and noseclip, hood, or helmet;
(2) Cartridge;
(3) Cartridge with filter;
(4) Harness;
(5) Breathing tube; and
(6) Attached blower.

(b) The components of each chemical cartridge respirator shall meet the minimum construction requirements set forth in Subpart G of this part.

§ 11.152 Cartridges in parallel; resistance requirements.

Where two or more cartridges are used in parallel, their resistance to airflow shall be essentially equal.

§ 11.153 Cartridges; color and markings; requirements.

The color and markings of all cartridges or labels shall conform with the requirements of the American National Standard for Identification of Gas Mask

Canisters, K13.1, obtainable from American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

§ 11.154 Filters used with chemical cartridges; location; replacement

(a) Particulate matter filters used in conjunction with a chemical cartridge shall be located on the inlet side of the cartridge.

(b) Filters shall be incorporated in or firmly attached to the cartridge and each filter assembly shall, where applicable, be designed to permit its easy removal from and replacement on the cartridge.

§ 11.155 Breathing tubes; minimum requirements.

(a) Flexible breathing tubes used in conjunction with respirators shall be designed and constructed to prevent:

(1) Restriction of free head movement;

(2) Disturbance of the fit of facepieces, mouthpieces, hoods, or helmets;

(3) Interference with the wearer's activities; and

(4) Shutoff of airflow due to kinking, or from chin or arm pressure.

§ 11.156 Harnesses; installation and construction; minimum requirements.

(a) Each respirator shall, where necessary, be equipped with a suitable harness designed and constructed to hold the components of the respirator in position against the wearer's body.

(b) Harnesses shall be designed and constructed to permit easy removal and replacement of respirator parts and, where applicable, provide for holding a full facepiece in the ready position when not in use.

§ 11.157 Respirator containers; minimum requirements.

Respirators shall be equipped with a substantial, durable container bearing markings which show the applicant's name, the type and commercial designation of the respirator it contains and all appropriate approval labels.

§ 11.158 Half-mask facepieces, full facepieces, mouthpieces, hoods, and helmets; fit; minimum requirements.

(a) Half-mask facepieces and full facepieces shall be designed and constructed to fit persons with various facial shapes and sizes either: (1) By providing more than one facepiece size, or (2) by providing one facepiece size which will fit varying facial shapes and sizes.

(b) Hoods and helmets shall be designed and constructed to fit persons with various head sizes, provide for the optional use of corrective spectacles or lenses, and insure against any restriction of movement by the wearer.

(c) Mouthpieces shall be equipped with noseclips which are securely attached to the mouthpiece or respirator and provide an airtight fit.

(d) Full facepieces shall provide for optional use of corrective spectacles or lenses which shall not reduce the respiratory protective qualities of the respirator.

(e) Facepieces, hoods, and helmets shall be designed to prevent eyepiece fogging.

§ 11.158–1 Facepieces, hoods, and helmets; eyepieces; minimum requirements.

Facepieces, hoods, and helmets shall be designed and constructed to provide adequate vision which is not distorted by the eyepieces.

§ 11.159 Inhalation and exhalation valves; minimum requirements.

(a) Inhalation and exhalation valves shall be provided where necessary and protected against distortion.

(b) Inhalation valves shall be designed and constructed to prevent excessive exhaled air from entering cartridges or adversely affecting canisters.

(c) Exhalation valves shall be: (1) Protected against damage and external influence, and (2) designed and constructed to prevent inward leakage of contaminated air.

§ 11.160 Head harnesses; minimum requirements.

(a) Facepieces shall be equipped with adjustable and replaceable head harnesses designed and constructed to provide adequate tension during use and an even distribution of pressure over the entire area in contact with the face.

(b) Mouthpieces shall be equipped where applicable, with an adjustable and replaceable harness designed and constructed to hold the mouthpiece in place.

§ 11.161 Air velocity and noise levels; hoods and helmets; minimum requirements.

Noise levels generated by the respirator will be measured inside the hood or helmet at maximum airflow obtainable and shall not exceed 90 dBA.

§ 11.162 Chemical cartridge respirators; performance requirements; general.

Chemical cartridge respirators and the individual components of each such device shall, as appropriate, meet the minimum requirements for performance and protection specified in the tests described in §§ 11.162–1 through 11.162–8.

§ 11.162–1 Breathing resistance test; minimum requirements.

(a) Resistance to airflow will be measured in the facepiece, mouthpiece, hood, or helmet of a chemical cartridge respirator mounted on a test fixture with air flowing at a continuous rate of 85 liters per minute, both before and after each test conducted in accordance with §§ 11.162–5 through 11.162–8.

(b) The maximum allowable resistance requirements for chemical cartridge respirators are as follows:

Type of chemical cartridge respirator	Maximum Resistance (mm. water-column height)		
	Inhalation		Exhalation
	Initial	Final [1]	
For gases, vapors, or gases and vapors	60	65	25
For gases, vapors, or gases and vapors, and dusts, fumes, and mists	30	70	30
For gases, vapors, or gases and vapors, and mists of paints, lacquers, and enamels	60	70	30

[1] Measured at end of service life specified in Table 11.

§ 11.162–2 Exhalation valve leakage test; minimum requirements.

(a) Dry exhalation valves and valve seats will be subjected to a suction of 25 mm. water-column height while in a normal operating position.

(b) Leakage between the valve and valve seat shall not exceed 30 milliliters per minute.

§ 11.162–3 Facepiece test; minimum requirements.

(a) The complete chemical cartridge respirator will be fitted to the faces of persons having varying facial shapes and sizes.

(b) Where the applicant specifies a facepiece size or sizes for the respirator together with the approximate measurement of faces they are designed to fit, the Bureau will provide test subjects to suit such facial measurements.

(c) Any chemical cartridge respirator part which must be removed to perform the facepiece or mouthpiece fit test shall be replaceable without special tools and without disturbing facepiece or mouthpiece fit.

(d) The facepiece or mouthpiece fit test using the positive or negative pressure recommended by the applicant and described in his instructions will be used before each test.

(e) (1) Each wearer will enter a chamber containing 100 p.p.m. isoamyl acetate vapor for half-mask facepieces, and 1,000 p.p.m. for full facepieces, mouthpieces, hoods, and helmets.

(2) The facepiece or mouthpiece may be adjusted, if necessary, in the test chamber before starting the test.

(3) Each wearer will remain in the chamber for 8 minutes while performing the following activities:

(i) Two minutes, nodding and turning head;

(ii) Two minutes, calisthenic arm movements;

(iii) Two minutes, running in place; and

(iv) Two minutes, pumping with a tire pump into a 28-liter (1 cubic-foot) container.

(4) Each wearer shall not detect the odor of isoamyl-acetate vapor during the test.

§ 11.162–4 Lacquer and enamel mist tests; respirators with filters; minimum requirements; general.

(a) Three respirators with cartridges containing or having attached to them, filters for protection against mists of paints, lacquers, and enamels shall be tested in accordance with the provisions of § 11.162–8.

(b) In addition to the test requirements set forth in paragraph (a) of this section, three such respirators will be tested against each aerosol in accordance with the provisions of §§ 11.162–5 and 11.162–6.

§ 11.162–5 Lacquer mist test; minimum requirements.

(a) Temperature in the test chamber will be approximately 25° C.

(b) Continuous airflow through the respirator will be 32 liters per minute for air-purifying respirators, and not less than 115 liters per minute to tight fitting facepieces and 170 liters per minute to loose-fitting hoods and helmets of powered air-purifying respirators.

(c) Airflow through the chamber will be 20–25 air changes per minute.

(d) The atomizer employed will be a No. 64–5 nozzle with setup 3, or equivalent, operating at 69 kN/m². (10 pounds per square inch gage).

(e) The test aerosol will be prepared by atomizing a mixture of one volume of clear cellulose nitrate lacquer and one volume of lacquer thinner.

(f) The lacquer used will conform essentially to Federal Specification TT–L–31, October 7, 1953.

(g) The concentration of cellulose nitrate in the test aerosol will be 95–125 milligrams per cubic meter.

(h) The test aerosol will be drawn to each respirator for a total of 156 minutes for air-purifying respirators and 240 minutes for powered air-purifying respirators.

(i) The total amount of unretained mist in the samples taken during testing, weighed as cellulose nitrate, shall not exceed 5 milligrams for an air-purifying respirator, 28 milligrams for a powered air-purifying respirator with tight-fitting facepiece, and 41 milligrams for a powered air-purifying respirator with loose-fitting hood or helmet.

§ 11.162–6 Enamel mist test; minimum requirements.

(a) Temperature in the test chamber will be approximately 25° C.

(b) Continuous airflow through the respirator will be 32 liters per minute for air-purifying respirators, and not less than 115 liters per minute to tight-fitting facepieces and 170 liters per minute to loose-fitting hoods and helmets of powered air-purifying respirators.

(c) Airflow through the chamber will be 20–25 air changes per minute.

(d) The atomizer employed will be a No. 64 nozzle with setup 1A, or equivalent, operating at 69 kN/m². (10 pounds per square inch gage).

(e) The test aerosol will be prepared by atomizing a mixture of 1 volume of white enamel and 1 volume of turpentine.

(f) The enamel used will conform essentially to Federal Specification TT–E–489b, May 12, 1953 (an enamel having a phthalic alkyd resin vehicle and a titanium dioxide pigment).

(g) The concentration of pigment in the test aerosol, weighed as ash, will be 95–125 milligrams per cubic meter.

(h) The test aerosol will be drawn to each respirator for a total of 156 minutes for air-purifying respirators and 240 minutes for power air-purifying respirators.

(i) The total amount of unretained mist in the samples taken during testing, weighed as ash, shall not exceed 1.5 milligrams for any air-purifying respirator, 8.3 milligrams for a powered air-purifying respirator with tight-fitting facepiece, and 12.3 milligrams for a powered air-purifying respirator with loose-fitting hood or helmet.

§ 11.162–7 Dust, fume, and mist tests; respirators with filters; minimum requirements; general.

(a) Three respirators with cartridges containing, or having attached to them, filters for protection against dusts, fumes, and mists, except the mists of paints, lacquers, and enamels, will be tested in accordance with the provisions of § 11.162–8.

(b) In addition to the test requirements set forth in paragraph (a) of this section, three such respirators will be tested, as appropriate, in accordance with the provisions of §§ 11.140–1 through 11.140–14, however, the maximum allowable resistance of complete dust, fume, and mist, and gas, vapor, or gas and vapor chemical cartridge respirators shall not exceed the maximum allowable limits set forth in § 11.162–1.

§ 11.162–8 Bench tests; gas and vapor tests; minimum requirements; general.

(a) Bench tests will be made on an apparatus that allows the test atmosphere at 50 ±5 percent relative humidity and room temperature, approximately 25° C., to enter the cartridges continuously at predetermined concentrations and rates of flow, and that has means for determining the test life of the cartridges.

(b) Where two cartridges are used in parallel on a chemical cartridge respirator, the bench test will be performed with the cartridges arranged in parallel, and the test requirements will apply to the combination rather than to the individual cartridges.

(c) Three cartridges or pairs of cartridges will be removed from containers and tested as received from the applicant.

(d) Two cartridges or pairs of cartridges will be equilibrated at room temperature by passing 25 percent relative humidity air through them at the following flow rates (expressed in liters per minute (l.p.m.)) for 6 hours:

Type of cartridge:	*Airflow rate, l.p.m.*
Air purifying	32
Powered air purifying with tight-fitting facepiece	115
Powered air purifying with loose-fitting hood or helmet	170

(e) Two cartridges or pairs of cartridges will be equilibrated by passing 85 percent relative humidity air through them at the flow rates stated in paragraph (d) of this section.

(f) All cartridges will be resealed, kept in an upright position, at room temperatures, and tested within 18 hours.

(g) Cartridges will be tested and shall meet the minimum requirements set forth in Table 11.

TABLE 11.—CARTRIDGE BENCH TESTS AND REQUIREMENTS

(30 CFR Part 11, Subpart L, § 11.162–8)

Cartridge	Test condition	Test atmosphere: Gas or vapor	Test atmosphere: Concentration (p.p.m.)	Flowrate (l.p.m.)	Number of tests	Penetration[1] (p.p.m.)	Minimum life[1] (min.)
Ammonia	As received	NH_3	1000	64	3	50	50
Ammonia	Equilibrated	NH_3	1000	32	4	50	50
Chlorine	As received	Cl_2	500	64	3	5	25
Chlorine	Equilibrated	Cl_2	500	32	4	5	25
Hydrogen chloride	As received	HCl	500	64	3	5	50
Hydrogen chloride	Equilibrated	HCl	500	32	4	5	50
Methylamine	As received	CH_3NH_2	1000	64	3	10	25
Methylamine	Equilibrated	CH_3NH_2	1000	32	4	10	25
Organic vapors	As received	CCl_4	1000	64	3	5	50
Organic vapors	Equilibrated	CCl_4	1000	32	4	5	50
Sulfur dioxide	As received	SO_2	500	64	3	5	30
Sulfur dioxide	Equilibrated	SO_2	500	32	4	5	30

[1] Minimum life will be determined at the indicated penetration.

Where a respirator is designed for respiratory protection against more than one type of gas or vapor, as for use in ammonia and in chlorine, the minimum life shall be one-half that shown for each type of gas or vapor. Where a respirator is designed for respiratory protection against more than one gas of a type, as for use in chlorine and sulfur dioxide, the stated minimal life shall apply.

Subpart M—Pesticide Respirators

§ 11.170 Pesticide respirators; description.

Pesticide respirators, including all completely assembled respirators which are designed for use as respiratory protection during entry into and escape from atmospheres which contain pesticide hazards, are described according to their construction as follows:

(a) Front-mounted or back-mounted gas masks;

(b) Chin-style gas mask;

(c) Chemical cartridge;

(d) Air-purifying respirator with attached blower; and,

(e) Other devices, including combination respirators.

§ 11.171 Pesticide respirators; required components.

(a) Each pesticide respirator described in § 11.170 shall, where its design requires, contain the following component parts:

(1) Facepiece, mouthpiece, and noseclip, helmet, or hood;

(2) Canister with filter;

(3) Cartridge with filter;

(4) Harness;

(5) Attached blower; and,

(6) Breathing tube.

(b) The components of each pesticide respirator shall meet the minimum construction requirements set forth in Subpart G of this part.

§ 11.172 Canisters and cartridges in parallel; resistance requirements.

Where two or more canisters or cartridges are used in parallel, their resistance to airflow shall be essentially equal.

§ 11.173 Canisters and cartridges; color and markings; requirements.

The color and markings of all canisters and cartridges or labels shall conform with the requirements of the American National Standard for Identification of Gas Mask Canisters, K13.1.

§ 11.174 Filters used with canisters and cartridges; location; replacement.

(a) Particulate matter filters used in conjunction with a canister or cartridge shall be located on the inlet side of the canister or cartridge.

(b) Filters shall be incorporated into or firmly attached to the canister or cartridge and each filter assembly shall, where applicable, be designed to permit its easy removal from and replacement on the canister or cartridge.

§ 11.175 Breathing tubes; minimum requirements.

(a) Flexible breathing tubes used in conjunction with respirators shall be designed and constructed to prevent:

(1) Restriction of free head movement;

(2) Disturbance of the fit of facepieces, mouthpieces, hoods, or helmets;

(3) Interference with the wearer's activities; and,

(4) Shutoff of airflow due to kinking, or from chin or arm pressure.

§ 11.176 Harnesses; installation and construction; minimum requirements.

(a) Each respirator shall, where necessary, be equipped with a suitable harness designed and constructed to hold the components of the respirator in position against the wearer's body.

(b) Harnesses shall be designed and constructed to permit easy removal and replacement of respirator parts, and, where applicable, provide for holding a full facepiece in the ready position when not in use.

§ 11.177 Respirator containers; minimum requirements.

(a) Respirators shall be equipped with a substantial, durable, container bearing markings which show the applicant's name, type, and commercial designation of the respirator it contains, and all appropriate approval labels.

(b) Containers for gas masks shall be designed and constructed to permit easy removal of the mask.

§ 11.178 Half-mask facepieces, full facepieces, hoods and helmets, and mouthpieces; fit; minimum requirements.

(a) Half-mask facepieces and full facepieces shall be designed and constructed to fit persons with various facial shapes and sizes either: (1) By providing more than one facepiece size, or (2) by providing one facepiece size which will fit varying facial shapes and sizes.

(b) Full facepieces shall provide for optional use of corrective spectacles or lenses, which shall not reduce the respiratory protective quality of the respirator.

(c) Hoods and helmets shall be designed and constructed to fit persons with various head sizes, permit optional use of corrective spectacles without reducing the respiratory protective qualities of the respirator, and insure against any restriction of movement by the wearer.

(d) Pesticide respirators with mouthpieces shall be equipped with noseclips which are securely attached to the mouthpiece or respirator and provide an airtight seal.

(e) Facepieces, hoods, and helmets shall be designed to prevent eyepiece fogging.

(f) Half-mask facepieces shall not interfere with the fit of common industrial safety corrective spectacles as determined by the facepiece tests in § 11.183–3.

§ 11.179 Facepieces, hoods, and helmets; eyepieces; minimum requirements.

(a) Facepieces, hoods, and helmets shall be designed and constructed to provide adequate vision which is not distorted by the eyepiece.

(b) All eyepieces of gas masks shall be designed and constructed to meet the impact and penetration requirements specified in Federal Specification, Mask, Air line: and Respirator, Air Filtering, Industrial, GGG-M-125d, October 11, 1965.

§ 11.180 Inhalation and exhalation valves; minimum requirements.

(a) Inhalation and exhalation valves shall be protected against distortion.

(b) Inhalation valves shall be designed and constructed and provided where necessary to prevent excessive exhaled air from adversely affecting cartridges, canisters, and filters.

(c) Exhalation valves shall be:

(1) Provided where necessary;

(2) Protected against damage and external influence; and,

(3) Designed and constructed to prevent inward leakage of contaminated air.

§ 11.181 Head harnesses; minimum requirements.

(a) Facepieces shall be equipped with adjustable and replaceable head harnesses designed and constructed to provide adequate tension during use and an even distribution of pressure over the entire area in contact with the face.

(b) Mouthpieces shall be equipped, where applicable, with adjustable and replaceable harnesses designed and constructed to hold the mouthpiece in place.

§ 11.182 Air velocity and noise levels; hoods and helmets; minimum requirements.

Noise levels generated by the respirator will be measured inside the hood or helmet at maximum obtainable airflow and shall not exceed 80 dBA.

§ 11.183 Pesticide respirators; performance requirements; general.

Pesticide respirators and the individual components of each such device shall, as appropriate, meet the requirements for performance and protection specified in the tests described in §§ 11.183–1 through 11.183–7.

§ 11.183–1 Breathing resistance test; minimum requirements.

(a) Airflow resistance will be measured in the facepiece, mouthpiece, hood, or helmet of a pesticide respirator mounted on a test fixture with air flowing at a continuous rate of 85 liters per minute, both before and after each test conducted in accordance with §§ 11.183–4 and 11.183–7.

(b) The maximum allowable resistance requirements for pesticide respirators are as follows:

MAXIMUM RESISTANCE
(mm. water-column height)

Type of Pesticide respirator	Inhalation		Exhalation
	Initial	Final[1]	
Front- or back-mounted gas mask	70	84	20
Chin-style gas mask	68	80	20
Powered air-purifying	[2] 50	[2] 70	[2] 20
Chemical cartridge	50	70	20

[1] Measured at end of the service life specified in Table 12.

[2] Resistance of filter(s), cartridge(s), and breathing tube(s) only with blower not operating.

§ 11.183–2 Exhalation valve leakage test; minimum requirements.

(a) Dry exhalation valves and valve seats will be subjected to a suction of 25 mm. water-column height while in a normal operating position.

(b) Leakage between the valve and valve seat shall not exceed 30 milliliters per minute.

§ 11.183–3 *Facepiece test; minimum requirements.*

(a) The complete pesticide respirator will be fitted to the faces of persons having varying facial shapes and sizes.

(b) Where the applicant specifies a facepiece size or sizes for his respirator together with the approximate measurements of faces they are designed to fit, the Bureau will provide test subjects to suit such facial measurements.

(c) Any pesticide respirator part which must be removed to perform the facepiece fit test shall be replaceable without special tools and without disturbing facepiece fit.

(d) The facepiece or mouthpiece fit test using positive or negative pressure recommended by the applicant and described in his instructions will be used during each test.

(e) (1) Each wearer will enter a chamber containing 1,000 p.p.m. isoamyl-acetate vapor for a respirator equipped with a full facepiece, mouthpiece, hood, or helmet and 100 p.p.m. isoamyl-acetate vapor for a respirator equipped with a half-mask facepiece.

(2) The facepiece, mouthpiece, hood, or helmet may be adjusted, if necessary, in the test chamber before starting the test.

(3) Each wearer will remain in the chamber while performing the following activities:

(i) Two minutes, nodding and turning head;

(ii) Two minutes, calisthenic arm movements;

(iii) Two minutes, running in place; and,

(iv) Two minutes, pumping with a tire pump into a 28-liter (1 cubic foot) container.

(4) Each wearer shall not detect the odor of isoamyl-acetate during the test.

§ 11.183–4 Silica dust test; minimum requirements.

Three completely assembled pesticide respirators will be tested with a mechanical-testing apparatus as follows:

(a) Temperature in the test chamber will be approximately 25° C.

(b) Continuous airflow through the respirator will be 32 liters per minute for front-mounted, back-mounted, and chin-style gas mask pesticide respirators and chemical cartridge pesticide respirators, and not less than 115 (4 cubic feet) liters per minute to tight-fitting facepieces and 170 liters (6 cubic feet) per minute to loose-fitting hoods and helmets of powered air-purifying respirators.

(c) The test aerosol will contain 50–60 milligrams of 99+ percent free silica per cubic meter of air.

(d) The particle size distribution of the test suspension will have a geometric mean diameter of 0.4 to 0.6 micrometer, with a standard geometric deviation less than 2.

( ) Front-mounted, back-mounted, and chin-style gas mask pesticide respirators and chemical cartridge pesticide respirators will be tested for 90 minutes and powered air-purifying respirators will be tested for 4 hours.

§ 11.183–5 Lead fume test; minimum requirements.

Three completely assembled pesticide respirators will be tested with a mechanical-testing apparatus as follows:

(a) Continuous airflow through the respirator will be 32 liters per minute for front-mounted, back-mounted, and chin-style gas mask pesticide respirators and chemical cartridge pesticide respirators and not less than 115 liters (4 cubic feet) per minute, for powered air-purifying respirators with tight-fitting facepieces, and not less than 170 liters (6 cubic feet) per minute for powered air-purifying respirators with loose-fitting hoods and helmets.

(b) The test aerosol will contain 15–20 milligrams of freshly generated lead-oxide fume, calculated as lead, per cubic meter of air.

(c) The fume will be generated by impinging an oxygen-gas flame on molten lead.

(d) Front-mounted, back-mounted, and chin-style gas mask pesticide respirators and chemical cartridge pesticide respirators will be tested for 90 minutes and powered air-purifying pesticide respirators will be tested for 4 hours.

(e) The total amount of unretained test suspension, which is analyzed and calculated as lead, shall not exceed: (1) 0.43 milligram for any 90-minute test; (2) 4.8 milligrams for any 4-hour test made at 115 liters (4 cubic feet) per minute; or (3) 6.2 milligrams for any 4-hour test made at 170 liters (6 cubic feet) per minute.

§ 11.183–6 *Dioctyl-phthalate test; minimum requirements.*

(a) All canisters submitted for use with front-mounted and back-mounted gas mask pesticide respirators will be tested in an atmospheric concentration of 100 micrograms of dioctyl-phthalate per liter of air at continuous flow rates of 32 and 85 liters per minute for a test period of 5 to 10 seconds.

(b) The DOP leakage through the canister shall not exceed 0.03 percent of the ambient DOP concentration.

§ 11.183–7 Bench tests; minimum requirements.

(a) (1) Bench tests will be made on an apparatus that allows the test atmosphere at 50±5 percent relative humidity and at room temperature (25°±2.5° C.) to enter the canister or cartridge at predetermined concentrations and rates of flow, and that has a means for determining the test life of the canister or cartridge against carbon tetrachloride.

(2) Canisters and cartridges will be tested as they are used on each pesticide respirator, either singly or in pairs.

(3) Three canisters or cartridges or pairs of cartridges will be removed from containers and tested as received from the applicant.

(4) Two canisters, cartridges, or pairs of cartridges will be equilibrated at room temperature by passing 25 percent relative humidity air through them at the following flow rates (expressed as liters per minute (l.p.m.)) for 6 hours:

Type of canister or cartridge	*Airflow rate, l.p.m.*
Air-purifying canister	64
Air-purifying cartridge	26
Powered air-purifying with tight-fitting facepiece	115
Powered air-purifying with loose-fitting hood or helmet	170

(5) Two canisters, cartridges, or pairs of cartridges will be equilibrated at room temperature by passing 85 percent relative humidity air through them at the flow rates stated in subparagraph (4) of this paragraph for 6 hours.

(6) The equilibrated canisters or cartridges will be resealed, kept in an upright position at room temperature, and tested within 18 hours.

(b) Canisters and cartridges tested in accordance with the provisions of this section shall meet the requirements specified in Table 12.

TABLE 12.—CARBON TETRACHLORIDE BENCH TESTS AND REQUIREMENTS FOR CANISTERS AND CARTRIDGES

(30 CFR Part 11, Subpart M, § 11.183–7)

Type of pesticide respirator	Test concentrations, p.p.m. CCl_4	Flow rate l.p.m.	Number of tests	Minimum life, minutes [1]
Chest-mounted or back-mounted gas mask (as received)	20,000	64	3	12
Chest-mounted or back-mounted gas mask (equilibrated)	20,000	32	4	12
Chin-style gas mask (as received)	5,000	64	3	9
Chin-style gas mask (equilibrated)	5,000	32	4	9
Chemical-cartridge respirator (as received)	1,000	64	3	50
Chemical-cartridge respirator (equilibrated)	1,000	32	4	50
Powered air-purifying respirator (tight-fitting facepiece, as received)	1,000	[2] 115	3	90
Powered air-purifying respirator (tight-fitting facepiece, equilibrated)	1,000	[2] 115	4	2
Powered air-purifying respirator (loose-fitting hood or helmet as received)	1,000	[3] 170	3	90
Powered air-purifying respirator (loose-fitting hood or helmet, equilibrated)	1,000	[3] 170	4	25

[1] Minimum life will be determined at 5 p.p.m. leakage.
[2] The flow rate shall be the effective flow rate of the device, but shall be not less than 115 l.p.m.
[3] The flow rate shall be the effective flow rate of the device, but shall be not less than 170 l. p.m.

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Title 30—Mineral Resources

CHAPTER I—BUREAU OF MINES, DEPARTMENT OF THE INTERIOR

PART 11—RESPIRATORY PROTECTIVE DEVICES, TESTS FOR PERMISSIBILITY; FEES

Respirators Used in Hazardous Atmospheres

The Secretary of the Interior, through the Mining Enforcement and Safety Administration (MESA), and the Secretary of Health, Education, and Welfare, through the National Institute for Occupational Safety and Health (NIOSH), conduct a testing and approval program for respirators used in hazardous atmospheres pursuant to the regulations contained in 30 CFR Part 11 issued jointly by the Secretaries on March 25, 1972 (37 FR 6244), as amended on March 15, 1973 (38 FR 6993) Section 11.2 provides that until March 30, 1974, respirators shall be considered to be approved for use in hazardous atmospheres if approved under either Part 11 or those Bureau of Mines respirator approval schedules in effect prior to Part 11, but that after March 30, 1974, only respirators tested and approved under Part 11 shall be considered to be approved.

After receiving a written request for a two year extension of the March 30, 1974, deadline from the Industrial Safety Equipment Association, a trade association of respirator manufacturers, MESA and NIOSH decided to conduct a public meeting to consider this request.

Notice of the public meeting was published in the FEDERAL REGISTER for October 18, 1973 (38 FR 28961), and the meeting was held on November 14, 1973, in the Department of Health, Education, and Welfare's Parklawn Building, 5600 Fishers Lane, Rockville, Maryland. Presentations were made by the following organizations: Industrial Safety Equipment Association, American Iron and Steel Institute, Boston Fire Department, Manufacturing Chemists Association, and Teneco, Inc. A verbatim transcript of the meeting is available for public inspection at the National Institute for Occupational Safety and Health, Parklawn Annex Room 3-32, Parklawn Drive, Rockville, Maryland, and at the office of the Assistant Administrator-Technical Support, MESA, Room 927, 4015 Wilson Boulevard, Arlington, Virginia.

On the basis of information presented at the hearing, numerous written comments, and information developed by NIOSH and MESA, it has been determined that only approximately 35 of the 400 currently approved types of respirators will have been certified under Part 11 by March 30, 1974. Additionally, among the 35 certified types of respirators, there are not enough units manufactured or in process to supply the needs of those who would be required to use approved respirators. Moreover, it appears that manufacturers, particularly the smaller ones, need additional time to establish and implement the formal quality control procedures required by Part 11.

Accordingly, it has been determined, after consultation with the Occupational Safety and Health Administration and the Atomic Energy Commission, that it is necessary to amend Part 11 as set forth below. The amendments provide that on or before September 30, 1974, respirators approved under Part 11 or a Bureau of Mines respirator approval schedule will be approved for use in hazardous atmospheres. The effect of this amendment is to extend the period for complying with the requirements of Part 11 for six months. The amendments further provide that after September 30, 1974, only respirators approved under Part 11 or manufactured pursuant to a quality control plan approved under Part 11 will be approved for such use, except that if a respirator is purchased on or before September 30, 1974, and at the time of purchase was approved under a Bureau of Mines respirator approval schedule, it shall be approved for use until the dates specified in § 11.2(b). Finally, the amendments provide that after March 31, 1975, only respirators approved under Part 11 will be approved for use except that if a respirator is purchased on or before March 31, 1975 and at the time of purchase was approved under a Bureau of Mines respirator approval schedule and manufactured pursuant to a quality control plan approved under Part 11, it shall be approved for use until the dates specified in § 11.2(c). The effect of this amendment is to clarify that users of equipment previously approved under Bureau of Mines schedules may continue to use such equipment, and to permit a gradual phasing out of such equipment in a manner consistent with the ability of these devices to provide effective respiratory protection.

Notice of proposed rulemaking, public rulemaking procedures, and postponements of effective date have been omitted in the issuance of the amendments to section 11.2 because the public has had an opportunity to present its views in the public meeting, and to delay the decision in this matter would be contrary to the public interest. Accordingly these amendments will be effective on April 9, 1974.

Dated: March 29, 1974.

WILLIAM A. VOGELY,
Acting Deputy Assistant Secretary of the Interior.

Dated: April 3, 1974.

FRANK CARLUCCI,
Acting Secretary of Health, Education, and Welfare.

Section 11.2 is revised to read as follows:

§ 11.2 Approved respirators.

(a) Until September 30, 1974, respirators or combination of respirators shall be approved for use in hazardous atmospheres where such respirators or combinations of respirators are maintained in an approved condition and are the same in all respects as those respirators:

(1) For which a certificate of approval has been issued under this part; or

(2) Fabricated, assembled, or built under any approval or any modification thereof, issued by the U.S. Bureau of Mines, Department of the Interior, in accordance with the schedules set forth in this paragraph;

(i) Self-contained Breathing Apparatus, Bureau of Mines Schedules 13, March 5, 1919; 13A, January 21, 1930; 13B, August 12, 1935; 13C, July 9, 1945; 13D, September 22, 1956, and 13E, July 19, 1968.

(ii) Gas Masks, Bureau of Mines Schedule 14F, April 23, 1955.

(iii) Supplied-air Respirators, Bureau of Mines Schedule 19B, April 19, 1955.

(iv) Filter-type Dust, Fume, and Mist Respirators, Bureau of Mines Schedule 21B, January 19, 1965.

(v) Nonemergency Gas Respirators, Bureau of Mines Schedule 23B, August 4, 1959.

(b) After September 30, 1974, respirators or combinations of respirators shall be approved for use in hazardous atmospheres where such respirators or combinations of respirators are maintained in an approved condition and are the same in all respects as those respirators: (1) For which a certificate of approval has been issued under this part; or (2) fabricated, assembled, or built under any approval or any modification thereof issued by the U.S. Bureau of Mines in accordance with the schedules set forth in paragraph (a) and in accordance with a quality control plan approved under this part: *Provided*, That if a respirator is purchased on or before September 30, 1974 and at the time of purchase was the same in all respects as a respirator approved under a Bureau of Mines Schedule, it shall be approved for use until the following dates:

Until March 31, 1979, for self-contained breathing apparatus approved under Bureau of Mines Schedules 13-13E;

Until March 31, 1977, for gas masks approved under Bureau of Mines Schedule 14F,

Until March 31, 1980, for supplied-air respirators approved under Bureau of Mines Schedule 19B,

Until March 31, 1976, for filter-type dust, fume, and mist respirators approved under Bureau of Mines Schedule 21B and for nonemergency gas respirators approved under Bureau of Mines Schedule 23B.

(c) After March 31, 1975, respirators or combinations of respirators shall be approved for use in hazardous atmospheres where such respirators or combinations of respirators are maintained in an approved condition and are the same in all respects as those respirators for which a certificate of approval has been issued under this part: *Provided*, That if a respirator is purchased on or before March 31, 1975, and at the time of purchase was the same in all respects as a respirator approved under a Bureau of Mines Schedule and was manufactured pursuant to a quality control plan approved under this part, it shall be approved for use until the following dates:

Until March 31, 1979, for self-contained breathing apparatus approved under Bureau of Mines Schedule 13-13E;

Until March 31, 1977, for gas masks approved under Bureau of Mines Schedule 14F;

Until March 31, 1980, for supplied-air respirators approved under Bureau of Mines Schedule 19B;

Until March 31, 1976, for filter-type dust, fume, and mist respirators approved under Bureau of Mines Schedule 21B and for nonemergency gas respirators approved under Bureau of Mines Schedule 23B.

(Secs. 202(b), 204, 508, 83 Stat. 763, 764, 803 (30 U.S.C. 842(b), 844, 957); secs. 2, 3, 5, 36 Stat. 370, as amended 37 Stat. 681 (30 U.S.C. 3, 5, 7); sec. 6(g), 84 Stat. 1600 (29 U.S.C. 667(g)))

[FR Doc.74-8100 Filed 4-8-74;8:45 am]

Title 30—Mineral Resources

CHAPTER I—MINING ENFORCEMENT AND SAFETY ADMINISTRATION, DEPARTMENT OF THE INTERIOR

SUBCHAPTER B—RESPIRATORY PROTECTIVE APPARATUS; TESTS FOR PERMISSIBILITY; FEES

PART 11—RESPIRATORY PROTECTIVE DEVICES; TESTS FOR PERMISSIBILITY; FEES

Deadline Extension

The Secretary of the Interior, through the Mining Enforcement and Safety Administration (MESA) and the Secretary of Health, Education, and Welfare, through the National Institute for Occupational Safety and Health, (NIOSH), conduct a testing and approval program for respirators used in hazardous atmospheres pursuant to the regulations contained in 30 CFR Part 11 issued jointly by the Secretaries (37 FR 6244).

On April 9, 1974, following a public hearing on the issue, Part 11 was amended (39 FR 12864) to provide that until September 30, 1974 respirators approved under Part 11 or a Bureau of Mines respirator schedule would be approved for use in hazardous atmospheres.

The amendments provided that after September 30, 1974, only respirators approved under Part 11 or manufactured pursuant to a quality control plan approved under Part 11 would be approved for such use except that if a respirator was purchased before September 30, 1974 and at the time of purchase was approved for use under a Bureau of Mines respirator schedule, it would be approved for use until the dates specified in the regulation. The amendment further provided that after March 31, 1975 only respirators approved under Part 11 would be approved for use except that if a respirator was purchased before March 31 and at that time was approved under a Bureau of Mines respirator schedule and manufactured pursuant to an approved quality control plan, it would be approved for use until the dates specified in the regulation.

Following adoption of the April 9 amendments, respirator manufacturers submitted quality control plans for NIOSH review and approval. While some plans were submitted in a timely manner, a number was not received until after July 1974, and a substantial number has not yet been received. Due to the complexity of the plans and the shortage of qualified manpower to review these detailed plans, there are devices for which a quality control plan has been submitted but not reviewed and approved. The result is that, unless the regulations are amended, after September 30 these devices will no longer be permitted to be sold as approved equipment. Moreover, it is anticipated that a similar situation will develop with respect to the March 31, 1975 deadline.

The purpose of these amendments is to eliminate September 30, 1974 as a deadline date and to extend the March 31, 1975 date described above to June 30, 1975. By that time NIOSH will have had an opportunity to review all of the quality control plans previously submitted as well as those anticipated to be received.

Respiratory equipment already in the possession of industrial users or acquired on or before June 30, 1975 and previously approved under Bureau of Mines respirator approval schedules will continue to be approved for use in accordance with the dates adopted in the April 9, 1974 amendments (39 FR 12864).

Finally, since the requirements for the approval and certification of gas masks are under revision, the deadline date for the approval of those devices has not been established and those devices have been excepted from the June 30, 1975 deadline date. A deadline date for approval and certification of gas masks under Part 11 will be adopted in the future.

Since it is essential that approved respiratory protective devices remain available to industrial users, the Departments find that good cause exists for omitting notice of proposed rulemaking and postponement of the effective date in the issuance of the amendments to Part 11. Accordingly, these amendments, as set forth below, will be effective on September 30, 1974.

Part 11 of Title 30, Code of Federal Regulations is amended and revised as set forth below.

Dated: November 12, 1974.

JACK W. CARLSON,
Assistant Secretary of the Interior

Dated: November 18, 1974.

CASPAR W. WEINBERGER,
Secretary of Health, Education, and Welfare.

In Part 11, a new § 11.2-1 is added and § 11.2 is revised to read as follows:

§ 11.2 Approved respirators other than gas masks.

(a) Until June 30, 1975, respirators or combinations of respirators other than gas masks shall be approved for use in hazardous atmospheres where such respirators or combinations of respirators are maintained in an approved condition and are the same in all respects as those respirators:

(1) For which a certificate of approval has been issued under this part; or

(2) Fabricated, assembled or built under any approval or any modification thereof issued by the U.S. Bureau of Mines, Department of the Interior, in accordance with the schedules set forth in this paragraph:

(i) Self-contained Breathing Apparatus, Bureau of Mines Schedules 13, March 5, 1919; 13A, January 21, 1930; 13B, August 12, 1935; 13c, July 9, 1946; 13D, September 22, 1956, and 13E, July 19, 1963.

(ii) Supplied-air Respirators, Bureau of Mines Schedule 19B, April 19, 1955

(iii) Filter-type Dust, Fume, and Mist Respirators, Bureau of Mines Schedule 21B, January 19, 1965.

(iv) Nonemergency Gas Respirators, Bureau of Mines Schedule 23B, August 4, 1959.

(b) After June 30, 1975, respirators or combinations of respirators other than gas masks shall be approved for use in hazardous atmospheres where such respirators or combinations of respirators are maintained in an approved condition and are the same in all respects as those respirators for which a certificate has been issued under this part: *Provided*, That if a respirator is purchased on or before June 30, 1975 and at the time of purchase was the same in all respects as a respirator approved under a Bureau of Mines Schedule, it shall be approved for use until the following dates:

Until March 31, 1979, for self-contained breathing apparatus approved under Bureau of Mines Schedules 13-13F.

Until March 31, 1980, for supplied-air respirators approved under Bureau of Mines Schedule 19D.

Until March 31, 1976, for filter-type dust, fume, and mist respirators approved under Bureau of Mines Schedule 21B and for nonemergency gas respirators approved under Bureau of Mines Schedule 23B.

§ 11.2-1 Approved gas masks.

Gas masks shall be approved for use in hazardous atmospheres where such gas masks are maintained in an approved condition and are the same in all respects as those gas masks:

(a) For which a certificate of approval has been issued under this part; or

(b) Fabricated, assembled or built under any approval or any modification thereof issued by the U.S. Bureau of Mines, Department of the Interior in accordance with Bureau of Mines Schedule 14F, April 23, 1955.

(Secs. 202(b), 204, 508, 83 Stat. 763, 764, 803 (30 U.S.C. 842(b), 844, 957); secs. 2, 3, 5, 36 Stat. 370, as amended 37 Stat. 681 (30 U.S.C. 3, 5, 7); sec. 6(g), 84 Stat. 1600 (29 U.S.C. 667(g)))

[FR Doc.74-27365 Filed 11-21-74;8:45 am]

Title 30—Mineral Resources

CHAPTER I—MINING ENFORCEMENT AND SAFETY ADMINISTRATION, DEPARTMENT OF THE INTERIOR

PART 11—RESPIRATORY PROTECTIVE DEVICES; TESTS FOR PERMISSIBILITY; FEES

Respiratory Protection Against Exposure to Vinyl Chloride

The Secretary of the Interior, through the Mining Enforcement and Safety Administration, and the Secretary of Health, Education, and Welfare, through the National Institute for Occupational Safety and Health, conduct a testing and approval program for respirators used in occupationally hazardous atmospheres pursuant to regulation contained in this part.

On October 4, 1974, the Occupational Safety and Health Administration, following a public hearing on the matter, promulgated a standard for the control of employee exposure to vinyl chloride. The standard provides that respiratory protection shall be provided at the request of employees exposed to 25 ppm or less vinyl chloride and requires that respirators shall be selected from those approved under Part 11. Specifically, the standard requires, among other things, that where the atmospheric concentration of vinyl chloride is not over 25 ppm, any gas mask with front- or back-mounted canister or powered air-purifying respirator with canister which provides a service life of at least four hours may be used, and where the concentration is not over 10 ppm, any chemical cartridge respirator with an organic vapor cartridge which provides a service life of at least one hour may be used. The standard further requires a program to assure timely replacement of canisters or cartridges.

The purpose of the amendments set forth below is to establish special procedures for testing vinyl chloride respirators and to adopt a requirement that any canister or cartridge used to protect employees against exposure to vinyl chloride, have an end-of-service-life indicator. Unlike many other gases, vinyl chloride has no inherent warning properties. Where a gas has an odor and where a canister or cartridge is nearing or is at the end of its useful life, the worker is aware because he can smell the gas. Vinyl chloride is odorless and colorless. Thus, with due regard for the wearer's health, any cartridge or canister should possess an end-of-service-life indicator. Section 11.205 provides that after June 30, 1975, each canister or cartridge submitted for approval must have an end-of-service-life indicator. The delay in this requirement is to give the Institute an opportunity to test the effectiveness of the indicators. Section 11.205 further provides that after December 31, 1975—when respiratory protection at 25 ppm or less becomes mandatory—respirators without an end-of-service-life indicator will not be considered approved for use by employees exposed to vinyl chloride. There is no delay in the effective date for the special tests adopted for vinyl chloride respirators.

Since it is essential that there are available approved respiratory devices for protection against exposure to vinyl chloride the Departments find that good cause exists for omitting notice of proposed amendments to Part 11. Accordingly, these amendments, as set forth below, will be effective on December 30, 1974.

Dated: December 24, 1974.

JACK W. CARLSON,
Secretary of the Interior.

Dated: December 10, 1974.

CASPAR W. WEINBERGER,
Secretary of Health, Education, and Welfare.

In Part 11 a new Subpart N for special use respirators is established and Sections 11.200–11.208 applicable to vinyl chloride respirators are added to read as follows:

Subpart N—Special Use Respirators

Sec.
11.200 Vinyl chloride respirators; description.
11.201 Required components.
11.202 Gas masks; requirements and tests.
11.203 Chemical-cartridge respirators; requirements and tests.
11.204 Powered air-purifying respirators; requirements and tests.
11.205 Requirements for end-of-service-life indicator.
11.206 Quality control requirements.
11.207 Labeling requirements.
11.208 Fees.

AUTHORITY: Secs. 202(h), 204, 508, 83 Stat. 763, 784, 803 (30 U.S.C. 812(h), 844, 957); secs. 2, 3, 5, 36 Stat. 370, as amended 37 Stat. 681 (30 U.S.C. 3, 5, 7); sec. 8(g), 84 Stat. 1600 (29 U.S.C. 657(g)).

§ 11.200 Vinyl chloride respirators; description.

Vinyl chloride respirators, including all completely assembled respirators which are designed for use as respiratory protection during entry into and escape from vinyl chloride atmospheres containing adequate oxygen to support life, are described according to their construction as follows:

(a) Front-mounted or back-mounted gas masks;
(b) Chin-style gas masks;
(c) Chemical-cartridge respirators;
(d) Powered air-purifying respirators; and,
(e) Other devices, including combination respirators.

11.201 Required components.

(a) Each vinyl chloride respirator described in 11.200 shall, where its design requires, contain the following component parts:
(1) Facepiece;
(2) Canister with end-of-service-life indicator;
(3) Cartridge with end-of-service-life indicator;
(4) Harness;
(5) Attached blower; and,
(6) Breathing tube.

(b) The components of each vinyl chloride respirator shall meet the minimum construction requirements set forth in Subpart G of this part.

§ 11.202 Gas masks; requirements and tests.

(a) Except for the tests prescribed in 11.102–5, the minimum requirements and performance tests for gas masks prescribed in Subpart I of this part are applicable to vinyl chloride gas masks.

(b) The following bench tests are applicable to canisters designed for use with gas masks for entry into and escape from vinyl chloride atmospheres containing adequate oxygen to support life:

(1) Four canisters will be equilibrated at 25±5° C by passing 85±5 percent relative humidity air through them at 64 liters per minute for six hours.

(2) The equilibrated canisters will be resealed, kept in an upright position at room temperature, and tested according to subparagraph (3) of this paragraph within 18 hours.

(3) The canisters equilibrated and stored as described in subparagraphs (1) and (2) of this paragraph will be tested on an apparatus that allows the test atmosphere at 85±5 percent relative humidity and 25±5° C to enter the canister continuously at a concentration of 25 ppm vinyl chloride monomer at a total flow rate of 64 liters per minute. The maximum allowable penetration after six hours of testing according to subparagraph (3) of this paragraph shall not exceed 1 ppm vinyl chloride.

(c) Where canisters are submitted for testing and approval with a service life of more than four hours, the period of time for testing for vinyl chloride penetration will be performed at 150% of the service life specified in the manufacturer's application. Example: If a manufacturer requests approval of a respirator for six hours use against exposure to vinyl chloride, the maximum allowable penetration after nine hours of testing shall not exceed 1 ppm vinyl chloride.

11.203 Chemical-cartridge respirators; requirements and tests.

(a) Except for the tests prescribed in 11.102–5, the minimum requirements and performance tests for chemical-cartridge respirators prescribed in Subpart I of this part are applicable to vinyl chloride chemical-cartridge respirators.

(b) The following bench tests are applicable to cartridges designed for use with chemical-cartridge respirators for entry into and escape from vinyl chloride atmospheres containing adequate oxygen to support life:

(1) Where two cartridges are used in parallel on a chemical-cartridge respirator, the bench test requirements will apply to the combination rather than the individual cartridges.

(2) Four cartridges or pairs of cartridges will be equilibrated at 25±5° C by passing 85±5 percent relative humidity air through them at 25 liters per minute for six hours.

(3) The equilibrated cartridges will be resealed, kept in an upright position, at room temperature, and tested according to subparagraph (4) of this paragraph within 18 hours.

(4) The cartridges equilibrated and stored as described in subparagraphs (1), (2), and (3) of this paragraph will be tested on an apparatus that allows the test atmosphere at 85±5 percent relative humidity and 25±5° C. to enter the cartridges or pairs of cartridges continuously at a concentration of 10 ppm vinyl chloride monomer at a total flow rate of 64 liters per minute.

(5) The maximum allowable penetration after two hours of testing according to subparagraph (4) of this paragraph shall not exceed 1 ppm vinyl chloride.

11.204 Powered air-purifying respirators; requirements and tests.

(a) Except for the tests prescribed in 11.162-8, the minimum requirements and performance tests for powered air-purifying respirators prescribed in Subpart L of this part are applicable to vinyl chloride powered air-purifying respirators.

(b) The following bench tests are applicable to cartridges designed for use with powered air-purifying respirators for entry into and escape from vinyl chloride atmospheres containing adequate oxygen to support life.

(1) Four cartridges will be equilibrated at 25±5° C by passing 85±5 percent relative humidity air through them at 115 liters per minute for tight-fitting facepieces and 170 liters per minute for loose-fitting hoods and helmets, for six hours.

(2) The equilibrated cartridges will be resealed, kept in an upright position at room temperature and tested according to subparagraph (3) of this paragraph within 18 hours.

(3) The cartridges equilibrated and stored as described in subparagraphs (1) and (2) of this paragraph will be tested on an apparatus that allows the test atmosphere at 85±5 percent relative humidity and 25±5° C to enter the cartridge continuously at a concentration of 25 ppm vinyl chloride monomer at a total flow rate of 115 liters per minute for tight-fitting facepieces and 170 liters per minute for loose-fitting hoods and helmets.

(4) The maximum allowable penetration after six hours of testing according to subparagraph (3) of this paragraph shall not exceed 1 ppm vinyl chloride.

§ 11.205 Requirements for end-of-service-life indicator.

(a) After June 30, 1975, each canister or cartridge submitted for testing and approval in accordance with §§ 11.202, and 11.203, and 11.204 shall be equipped with a canister or cartridge end-of-service-life indicator which shows a satisfactory indicator change or other obvious warning before 1 ppm vinyl chloride penetration occurs. The indicator shall show such change or afford such warning at 80±10 percent of the total service life to 1 ppm leakage, as determined by continuing each test described in paragraphs (b) of each of §§ 11.202, 11.203, and 11.204 of this Subpart until a 1 ppm leakage of vinyl chloride occurs. After December 31, 1975, a cartridge or canister without an end-of-service-life indicator will not be considered approved for use by employees exposed to vinyl chloride.

(b) The applicant shall provide sufficient pretest data to verify the performance of the end-of-service-life indicator required in paragraph (a) of this Section.

§ 11.206 Quality control requirements.

(a) In addition to the construction and performance requirements specified in Sections 11.201, 11.202, 11.203, 11.204, and 11.205 of this Subpart, the quality control requirements in paragraphs (b), (c), and (d) of this section apply to approval of gas masks, chemical cartridge respirators, and powered air-purifying respirators for entry into and escape from vinyl chloride atmospheres containing adequate oxygen to support life.

(b) The respirators submitted for approval as described in paragraph (a) of this Section shall be accompanied by a complete quality control plan meeting the requirements of Subpart E of this Part.

(c) The applicant shall specify in the plan that a sufficient number of samples will be drawn from each bulk container of sorbent material and that where activated carbon is used, the following specific tests will be performed:

1. Apparent density,
2. Iodine number,
3. Moisture content,
4. Carbon tetrachloride number, and,
5. Mesh size.

Such tests shall be performed in a quantity necessary to assure continued satisfactory conformance of the canisters and cartridges to the requirements of this Subpart.

(d) Final performance quality control tests on the complete canisters and cartridges shall be accomplished using the bench tests and procedures prescribed in §§ 11.202, 11.203, 11.204, and 11.205 of this Subpart.

11.207 Labeling requirements.

A warning shall be placed on the label of each gas mask, chemical-cartridge respirator, and powered air-purifying respirator, and on the label of each canister and cartridge, alerting the wearer to the need for a fitting test in accordance with the manufacturer's facepiece fitting instructions, providing service life information, providing specific instructions for disposal, and advising that the wearer may communicate to NIOSH any difficulties that may be experienced in the design and performance of any gas mask, chemical-cartridge respirator, or powered air-purifying respirator approved under the requirements of this Subpart. The service lives of respirators meeting the test requirements of this Subpart shall be specified as follows:

(a) Chemical-cartridge respirator.	1 hour
(b) Gas mask	4 hours
(c) Powered air-purifying respirator.	4 hours

(d) Where the service life of a respirator is approved for more than four hours, the service life for which the respirator has been approved will be specified.

11.208 Fees.

The following fees shall be charged for the examination, inspection, and testing of complete assemblies and components of respirators described in §§ 11.200 and 11.201 of this Subpart.

(a) Complete gas mask	$1,100
(b) Complete chemical-cartridge respirator.	1,150
(c) Complete powered air-purifying respirator.	1,500
(d) Canister or cartridge only.	750

[FR Doc.74-30352 Filed 12-27-8:45 am]

APPENDIX C

RESPIRATOR DRYING CABINET

One 18 by 36 by 78-in. three-shelf cabinet with double doors
Three 15-3/4 by 35-3/4-in. pieces of 1/4-in. stainless steel mesh for shelves
One 10 by 10-in. piece of window screen for exhaust port
One small portable electric heater with fan, 115 V ac, 1650 W
Thirty-two size 10 eyebolts
Thirty-two clothespins with metal hanging clips
Thirty-two spring clips
0 to 180°F thermometer
Size 20 nuts and bolts.

CABINET MODIFICATION

On one side, near the bottom, cut a hole and bolt the heater in place. Make sure the heater has a three-wire (grounded) plug. In the top of the cabinet, cut an 8 by 8-in. exhaust port and cover it with window screen. Cut away each shelf, leaving 1-1/2 in. at each edge, and bolt the stainless steel mesh in place. On the bottom and second shelves screw the small eye bolts into this mesh about 3 in. apart, and spaced so that 16 masks can hang in a double row from each shelf without touching each other. The clothespins hang from the eyebolts by specially fabricated metal clips. The thermometer is suspended by a small clamp.

The temperature inside the cabinet is kept at 120 to 140°F. After the cabinet has been loaded with masks, the temperature averages about 125°F on the top shelf to 135°F at the bottom of the low-hanging masks.

The normal cabinet load is 10 to 15 full-face and 24 half-mask respirators and their filter holders. The greatest practical capacity, using both hangers and shelves, is 30 full-face or 60 half-mask respirators. The average drying time is 1 to 1-1/2 h. The total cost of materials and labor is less than $150.00. Figures C-1 through C-3 show this cabinet.

Fig. C-1.
Outside of cabinet showing heater unit.

Fig. C-2.
Unloaded cabinet.

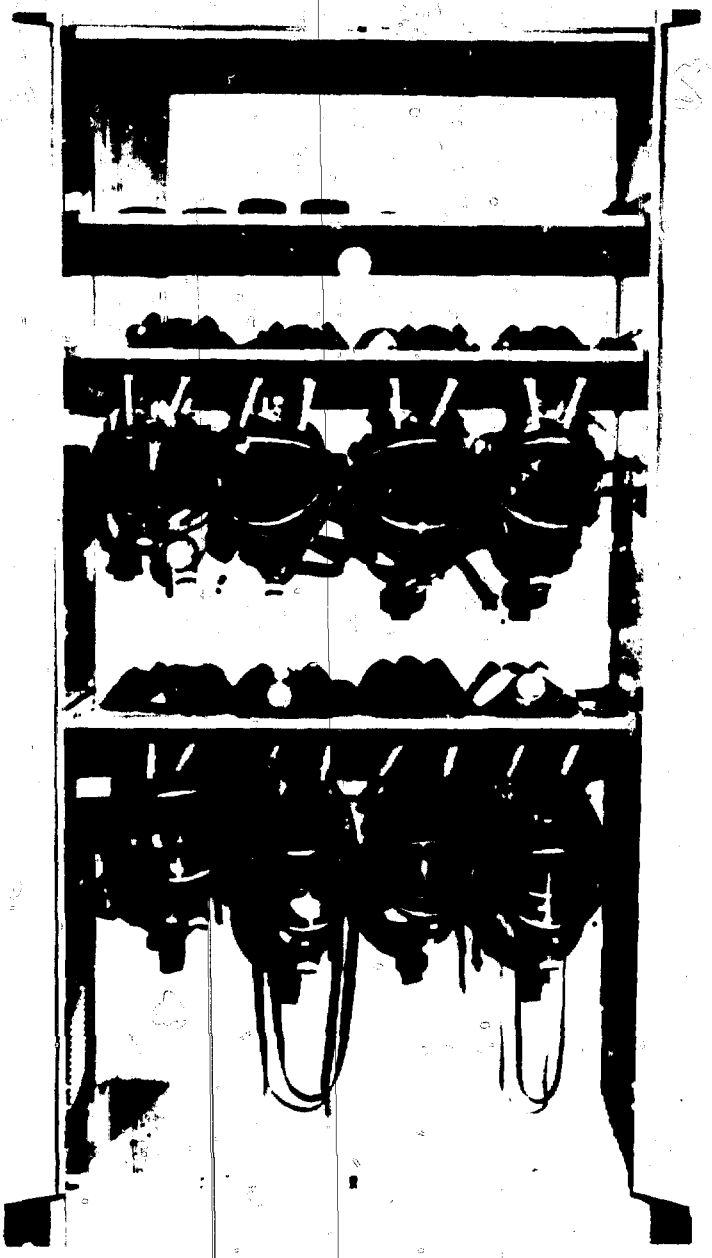

Fig. C-3.
Cabinet loaded with masks.

APPENDIX D

QUANTITATIVE RESPIRATOR FITTING 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 Chap. Nine.

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 he fully understands its purpose, the procedures, and the actions expected of him.

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

D. Have the subject put on the respirator, according to manufacturer's instructions. Be sure he 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 or 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 min) 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 min;

(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 from side to side while breathing normally, pausing for at least two breaths before changing direction. Continue for at least 1 min;

(4) Moving head slowly up and down while breathing normally, pausing for at least two breaths before changing direction. Continue for at least 2 min;

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

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

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. On the basis of a protection factor (PF) of 10 for respirators with half- and quarter-mask facepieces and 50 for those with full facepieces, maximum penetrations by the test agent should not significantly exceed 10 and 2%, respectively. A certain amount of professional judgment is involved in using this method.

The second, much preferred, method is to record the entire test using a strip-chart recorder operated at a chart speed of about 2 in. per min. Figure D-1 is a simulated recording that illustrates most of the things likely to occur in a test.

Starting at the bottom of Fig. D-1, the first information should uniquely identify the test by number, date, subject, and type of respirator. Next comes the test system calibration 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.

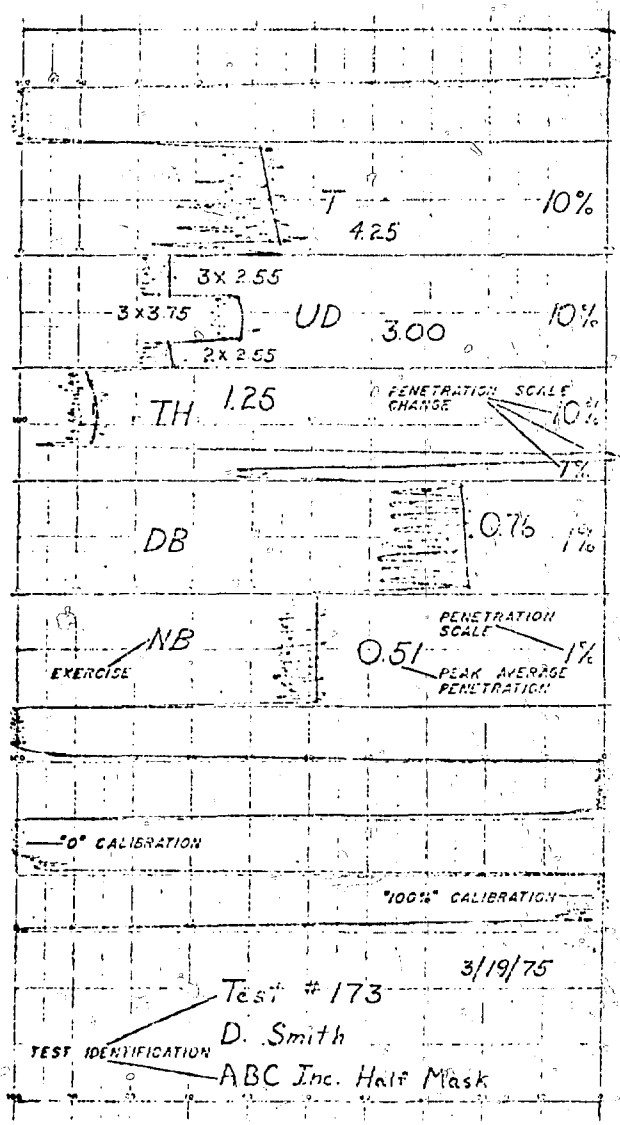

Fig. D-1.
Typical quantitative fitting test strip-chart recording.

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. In Fig. D-1 the following were used.

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, as in Fig. D-1 during the moving head up and down (UD) exercise, it is usally advantageous to split the data into more than one section and treat each separately.

In the example, five chart divisions under UD showed a penetration of 2.55% and three showed 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 the fitting test record, shown in Fig. D-2. This form is only a suggestion, other formats may be devised to better meet individual needs.

Shown in Fig. D-2 on lines (1)-(3), is the information from the recorder chart which uniquely identifies the test. Lines (4) and (5) show the results of the qualitative pretest. In this case, the subject did not have a qualitative fit and had to readjust the respirator or tighten the headstraps. As line (5) shows, he then obtained a satisfactory seal. Line (6) indicates that the subject was able to wear safety glasses with the particular respirator without interference. This is important information as most workers are now required to wear eye protection.

(1) Test No. 173

(2) Subject D. Smith Date 3/19/75
(3) Respirator ABC Inc. Half Mask
(4) Qualitative Pretest: Irr. Smoke Yes No. X
(5) Refit: Yes X No
(6) Compatible with safety glasses: Yes X No

TEST RESULTS

Exercise	Peak Average Penetration
(7) Normal Breathing	0.51
(8) Deep Breathing	0.76
(9) Turning Head from Side to Side	1.25
(10) Moving Head Up and Down	3.00
(11) Talking	4.25

(12) Average Allowable 10 % Test Average 1.95 %
(13) Fit: Satisfactory X Unsatisfactory

(14) Comfort Ratings 1 2 (3) 4 5

Fig. D-2.
Fitting test record.

Lines (7)-(11) show the average peak penetrations calculated for each exercise. Line (12) shows the test criterion expressed as the maximum allowable average peak penetration. This is 10%, as the test involved an air-purifying respirator with a half-mask facepiece. Line (12) also shows the test average peak penetration of 1.95% obtained by averaging the average peak penetrations for each exercise. Line (13) shows whether the overall performance was satisfactory or not. This determination is based on the qualitative fit, compatibility with safety glasses, and average penetration, which in this example had to be less than 10%.

The subjective evaluation of the comfort of the particular respirator, shown on line (14), is based on the criteria shown in Fig. D-3. 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 te: , evaluating the results, and recording the da meaningfully, without laborious record keepin . Moreover, the data will be compatible with thos from other work.

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 HOUR TO 1 HOUR WITH SOME 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.

NOTE: This table can be used as the prepared text for the "Talking" exercise during the quantitative fitting test. This will save the time for the subject to acquaint himself with this table after the test.

Fig. D-3.
Respirator comfort ratings.

APPENDIX E

QUANTITATIVE RESPIRATOR-FITTING TEST EQUIPMENT

Both NaCl and DOP aerosol systems are commercially available (1975) from Air Techniques, Inc., 1717 Whitehead Road, Baltimore, MD 21207 and Frontier Enterprises, Inc., Box 30041, Albuquerque, NM 87110. The systems these concerns make differ little from the basic designs developed by the Los Alamos Scientific Laboratory (LASL). The cost may vary, depending upon accessories, but it is generally about $8-10,000. Both the NaCl and DOP systems consist of an aerosol generation and dilution air system, an analyzing system, and a test enclosure.

Figure E-1 illustrates a typical NaCl test system consisting of an internal or external compressed air source (1) that provides clean air at 50-100 psig to the aerosol generators (2) and combustion air to the burner (12). A Wright-design nebulizer is used in all commercial systems and has been adopted as the standard means of generating an NaCl aerosol. Operated at 24 psi with a 1% NaCl solution, it produces an aerosol with an aerodynamic mass median diameter (AMMD) of 0.6 μm. Two nebulizers are provided in most systems, although the output from one is sufficient for most purposes.

The aerosol generator injects the liquid droplets perpendicularly into the air stream flowing through the mixing and drying chamber (3), in Fig. E-1. The air for drying the aerosol (~4 cfm) is supplied by an internal blower ahead of which is mounted a high-efficiency filter. In passing through the mixing and drying chamber, the liquid NaCl droplets dry into discrete solid particles that are carried in the aerosol stream to the test enclosure. In this instance, the enclosure (5) is a test hood that covers the subject

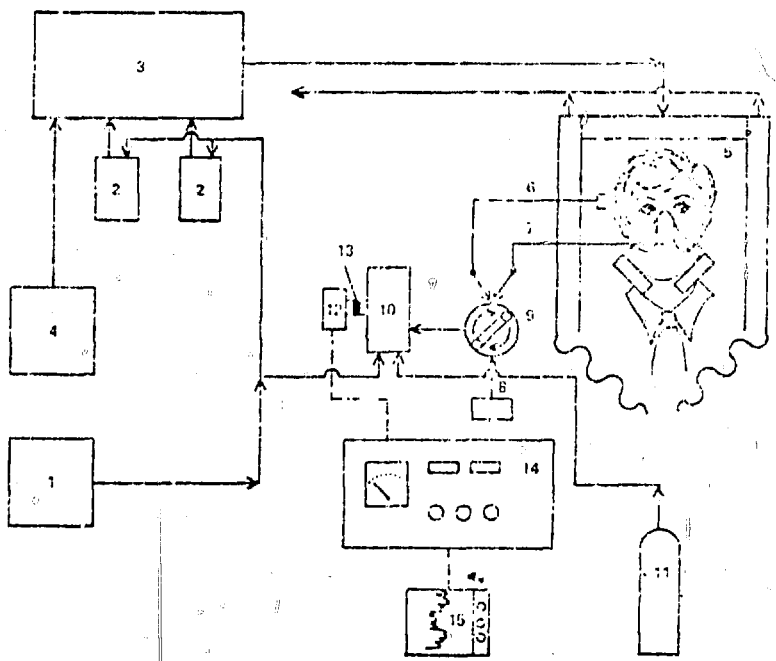

Fig. E-1.
NaCl quantitative fitting test system schematic.

down to his waist, but particles also could be delivered to a small chamber. This test hood, based on a Harvard School of Public Health design, is commercially available. The aerosol is delivered to the center top of the hood. Directly below the inlet is a small circular plate that helps distribute the aerosol stream evenly inside the hood. Even distribution is further ensured by a large perforated plate that forms the bottom of the aerosol distribution section.

The chamber part of the hood is made of two, slightly separated, cylindrical walls of thin, transparent plastic. At the bottom of the outer wall is a cloth skirt that can be drawn snugly around the subject's waist to minimize leakage into the surrounding area. The aerosol is exhausted through the annular space between the inner and outer walls.

As Fig. E-1 shows, two sampling tubes lead from the hood to the aerosol-analyzing system. One tube (6) samples the concentration of NaCl aerosol particles in the chamber atmosphere, and it is used in calibrating the flame photometer. The other tube (7) samples the NaCl aerosol particles in the air inside the respirator. A peristaltic (tubing) pump (9) is used to inject the sample into the flame photometer burner (10).

On the inlet side of this pump are connected the sampling tubes from the test hood as well as a third sampling tube which is connected to a small high-efficiency filter. This tube and filter (8) supply clean sampling air to the burner to calibrate the photometer.

Combustion air for the burner (10) is supplied from the external or internal compressed air source (1), and the propane fuel is supplied from an external tank (11). The amount of NaCl in the sample stream is determined by vaporizing the NaCl particles in the burner and detecting the emitted yellow light characteristic of sodium by using a sensitive photomultiplier tube (12) ahead of which is placed an optical filter (13) that passes only the sodium emission lines. The light intensity is directly related to the concentration of NaCl aerosol particles.

The photomultiplier tube output is fed into the electronics (14) of the test system analyzing section, and the amount of aerosol in the sampled air is displayed as percentage of the ambient concentration in the hood, either on a meter or a separate strip chart recorder (15).

The DOP quantitative respirator fitting test system is very like the NaCl system. As Fig. E-2 shows, an internal or external compressed air source (1) supplies 3- to 5-psig air to the Naval Research Laboratory Model III design DOP generator (2) and LASL-designed round jet impactor (3). The equivalent generator and impactor are found in commercial systems, but external construction details may differ.

The output from the generator and impactor assembly is injected into the dilution air chamber (4), perpendicularly to the air flowing through this chamber. The purpose is not to dry the aersol, as it is an oil mist, but to reduce the aerosol mass concentration to an acceptable level and maintain adequate air flow to the test enclosure. The test enclosure (6) is identical to that for the NaCl system, and two sampling tubes sample the DOP aerosol in the hood and the interior of the respirator. A third sampling tube outside the test hood is connected to a small high-efficiency filter (9) to provide clean air to the forward light-scattering photometer (10). The amount of DOP aerosol in the sample stream is determined by the intensity of the light scattered forward from particles passing through the center of the conical scattering chamber. This light strikes the photomultiplier tube (12), and the tube output is fed into the electronic section (13) of the analyzer which is almost identical to that used in the NaCl system.

The DOP concentration in the sample stream from the respirator, expressed as a percentage of the concentration in the test hood is displayed either on a meter or on a separate strip chart recorder (14).

This description applies primarily to the prototype units designed and built at LASL, upon which the commercial systems are based. Improvements and changes are made continually, so presently available systems may not look like those described. The important point is that the hearts of these systems, the aerosol generators, are identical in all respects.

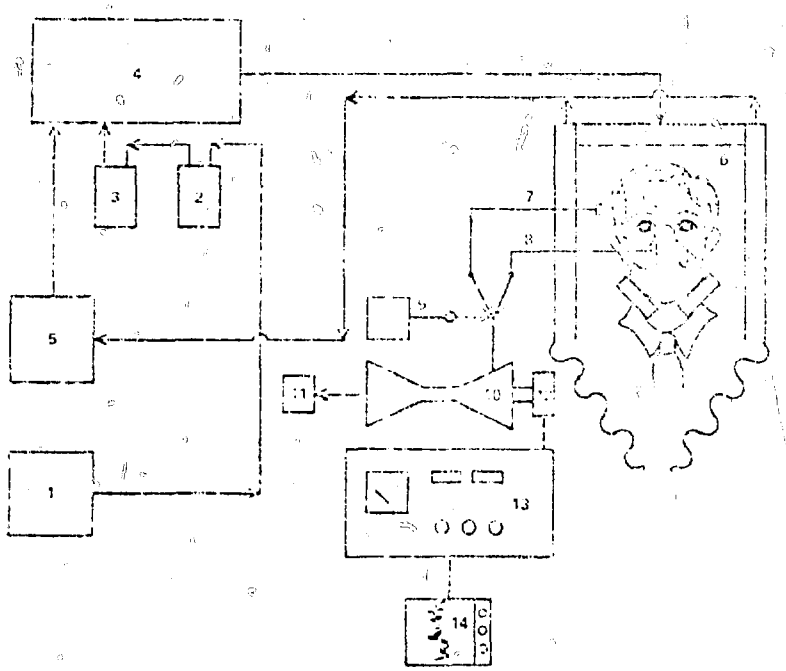

Fig. E-2.
DOP quantitative fitting test system schematic.

In summary, these quantitative respirator fitting test systems provide the ultimate method for determining respirator fit. However, it is unrealistic to suggest that every respirator program have this capability. These systems are expensive and complex and require trained operators. Therefore, they are most widely used by industrial firms that have very comprehensive respirator programs. On the other hand, if a small industrial firm must protect workers against highly toxic contaminants, the expenditure for a quantitative respirator fit test system may be justified.

APPENDIX F

JOINT NIOSH/OSHA STANDARDS COMPLETION PROGRAM

RESPIRATOR DECISION LOGIC

AUGUST 2, 1976

I. INTRODUCTION

The purpose of the Respirator Decision Logic is to assure technical accuracy and uniformity between substances in the selection of respirators and to provide necessary criteria to support this selection. The Decision Logic is a step by-step elimination of inappropriate respirators until only those which are acceptable remain. Judgment by persons knowledgeable of inhalation hazards and respiratory protection equipment is essential to ensure appropriate selection of respirators.

The primary technical criteria for what constitutes a permissible respirator are based on the technical requirements of 30 CFR Part 11 (Department of the Interior, Bureau of Mines, Respiratory Protective Devices and Tests for Permissibility). The proposed substance health standards will allow only respirators approved by the Bureau of Mines (or Mining Enforcement and Safety Administration (MESA)) and NIOSH under 30 CRF 11. Classes of respirators are included only if at least one device has been approved.

Protection factors are criteria used in determining what limiting concentrations are to be permitted for each respirator type that will afford adequate protection to the wearer. The referenced subparts of 30 CFR 11 give technical descriptions of each type or class of respirators referenced in the Decision Logic. 30 CFR 11 should be used with the Decision Logic in order to properly understand the criteria for the specification of allowable respirators.

II. GENERAL DECISION LOGIC FLOWCHART

Step 1 - Assemble Information on Substance

Assemble necessary toxicological safety, and research information for the particular contaminant. Typically the following are required:

(1) Permissible exposure limits specified in 29 CFR 1910.1000 (Tables Z-1, Z-2, and Z-3). These are the former 29 CFR 1910.93 tables.

(2) Warning properties if the substance is a gas or a vapor. Refer to Part IV(B) of this logic.

(3) Eye irritation potential of the substance. Refer to Part IV(D) of this logic.

(4) LEL (Lower Flammable Limit) for the substance. Refer to Part IV(F) of this logic.

(5) Immediately dangerous to life and health (IDLH) concentration for the substance. See Part IV(E) of this logic.

(6) Any possibility of poor sorbent efficiency at IDLH concentration and below. Refer to Part IV(C) of this logic.

(7) Any possibility of systemic injury or death resulting from absorbance of the substance (as a gas or vapor) through the skin. Refer to Part IV(A) of this logic.

(8) Any possibility of severe skin irritation resulting from contact of the skin with corrosive gases, vapors, or particulates (see Part IV A of this logic).

(9) The vapor pressure of the substance (and equivalent ppm).
(10) Any possibility of high heat of reaction with sorbent material in cartridge or canister.
(11) Any possibility of shock sensitivity of substance sorbed on cartridge or canister sorbent.

Step 2 - Determine Physical State of Substance

Determine the physical state(s) of the substance as it is likely to be encountered in the occupational environment. It will be either:

(A) Gas or vapor.
(B) Particulate (dust, fume or mist), or
(C) Combination of (A) and (B).

Step 3 - Assemble a Table of Permissible Respiratory Protection for Substance

This is done using the material from Step 1 and the appropriate specific decision logic chart from Part III of this logic and the respirator protection factors in Appendix I. Classes of respirators are included only if at least one device has been approved.

III.A. SPECIFIC DECISION LOGIC CHART FOR RESPIRATORY PROTECTION AGAINST GASES OR VAPORS

Condition	Selection Sequence
Routine Use	(A) Consider irritation and sorption of the material through the skin. (See IV A).
	(B) Poor warning properties - eliminate all air purifying respirators (see IV B).
	(C) Eye irritation - eliminate or restrict use of half-mask respirators (see IV D).
	(D) IDLH or LEL - above this concentration eliminate all but positive pressure self-contained breathing apparatus and combination positive pressure supplied air respirator with auxiliary positive pressure self-contained breathing apparatus (see IV E and F).
	(E) List all allowed respirators by condition of use and type.
Entry and Escape From Unknown Concentrations	Use positive pressure self-contained breathing apparatus or combination positive pressure supplied air respirator with auxiliary positive pressure self-contained breathing apparatus.
Firefighting	Use positive pressure self-contained breathing apparatus.
Escape	Gas mask or escape self-contained breathing apparatus (see IV C).

III.B. SPECIFIC DECISION LOGIC CHART FOR RESPIRATORY PROTECTION AGAINST PARTICULATES

Condition	Selection Sequence
Routine Use	(A) Consider skin irritation or sorption of the material through the skin (see IV A).
	(B) Eye irritation - eliminate or restrict use of half mask respirator (see IV D).
	(C) Systemic poison - eliminate single-use respirator.
	(D) For permissible exposures less than 0.05 mg/cu.m. - eliminate DFM respirators except with high efficiency particulate filter
	(E) IDLH or LFL - above this concentration eliminate all but positive pressure self-contained breathing apparatus and combination positive pressure supplied-air respirator with auxiliary positive pressure self-contained breathing apparatus (see IV E).
	(F) List all allowed respirators by condition of use and type.
Entry and Escape From Unknown Concentrations	Use positive pressure self-contained breathing apparatus or combination positive pressure supplied air respirator with positive pressure self-contained breathing apparatus.
Firefighting	Use positive pressure self-contained breathing apparatus (see IV F).
Escape	Use any dust, fume, or mist respirator, except single use, or any escape self-contained breathing apparatus.

III.C. SPECIFIC DECISION LOGIC CHART FOR RESPIRATORY PROTECTION AGAINST COMBINATION OF GAS OR VAPOR AND PARTICULATES

Condition	Selection Sequence
Routine Use	(A) Consider skin irritation or sorption of material through the skin (see IV A).
	(B) Poor warning properties or inadequate sorbent efficiency - eliminate all air purifying respirators (see IV B & C).
	(C) Eliminate all respirators except with combination sorbent-particulate filter.
	(D) Eye irritation - eliminate or restrict use of half mask respirator (see IV D).
	(E) For permissible exposures less than 0.05 mg m^{3}, - eliminate all respirators except with sorbent high efficiency particulate filter.
	(F) IDLH or LEL - above this concentration eliminate all but positive pressure self-contained breathing apparatus and combination positive pressure supplied-air respirator with auxiliary positive pressure self-contained breathing apparatus. (see IV E).
	(G) List all allowed respirators by condition of use and type.
Entry and Escape From Unknown Concentration	Use positive pressure self-contained breathing apparatus or combination positive pressure supplied air respirator with positive pressure self-contained breathing apparatus.
Firefighting	Use positive pressure self-contained breathing apparatus (see IV F).
Escape	Gas mask or escape self-contained breathing apparatus (see IV C).

IV.A. SKIN ABSORPTION

Personal protection requirements for protection against exposure to substances which may cause injury by absorption through the skin from materials splashed or spilled on the skin are covered in Section (F) of each substance standard. Respirator selection criteria are based primarily on the inhalation hazard of the substance. A supplied-air suit may provide skin protection for extremely toxic substances which may be absorbed through the skin, or substances that may cause severe skin irritation or injury.

Where information is available indicating systemic injury or death resulting from absorbance of a gas or vapor through the skin or where severe skin irritation or injury may occur from exposure to a gas, corrosive vapor, or particulate, the following statement is included as a footnote to the respirator tables and both the employee and employer are cautioned in the appendices concerning their use:

> Use of supplied-air suits may be necessary to prevent skin contact and respiratory exposure from airborne concentrations of (specific substance). Supplied-air suits should be selected, used, and maintained under the immediate supervision of persons knowledgeable in the limitations and potential life endangering characteristics of supplied air suits. Where supplied-air suits are used above a concentration which may be immediately dangerous to life and health, (concentration) an auxiliary positive-pressure self-contained breathing apparatus must also be worn

The supplied-air suit statement is an advisory footnote. The decision whether or not to include the footnote is made by the NIOSH OSHA review committees based on available information. Since most information concerning skin irritation is not quantative, but rather presented in commonly used descriptive terms, such as "a strong skin irritant, highly irritating to the skin", "corrosive to the skin", etc., the decision made by the committees concerning skin irritation is a judgmental decision often based on non-quantitative information. As a guideline for inclusion of the supplied-air suit statement for substances which are sorbed through the skin, a single skin penetration LD50 of 2 grams/kilogram for any species is used.

The footnote is advisory in nature and its inclusion does not make the use of supplied-air suits mandatory. Further, employers may use supplied-air suits in any situation where they provide adequate protection, whether there is an advisory footnote in the respirator table or not. To assure the health and safety of persons using supplied-air suits, it is imperative that they be used under the immediate supervision of persons knowledgeable in the limitations and potential life endangering characteristics of supplied-air suits.

IV.B. POOR WARNING PROPERTIES

It is important to realize that 30 CFR 11 NIOSH MESA approvals for air-purifying (organic vapor) devices prohibit use against organic vapors with poor warning properties. Specifically, 30 CFR 11.90(B) (Note 4) covers gas masks (canister respirators) and 30 CFR 11.150 (Note 7) covers chemical cartridge respirators. Thus these approvals are only for those organic vapors with adequate warning properties and not all organic vapors.

Warning properties relying upon human senses are not foolproof, however, they provide some indication to the employee of possible sorbent exhaustion or of poor facepiece fit or other respirator malfunction. Warning properties include odor, eye irritation, and respiratory irritation.

Adequate warning properties can be assumed when the substance odor, taste, or irritation effects are detectable and persistent at concentrations "at" or "below" the permissible exposure limit.

It is expected that environmental concentrations will vary considerably and, therefore, warning of a respirator failure would soon be perceived at contaminant concentrations somewhat above the permissible exposure limit.

If the odor or irritation threshold of a substance is more than three times greater than the permissible exposure limit, this substance should be considered to have poor warning properties. If the substance odor or irritation threshold is somewhat above the permissible exposure limit (not in excess of three times the limit) and there is no ceiling limit, consideration is given as to whether or not undetected

exposure in this concentration range could cause serious or irreversible health effects, if not, the substance is considered to have adequate warning properties. Some substances have extremely low thresholds of odor and irritation in relation to the permissible exposure limit. Because of this, these substances can be detected by a worker within the facepiece of the respirator even when the respirator is functioning properly. These substances are, therefore, considered to have poor warning properties.

Though 30 CFR 11 does not specify eliminating air purifying respirators for pesticides with poor warning properties, the SCP respirator review committee believes the standard completion program should not allow pesticide respirators for gases and vapors with poor warning properties.

IV.C. SORBENT EFFICIENCIES

Where supporting evidence exists on immediate (less than three minutes) breakthrough time at the IDLH concentration and below for a cartridge or canister sorbent, air-purifying devices shall not be allowed for any use, escape or otherwise.

Where there is reason to suspect that the commonly used sorbents (e.g., activated charcoal) do not provide adequate sorption efficiency against a specific contaminant, use of such sorbents shall not be allowed. However, where another sorbent material has been demonstrated to be effective against a specific contaminant, approved respirators utilizing the effective sorbent material shall be allowed. The statement in the respirator table shall read, "Any chemical cartridge respirator providing protection against (specific substance)", and "any gas mask providing protection against (specific substance)".

Where there is reason to suspect that a sorbent has a high heat of reaction with a substance, use of that sorbent is not allowed. In such cases, only sorbents providing safe protection against (specific substance) may be used. For such substances, a footnote is added to the respirator table which reads as follows: "(specific substance) is a strong oxidizer and should be kept away from oxidizable material. Some cartridges and canisters may contain activated charcoal and shall not be used to provide protection against (specific substance). Only non-oxidizable sorbents are allowed." Where the oxidizable material may be an oxidizable filter, the footnote reads: "(specific substance) is a strong oxidizer and should be kept away from oxidizable substances. Only air purifying respirators with non-oxidizable filters are allowed.

Where there is reason to suspect that a substance sorbed on a sorbent of a cartridge or canister is shock sensitive, use of air purifying respirators is disallowed.

IV.D. EYE IRRITATION

For routine work operations, any perceptible eye irritation is considered unacceptable. Therefore, only full facepiece respirators are permissible in contaminant concentrations which produce eye irritation. Note that 30 CFR 11.90(B) (Note 6) specifies that eye protection may be required in certain concentrations of acid gases and organic vapors. For escape, some eye irritation is permissible if it is determined that such irritation would not inhibit escape and such irritation is reversible.

Where quantitative eye irritation data cannot be found in literature references, and theoretical considerations indicate the substance should not be an eye irritant, half facepiece respirators are allowed. Where a review of the literature indicates a substance causes eye irritation but no eye irritation threshold is specified, the data will be evaluated to determine whether quarter or half-facepiece respirators are to be included in the respirator tables. When a table is developed for such substances, the respirators with quarter- and half-facepieces shall be footnoted as follows: When an employee informs his employer that he is experiencing eye irritation from ** NAME ** while wearing a respirator allowed in Table 2, the employer shall provide and ensure that the employee use an equivalent respirator with a full facepiece, helmet or hood.

IV.E. IDLH

The definition of IDLH provided in 30 CFR 11.3(T) is as follows:

> "Immediately dangerous to life or health" means conditions that pose an immediate threat to life or health or conditions that pose an immediate threat of severe exposure to contaminants, such as radioactive materials, which are likely to have adverse cumulative or delayed effects on health."

The purpose of establishing an IDLH exposure concentration is to insure that the worker can escape without injury or irreversible health effects from an IDLH concentration in the event of failure of the respiratory protective equipment. The IDLH is considered a maximum concentration above which only highly reliable breathing apparatus providing maximum worker protection is permitted. Since IDLH values are conservatively set, any approved respirator may be used up to its maximum use concentration below the IDLH.

In establishing the IDLH concentration, the following factors are considered:

1. Escape without loss of life or irreversible health effects. Thirty minutes is considered the maximum permissible exposure time for escape.
2. Severe eye or respiratory irritation or other reactions which would prevent escape without injury.

IDLH should be determined from the following sources:

1. Specific IDLH provided in the literature such as the AIHA Hygienic Guides.
2. Human exposure data.
3. Acute animal exposure data.
4. Where such data are lacking toxicological data from analogous substances may be considered.

The following guidelines should be used to interpret toxicological data reported in the literature for animal species:

1. Where acute exposure animal data are available (30-minute to 4-hour exposures), the lowest exposure concentration causing death or irreversible health effects in any species is determined to be the IDLH concentration.
2. Chronic exposure data may have no relevance to the acute effects and should be used in determining the IDLH concentration only upon competent toxicologic judgment.
3. Where there is no toxicologic evidence of an IDLH concentration, 500 times the permissible exposure limit shall determine the upper limit above which only highly reliable breathing apparatus providing maximum worker protection is used.

IV.F. LOWER FLAMMABLE LIMIT AND FIRE-FIGHTING

Contaminant concentrations in excess of the LFL are considered to be immediately dangerous to life or health. At or above the LFL, the use of respirators is limited to those devices which provide the maximum protection, i.e., positive-pressure SCBA, and combination positive-pressure supplied-air respirators with positive pressure SCBA.

Firefighting is defined by ANSI Z88.5-1971 as being immediately dangerous to life. For firefighting, the only device providing adequate protection is the positive pressure self-contained breathing apparatus.

IV.G. PROTECTION FACTORS

Protection factors are a measure of the overall effectiveness of a respirator. Filtering efficiency is a part of the protection factor and becomes a significant consideration for less efficient air purifying respirators.

The protection factors used in the preparation of the standards are based on quantitative fit tests performed at Los Alamos Scientific Laboratory and elsewhere, and in some instances on professional judgment. In Appendix I, the protection factors for each class of respirators listed in the checklists are shown. The entries in each list are for an entire class of respirators, and are assigned the protection factor of the lowest performing device within each class.

IV.H. VARIATIONS WITH 30 CFR 11

1. The type A supplied-air respirator is allowed in 30 CFR 11 for use in immediately dangerous to life and health atmospheres. However, air supply requirements of 50 l/min are insufficient to maintain a positive pressure in the facepiece under all working conditions. Therefore, this device should have the same protection factor as applied to other air-purifying and atmosphere supplying respirators having a negative pressure in the facepiece (see Appendix D). 30 CFR 11 will require a revision to eliminate approval of type A supplied air respirators for IDLH atmospheres.

2. 30 CFR 11 does not contain protection factor requirements. Protection factors are used in the decision logic. An amendment to 30 CFR 11 is planned to include protection factor requirements for DFM respirators. Future amendments are contemplated for other types of respirators.

3. 30 CFR 11 does not permit the use of an escape gas mask against acid gases or organic vapors with poor warning properties. A change to 30 CFR 11 is necessary to permit the use of an escape gas mask against substances with poor warning properties.

IV.I. ESCAPE

Where escape respirators are provided, they shall be selected from the escape category in Table 2. The employer shall provide and ensure that employees carry an escape respirator where exposure to extremely toxic substances may occur. (An extremely toxic substance is defined as a gas or vapor having a RAT LC50 of less than 10 ppm.)

The following statement is added to the introduction to the respirator table for these substances:

> Employers shall provide each employee working in areas where **name** may be released into the workplace air with an approved escape respirator as specified in Table 2. The employer shall ensure that each employee carry the escape respirator in the area where **name** may be released into the workplace.

IV.J. "ENTRY INTO TANKS OR CLOSED VESSELS, OR . . ."

Item (D)(4)(IV) is a variable provision in the introductory statements to the respirator tables which lists the specific operations where a respirator is considered to be an acceptable means of control. Examples of where this may occur are for operations which require occasional entry into tanks or other closed vessels.

APPENDIX I

A. PROTECTION FACTORS FOR PARTICULATE FILTER RESPIRATORS

Protection Factor	Permissible respiratory protection
5X	Any dust and mist respirator (30 CFR 11.130)
5X	Any dust and mist respirator except single use (30 CFR 11.130).
10X	Any dust and mist respirator, except single-use or quarter-mask respirator (30 CFR 11.130).
10X	Any fume respirator (30 CFR 11.130).
10X	Any high efficiency particulate filter respirator (30 CFR 11.130).
50X	A high efficiency particulate filter respirator with a full facepiece (30 CFR 11.130).
1000X	A powered air-purifying respirator with a high efficiency particulate filter (30 CFR 11.130).

B. PROTECTION FACTORS FOR CHEMICAL CARTRIDGES AND GAS MASKS

Protection Factor	Permissible respiratory protection
(Minimal)	
10X	Any chemical cartridge respirator with a **NAME** cartridge(s) (30 CFR 11.150)
50X	A chemical cartridge respirator with full facepiece and **NAME** cartridge(s) (30 CFR 11.150)
50X	A gas mask with a full facepiece and ** NAME ** canister (30 CFR 11.90 (A))
1000X	A powered air-purifying chemical cartridge respirator with a ** NAME ** cartridge (unlisted device).*
Escape	Any gas mask providing protection against ** NAME ** vapors (30 CFR 11.90)

*Classes of respirators are included only if at least one device has been approved.

NOTE: The approval ** NAME ** may consist of acid gases or organic vapors as a class or specific acid gases, ammonia or organic vapors. It may also consist of combinations of acid gases, organic vapors, and other gases and vapors.

C. PROTECTION FACTORS FOR COMBINATION CHEMICAL CARTRIDGES AND PARTICULATE FILTERS AND GAS MASKS AND PARTICULATE FILTERS

Protection Factors	Permissible respiratory protection
10X	Any chemical cartridge respirator with ** NAME ** cartridge(s) and ** NAME ** filter(s) (30 CFR 11.150 and 11.1300)
50X	A chemical cartridge respirator with a full facepiece, ** NAME ** cartridge(s) and high efficiency filter(s) (30 CFR 11.150 and 11.130)
50X	A gas mask with a full facepiece and ** NAME ** canister and high efficiency filter (30 CFR 11.90(A) and 11.130).
1000X	A powered air purifying chemical cartridge respirator with a ** NAME ** cartridge and high efficiency particulate filter.
Escape	Any gas mask providing protection against ** NAME ** and particulates (30 CFR 11.90 and 11.130)

** NAME ** refers to any acid gas, akaline gas, organic vapor, or other specific gas or vapor.
** TYPE ** refers to dust and mist, fume, or high efficiency particulate.

NOTE: A pesticide respirator is a special type of chemical cartridge respirator or gas mask with a combination sorbent and particulate filter. Where a substance is a pesticide the following phrase is added as a footnote to the respirator tables: "Including pesticide respirators which meet the requirements of this class."

D. PROTECTION FACTORS FOR SUPPLIED-AIR RESPIRATORS

Protection Factor	Permissible respiratory protection
10X	Any supplied-air respirator (30 CFR 11.110(A))
50X	Any supplied-air respirator with a full facepiece, helmet, or hood. (30 CFR 11.110(A))

1000X	*A type C supplied-air respirator operated in pressure-demand or other positive pressure of continuous flow mode (30 CFR 11.110(A))
2000X	A type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure mode or with a full facepiece, hood, or helmet operated in continuous flow mode (30 CFR 11.110(A))

*This category is not fully covered by preceding category

E. PROTECTION FACTORS FOR SELF-CONTAINED BREATHING APPARATUS

Protection Factor	Permissible respiratory protection
10X	Any self-contained breathing apparatus (30 CFR 11.70(A))
50X	Any self-contained breathing apparatus with a full facepiece (30 CFR 11.70(A))
10,000+X or Fire Fighting	Self-contained breathing apparatus with a full facepiece operated in pressure-demand or other positive pressure mode (30 CFR 11.70(A))
10,000+X	A combination respirator which includes a Type C supplied-air respirator with a full facepiece operated in pressure-demand or other positive pressure or continuous flow mode and an auxiliary self-contained breathing apparatus operated in pressure-demand or positive pressure mode (30 CFR 11.70(B))
Escape	Any escape self-contained breathing apparatus (30 CFR 11.70(A))

APPENDIX II

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APPENDIX G

STANDARD OPERATING PROCEDURES

Selection of the proper type of respirator is vital, but it is only part of the complete respirator program. Unless a standard operating procedure is set up, a correctly chosen respirator may be used incorrectly. The OSHA regulations 1910.134b require written standard operating procedures whenever respirators are used. Examples are given below.

STANDARD OPERATING PROCEDURES FOR USE OF RESPIRATORS IN THE MULLER AREA

The first respirator selection example in Chap. Six concerned a muller operator in a foundry. If we assume that this is a small foundry with only one operator, we can write a simple procedure as follows.

Respirator Selection

On the basis of the 5-mg/m³ dust concentration and a permissible exposure limit of 1.5 mg/cm of silica dust, we have chosen the brand X disposable respirator, approved for use in silica dust, to be worn whenever the muller is operated. Properly used, this respirator provides a protection factor of 5.

User Instructions in Training

The muller operator who wears this respirator is trained in its use when hired and yearly thereafter. During training, he is taught to wear the respirator and a fit test using talc dust is performed to see whether the respirator leaks. If it does leak, another brand of disposable respirator is obtained. After the fit test, the employee continues to wear the respirator during the rest of the instruction and training class. He is told that he may have a new respirator whenever he wants and that he must use a new one whenever breathing becomes difficult and at the start of each shift. He is also told that silica dust may be harmful to health some years after exposure and that it is important that he use the respirators provided. It is further explained that it is impossible to install a ventilation system to take care of the dust problem in this area.

Respirator Sanitation Program

As the respirators are discarded after each day's use, there is no need for a sanitation program.

Respirator Use Surveillance

It is the foreman's responsibility to see that safety devices provided are used. He checks the muller operator's use of the respirator daily.

Work Area Surveillance

If operating conditions change, dust concentration in the muller area will be remeasured to ensure that the respiratory protection provided is still adequate.

STANDARD OPERATING PROCEDURES FOR USE OF SELF-CONTAINED BREATHING APPARATUS DURING DEGREASER PIT MAINTENANCE

In the fourth example in Chap. Six, maintenance personnel occasionally had to enter a degreaser pit while it was cool to clean it and perform necessary maintenance. The written operating procedure might be as follows.

Respirator Selection

Extremely high trichlor concentrations may be encountered during degreaser cleaning. The pit is to be ventilated, but use of pressure demand supplied-air respirators with escape packs is required.

User Instruction and Training

Maintenance men required to wear this equipment are trained in its use within 30 days of their employment. The training consists of wearing the equipment in fresh air and being taught how to regulate air flow and how to react in emergencies and if the main air supply fails. They are shown the alarm bell in the degreaser pit which rings if the air compressor fails. They are told that at that time they have 10 minutes air supply from their escape packs.

The equipment is used in a training exercise four times a year and is cleaned approximately twice a year. The exercise consists of entering the pit after it has been ventilated and inspecting the equipment in the bottom of it. Escape bottles of compressed air that have been opened are replaced through an arrangement with the distributor.

Cleaning, Maintenance, and Storage

After use, the respirators are cleaned by the maintenance staff using the manufacturer's sanitizing solutions. They are dried and stored in special cases in the maintenance department.

Respirator Air Supply

Air for normal use of these masks is supplied by an oilless portable compressor placed at the edge of the pit.

Respirator Use Surveillance

The Safety Director is responsible for seeing that training is carried out as specified and he must oversee the training.

Emergency Respirator Inspection

The respirators are inspected monthly for deterioration and to see that the escape bottles are fully charged. This is the Safety Director's responsibility.

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