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American Standard Safety Code for

Head, Eye, and Respiratory Protection

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Foreword

(This Foreword is not a part of American Standard Safety Code for Head, Eye, and Respiratory Protection, Z2.1-1959.)

The first edition of this code was completed in the fall of 1920 and issued early in 1921. It was prepared with the cooperation of an advisory committee of 19 men who had been selected because of their interest in and knowledge of the subject and as being typical representatives of the interests most closely concerned. The code was developed from a set of safety standards originally prepared in cooperation between the War and Navy Departments and the National Bureau of Standards.

The second edition was issued in 1922, after revision by a sectional committee organized under the procedures of the American Standards Association, and was published as National Bureau of Standards Handbook H2.

The scope of the Z2 project was enlarged to include respiratory protection because of the many processes where simultaneous protection of lungs and eyes was needed, and a revision was published in 1938 as National Bureau of Standards Handbook H24.

In 1946 the sectional committee was reconvened and started work on a revision. A subcommittee on eye protection was organized under the direct supervision of the National Bureau of Standards; a subcommittee on respiratory protection was organized under the supervision of the U.S. Bureau of Mines; and a subcomittee on head protection was organized under supervision of the Department of the Navy. All parts of the standard had to be reviewed and brought up to date in order to include new materials and devices which had been developed since 1938, particularly the use of plastics for eye protection.

Suggestions for improvement gained in the use of this standard will be welcomed. They should be sent to the American Standards Association, Incorporated, **10 East 40th Street, New York 16, N. Y.**

The committee that developed this standard is as follows:

Dr Leonard Greenburg, *Chairman* R. L. Lloyd, *Secretary*

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Contents

Table 3

Selection of Eye- and Face-Protective Devices

Hazard Involved	Part To Be Protected	Permissible Protective Devices	
		Type	Reference
Relatively large flying objects	Eyes, Face	Goggles Spectacles Face shields	6.1.1, 6.1.4, and 6.1.6 6.1.2, 6.1.5 5.3.3
Dust and small flying particles	Eyes, Face	Goggles Spectacles Face shields	6.1.1, 6.1.4, and 6.1.6 6.1.2, 6.1.5 5.3.3
Dust and wind	Eyes	Goggles Spectacles	6.1.1, 6.1.4 6.1.2, 6.1.5
Molten metal	Eyes, Face	Goggles Spectacles Face shields	6.1.1, 6.1.4, and 6.1.6 6.1.2, 6.1.5 5.3.3
Gases, fumes, and smoke	Eyes, Face	Goggles	6.1.3, 6.1.4
Liquids	Eyes, Face	Goggles Face shields	6.1.3, 6.1.4 5.3.3
Reflected light or glare	Eyes	Goggles Spectacles	6.1.4 6.1.2, 6.1.5
Injurious radiant energy (moderate)	Eyes	Goggles Helmets Hand shields Face shields	6.1.1 All described in 5.2 All described in 5.2.4.2 5.3.3 (must include crown protector and chin protector)
Injurious radiant energy (intense)	Eyes, Face	Helmets Hand shields	All with spectacles described in 6.1.2 All with spectacles described in 6.1.2

7. Respiratory Protection

7.1 Classification of Hazards. Hazardous atmospheres fall into the following broad groupings:

- Oxygen deficiency
- Gaseous contaminants:
  - Immediately dangerous to life
  - Not immediately dangerous to life
- Particulate contaminants (dusts, fumes, mists, fogs)
- Combination of gaseous and particulate contaminants
  - Immediately dangerous to life
  - Not immediately dangerous to life

7.1.1 ***Oxygen Deficiency.*** The oxygen content of normal air is about 20.9 percent by volume. Atmospheres in confined spaces such as wells, mines, holds of ships, tanks, and burning buildings may contain a lower percentage of oxygen because of dilution or displacement of the air by other gases or vapors, or because of the loss of oxygen by its reaction with, or absorption by, other substances. When the oxygen content of the air is about 16 percent, the flame of a safety lamp will be extinguished. Below this concentration, a person breathing the air exhibits symptoms ranging from increased volume of breathing and acceleration of pulse rate to unconsciousness and death, depending on the oxygen content of the air and the degree of his physical activity.

7.1.2 ***Gaseous Contaminants.*** Gaseous contaminants may be classified into two broad groups as follows: toxic and inert. The toxic or poisonous gases may produce harmful or objectionable response in man in relatively low concentrations, whereas the inert gases produce undesirable effects primarily by displacement of oxygen. The term "gases" as used here applies equally to gaseous substances (such as nitrogen, carbon monoxide, and carbon dioxide) and the vapors of volatile substances (such as benzene and carbon tetrachloride).

The toxicity of gases and vapors for man varies over a wide range. For instance, a 10-minute exposure to a concentration of 120 parts per million (ppm) of phosgene may be fatal, whereas one may safely breathe 1,000 ppm of dichlorodifluoro-methane (freon) throughout a working day.

7.1.2.1 *Gaseous Contaminants Immediately Dangerous to Life.* Gaseous contaminants immediately dangerous to life are gases present in concentrations that would endanger the life of a person breathing them for even a short period of time. For example, 400 to 500 parts of sulfur dioxide per million parts of air (0.04 to 0.05 percent) by volume is considered to be dangerous for a short exposure.

7.1.2.2 *Gaseous Contaminants Not Immediately Dangerous to Life.* Gaseous contaminants not immediately dangerous to life are gases present in concentrations that could be breathed for a short period without endangering the life of a person breathing them, but which might produce discomfort and possible injury after a prolonged single exposure or repeated short exposures. For instance, the threshold limit value for sulfur dioxide has been set at 5 ppm, based primarily on the irritating effect of this gas on the nose, eyes, and throat.

7.1.3 ***Particulate Contaminants (Dusts, Fumes, Smokes, Mists, Fogs).*** Particulate contaminants may be classified, according to their mode of action, into three broad groups as follows: (1) Toxic particulate contaminants that may pass from the lungs into the blood stream and are carried to the various parts of the body to exert their injurious effects. These effects may be chemical irritation, systemic poisoning, neoplasms (tumors), or such effects as hay fever, asthma, or simple febrile reactions. (2) Fibrosis-producing dust, such as asbestos and free silica, or other pneumoconiosis-producing dusts that are not taken up by the blood stream but remain in the lungs and may cause significant pulmonary impairment. (3) Nontoxic and nonfibrosis-producing particles (so-called nuisance dusts and mists) that may dissolve and pass directly into the blood stream or may remain in the lungs producing neither local nor systemic effects.

Particulate contaminants may be classified according to their physical properties into three broad groups as follows: (1) solid, such as dusts and fumes; (2) liquid, such as mists and fogs; and (3) a combination of solid and liquid, such as silica-water sprays and paint sprays.

The majority of particulate contaminants are not immediately dangerous to life; that is, days, weeks, or even years of exposure may transpire before harmful effects are noted. Notable exceptions are dusts and mists containing the organic phosphorus insecticides which, if present in high concentrations, may incapacitate or even kill a man in a very short time. Other exceptions to this generalization are certain radioactive particulates and the toxic war smokes such as diphenylchloroarsine (DA) and diphenylaminechloroarsine (DM).

7.1.4 ***Combination of Gaseous and Particulate Contaminants.*** In addition to atmospheres containing gaseous or particulate contaminants, there are those in which both types occur simultaneously. The contaminants may be entirely different substances, such as carbon monoxide and oxides of nitrogen produced by blasting and the dust from the blasted material, or they may be the same substance in the liquid and in the vapor form, such as slightly volatile liquids that are atomized. The simultaneous occurence of both gaseous and particulate contaminants in an atmosphere complicates the procedure for providing adequate respiratory protection against them.

7.2 Classification of Respiratory Protective Devices. Respiratory protective devices fall into the following broad groupings on the basis of their mode of functioning:

- Atmosphere-supplying respirators
  - Self-contained type
  - Hose type
- Air-purifying respirators
  - Gas masks or chemical cartridge respirators
  - Self-rescue-type respirators
  - Dispersoid (dust, fume, mist) respirators
  - Combination gas and dispersoid respirators

A more detailed classification, brief description, and the limitations of the various types of respirators follow:

7.2.1 ***Atmosphere-Supplying Respirators.*** Atmosphere-supplying respirators provide a respirable atmosphere to the wearer independent of his immediate atmospheric environment. They may be divided into two main subgroups: self-contained breathing apparatus and hose-type respirators.

7.2.1.1 *Self-Contained Breathing Apparatus.* A self-contained breathing apparatus is a respirator by means of which the user may obtain respirable air or oxygen from a supply of air, oxygen, or oxygen-generating material which is an integral part of the respirator as worn. Self-contained breathing apparatus may be divided into two main subgroups: recirculating-type and demand-type.

7.2.1.1.1 Recirculating-Type Self-Contained Breathing Apparatus. Recirculating-type self-contained breathing apparatus may furnish respirable oxygen to the wearer from either (1) a cylinder of compressed oxygen or (2) a canister containing an oxygen-generating material.

(1) *Compressed Oxygen Type.* The mode of functioning of the compressed-oxygen type is as follows: High-pressure oxygen from the cylinder passes through a pressure-reducing-and-regulating valve and an admission valve into a breathing bag from which the wearer inhales through a corrugated breathing tube connected to a mouthpiece or facepiece through a one-way check valve. The wearer's exhaled breath passes through another check valve and corrugated breathing tube to a container of chemical which removes the exhaled carbon dioxide. It then passes through a cooler and enters the breathing bag. In normal use, oxygen enters the breathing bag from the supply cylinder only when the volume of gas in the bag has decreased sufficiently to allow a pressure plate to act upon the admission valve which then admits oxygen until the wearer exhales. In the event that the pressure-reducing-and-regulating valve or the admission valve does not function properly, oxygen may be admitted directly from the oxygen cylinder to the bag through a manually operated by-pass valve. Suitable pressure-release and saliva traps are provided.

(2) *Self-Generating Type.* The mode of functioning of the self-generating type is as follows: Water vapor in the wearer's exhaled breath reacts with the granular chemical fill of the canister to liberate oxygen which then enters the breathing bag from which the wearer inhales through a corrugated breathing tube connected to a facepiece. Check valves maintain a unidirectional flow of gases in the closed system. The rate of evolution of oxygen is governed by the volume rate of breathing of the wearer. Exhaled carbon dioxide is removed by the canister. A suitable manually operated pressure-relief valve is provided.

7.2.1.1.2 Demand-Type Self-Contained Breathing Apparatus. Demand-type self-contained apparatus is designed to supply air or oxygen to the wearer. These gases are not to be used interchangeably; that is, oxygen should never be used in an apparatus designed for compressed air, and vice versa.

The mode of functioning of the demand-type self-contained breathing apparatus is as follows: Oxygen or air is admitted to the facepiece from a cylinder of the compressed gas through a two-stage pressure-reducing mechanism only when the wearer inhales, and in quantities governed by his breathing. The wearer's exhaled breath escapes to the surrounding atmosphere.

7.2.1.1.3 Limitations of Self-Contained Breathing Apparatus. The self-contained breathing apparatus has no limitation as to the concentration of gas or particulate matter or as to a deficiency of oxygen in the atmosphere in which it is worn. However, many gases are very irritating to the skin and to mucous membranes when present in high concentrations; and hydrocyanic acid gas can be absorbed in dangerous amounts through the unbroken skin. The wearer has complete freedom of movement, and may leave the work area through any available exit. The length of time that he may remain in the irrespirable atmosphere is dependent upon the amount of oxygen or air made available to him by the apparatus and upon his activity. Self-contained breathing apparatuses are rated according to whether they will protect for two hours, one hour, three quarters of an hour, or one-half hour while doing heavy work. If this type of respirator is to be used safely and with confidence, rather extensive training is required not only in its care and use but also in an understanding of its limitations.

7.2.1.2 *Hose-Type Atmosphere-Supplying Respirators.* Hose-type atmosphere-supplying respirators make air available to the wearer through a hose connected to a supply of respirable air. They may be divided into four main subgroups: (1) hose mask with blower, (2) hose mask without blower, (3) air-line respirator, and (4) abrasive-blasting respirator.

7.2.1.2.1 Hose Mask with Blower. The hose mask with blower (Type A supplied-air respirator) consists of a full facepiece to which respirable air is forced through a large-diameter flexible hose by a hand or motor-operated blower, and through which the wearer can inhale whether or not the blower is operated. Check valves allow air flow only toward the facepiece. The hose is attached to the wearer's body by means of a rugged safety harness which has provision for the attachment of a safety line; with this harness and line the wearer may be drawn to safety in an emergency. Usually, the hose mask with blower is designed so that two facepiece-harness-and-hose assemblies may be attached to a single, double-outlet blower.

7.2.1.2.2 Limitations of Hose Mask With Blower. The hose mask with blower (Type A supplied-air respirator) has no limitations as to concentration of gas or particulate matter or a deficiency of oxygen in the atmosphere in which it is worn. However, many gases are very irritating to the skin and mucous membranes when present in high concentrations; and hydrocyanic acid gas can be absorbed in dangerous amounts through the unbroken skin. The wearer is limited by the length of the air-supply hose to travel within 150 feet of the blower which must be in respirable air. He must return to fresh air by retracing his route in the contaminated atmosphere, otherwise the air-supply hose would become entangled. It provides respiratory protection for an unlimited period.

7.2.1.2.3 Hose Mask Without Blower. The hose mask without blower (Type B supplied-air respirator) consists of a full facepiece to which a supply of respirable air may be drawn through a large-diameter flexible hose by the wearer's breathing effort. Check valves allow air flow only toward the facepiece. The hose is attached to the wearer's body by a suitable harness. The air-inlet end of the hose is provided with a fine-mesh screen to prevent entrance of coarse particulate matter and with a means of anchoring the inlet in respirable air.

7.2.1.2.4 Limitations of Hose Mask Without Blower. The hose mask without blower (Type B supplied-air respirator) is limited to use in any atmosphere from which the wearer can escape unharmed without the aid of the respirator. The wearer is limited by the length of the air-supply hose to travel within 75 feet of an assured source of respirable air in which the air-inlet end of the hose must be placed. It provides respiratory protection for an unlimited period.

7.2.1.2.5 Air-Line Respirator. Air-line respirators (Type C supplied-air respirators) consist of a half-mask facepiece, full facepiece, or a loose-fitting helmet or hood to which respirable air is supplied through a small-diameter hose. They may be divided into two classes: (1) continuous-flow class and (2) demand class.

7.2.1.2.5.1 Continuous-Flow Class Air-Line Respirator. Continuous-flow class air-line respirators (Type C and CE supplied-air respirators) supply a continuous flow of respirable air to the facepiece, helmet, or hood through a small-diameter hose. The wearer's exhaled air and the excess air entering the facepiece, helmet, or hood covering escapes to the surrounding atmosphere. Provision is made for attaching the air-supply hose to the wearer and for detaching the air-supply hose rapidly in an emergency. The respirator is designed to allow at least 4 cubic feet of air per minute to enter the facepiece and at least 6 cubic feet of air per minute to enter the helmet or hood.

7.2.1.2.5.2 Abrasive-Blasting Respirator. The principle of operation of the abrasive-blasting respirator (Type CE supplied-air respirator) is the same as that of the continuous-flow class air-line respirator. However, it is constructed so that it will protect the head and the neck of the wearer and the eyepiece of the respirator from the rebounding abrasive. The respirator is designed to allow at least 4 cubic feet of air per minute to enter the facepiece and at least 6 cubic feet of air per minute to enter the helmet or hood. Only a full facepiece or hood and helmet is used with this respirator.

7.2.1.2.5.3 Demand-Class Air-Line Respirator. Demand-class air-line respirators (Type C supplied-air respirators) supply respirable air to the facepiece only when the wearer inhales, and at a rate governed by his volume rate of breathing. A source of respirable air, either an air compressor or a container of compressed air, is attached by a small-diameter hose to a demand valve which is actuated by a slight negative pressure created when the wearer inhales. Upon actuation, it allows air to flow to the facepiece through a flexible corrugated breathing tube. Upon exhalation, the demand valve closes and permits no air to flow to the respirator. The exhaled breath escapes to the surrounding atmosphere through an exhalation valve or valves. The demand valve is attached to the wearer so as to allow the air-supply line to be dragged behind the wearer without exerting a pull on the facepiece. Provision is made for detaching the air-supply hose rapidly in an emergency. Helmets or hoods are not used with this respirator.

7.2.1.2.6 Limitations of Air-Line Respirators. The air-line respirator (Type C supplied-air respirator) and the abrasive-blasting respirator (Type CE supplied-air respirator) are limited to use in concentrations of gases or vapors that are not immediately harmful or from which the wearer can escape unharmed without the aid of the respirator. They are not to be worn in an oxygen-deficient atmosphere. The wearer's travel is limited by the length of the air-supply hose, and he must retrace his route in the contaminated atmosphere to return to fresh air while wearing the respirator. These respirators shall be used within the limits set by the manufacturer for air-supply hose length and range of air pressure applied to the inlet of the air-supply hose. They provide respiratory protection for an unlimited period.

7.2.2 ***Air-Purifying Respirators.*** Air-purifying respirators remove gaseous or particulate contaminants, or both, from otherwise respirable air that is inhaled by the wearer. They may be divided into three classes: (1) chemical-filter type, (2) mechanical-filter type, and (3) combination chemical- and mechanical-filter type.

7.2.2.1 *Chemical-Filter Respirators.* Chemical-filter respirators such as gas masks, chemical-cartridge respirators (non-emergency gas respirators), and self-rescue-type respirators remove toxic gases and vapors from inspired air by sorption, chemical reaction, or oxidation by the granular fill of the canister or cartridge. The exhaled breath escapes to the surrounding atmosphere.

7.2.2.1.1 Gas Masks. Gas masks consist of a canister, containing the appropriate granular fill, a full facepiece, and a body harness to hold the canister securely in place on the body of the wearer. The inspired air is drawn through the canister and enters the facepiece in such a manner as to inhibit the accumulation of moisture on the eyepieces. A check valve prevents exhaled breath from entering the canister and allows it to be forced out through an exhalation valve in the facepiece to the surrounding atmosphere. The facepiece is held securely to the wearer's face by an elastic head harness. Universal gas masks have an indicator or timer which shows when the canister should be changed for protection against carbon monoxide.

Gas masks are designed to provide respiratory protection against a single specific gas such as chlorine, a single class of gases or vapors such as organic vapors, or a combination of two or more classes of gases or vapors such as acid gases and organic vapors or all gases and vapors. The canisters of many types of gas masks are manufactured in two sizes, namely, regular or "industrial size," and the large or "supersize" canisters. Everthing else being equal, the large canister provides a longer service time than the regular size between changes of canisters, but the limitations of both in regard to maximum concentration of gas against which they will protect are the same. In most cases, a canister designed for a single gas or a single class of gases and vapors will afford respiratory protection for a considerably longer period than will a canister of the same size designed for protection against a multiplicity of gases and vapors.

Gas-mask canisters manufactured in the United States of America are marked in bold letters with the name of the atmospheric contaminants for which the canister is intended or with the words "UNIVERSAL GAS-MASK CANISTER" in capitals, as well as being given a distinctive color in accordance with the American Standard Safety Code for Identification of Gas-Mask Canisters, K13.1-1950. These colors serve as an aid to rapid identification of canisters. The table from 6.1 of the above code is reproduced here for ready reference (see Table 4).

Table 4

Color Code for Gas-Mask Canisters

Canister, Type Letter	Atmospheric Contaminants To Be Protected Against	Color Assigned[1]
A	Acid gases	White[2]
A	Hydrocyanic acid gas	White with ½-inch green stripe around the canister near the botton
A	Chlorine gas	White with ½-inch yellow stripe around the canister near the bottom
B	Organic vapors	Black[2]
C	Ammonia gas	Green
D	Carbon monoxide	Blue
AE, etc	Dust, fumes, mists, fogs, and smokes in combination with any of the above gases or vapors	½-inch contrasting black or white stripe around the canister near the top
AB	Acid gases and organic vapors	Yellow
ABC	Acid gases, organic vapors, and ammonia gas	Brown
N	All of the above atmospheric contaminants	Red. Filters are included in this canister, but stripes to indicate them are unnecessary.

NOTE 1: Gray shall not be assigned as the color for any gas-mask canister.

NOTE 2: Canisters for a single gas or vapor other than ammonia or carbon monoxide shall have a ½-inch colored stripe around the canister near the bottom.

7.2.2.1.2 Limitations of Gas Masks. The gas mask is limited to use in atmospheres containing at least 16 percent of oxygen and not more than 2 percent of most toxic gases (3 percent of ammonia). Many gases are very irritating to the skin and to the mucous membranes when present in these maximum concentrations; and hydrocyanic acid gas can be absorbed in dangerous amounts through the unbroken skin, its effects depending mainly upon the concentration of the gas and the duration of the exposure. The wearer has complete freedom of movement. A gas mask provides respiratory protection for a period that depends on the type of canister, the concentration of the gas, and the activity of the wearer. A gas mask with canister for protection against carbon monoxide should have an indicator to show when the canister is to be replaced. No practicable method is available to warn the wearer of leakage of relatively odorless gases through the canister. It is important that the proper gas-mask canister be used for the intended purpose. For instance, an ammonia gas-mask canister will not afford respiratory protection against acid gases, organic vapors, or carbon monoxide.

7.2.2.1.3 Chemical-Cartridge Respirators. Chemical-cartridge respirators (non-emergency gas respirators) consist of a half-mask facepiece to which is attached one or two cartridges. Like canisters, the cartridges are filled with granular materials that remove gases or vapors from the air drawn through them. Check valves prevent exhaled breath from entering the cartridges and allow it to be forced out through an exhalation valve in the facepiece to the surrounding atmosphere. The facepiece is held securely to the wearer's face by elastic headbands. The cartridges are usually designed to provide respiratory protection against single gases or vapors or against single classes of gases and vapors. They are easily removed and replaced.

7.2.2.1.4 Limitations of Chemical-Cartridge Respirators. The chemical-cartridge respirator (non-emergency gas respirator) is limited to use in atmospheres that are not immediately dangerous to life; hence, it shall not be worn in an atmosphere deficient in oxygen. The wearer has complete freedom of movement. A chemical-cartridge respirator provides respiratory protection for a period that depends on the type of cartridge used, the concentration of the gas or vapor, and the wearer's activity. Its use is limited to low concentrations of certain gases and vapors such as a maximum of 0.1 percent (1,000 ppm) of organic vapors. It should not be used for protection against (1) harmful gases or vapors that cannot be detected by the sense of smell; (2) gases or vapors that are highly toxic in low concentration, such as phosgene and arsine; or (3) concentrations of gases and vapors that are highly irritating to the eyes. It is important that the proper chemical cartridge be used for the intended purpose; for instance, an organic vapor cartridge will not afford respiratory protection against ammonia. Knitted cotton covers for the face-contacting surface of the facepiece should not be used since they are not gastight.

7.2.2.1.5 Self-Rescue-Type Respirators. The self-rescue-type respirator is designed to provide the greatest possible respiratory protection consistent with the practicability of carrying the device at all times so that it is always available for use during escape in the event of a catastrophe. It consists essentially of a small filter element, a mouthpiece, a nose clip, and a means of carrying the device conveniently on the body or storing it near the work location. Most filter elements are similar to chemical cartridges made for protection against specific gases or vapors, but particulate filters are also available. One self-rescue-type respirator offers protection against carbon monoxide present in the atmosphere following an explosion or fire in a mine. The filter cartridge for this type shall be protected from moisture to keep the chemical fill active.

7.2.2.1.6 Limitations of Self-Rescue-Type Respirators. Self-rescue-type respirators should never be used as a working tool, but only as a means during escape from a contaminated area to enhance the possibility of reaching a safe atmosphere or a more positive type of respiratory protective equipment. The magnitude of protection afforded usually falls between that provided by gas masks and by chemical-cartridge respirators. For example, the self-rescue-type respirator for protection against carbon monoxide will provide at least 30 minutes service in an atmosphere containing 1 percent by volume of carbon monoxide.

7.2.2.2 *Mechanical-Filter Respirators.* Mechanical-filter respirators such as dust, fume, or mist respirators remove particulate matter from the inspired air by capture on the filter, which is usually a fibrous pad. These respirators consist of a full or half-mask facepiece to which are attached one or two filters through which the inspired air is drawn. Check valves, present in most mechanical-filter respirators, prevent exhaled breath from passing through the filters and allow it to be forced out through an exhalation valve in the facepiece to the surrounding atmosphere. The facepiece is held securely to the wearer's face by elastic headbands. Knitted cotton covers are sometimes used to cover the face-contacting surface of the facepiece to absorb perspiration and to prevent irritation of the skin when the respirator is worn in hot places or in air containing certain irritating dusts such as lime.

Mechanical-filter respirators are designed to provide respiratory protection against a single specific dust, fume, or mist, a single class such as toxic dusts, or a combination of several classes of particulate matter such as dusts, fumes, and mists.

The filters may be of the single-use or re-usable type. Single-use filters cannot be cleaned and re-used, but should be discarded after they have served their purpose. Re-usable filters, cleaned mechanically according to the manufacturer's instructions, may be re-used. They should never be washed or treated with solvents.

7.2.2.3 *Limitations of Mechanical-Filter Respirators.* There is a practical limit for the concentrations in which a mechanical-filter respirator should be used. This is determined by the time required to plug the filter. For example, if the concentration is so high that the filter must be changed several times an hour in order that the wearer can inhale without undue resistance, a more suitable type of respiratory protective device should be selected. Mechanical-filter respirators should not be used in sand- or shot-blasting operations in which one might be exposed to heavy concentrations of particulate matter and to rapidly rebounding particles of the abrasive. For such conditions, the abrasive-blasting respirator shall be used.

Mechanical-filter respirators do not protect against gases and vapors or against an atmosphere deficient in oxygen. The wearer has complete freedom of movement. The useful life of the filters is limited by the build-up of resistance to inhalation as the contaminant is removed by the filter. The higher the concentration of contaminant in the air drawn into the filter and the greater the wearer's activity, the more rapidly the resistance to inhalation increases. This applies particularly to dusts and fumes. Hence, the use of dust and fume respirators in high concentrations of these contaminants requires frequent replacement of disposable filters or frequent cleaning of re-usable filters.

7.2.2.4 *Combination Chemical-and-Mechanical-Filter Respirators.* Combination chemical-and-mechanical-filter respirators remove toxic gases and vapors and particulate matter from inspired air. Some gas-mask canisters contain special filters which provide respiratory protection against particulate matter, in addition to the respiratory protection against gases and vapors furnished by their granular fill. Some chemical-cartridge respirators contain filters for the same purpose. Others have filters attached so that the filters may be changed one or more times before the cartridges are changed. The type of protection afforded by the filters in gas-mask canisters and chemical-cartridge-respirator cartridges is stated on their labels.

7.2.2.5 *Limitations of Combination Chemical-and-Mechanical-Filter Respirators.* The limitations of combination chemical-and-mechanical-filter respirators generally are the same as for each type of respirator given in the preceding sections. However, the limitation of dust filters in regard to protection against gases and vapors given in 7.2.2.3 obviously is modified by the type of protection afforded by the chemical-filter respirator (gas-mask or chemical-cartridge respirator) against gases and vapors.

7.3 Requirements for Respirators. Respirators of all types should be capable of providing an adequate degree of respiratory protection against given atmospheric contaminants when the proper type has been chosen and when it is maintained and used correctly. Specific requirements for most of the types of respirators used in industry in the United States of America have been set up by the Federal Bureau of Mines. These requirements are published as Bureau of Mines Schedules, a list of which follows:[2]

Bureau of Mines, Procedure for Establishing a List of Permissible Self-Contained Mine Rescue Breathing Apparatus; Fees, Character of Tests, and Conditions Under Which Mine Rescue Breathing Apparatus Will Be Tested: Schedule 13, March 5, 1919, 13 pp; Schedule 13A (revision of Schedule 13), January 21, 1930, 12 pp; Schedule 13B (revision of Schedule 13A), August 12, 1935, 12 pp; Schedule 13C (revision of Schedule 13B), July 9, 1946, 11 pp; Schedule 13D (revision of Schedule 13C), September 22, 1956, 12 pp. (Code of Federal Regulations reference: 30 CFR Part 11.)

Bureau of Mines, Procedure for Establishing a List of Permissible Gas Masks; Fees, Character of Tests, and Conditions Under Which Gas Masks Will Be Tested: Schedule 14, May 22, 1919, 13 pp; Supplement to Schedule 14, January 6, 1920, 4 pp;

[2] Copies of the most recent Bureau of Mines Schedules and List of Respiratory Protective Devices Approved by the Bureau of Mines may be obtained from the Publications Distribution Section, Bureau of Mines, 4800 Forbes Street, Pittsburgh 13, Pennsylvania.

Schedule 14A (revision of Schedule 14), August 25, 1923, 15 pp; Schedule 14B (revision of Schedule 14A), August 7, 1930, 13 pp; Schedule 14C (revision of Schedule 14B), August 20, 1934, 17 pp; Schedule 14D (revision of Schedule 14C), May 9, 1935, 17 pp; Schedule 14E (revision of Schedule 14D), December 24, 1941, 19 pp; Schedule 14F (revision of Schedule 14E), April 23, 1955. (Code of Federal Regulations reference: 30 CFR Part 13.)

Bureau of Mines, Procedure for Testing Hose Masks for Permissibility: Schedule 19, April 28, 1927, 8 pp; Supplement to Schedule 19, August 20, 1934, 3 pp. Procedure for Testing Supplied-Air Respirators for Permissibility: Schedule 19A (revision of Schedule 19 and supplement, enlarged to include special hose masks without blowers, air-line respirators, and abrasive-blasting helmets, hoods, or masks), August 9, 1937, 21 pp; Schedule 19A as amended in the Federal Register on March 13, 1948, to include Type C, demand-class supplied-air respirators; Schedule 19B (revision of Schedule 19A), April 19, 1955. (Code of Federal Regulations reference: 30 CFR Part 12.)

Bureau of Mines, Procedure for Testing Filter-Type Dust, Fume, and Mist Respirators for Permissibility: Schedule 21, August 20, 1934, 14 pp; Schedule 21A (revision of Schedule 21), April 19, 1955. (Code of Federal Regulations reference: 30 CFR Part 14.)

Bureau of Mines, Procedure for Testing Non-emergency Gas Respirators (Chemical Cartridge Respirators) for Permissibility: Schedule 23, November 13, 1944, 10 pp; Schedule 23A (revision of Schedule 23), April 23, 1955. (Code of Federal Regulations reference: 30 CFR Part 14A.)

Each respirator that has been approved by the Bureau of Mines has met the requirements of the pertinent schedule that was in effect at the time of the approval. In general, each revision of a Bureau of Mines schedule makes these requirements more severe. A Bureau of Mines approval on a respirator remains in effect even though the schedule under which it was approved has been revised one or more times since then. Hence, if the user wishes to check on the minimum performance that he may expect from the respirator, he should consult the schedule or revision thereof, which is shown in the list of schedules as being in effect when the approval was granted.

The Bureau of Mines performance requirements for a respirator are based on its field of use and upon three fundamental requirements for a satisfactory device: (1) It must provide adequate protection for a satisfactory period; (2) It must be reasonably comfortable and convenient to wear; and (3) It must be constructed of durable materials. If no Bureau of Mines schedule applies to a respirator being considered for use, it should be examined to see that it fulfills these three requirements. Further judgment might be based on its compliance with the performance requirements of the most closely related respirator approved by the Bureau of Mines.

7.4 Selection of Respirators

7.4.1 ***General Considerations.*** In choosing a respirator to be used for respiratory protection in any given situation, the following factors should be considered: (1) the nature of the hazard; (2) the severity of the hazard; (3) the type of contaminant; (4) the concentration of the contaminant; (5) the period for which respiratory protection must be afforded; (6) the location of the contaminated area with respect to a source of respirable air; (7) the expected activity of the wearer; and (8) the operating characteristics and limitations of the available respirators.

Table 5 lists the hazards and the respirators that are designed specifically to afford respiratory protection against them. By reference to this table, and by considering the foregoing factors, the user can determine the type of respirator that should be used. The self-contained breathing apparatus and the hose mask with blower would give respiratory protection against any of the hazards listed, but these devices are not included in the list of respirators that could be used in the less hazardous situations because their use would amount to "over-engineering."

Even though most of the factors in 7.4.1 are interrelated, a brief discussion of each follows:

7.4.1.1 *Nature of the Hazard.* The user should determine whether or not the atmosphere is deficient in oxygen, and whether the contaminant is gaseous or particulate, or a combination of the two.

7.4.1.2 *Severity of the Hazard.* The user should determine whether or not the atmosphere is immediately dangerous to life. This is discussed under Classification of Hazards in 7.1.

7.4.1.3 *Type of Contaminant*

7.4.1.3.1 Gaseous Contaminant. Where the contaminant is gaseous, the user should determine whether it is an acid gas, an organic vapor, ammonia, carbon monoxide, or a mixture of two or more of these gaseous contaminants. This information is essential to the choice of the proper gas mask or chemical-cartridge respirator because the different

Table 5
Selection of Respiratory Protective Device

Hazard	Respirator
Oxygen deficiency	Self-contained breathing apparatus Hose mask with blower
Gaseous contaminant Immediately dangerous to life	Self-contained breathing apparatus Hose mask with blower Gas mask
Not immediately dangerous to life	Air-line respirator Hose mask without blower Chemical-cartridge respirator
Particulate contaminant	Dust, mist, or fume respirator Air-line respirator Abrasive-blasting respirator
Combination gaseous and particulated contaminant Immediately dangerous to life	Self-contained breathing apparatus Hose mask with blower Gas mask with special filter
Not immediately dangerous to life	Air-line respirator Hose mask without blower Chemical-cartridge respirator with special filter

types of gases require different absorbents or combinations of absorbents to remove them from the inspired air.

7.4.1.3.2 Particulate Contaminant. Where the contaminant is particulate, the user should know its physical form; that is, whether it is a dust, fume, or mist. Furthermore, he should know whether it is a toxic type (containing, for instance, arsenic, antimony, cadmium, or lead), a pneumoconiosis-producing type (containing, for instance, asbestos or free silica), or a type having a low order of toxicity and being nonfibrosis producing (containing, for instance, flour or wood). This information is essential to the choice of the proper dispersoid respirator, as a respirator designed to protect against one type of particulate matter does not necessarily afford adequate protection or service life against the other types.

7.4.1.4 *Concentration of Contaminant*

7.4.1.4.1 Gaseous Contaminant. Where the contaminant is gaseous, the maximum expected concentration of the gas should be known. Where this is above 3 percent by volume of ammonia gas, or 2 percent by volume of other gases, a gas mask is not adequate and should not be used. If it is above 0.1 percent by volume (1,000 ppm) of organic-vapors, an organic-vapor chemical-cartridge respirator is not adequate and should not be used.

7.4.1.4.2 Particulate Contaminant. Where the contaminant is particulate, the proper type of dispersoid respirator may give an adequate degree of protection, yet its service life may be too short to be practicable or economical. That is, the filter may plug too readily with a rapid increase in the inhalation resistance, thus necessitating frequent changing or cleaning of the filter material. Where practicable, an air-line respirator should be used in high concentrations of particulate matter.

7.4.1.5 *Period of Required Respiratory Protection.* The period of respiratory protection required has considerable bearing on the decision about which type of respirator to use in any given situation. The self-contained breathing apparatus, the gas mask, and the chemical-cartridge respirator provide respiratory protection for a limited period, whereas the hose mask with blower, the air-line respirator, and the abrasive-blasting respirator do so for an unlimited period; thus, for protracted periods of use, the latter types offer some advantages.

7.4.1.6 *Location of Contaminated Area with Respect to Source of Respirable Air.* This is a factor that is frequently overlooked when choosing a respirator. In using a hose mask, air-line respirator, or abrasive-blasting respirator, the distance that the wearer can go into a contaminated atmosphere is limited by the length of the hose connected to the source of respirable air. Furthermore, the presence of the hose requires that he enter and leave the area by the same route. When wearing a self-contained breathing apparatus or a gas mask, a person may leave the contaminated area by another exit, but he should make certain that the device will afford protection for a period adequate for him to reach fresh air, taking into account possible delays. For instance, in mine-rescue work, the maximum distance from fresh air that a crew wearing 2-hour self-contained breathing apparatus should cover is 1,000 feet (2,000 feet round trip) under ideal conditions. This distance is decreased to not more than 50 feet from fresh air if the crew has to crawl in a low passage.

7.4.1.7 *Activity of the Wearer.* In many instances, the respirator that would be first choice from the standpoint of respiratory protection or period of protection cannot be used because it would limit the activity of the wearer. For instance, a hose mask would not be practicable for use where the wearer has to weave in and out of a series of obstructions such as pipes because of the difficulty of pulling the heavy hose after him and his inability to escape quickly to fresh air in event of danger. An air-line respirator would likewise be rather impracticable for use where the wearer must be moving about constantly in the contaminated area, or going from one room to another, because of the inconvenience and tripping hazard of the air-supply hose.

The activity of the wearer has a marked effect on the life to be expected from a self-contained breathing apparatus, gas mask, chemical-cartridge respirator, or dispersoid respirator. The volume of air breathed by a man walking at a rate of 4 miles per hour is more than three times that breathed when he is standing still. Hence, the supply of oxygen in a self-contained breathing apparatus is used up faster, the absorbent capacity of a gas-mask canister or a chemical cartridge is exhausted faster, and the filter of a dispersoid respirator would be plugged faster while the wearer is exercising than when he is at rest.

7.4.1.8 *Operating Characteristics and Limitations of the Available Respirators.* The operating characteristics and limitations of respirators have been discussed in 7.2.

7.5 Use and Maintenance of Respirators

7.5.1 ***General Considerations.*** Respirators are used to supplement other methods of control of airborne contaminants rather than to substitute for them. Every effort should be made to prevent the dissemination of contaminants into the breathing zones of the workers. In some instances, it is necessary to use respirators only until these control measures have been taken; in others, such measures are impracticable, and the continued use of respirators is necessary.

7.5.2 *Precautions To Be Taken in the Use of Respirators*

7.5.2.1 *Precautions To Be Taken in the Use of a Self-Contained Breathing Apparatus*

(1) The wearer of a self-contained breathing apparatus should be physically sound and fit and should be thoroughly trained in the construction, testing, use, care, and limitations of the apparatus before he attempts to wear such apparatus in a hazardous situation.

(2) Make certain that the self-contained breathing apparatus is in good operating condition.

(3) Make certain that the apparatus is capable of supplying air or oxygen for the period that the wearer must remain in the contaminated area.

(4) Adjust the apparatus to the wearer and test for tightness according to the manufacturer's instructions.

(5) If the wearer is to enter a confined space containing an atmosphere that is extremely hazardous, connect a strong life line to his body. This will serve (a) as a means of guiding him to the exit; (b) as a means of transmitting prearranged signals between him and the men at the fresh-air base; and (c) as a means of aiding in rescue operations in case of an accident or emergency. This life line should be held by two attendants, at least one of whom is wearing a similar apparatus.

(6) Enter the contaminated area cautiously, and, if the contaminant is detected by odor, taste, or eye, nose, or throat irritation, return to fresh air immediately and ascertain the cause.

(7) Bear in mind the time limitations of the apparatus and allow an adequate margin of time for the return to fresh air.

(8) The mouthpiece and nose clip, or the facepiece, should not be removed until the wearer is certain that he is in respirable air.

7.5.2.2 *Precautions To Be Taken in the Use of a Gas Mask*

(1) Make certain that the gas mask is in good operating condition.

(2) Adjust the canister harness on the body so that, when the facepiece is put on, there is some slack in the breathing tube when the wearer's head is in the normal position.

(3) Adjust the facepiece to make a gastight fit on the wearer's face. There are two means of testing a facepiece for a gastight fit: (a) Close off the exhalation valve and exhale gently into the facepiece. If a slight positive pressure can be built up in the facepiece without any indication of outward leakage of

air between the facepiece and the face, it is adjusted properly. (b) Close off the breathing tube, inhale so that the facepiece starts to collapse, and hold the breath for about ten seconds. If the facepiece stays in its partially collapsed condition and no inward leakage of air is detected, it is adjusted properly.

(4) Test the complete gas mask for gas-tightness by closing off the air-intake at the bottom of the canister, either with the palm of the hand or with the bottom canister seal, and inhaling as in (3) (b) above.

This test checks the gastightness of the canister or timer gaskets and of the connection between the breathing tube and the canister or timer.

(5) Make certain that the contaminated atmosphere is not deficient in oxygen.

(6) Enter the contaminated area cautiously. If the odor of the contaminant is noted, return to fresh air immediately and ascertain the cause of the leakage.

(7) Make certain that the canister has enough residual life to give respiratory protection for the period that the wearer expects to be in the contaminated area. It is good practice to attach a fresh canister to the mask before entering an extremely hazardous atmosphere, especially one containing a gas that has poor warning properties, such as methyl bromide.

(8) The facepiece should not be removed or fresh canisters attached until the wearer is certain that he is in respirable air.

(9) After leaving the contaminated area, replace the bottom seal on the canister to prevent deterioration of the canister contents. This is particularly important in the case of universal gas-mask canisters.

(10) Where the contaminant is a single gas or vapor, or a mixture of two or more gases or vapors of the same type, longer service time will be obtained if a canister is used that is designed especially for protection against the contaminant than would be obtained if a universal gas-mask canister were used. Firemen generally use the universal gas-mask canister because they are never certain what gases they might encounter.

7.5.2.3 *Precautions To Be Taken in the Use of a Hose Mask With Blower*

(1) Make certain that the hose mask is in good operating condition.

(2) Set the blower in an assured source of respirable air.

(3) Connect the proper length of hose (not over 150 feet) to the blower and to the facepiece, making sure that all gaskets are in place and that the connections are tight. Where more than one hose line is to be used, each should originate at the blower.

(4) Before entering a confined space such as a tank or sewer containing an atmosphere that is extremely hazardous, connect a strong life line to the D-ring of the body harness. This life line should be held by two attendants so that the wearer can be removed from the contaminated atmosphere in case of accident or emergency.

(5) Operate the blower for a minute or two at a rapid rate to blow any dust out of the hose and to make sure that air is being delivered to the facepiece.

(6) Adjust the body harness securely to the wearer.

(7) Adjust the facepiece to the wearer so that it makes a gastight fit with his face. There are two means of testing for a satisfactory facepiece fit: (a) Close off the exhalation valve and exhale gently into the facepiece. If a slight positive pressure can be built up in the facepiece without any indication of outward leakage of air between the facepiece and the face, it is adjusted properly. (b) Close off the breathing tube or tubes, inhale so that the facepiece starts to collapse, and hold the breath for about 10 seconds. If the facepiece stays in its partially collapsed conditions and no inward leakage of air is detected, it is adjusted properly.

(8) Operate the blower, and adjust the flow of air to the wearer's satisfaction. The blower should be operated continuously during the use of the mask.

(9) Check on the prearranged signals between the wearer and the blower operator.

(10) Enter the contaminated area cautiously.

(11) Be careful that the hose is not endangered by sharp edges or falling objects, and remember that the wearer must retrace his steps and leave by the same route that he entered.

(12) If the continuous flow of air to the facepiece is interrupted, the wearer should return to fresh air and ascertain the cause.

(13) The facepiece should not be removed until the wearer is certain that he is in respirable air.

7.5.2.4 *Precautions To Be Taken in the Use of a Hose Mask Without Blower*

(1) Make certain that the hose mask is in good operating condition.

(2) Securely fasten the air-intake of the respirator in an assured source of respirable air.

(3) Connect the proper length of hose (not over 75 feet) to the air-intake and to the facepiece, making sure that all gaskets are in place and that the connections are tight.

(4) Adjust the body harness to the wearer.

(5) Adjust the facepiece to the wearer so that it makes a gastight fit with his face.

There are two means of testing for a satisfactory facepiece fit: (a) Close off the exhalation valve and exhale gently into the facepiece. If a slight positive pressure can be built up in the facepiece without any indication of outward leakage of air between the facepiece and the face, it is adjusted properly. (b) Close off the breathing tube, inhale so that the facepiece starts to collapse, and hold the breath for about 10 seconds. If the facepiece stays in its partially collapsed condition and no inward leakage of air is detected, it is adjusted properly and is gastight.

(6) Make certain that the atmosphere to be entered is not so hazardous that the wearer cannot escape unharmed without the aid of the respirator.

(7) Enter the contaminated area cautiously and leave by the same route.

7.5.2.5 *Precautions To Be Taken in the Use of an Air-Line Respirator*

(1) Make certain that the air supply is respirable. Close attention should be paid to the location of the intake to the air-supply device to make certain that the entering air is not contaminated. A suitable filter should be provided to remove objectionable odors, oil and water mist, and rust particles from the air delivered to the air-supply line. A suitable reducing-type or demand-type valve and an excess-pressure relief valve should also be provided. For supplying respirable air, the use of low-pressure externally lubricated blowers is preferable to high-pressure internally lubricated compressors, since the latter may add objectionable odors to the air and may produce carbon monoxide upon overheating. Internally lubricated compressors should be equipped with an automatic shut-off which is actuated if they become overheated.

(2) Make certain that the air-line respirator is in good operating condition.

(3) Attach the proper length of air-supply hose to the source of compressed air and to the breathing tube.

(4) Adjust the pressure of the air at the inlet to the air-supply hose so that it is within the proper pressure range.

(5) Adjust the facepiece, helmet, or hood to the wearer according to the manufacturer's instructions. A full facepiece or half-mask facepiece should be adjusted so that all the excess air leaves the facepiece through the exhalation valve and none is felt leaking out under the edge of the facepiece.

(6) When the rate of flow of air into the facepiece, helmet, or hood seems to be excessive, the wearer may decrease the flow of air by means of the air-regulating valve with which most air-line respirators are equipped. However, to prevent the contaminant in the surrounding air from reaching the wearer's breathing zone, the flow of air should not be decreased below 4 cubic feet per minute for facepieces, or below 6 cubic feet per minute for helmets or hoods. Hence, the air-regulating valve should be used judiciously on an air-line respirator.

(7) Enter the contaminated area cautiously and leave by the same route.

(8) Each air-line respirator is equipped with a quick-acting detachable coupling by means of which the wearer can quickly disconnect the respirator from the air-supply line to facilitate escape in an emergency such as fire. The wearer should practice using this coupling before wearing the respirator in a contaminated atmosphere.

7.5.2.6 *Precautions To Be Taken in the Use of an Abrasive-Blasting Respirator.* The precautions to be taken in the use of an abrasive-blasting respirator are the same as those given for the air-line respirator, with the following additional precautions.

(1) Make certain that the shatterproof eyepiece and the protective cover glass (if furnished) are in place. Under no circumstances should regular window glass be used in place of the shatterproof eyepiece. Clean the inner and outer surfaces of all eyepieces.

(2) Make certain that the protective wire screen or perforated-metal eyepiece is clean and in place.

7.5.2.7 *Precautions To Be Taken in the Use of a Chemical-Cartridge Respirator*

(1) Make certain that the atmosphere to be entered is not dangerous to life.

(2) Make certain that the respirator is in good operating condition, that the gaskets are in place, and that the proper chemical cartridges are securely mounted in the respirator.

(3) Adjust the respirator to the wearer's face so that it makes a gastight fit with his face. There are two means of testing for a gastight fit: (a) Close off the exhalation valve and exhale gently into the facepiece. If a slight positive pressure can be built

up in the facepiece without any indication of outward leakage of air between the facepiece and the face, it is adjusted properly. (b) Close off the inlets to the facepiece by cardboard discs or stoppers usually furnished by the manufacturer, inhale so that the facepiece starts to collapse, and hold the breath for about 10 seconds. If the facepiece remains in its partially collapsed condition and no inward leakage of air is detected, it is adjusted properly. If the second method is used, the cardboard discs or stoppers must be removed and the cartridges assembled with the facepiece without disturbing the fit of the facepiece on the wearer's face.

(4) Enter the contaminated area cautiously.

(5) When leakage of the contaminant is noted by the wearer, he should discard the used cartridges and replace them with fresh ones.

(6) Knitted cotton cloth must never be used to cover the face-contacting edges of chemical-cartridge respirators, since the cloth cover is not gas-tight.

7.5.2.8 *Precautions To Be Taken in the Use of a Dispersoid (Dust, Mist, or Fume) Respirator*

(1) Make certain that the respirator is in good operating condition and that the proper filters are securely fastened in place.

(2) Adjust the respirator to the wearer's face so that it makes a dust-tight fit with his face. There are two means of testing for a satisfactory facepiece fit: (a) Close off the exhalation valve and exhale gently into the facepiece. If a slight positive pressure can be built up in the facepiece without any indication of outward leakage of air between the facepiece and the face, it is adjusted properly. (b) Close off the inlets to the facepiece by cardboard discs or stoppers usually furnished by the manufacturer, inhale so that the facepiece starts to collapse, and hold the breath for about 10 seconds. If the facepiece remains in its partially collapsed condition, and no inward leakage of air is detected, it is adjusted properly. If the second method is used, the cardboard discs or stoppers must be removed and the filters assembled with the facepiece without disturbing the fit of the facepiece on the wearer's face.

(3) As the total amount of solid particulate matter removed from the inspired air by the filter increases, the resistance to inhalation increases and finally reaches a value such that the wearer is conscious of increased difficulty in breathing. At this time, disposable-type filters should be discarded and replaced by fresh filters, and recleanable-type filters should be cleaned in accordance with the manufacturer's instruction. Under no circumstances should respirator filters be washed or dry cleaned.

(4) In atmospheres containing particulate matter that is irritating to the skin, or where excessive perspiration may occur, a knitted cotton cloth, furnished by the manufacturer, may be used over the edge of the facepiece to prevent contact between the rubber portion of the facepiece and the wearer's face. This must not be used on fume respirators.

(5) When the facepiece is removed, the wearer may obtain visual evidence of the dust-tightness of the facepiece fit by looking at his reflection in a mirror and noting the presence or absence of dust streaks on that portion of his face that was covered by the facepiece.

7.5.3 *Instruction in Use of Respirators*

7.5.3.1 *General Considerations.* For the safe use of any device, it is essential that the user be properly instructed in its selection, use, and maintenance. This is particularly important with respect to respirators. Competent persons should give such instruction to the supervisors of all groups who may be required to wear respirators at their work. The supervisors, in turn, should instruct their men. No person should be allowed to wear a respirator of any type until he has received such instruction. Such instruction should cover:

(1) An explanation of the need for using the respirator

(2) Its operating principle

(3) Steps to be taken to assure that it is in good operating condition

(4) Proper adjustment of the respirator to the wearer

(5) Proper use and maintenance of the respirator

The very presence of self-contained breathing apparatus, hose masks with blowers, or gas masks on the property of any organization is an indication that they are expected to be used in an emergency situation or in one that is dangerous to life. All persons who may have occasion to use these respirators, or cause them to be used, should be properly trained in their use before circumstances require that they use them to protect their lives and the property of their employer. In addition to this, efforts should be made to foresee possible emergencies and plans of action should be formulated so that when respiratory protection is needed, rescue or repair operations will proceed smoothly and safely.

Merely talking about such respirators as the self-contained breathing apparatus, the hose mask with blower, and the gas mask is not enough. The men should be given an opportunity to handle the respirator, have it fitted to them properly, test the gastightness of the facepiece fit, wear it in normal air for a period long enough for them to become familiar with it, and, finally, they should actually wear it in an irrespirable atmosphere. Such an atmosphere may be created by burning a half-ounce formaldehyde candle in a room of about 4,000 cubic foot capacity. Not only would this atmosphere be irrespirable, but it would be irritating to the eyes. This atmosphere is similar to that used by the Bureau of Mines in the training of men in the use of the self-contained breathing apparatus. After a person has worn one of these devices for a prolonged period in this formaldehyde-air mixture without any ill effect, he need only remove the facepiece or nose clip momentarily to be convinced of the efficacy of the respirator. Such training breeds confidence in the trainees that should stand them in good stead in an emergency situation.

A less severe training atmosphere that can be built up in any room without damage to its contents, or to other people in the same building, may be prepared by vaporizing isoamyl acetate to the amount of 173 cubic centimeters per 1,000 cubic foot capacity of the room. The liquid isoamyl acetate is vaporized from a cloth wick placed in front of a fan in the room. This produces a concentration of about 1,000 parts of isoamyl acetate per million parts of air (0.1 percent) by volume. If the odor of isoamyl acetate is detected by a person wearing an emergency-type respirator, he would be able to detect the odor of phosgene or chlorine if he entered a 2-percent concentration of either of these gases while wearing the device. Isoamyl acetate vapor in this concentration is used by the Bureau of Mines as a preliminary means of testing the gastightness of gas-mask facepieces before actually wearing them in highly toxic concentrations of gases.

7.5.4 *Maintaining, Cleaning, Disinfecting, and Storing Respirators*

7.5.4.1 *General Considerations.* It is especially important that respirators be properly maintained and stored. The life of the wearer may be dependent on their proper functioning and ready availability. Adequate attention to cleaning and disinfecting is also required because the respiratory inlet coverings are worn on the face. Whenever possible, a centralized maintenance, cleaning, and storage station should be established to care for equipment of this type. It should be equipped adequately and manned by trained personnel.

7.5.4.2 *Procedures Applicable to All Respirators*

7.5.4.2.1 Inspection. All respirators should be inspected at regular intervals to make sure that they are ready for use. For respirators that are used and maintained daily, inspection becomes a rather automatic function; however, it is often neglected for respirators that are stored throughout a plant for use in emergency situations. These devices should be checked as regularly as fire extinguishers; as a matter of fact, it is good practice to integrate these inspection and maintenance programs.

All rubber parts such as facepieces, mouthpieces, exhalation valves, breathing tubes, and headbands should be inspected carefully for signs of deterioration such as hardening, checking, or tackiness. During the inspection, time should be given to "working" the rubber between the fingers with a stretching and massaging action. This will reveal defects in rubber parts and prolong the life of non-defective parts.

A check should be made to see that all gaskets are present and that they are held in place tightly.

Metal parts should be checked for signs of corrosion, and plastic and glass parts for breakage.

7.5.4.2.2 Maintenance. When it is necessary to replace worn or deteriorated parts, only those made specifically for the device should be used and the repair work should be accomplished by experienced personnel. Makeshift repairs for respiratory protective equipment cannot be tolerated. After equipment that is used frequently is cleaned and disinfected, it should be repaired routinely; emergency equipment should be repaired immediately after inspection reveals the need for repairs.

Repairs to intricate parts should not be attempted unless adequate facilities and trained personnel are available. For most users, it is preferable that parts of this type be replaced as a unit or returned to the manufacturer for repair.

7.5.4.2.3 Cleaning and Disinfecting. Respiratory protective equipment should be cleaned and disinfected after each use. However, because of the wide variety of materials used in these devices, the manufacturer should be consulted for the cleaning and disinfecting method best suited to his products.

In general, facepieces and mouthpieces for respiratory protective devices are made from rubber or rubber-like compounds. Usually, these can be cleaned with detergent and lukewarm water by hand-brushing or agitation in a washing machine. Formaldehyde, modified phenolics, hypochlorite, or quaternary ammonium compounds in the proper strength can be used to disinfect the parts. Normally all detergent is rinsed from the protective device before disinfecting; however, there are several combination cleaning and disinfecting materials available in both liquid and powder form which contain a detergent and quaternary ammonium salts and this permits combining the washing and disinfecting operations. After cleaning and disinfecting, the parts should be rinsed in clean water and dried quickly for most disinfectants. It may not be desirable to rinse parts treated with quaternary ammonium compounds since their disinfectant properties will continue indefinitely and may not produce a skin irritation. After reassembly, the device should be placed in a clean and dust-tight container.

Hot water, steam, solvents, and ultraviolet light should be avoided in the cleaning and disinfecting of rubber parts because all have deteriorating effects. If paint or other difficult-to-remove substances are encountered, it is preferable that they be removed by mild caustic cleaners rather than by solvents.

7.5.4.2.4 Storage. All types of respirators should be stored in clean and dry compartments under conditions of moderate temperature. Most devices of this type are received in re-usable cartons or cases and should be kept in these containers during the period of storage. Exposure to heat, sunlight, extreme cold, and excessive moisture is harmful to respiratory protective devices if the exposure continues over extended periods.

In some cases, it is necessary to locate respiratory protective devices at convenient stations throughout the work area for ready availability in the event of an emergency. Special care must be taken to insure adequate storage under these conditions. In some instances, it is necessary to construct special compartments to protect the equipment from the process materials as well as from the elements.

Additional emergency-type respiratory protective devices should be stored just outside the immediate danger area so that men can retreat to them and don them for judicious re-entry into the contaminated area to carry out rescue or repair operations.

No respirator can be adequately stored outside its carrying case or carton in a tool box or clothing locker.

7.5.4.3 *Special Procedures for Maintaining, Cleaning, Disinfecting, and Storing Respirators*

7.5.4.3.1 Self-Contained Breathing Apparatus. In compressed-oxygen recirculating apparatus, make sure the carbon dioxide removing chemical is replaced after use and that the oxygen cylinder is refilled to rated capacity in order to insure full service life. The cylinder pressure should be checked periodically and brought to rated pressure if necessary. The tightness of the high pressure and low pressure sides of the apparatus should be checked periodically following the manufacturer's instructions. In self-generating apparatus, periodic tightness tests as outlined by the manufacturer should be followed.

7.5.4.3.2 Hose Masks. Check the blower periodically for proper operation. Check hose for wear and tear after each use and steam clean when necessary. Keeping hose capped when not in use will prevent entrance of dust or other contaminants.

7.5.4.3.3 Air-Line Respirators. The facepiece should be serviced after each use just as for all other respiratory protective equipment. The flow-control valves should be inspected after each use and cleaned and repaired if necessary. Chemical cartridges in the continuous-flow control-valve assemblies should be changed when necessary. Air-line hose should be checked for wear and tear after each use and be steam cleaned when necessary.

The air-supply system should be inspected routinely to insure continued proper functioning. Air compressors, air-cylinder manifold systems, pressure reducers, pressure-release valves, air-line filters, air-line instrumentation, and permanent piping and outlet fittings must be kept in good repair to assure satisfactory condition of the air reaching the breathing zone of the wearer.

7.5.4.3.4 Gas masks. Check the facepiece to be sure that (1) the eyepieces are not broken and that they are held firmly in place; (2) the rubber portion of the facepiece is flexible and free from cracks; (3) the head harness is flexible and that the straps and buckles are in good condition; (4) the exhalation valve is in place, works freely, and has no dirt on its contact surfaces; (5) the breathing tube is flexible and free from cuts and that it is securely fastened to the canister neck or to the outlet of the timer; (6) the canister is of the proper type, is free from dents and rust spots, and is securely attached to the canister harness. If a timer is used, check to be sure that the gaskets are in place and are making proper contact, and that the timer is reset when a new canister is attached. Universal gas-mask canisters should be replaced after one year from date of breaking seal if not exhausted before this time. Canisters should be stored in a cool, clean, dry location and the stock rotated so that no canister remains in storage for more than four years before it is used.

7.5.4.3.5 Self-Rescuers. Frequent inspection is the most important phase of the maintenance program with this type of equipment because the equipment is seldom used but must always be ready. The type which offers protection against carbon monoxide utilizes hopcalite in the chemical fill and must be protected from moisture to remain effective. Follow the manufacturer's recommendations for checking the moisture seal at regular and frequent intervals.

7.5.4.3.6 Dispersoid and Chemical-Cartridge Respirators. Mechanical filters of the "throw-away" type should be discarded when the breathing resistance becomes bothersome to the wearer. In most plants with centralized maintenance stations, the filters are destroyed and discarded at the time the respirator is serviced.

Some respirators employ re-cleanable filters, in which case the filters are cleaned when the respirator is being serviced.

Chemical cartridges should be changed when the wearer detects the odor or irritating effect of the contaminant. In plants with centralized maintenance stations, cartridges are sometimes discarded after a given period of use (based on group experience), but in most cases the wearer is responsible for discarding and replacing cartridges in his respirator.

Particular care should be exercised in the storage of chemical cartridges because they usually deteriorate if exposed to excess moisture and to gaseous air contaminants. Cartridges should not be stored in the area where it is necessary for the workmen to use chemical-cartridge respirators.