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Manual of Respiratory Protection Against Airborne Radioactive Materials

Nuclear Regulatory Commission, Washington, D C

Prepared for

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NUREG-0041
FINAL

MANUAL OF RESPIRATORY PROTECTION

AGAINST

AIRBORNE RADIOACTIVE MATERIALS

Office of Standards Development
U.S. Nuclear Regulatory Commission

BIBLIOGRAPHIC DATA SHEET	1. Report No. NUREG-0041	2.	3. Recipient's Accession No.
4. Title and Subtitle Manual of Respiratory Protection Against Airborne Radioactive Materials			5. Report Date September 1976 6.
7. Author(s) J.L. Caplin, B.J. Held, and R.J. Catlin			8. Performing Organization Rept No.
9. Performing Organization Name and Address U.S. Nuclear Regulatory Commission and Los Alamos Scientific Laboratory			10. Project/Task/Work Unit No. OH 908-4 11. Contract/Grant No.
12. Sponsoring Organization Name and Address U.S. Nuclear Regulatory Commission Office of Standards Development Washington, D.C. 20555			13. Type of Report & Period Covered Final Manual 14.

15. Supplementary Notes

This manual supplements Regulatory Guide 8.15.

16. Abstracts

This manual supplements Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection," which stipulates the use of respiratory protective equipment in estimating exposures of individuals to airborne radioactive materials. Manual sections are referenced in appropriate portions of Regulatory Guide 8.15. The manual includes sections on basic policy, elements of acceptable respiratory protection programs, hazard evaluation, classifications and limitations of respirators, protection factors, wearer requirements and limitations, training, maintenance, quality assurance, bioassay, administration, and special problems. The NRC staff will use the information in this manual in assessing the adequacy of respiratory protection programs pursuant to the guidance provided in Regulatory Guide 8.15.

17. Key Words and Document Analysis. 17a. Descriptors

17b. Identifiers/Open-Ended Terms

17c. COSATI Field Group

18. Availability Statement

Availability Unlimited

19. Security Class (This Report)	21. No. of Pages
20. Security Class (This Page)	22. Price

NUREG-0041
FINAL

Manual of Respiratory Protection Against Airborne Radioactive Materials

Jerrold L. Caplin, NRC
Bruce J. Held, LASL
Robert J. Catlin, ERDA - IAEA

From Los Alamos Scientific Laboratory:
Darell A. Bevis
Evan Campbell
Harry J. Ettinger
Louis A. Geoffrion
Alan L. Hack
Edwin C. Hyatt
John A. Pritchard
Charles P. Richards
George L. Voelz

Date Published: October 1976

Office of Standards Development
U.S. Nuclear Regulatory Commission
Washington, D.C., 20555

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ACKNOWLEDGMENTS

Many academic, industrial, and governmental experts gave liberally of their time and assistance in the preparation of this manual. A particular debt of gratitude is owed the late Dr. Leslie Silverman of the Harvard University School of Public Health who was instrumental in organizing the first Respiratory Protective Equipment Conference in 1963 at the Harvard School of Public Health. His extensive knowledge and his amiable and generous support contributed significantly to the development of background information.

Dr. William Burgess of the Harvard staff was especially helpful in preparing early drafts which were reviewed and commented on extensively by conference attendees and also by staff members of the Atomic Energy Commission (now Nuclear Regulatory Commission) and AEC contractors' staffs, all of whose constructive reviews and comments are gratefully acknowledged.

Particular thanks are extended to the Joint Respirator Committee of the American Industrial Hygiene Association-American Conference of Governmental Industrial Hygienists for their reviews and comments which have proved so valuable in the preparation of this manual.

The editors would appreciate any comments that you may have for use in the preparation of future editions.

CHAPTER 1

INTRODUCTION

1.1 PURPOSE

This manual has been prepared to supplement Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection," and to provide technical information to licensees of the Nuclear Regulatory Commission (NRC) on the application of respiratory protective devices for protection against airborne radioactive materials, as provided in § 20.103, "Exposure of individuals to concentrations of radioactive material in air in restricted areas" of 10 CFR Part 20 (Ref. 1). The various elements of a respirator program, including selection and maintenance of equipment and training of personnel, are described in this manual to assist licensees in establishing adequate programs.

1.2 SCOPE

This manual provides broad guidance for the planned use of respirators to protect individuals from airborne radioactive materials that might be encountered during certain operations. The guidance is intended for use by management in establishing and supervising programs and by operating personnel in implementing programs.

Guidance is primarily directed to the use of respirators to prevent the inhalation of airborne radioactive materials. Protection against other modes of intake (e.g., absorption, swallowing, wound injection) is, in general, not covered here nor is the use of protective equipment for head,

eye, or skin protection. When such additional modes of intake or concurrent hazards are present, they must also be considered, and equipment capable of providing protection against the combination of hazards encountered must be chosen. For example, if a high concentration of airborne radioactive material is present in an oxygen-deficient atmosphere, it is necessary to select equipment that both protects against the radioactive material and furnishes an adequate supply of oxygen or breathing quality air.

Subsequent chapters frequently refer to requirements specified in NRC or other Federal regulations; these requirements are generally differentiated from other technical information by the use of the words "shall" and "must" instead of "should". "Should" is used to refer to other acceptable practices within the provisions of Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection."

1.3 BACKGROUND

"American National Standard Practices for Respiratory Protection," ANSI Z88.2-1969, (Ref. 2) was developed and issued by the American National Standards Institute, Inc. (ANSI) in 1969 under the sponsorship of the U.S. Department of Interior, Bureau of Mines. This standard has been adopted by reference in the U.S. Department of Labor's Occupational Safety and Health Standards (29 CFR Part 11, § 1910.134, "Respiratory Protection"). ANSI Z88.2-1969 covers the general use of respiratory protective equipment against industrial hazards and includes some guidance on the use of such devices against airborne radioactive materials. The U.S. Bureau of Mines

and the National Institute for Occupational Safety and Health (NIOSH), U.S. Department of Health, Education, and Welfare, use schedules and certification requirements (discussed further in Chapter 3) for testing and approving specific types of respiratory protective devices. Until the issuance of Schedule 21B (Ref. 3) by the U.S. Bureau of Mines in 1965, the previously effective schedules did not include any provision for approval schedules and tests applicable to the use of respirators for airborne radioactive materials. However, since the 1940s, both the U.S. Bureau of Mines and the nuclear industry, in particular the contractors of the AEC (now the Energy Research and Development Administration, ERDA), have developed considerable guidance in the form of manuals, guides, and other data regarding such use.

In May 1963, the AEC Division of Licensing and Regulation sponsored a Respiratory Protective Equipment Conference at the Harvard School of Public Health to examine and evaluate practices and other information on the use of respirators for protection against airborne radioactive hazards. After the conference, the AEC decided to prepare a guide covering the aspects of respiratory protection peculiar to the needs of its licensees. A draft was prepared with the assistance of the Harvard University Graduate School of Public Health and a review conference, sponsored by the AEC Division of Safety Standards, was held in April of 1965 at AEC Headquarters.

Also in 1963, the American Industrial Hygiene Association (AIHA) and the American Conference of Governmental Industrial Hygienists (ACGIH)

published a Respiratory Protective Devices Manual (Ref. 4) as a guide for health physicists, industrial hygienists, and other health and safety specialists.

The results of the conferences, together with information from the AIHA-ACGIH manual, information from the AEC's Division of Operational Safety regarding the practices of AEC prime contractors, and information from a draft of a United States of America Standards Institute (now ANSI) code of recommended practice for respiratory protection then being prepared were used extensively in a second draft of this guide, dated October 1967. The second draft of the guide was made available for review and comment in connection with an AEC Notice of Proposed Rulemaking concerning use of respiratory protective equipment (32 FR 15432). Comments received on the proposed rule and draft guide demonstrated a need for development of additional technical information on the use of respirators.

Since 1969, the NRC Office of Standards Development has sponsored a respiratory protection studies project in the Respirator Research and Development Section, Industrial Hygiene Group, at Los Alamos Scientific Laboratory to develop necessary information for final preparation of this manual. As additional significant information is developed, it will also be made available for the guidance of licensees.

CHAPTER 2

BASIC POLICY REGARDING USE OF RESPIRATORS

2.1 USE CONDITIONS

The primary objective of respirator programs considered in this manual is to limit the inhalation of airborne radioactive materials. This objective is normally accomplished by the application of engineering controls, including process, containment, and ventilation equipment. When such controls are not feasible or cannot be applied, the use of respiratory protective devices may be appropriate. In general, the use of respirators is less desirable in providing respiratory protection than is the use of process, containment, and ventilation techniques. The use of respirators as a substitute entails both greater likelihood of accidental exposures and greater likelihood that such exposures may go undetected. It might also subject the wearer to additional stress and increase his risk of injury by interfering with his vision, freedom of motion, and ability to communicate. The provision and use of respiratory protective devices are subject to the following considerations regarding circumstances under which respiratory protection may be needed.

2.1.1 Routine Operations

Routine operations are planned activities that are generally repetitive and occur with various frequencies. For such operations, potential sources of airborne radioactive materials should be identified so that respiratory protection may be accomplished by the use of process, containment,

and ventilation measures and by preplanning of work. The use of respirators as a substitute for practicable engineering controls in routine operations is inappropriate. Respirators may be considered for use, however, while engineering controls are being instituted or evaluated.

2.1.2 Nonroutine Operations

Nonroutine operations are activities that are either nonrepetitive or else occur so infrequently that adequate limitation of exposures by engineering controls is impractical. To the extent that process, containment, and ventilation controls are not reasonably feasible in nonroutine operations, the use of respirators to avoid excessive exposure to airborne radioactive materials is appropriate.

2.1.3 Emergencies

Emergencies are unplanned events characterized by risks sufficient to require immediate action to avoid or mitigate an abrupt or rapidly deteriorating situation. Although emergencies are, of course, unplanned, preparations must be made for coping with potential emergencies. Such preparations properly include a program for providing necessary and sufficient respiratory protection for use in potential emergencies that are likely to entail respiratory hazards. The advance preparations appropriate to a particular potential emergency will depend on both its possible consequences and the probability of its occurrence.

Plans for dealing with emergencies should include consideration of postulated durations; quantities and kinds of materials against which

protection must be provided; sizes and other physical characteristics of the hazardous areas; access requirements; numbers of people and technical skills needed; amounts, types, and locations of equipment necessary; and need for and availability of backup and replenishment supplies for use in emergencies.

2.1.4 Other Considerations

Most operations can be readily categorized as "routine," "nonroutine," or "emergency." However, a few activities might be difficult to assign to one category or another. Persons who are responsible for establishing and maintaining respiratory protection programs must exercise sound judgment by providing and using engineering controls where feasible and by avoiding unwarranted use of respirators.

2.2 WORK PERIODS

The periods of time respirators are worn continuously and the overall durations of use should each be kept to a minimum. It is necessary to allow respirator users adequate relief from wearing respirators at reasonable intervals and to limit total time of use. However, it is difficult to realistically assign specific time limits on respirator use because of wide variations in job requirements and in the physical capacities and psychological attitudes of individuals. Such factors must be taken into account in establishing a respirator program. Provision is to be made for the respirator users to leave areas where respirator use is required for relief in case of equipment malfunction, undue physical or psychological distress, procedural or communication failure, significant deterioration of operational conditions, or any other condition that might require such relief.

CHAPTER 3

ELEMENTS OF AN ACCEPTABLE PROGRAM

Respiratory protection programs of NRC licensees are primarily regulated by the NRC "Standards for Protection Against Radiation," 10 CFR Part 20, which includes provisions for respiratory protection against radioactive materials, and by the Department of Labor's Occupational Safety and Health Administration's (OSHA) Standards, 29 CFR Part 1910, which includes requirements for respiratory protection against other hazards. Omission from this manual of any specific requirements of OSHA standards or any other Federal or State regulations governing use of respirators for protection against materials or situations other than those licensed by the Commission does not constitute permission for the licensee to neglect such requirements. Each licensee is obligated to know and follow all such regulations that may govern his operations.

Federal regulations currently in effect are listed in this chapter. (See Section 1.2 for use of "shall" and "should".) No attempt has been made to investigate or to incorporate in this chapter State requirements that might be in effect.

3.1 REGULATIONS PERTAINING TO RESPIRATOR USAGE

3.1.1 General Respirator Program Regulations and Recommendations

3.1.1.1 Occupational Safety and Health Administration

Occupational Safety and Health Administration Title 29, Code of Federal Regulations, Part 1910 (29 CFR Part 1910) sets forth respiratory

protection requirements in Subpart I, "Personal Protective Equipment," of § 1910.134, "Respiratory protection." Requirements are set forth covering "Permissible practice, Requirements for a minimal acceptable program, Selection of respirators, Air quality, Use of respirators, Maintenance and care of respirators, and Identification of gas mask canisters."

Contained in § 1910.134 are references to certain consensus standards. The referenced recommendations contained in these standards are considered to be part of the rule. The following standards are referenced.

3.1.1.2 American National Standards Institute (ANSI) Z88.2-1969, "Practices for Respiratory Protection"

This standard covers all major aspects of a minimum respirator program. Complete familiarity with this standard is essential to anyone supervising a respirator program.

3.1.2 Breathing Air Specifications

3.1.2.1 ANSI Z48.1-1954, "Method of Marking Portable Compressed Gas Containers to Identify the Material Contained"

This standard is referenced in 29 CFR Part 1910, § 1910.134(d), which concerns air quality. Compressed air cylinders for breathing must be marked in accordance with

a. ANSI Z48.1-1954, or

b. Federal Specification BB-A-1034a, June 21, 1968, "Air, Compressed for Breathing Purposes," or

c. Interim Federal Specification GG-B-00675b, April 27, 1965, "Breathing Apparatus, Self-Contained." The applicable standard

or specification should be specified on any purchase orders for such equipment or service contracts.

3.1.2.2 Compressed Gas Association Commodity Specification G-7.1-1966, "Commodity Specification for Air" (Also designated ANSI Z86.1-1972)

Breathing air in gas cylinders must meet the requirement, as a minimum, of Grade D as given in G-7.1 (see Section 5.2.4.1).

3.1.2.3 Department of Transportation, 49 CFR Part 178, "Shipping Container Specification Regulations"

These regulations specify the testing and maintenance requirements for compressed breathing air cylinders.

3.1.3 Bureau of Mines/National Institute for Occupational Safety and Health

Title 30, CFR, Part 11 (30 CFR Part 11), "Respiratory Protective Devices; Tests for Permissibility; Fees," *Federal Register* Volume 37, No. 59, March 23, 1972, replaced Parts 11, 12, 13, 14 and 14a, Subchapter B, Chapter 1, Title 30, CFR (Bureau of Mines Schedules 13E, 14F, 19B, 21B, and 23B). The new 30 CFR Part 11 prescribes the approval procedures, establishes the fees, and consolidates and extends the requirements for getting joint approval of respirators by the Bureau of Mines, Department of the Interior, and the National Institute for Occupational Safety and Health (NIOSH), Department of Health, Education, and Welfare.

Only those respirators approved under the requirements of 30 CFR Part 11 may now be sold as approved devices. However, respirators manufactured under the old Bureau of Mines approvals may be used until the following dates:

Type of Respirator	Bureau of Mines Approval Schedule	Terminal Date For Approved Use
Self-contained	13 - 13E	March 31, 1979
Gas mask	14F	March 31, 1977
Supplied-air	19B	March 31, 1980
Dust, fume, mist	21B	March 31, 1976
Chemical-cartridge	23B	March 31, 1976

Respirators approved under the former Bureau of Mines schedules have approval numbers preceded by the letters "BM". Respirators approved (tested and certified) under 30 CFR Part 11 have numbers preceded by the letters "TC". Those respirators with approval numbers that bear the prefix "TC" may be used for their normal lifetimes; respirators with approval numbers that bear the prefix "BM" are approved for use only until the dates listed above.

While 30 CFR Part 11 is not directly applicable to a licensee's respirator program, it is necessary for him to conduct his program in such a way that the respirator approvals are not voided. The approval for a respirator is automatically voided if:

a. The respirator is not the same in all respects as the respirators that have been approved by meeting the minimum requirements for performance and respiratory protection prescribed in 30 CFR Part 11, and

b. The respirator is not maintained in an approved condition.

3.1.4 U.S. Nuclear Regulatory Commission (10 CFR Part 20)

Where respiratory protection is used to control individual exposures to radioactive materials, all provisions in 10 CFR Part 20, § 20.103 must be followed by the licensee.

3.1.5 Minimum Acceptable Program Requirements Summary

The following are minimum general requirements for any respirator program (details are given in subsequent chapters of this manual and in the regulations previously cited):

a. Written standard operating procedures and a policy statement (see Sections 3.2 and Chapter 12);

b. Proper selection of equipment, based on the hazard (see Sections 4 and 5);

c. Proper training and instruction of users (see Section 8);

d. Proper fitting, use, cleaning, storage, inspection, quality assurance, and maintenance of equipment (see Chapter 9);

e. Appropriate surveillance of work area conditions, degree of employee exposure to stress (see Sections 2.2, 4.2, and 3.4.2);

f. Regular inspection and evaluation to determine the continued program effectiveness (see Section 12.3);

g. Program responsibility shall be vested in one qualified individual (see Section 12.1);

h. An adequate medical surveillance program for respirator users (see Section 7.4);

i. Use of only Bureau of Mines/NIOSH-certified or NRC-authorized equipment (see Section 3.1.3 and Chapter 5); and

j. Maintenance of a bioassay program (see Chapter 11).

3.2 POLICY STATEMENT

No respiratory protection program is considered adequate without a written policy statement on respirator usage issued from a sufficiently high management level to ensure that its provisions may be adequately enforced. Items in Chapter 2 are to be covered in the statement. Strong management backing is essential to an adequate respiratory protection program.

CHAPTER 4

EVALUATION OF RESPIRATORY HAZARDS

In general, the degree of protection against specific respiratory hazards varies with the design of the respirator. Some respirators provide a higher degree of protection than others. Some designs protect only against a single respiratory hazard or a limited number of hazards; others provide protection against a broad class of hazards. Thus, proper selection of respirators requires adequate identification of all respiratory hazards present.

4.1 CLASSIFICATION OF HAZARDS

Respiratory hazards may be classified as follows:

a. Oxygen Deficiency

b. Toxic and Nuisance Atmospheres

(1) Gaseous Contaminants (gases and vapors)

(2) Particulate Contaminants (dusts, fogs, fumes, mists, smoke, and sprays)

(Combinations of these hazards are, of course, possible.)

Radioactive air contaminants may be present either as gases or particulates. Concurrent hazards, such as oxygen deficiency or the presence of nonradioactive toxic airborne contaminants, may also exist. Although this guide deals mainly with airborne radioactive hazards, the use of respirators may involve protection against concurrent chemical and physical hazards. Consequently, it appears appropriate to examine the various types of respiratory hazards in more detail.

4.1.1 Oxygen Deficiency

Normal air contains about 21% oxygen (O_2) by volume. An atmosphere with an oxygen content less than about 16% by volume (at sea level) is insufficient for human needs. At decreased atmospheric pressures or increased altitudes, greater percentages of O_2 are required for human needs. For example, at an altitude of 7000 feet, a minimum of 18% O_2 content is required. Breathing gas used to supply approved supplied-air respirators is required to contain not less than 19.5 volume percent of oxygen (see Section 5.2.4.1).

Sufficient oxygen or breathing-quality air must be supplied to avoid the adverse physiological effects of oxygen deficiency. Oxygen deficiency may result from (1) depletion of oxygen by combustion, chemical reaction, or absorption, (2) displacement of air by other gases or vapors, or (3) use of inert atmospheres. It may also result from the failure of breathing air or oxygen supplies or from rebreathing air in a confined space. Particular care must be taken to avoid the use of air-purifying respirators (e.g., filter types) in oxygen-deficient atmospheres.

Table 4-1 gives the symptoms of O_2 deficiency as a function of oxygen content and altitude.

4.1.2 Toxic and Nuisance Atmospheres

The hazards in toxic and nuisance atmospheres may consist of radioactive contaminants, nonradioactive contaminants, or both. Standards for protection against radioactivity hazards and those for nonradioactivity hazards differ in several important aspects:

TABLE 4-1

SYMPTOMS OF OXYGEN DEFICIENCY vs OXYGEN CONTENT AND ALTITUDE

Symptoms	Sea Level[a] Oxygen Vol. %	5000 ft[b] Oxygen Vol. %	700 ft[b,c] Oxygen Vol. %
Breathing and pulse rate increased	12-16	15-19.5	16-21
Abnormal fatigue upon exertion, disturbed respiration, consciousness continues	10-14	12.5-17.5	13.5-18.5
Nausea and vomiting, inability to move freely, loss of consciousness may occur	6-10	7.5-12.5	8-13.5
Convulsive movements, gasping respiration, respiration stops, death	Below 6	Below 7.5	Below 8

[a]From F. A. Patty, "Industrial Hygiene and Toxicology," 2nd Ed., Interscience Publishers, Inc., N.Y. (Interscience Publishers, Ltd., London), 1958.

[b]Calculated. Based on data from "Physiology of Man in Space," J. H. U. Brown, Ed., Academic Press, N.Y., 1963.

[c]Does not take into account acclimatization, which occurs in 4 to 6 weeks.

a. They are based on different dose-effect relationships.

b. They involve different types or degrees of risk.

c. They are expressed in different and unrelated units.

4.1.2.1 Dose-Effect Relationships

Standards for protection against nonradioactive chemical hazards in industrial atmospheres are generally based on a threshold concept postulating that, although all substances may be toxic or irritant at sufficiently high concentrations, there is some limiting "threshold"

concentration (the "threshold limit value" or "TLV") below which an individual may be exposed repeatedly without any resultant injury (Ref. 5). In contrast to standards for protection against chemical hazards, where the emphasis is on a threshold limit, standards for radiation protection take into consideration a "no-threshold" concept, i.e., it is assumed that every increment of radiation dose, however small, contributes to risk.

Concentration limits for airborne radioactive materials are designed to keep cumulative radiation doses sufficiently low to prevent immediate effects and to make the risk of delayed effects so small as to be acceptable to the exposed individual and to competent medical authorities (Refs. 6-8). "Acceptable" is used in the sense that the risks involved are no greater than those commonly accepted in ordinary activities. This concept has been more fully examined by the National Council on Radiation Protection and Measurements and others (Ref. 9).

4.1.2.2 Differences in Risk Associated with Exposures Over Limits

Generally, the manner in which concentration limits for radioactive and nonradioactive contaminants in air are determined results in levels of risk that differ greatly when individuals are exposed to concentrations substantially in excess of the limits. Concentration limits for hazards other than radioactivity are usually not more than an order of magnitude below those levels of exposure that produce adverse effects (ranging widely from mere discomfort to severe irritation or rapid death) On the other hand, concentration limits for radioactivity hazards relate to levels of exposure that are far below those at which any observable

effect would be expected. Thus, exposure for an hour to airborne radioactive materials at levels two or three orders of magnitude above the maximum permissible concentration would not be expected to result in any acute effects; whereas similar exposure in excess of the threshold limit value for many nonradioactive contaminants would be likely to result in severe irritation, injury to health, or death. Note that these examples are used only to compare the differences in risk represented by the different types of limits. They do *not* imply that exposure to either hazard would be acceptable, even though acute effects would not be expected from exposures to the radioactive concentrations discussed. Within the recommended limits, actual exposures to radioactive contaminants must be kept as low as is reasonably achievable (Ref. 10).

4.1.2.3 Limits of Airborne Concentrations and Their Related Units

4.1.2.3.1 Threshold Limit Values. These are limits on airborne concentrations of a number of chemical and physical agents. Threshold limit values (TLVs) are developed by the Threshold Limits Committee of the American Conference of Governmental Industrial Hygienists (ACGIH) and are published (Ref. 11) with yearly revisions by the ACGIH. Respective limits for gases and vapors are listed in parts per million by volume of the substance in air (ppm at 25°C and 760 mm Hg); limits for liquids and solids as milligrams per cubic meter of air (mg/m^3); and limits for mineral dusts as millions of particles per cubic foot of air (mppcf) as determined by microscopic light field count techniques. The TLVs are published along with

precautionary notes and explanations that are important to their proper use and that must be taken into account.

Before 1963, all TLVs were defined as time-weighted average concentration limits; i.e., the concentrations might vary above and below the TLV over a working day if the average value did not exceed the TLV. However, in 1963, the ACGIH changed certain of the TLVs to upper "ceiling" limits, i.e., an absolute limit below which concentration might fluctuate if the "ceiling" itself were not exceeded. So some TLVs are given in terms of time-weighted average value and others are ceiling limits (listed with a "C" before them in the ACGIH tables). As shown in Table 4-2, TLVs are given "C" rating if exposure for 15 minutes in excess of the TLV would result in certain immediate adverse effects, such as intolerable irritation, chronic or irreversible tissue change, or narcosis sufficient to impair self rescue, increase accident-proneness, or materially reduce work efficiency. If the "test factor" multiplied by the TLV would produce these effects in 15 minutes, the TLV is given a ceiling rating.

TABLE 4-2[a]

CEILING LIMIT TEST CRITERIA

TLV Range (ppm or mg/m^3)	TLV Test Factor
0 - 1	3
>1 - 10	2
>10 - 100	1.5
>100 - 1000	1.25

[a]See Reference 5.

4.1.2.3.2 Maximum Acceptable Concentrations. These are ceiling limits on airborne concentrations of a number of chemical and physical agents. They are developed by the American National Standards Institute (ANSI).

The chief distinction between the TLV and the maximum acceptable concentrations (MAC) is that the MAC is always a ceiling limit[a] below which concentrations may fluctuate whereas the TLV may be either a ceiling value or an averaged value. MACs and TLVs are expressed in the same units; and the types of risk to which they pertain are almost always toxic or irritant effects. Even for TLVs that are not "C" listings, exposure to concentrations somewhat in excess of the TLV for a working day might result in immediately observed effects.

Since the TLVs and the MACs pertain to such a wide range of effects (from mere discomfort to rapid death), they do not represent uniform degrees of risk. For example, the TLV number may represent for one substance a risk of death if the TLV is exceeded by a factor of ten for a short time. For another substance, the same numerical value for its TLV may simply represent a risk of skin irritation if the number is exceeded by a considerably higher factor for a much longer period of time.

4.1.2.3.3 Maximum Permissible Concentrations. For occupational exposure, these are recommended limits on concentrations of radionuclides to

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[a]ANSI has been considering other limits that are not ceiling values. These include concepts such as "acceptable eight-hour time-weighted average," "acceptable maximum for 'peaks' above acceptable base line for continuous exposure," "acceptable concentration to avoid discomfort," and "minimum level for sensory response."

which workers may be exposed. They are issued by groups such as the International Commission on Radiological Protection (Ref. 6) and the National Council on Radiation Protection and Measurements (Ref. 12). Such recommendations may be used as the basis for limits in the regulations of agencies such as the NRC. Maximum permissible concentrations (MPCs) established for air and water are designated as MPC_a or MPC_w, respectively. In this manual the term MPC is used instead of MPC_a for simplicity. MPCs are generally expressed in microcuries per cubic centimeter or microcuries per milliliter ($\mu Ci/cm^3$ or $\mu Ci/ml$). They are generally used as averaged values, although they may sometimes be used as "ceiling," "peak," or "instantaneous" values. For example, in NRC licensing programs:

a. Averaged values over a calendar quarter are specified for reporting individual exposures in excess of limits.

b. Averaged values over not more than 7 consecutive days are used precautionarily to control airborne concentrations and individual exposures.

c. Peak values are specified for selection of respirators.

In contrast to TLVs and MACs, the MPCs are intended to represent a uniform degree of risk for any airborne radioactive material, to the extent that present knowledge permits. It is intended that control to the level of the MPC will limit annual radiation doses to maximum permissible levels, even after exposure to airborne radioactive materials throughout a working lifetime. Such exposures would not be expected to result in any

observable effect on the exposed individual. Further discussion of TLVs and MPCs may be found in Reference 5.

One note of caution to be observed in using MPCs and TLVs is that they are intended for use by people experienced in the field who are fully aware of the range of use, developmental background, and technical implications and limitations inherent in the concepts. Further discussion of respiratory hazards other than radiation is beyond the scope of this manual (Ref. 4,5).

4.1.2.4 Relation of MPC to Mode of Exposure

In most cases, the airborne concentration limits are based on internal dose from the amount of a radionuclide retained in the body (or critical organ) following inhalation. However, airborne concentration limits for large clouds of noble gases or other relatively inert gases are based on the external dose an individual would receive if he were surrounded by a semispherical infinite cloud of radioactive gas. Under these circumstances, the dose to the whole body or to the skin from the radioactive cloud would be higher than that from gas within the lungs or other body organs. The radioactive gases of major significance that have MPCs based on submersion dose to the whole body are argon-41, the kryptons, the xenons, and carbon-14 as CO_2. Lower-energy particle emitters such as argon-37 and hydrogen-3 (as tritium gas) have MPCs based on submersion dose to the skin.

Tritium in the oxide form as HTO vapor (less commonly as DTO vapor) in air presents an additional problem since approximately as much

tritium enters the body by absorption through the skin as enters by inhalation. The airborne concentration limits for tritium oxide vapor are therefore based on this dual mode of entry into the body.

4.2 AIR-SAMPLING PROGRAM

A comprehensive air-sampling program is essential to evaluate the hazards associated with work situations involving potentially toxic materials. In many instances, air-sampling data can also provide the basis for development and evaluation of control procedures and can indicate whether or not operational changes are necessary to provide adequate protection for the worker. In conjunction with a respiratory protection program, air-sampling data are necessary to define the air concentration levels so that the proper respiratory protective equipment can be selected.

Since respirator protection factors vary over several orders of magnitude, it is very important that an initial estimate be made of the air concentration levels, relative to specified regulatory limits. Thus, adequate protection can be provided while necessary inconvenience to the worker wearing a respirator is minimized. Air-sampling programs may also be designed to estimate the release of contaminants to the general work area and to the outside environment.

An air-sampling program directly related to respiratory protection would:

a. Provide an estimate of the potential intake of airborne radioactive materials and resulting exposure of the individual worker.

b. Provide data to assist in the selection of respiratory protective equipment that would provide adequate protection under exposure conditions.

c. Provide data for control of long-term exposures to workers.

d. Provide documentation of personnel exposures for legal or regulatory purposes.

e. Identify and characterize the contaminants and their sources.

f. Provide data for determining the requirements for engineering or administrative controls.

g. Indicate the continuing effectiveness of existing controls, and warn of the deterioration of control equipment or operating procedures.

h. Provide a record of long-term trends showing variations in contaminant levels.

i. Continuously measure the level of airborne contaminants in and about work areas and warn of releases of airborne contaminants to the outside environment.

4.2.1 Considerations in Air Sampling

An air-sampling program must be designed and operated so that the data obtained are directly and meaningfully related to the problem of concern. As part of a respiratory protection program, air-sampling procedures must take into account (a) the physical and chemical state of the contaminant, (b) aerodynamic size characteristics of airborne particulates,

(c) range of contaminant concentration, (d) environmental conditions such as temperature, (e) sampler location relative to the worker and the source of contamination, (f) instrument operating and response characteristics, (g) instrument portability, (h) sensitivity of the associated analytical procedures relative to the specified concentration limits and quantity of material sampled, (i) implications of short-term exposures, and (j) chemical reactiveness of the contaminants with sampling system materials.

For radioactive particulates, it is important to consider particle solubility, chemical composition, and aerodynamic size since these, along with metabolic parameters, determine final deposition sites within the body. These factors were emphasized by the 1959 report of Committee II of the International Commission on Radiation Protection (ICRP) (Ref. 6) and by the 1966 report of ICRP Task Group on Lung Dynamics (Ref. 13). Concentration limits for radioactive particulates such as those specified in 10 CFR Part 20 are based on the 1959 ICRP assumptions as to fractions of inhaled airborne material that will deposit in the lungs. These assumptions are set out in Table 4-3. When aerosols are present for which the deposited fraction retained in the lung is greater than that assumed by ICRP, account should be taken of this increased retention in limiting an individual's intake of radioactive materials.

4.2.2 Sampler Location

In some work situations, properly located fixed air samplers may be used to approximate exposure to the individual worker. However, since air

TABLE 4-3

PARTICULATES IN RESPIRATORY TRACT OF THE STANDARD MAN
(Based on ICRP Assumptions)

Retention of particulate matter in the lungs depends on many factors, such as the size, shape, and density of the particles; the chemical form; and whether or not the person is a mouth breather. When specific data are lacking, it is assumed the distribution is as shown below.

Distribution	Readily Soluble Compounds (%)	Other Compounds (%)
Exhaled	25	25
Deposited in upper respiratory passages and subsequently swallowed	50	50
Deposited in the lungs (lower respiratory passages)	25 (this is taken up into the body)	25[a]

[a] Of this, half is eliminated from the lungs and swallowed in the first 24 hours, making a total of 62-1/2% swallowed. The remaining 12-1/2% is retained in the lungs with a half-life of 120 days, it being assumed that this portion is taken up into body fluids.

concentration varies as a function of time and sampler location, this procedure can be considered to provide only an estimate of actual exposure. Breathing zone samples, which provide a more acceptable estimate of worker exposure, can be obtained by providing the worker with a small battery-operated sampler, using a pump and battery mounted on the worker's belt, and a sampler attached close to the worker's breathing zone. This technique provides the best estimate of individual worker exposure; but the

equipment may create additional inconvenience, and the low sampling flow rate might limit analytical sensitivity. However, these personal samplers detect contaminant concentrations considerably better than do well-located fixed area samplers.

Potential errors of 2- to 30-fold have been measured between personal and fixed air samplers; the fixed samplers tend to read lower. These errors may be even greater for a contaminant released from a point source. Fixed air samplers indicate general area contamination levels or changes in these levels provided that careful attention is directed to their location and mounting relative to the contaminant sources and the working area.

4.2.3 Sampling Procedures

Considerable information is available regarding air-sampling procedures, theory, equipment characteristics and limitations, measurement techniques, and data interpretation. In general, high-efficiency filter media (glass, cellulose, asbestos, and membrane) are used to provide an estimate of gross particulate concentrations. Considerable attention should be directed to the limitations inherent in this type of sample relative to the previously described concept of lung deposition as a function of particle size. Respirable fraction can be estimated by use of presamplers that have been calibrated to separate respirable from nonrespirable particles. Detailed particle size information can be obtained by using impactor samplers. Particle size information can then be compared with the more recent lung deposition model proposed by the ICRP in 1966.

Samples of gases can be obtained by using charcoal or other solid sorbents followed by either (1) radiometric counting or (2) desorption and the appropriate analytical chemistry techniques. In some procedures such as the sampling of noble gases, charcoal may be used under low-temperature conditions provided that sampling efficiency for each noble gas has been established (since adsorption of such gases on charcoal is highly variable). Direct-readout instruments have been developed for some contaminants of concern (e.g., carbon monoxide, ozone, nitrogen oxides), but frequently these instruments are nonspecific and respond also to other materials present.

For some work situations, measurement of the oxygen concentration is of major importance. Several portable direct-reading instruments are available that indicate an abnormal oxygen concentration. Monitoring of this situation is especially critical since air-purifying respirators provide no protection against oxygen deficiency and since a lack of oxygen has adverse effects very rapidly that are, of course, extremely dangerous.

When possible, the use of rapid-response instruments is desirable in work situations that might result in a highly variable level of contamination and where short duration exposures constitute a significant risk. In all cases, the efficiency of air sampling and the associated analytical procedures must be evaluated. High-efficiency filter media are extremely reliable for the measurement of airborne particulate concentrations. The collection efficiency of sorbents such as activated charcoal may vary, depending

on the chemical state of the contaminant and environmental conditions. However, the efficiency of charcoal used in air sampling need not be as high as it must be when charcoal is used for air purification.

Air-sampling data should be related to actual exposures by other techniques, including bioassay programs, and correlation of fixed or portable general air samplers and breathing zone samplers. When sampling results are interpreted, it is most important that consideration be given to (1) the variations inherent in air-sampling data due to changes in airborne contaminant concentration as a function of sampler location, (2) apparent losses due to burial of alpha-emitting particulates in the filter matrix, and (3) the variation inherent when sampling a relatively small number of particles.

Instrumentation techniques and other specifics related to air sampling and data interpretation constitute a separate topic and are not detailed in this manual.

CHAPTER 5

CLASSIFICATION, DESCRIPTION, AND LIMITATIONS OF RESPIRATORS

The degree of protection afforded against radioactive materials by a respirator that is properly fitted and worn depends chiefly on its design and mode of operation.

It should be kept in mind that there are limitations as well as advantages in the use of each of the various types of equipment. The advantages and limitations are summarized in ANSI Z88.2-1969 (Ref. 2). More detailed descriptions of equipment are given in the "Respiratory Protective Devices Manual" (Ref. 4).

5.1 FACEPIECES, HOODS, AND SUITS

Most respirators have an enclosure such as a facepiece, hood, or suit to ensure that the respirable atmosphere furnished by the respirator is conducted to the nostrils and mouth of the user and that the irrespirable atmosphere is excluded. These enclosures are sometimes referred to as "respiratory inlet coverings."

Some respirators utilize a clip to close off the nostrils and a mouthpiece or bit, through which the wearer breathes, connected to a cartridge, canister, or bottled air supply. These devices are intended to be worn where quick exits in emergency-escape situations might be necessary; they are considered unsuitable for any other use against radioactive materials. All other respirators considered here are designed to be used with one or more of the enclosures described in Sections 5.1.1 through 5.1.3.

5.1.1 Facepieces

A facepiece is a tight-fitting enclosure over all or a portion of the face. Two types of facepieces are commonly used: the half mask and the full facepiece mask. (Note: Quarter masks that fit *on* rather than *under* the chin are commercially available. However, they are not acceptable for protection against radioactive materials.)

The *half mask* that fits *under* the chin and encloses the wearer's nose and mouth (Figure 5-1) is the only respirator that is not a full-face type and that is acceptable for protection against radioactive particulates. The facepiece is supported by two headbands with an adjustable four-point suspension. (Note: Two-point suspension is not acceptable because it does not provide a stable and reliable method of maintaining an adequate seal against the face.) Woven elastic headbands are generally more desirable for half masks than rubber because of ease in adjustment and less rapid deterioration.

The *full facepiece mask* completely encloses the wearer's eyes, nose, mouth, and chin (Figure 5-2). This facepiece is supported by a head harness.

Facepieces are generally constructed of rubber or flexible plastic, and full facepieces have one or two transparent lenses for viewing. A full facepiece has a head harness that is attached to the facepiece at five or six points or has an adjustable semirigid "welder's type" suspension attached at the temples at two points.

HALF MASK

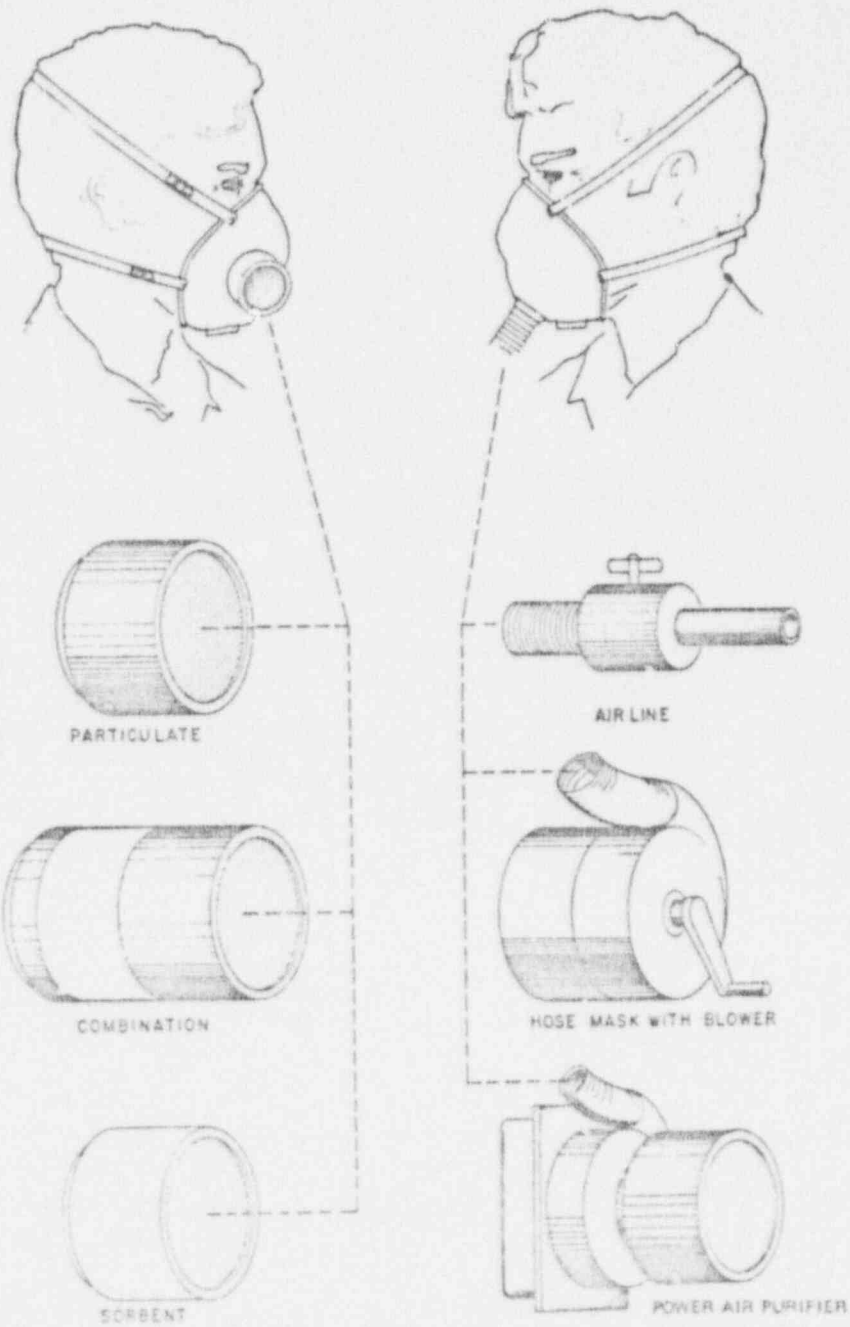

FIGURE 5-1

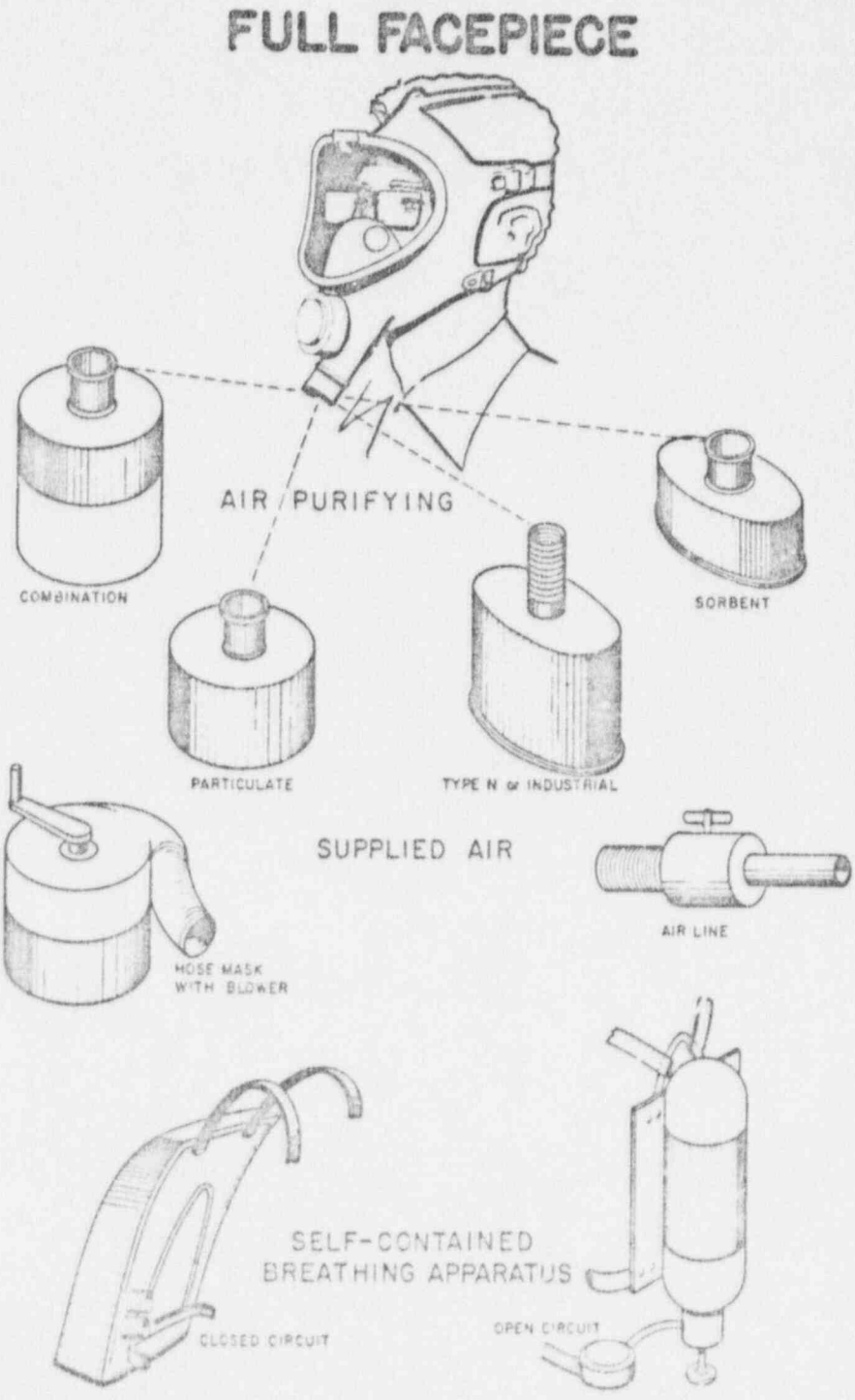
FULL FACEPIECE
AIR PURIFYING
COMBINATION
PARTICULATE
TYPE N or INDUSTRIAL
SORBENT
SUPPLIED AIR
HOSE MASK
WITH BLOWER
AIR LINE
SELF-CONTAINED
BREATHING APPARATUS
CLOSED CIRCUIT
OPEN CIRCUIT

FIGURE 5-2

In an air-purifying facepiece, the airflow is inward through a cartridge or canister and through an inhalation valve that prevents backflow of air through the cartridge during exhalation. An exhalation valve allows release of the exhaled breath to the atmosphere and prevents flow of contaminated ambient air into the facepiece during inhalation. Additionally, there is usually an exhalation valve cover that traps a small amount of clean exhaled air. This trapped clean air serves as a reservoir and is drawn into the facepiece as the exhalation valve closes at the very beginning of the inhalation cycle. Atmosphere-supplying devices generally have only an exhalation valve.

5.1.2 Hoods and Helmets

A hood is a loose-fitting enclosure over the head, neck, and the entire shoulders, gathered around the neck or below the shoulders to ensure a snug fit (Figure 5-3). The hood is generally constructed of light nonrigid plastic or coated or impregnated fabric and has a large transparent viewing window.

A helmet is a similar device of more rigid construction providing some impact protection to the eyes, face, and other parts of the head. Not all helmets are approved as hard hats.

Air to a hood or helmet is introduced into the head enclosure. The air flows past the breathing zone and escapes around the gathering perimeter. This design alleviates the need for an exhalation valve.

SUPPLIED-AIR HOOD

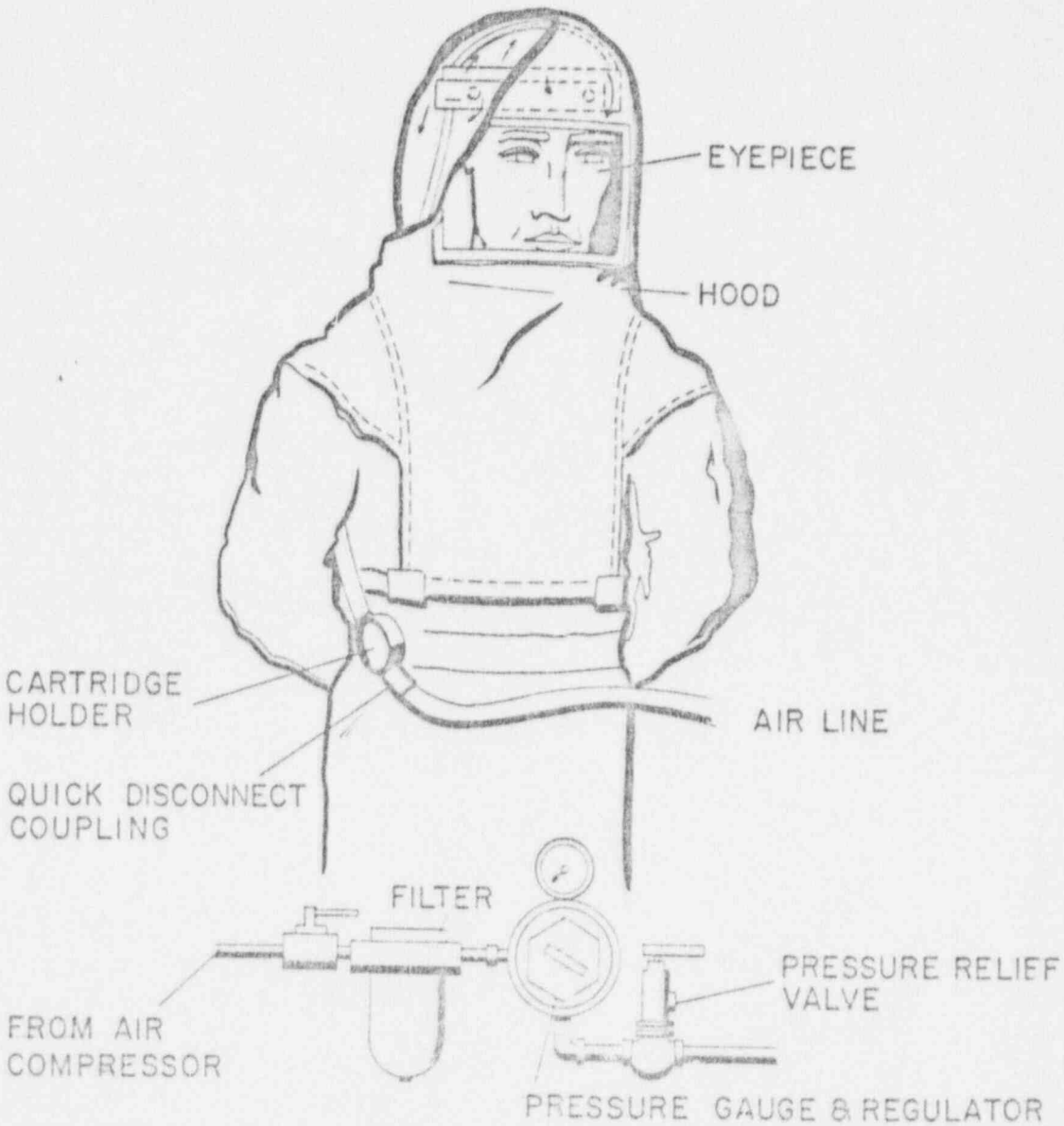

FIGURE 5-3

The hood or helmet acts as a positive pressure chamber that is continuously purged with respirable air at low velocity. There must be enough airflow to prevent contaminants from being aspirated into the hood by a "bellows effect" from the wearer's movements. With some hoods or helmets, this effect may be lessened by placing inside an outer garment hood material reaching below the shoulders (Ref.).

Bureau of Mines/NIOSH regulations for approved [illegible] helmets in 30 CFR Part 11 require a minimum air supply of 6 cubic feet per minute (cfm) and a maximum not to exceed 15 cfm. Flow rates of 8-10 cfm may well be required to provide reasonable thermal comfort depending on ambient temperatures, circulation of air inside the hood or helmet, and work rate. However, it should be noted that air impact on the face at these higher flow rates is frequently uncomfortable.

Noise from the airflow within a hood or helmet may be a hazard. Hoods must be designed to reduce the noise to acceptable levels (less than 80 dbA) while maintaining the airflow rates required for adequate protection, respiration, and thermal comfort (References 3, 15).

An air-control valve, if provided, is generally located on the wearer's belt in a position where the user may regulate his own supply. However, each air-control valve must be tested to ensure that a minimum flow rate of 6 cfm is provided irrespective of the wearer's setting of the valve's control in actual use.

5.1.3 Suits

An air-line suit (supplied-air suit) consists of a suit of plastic or of coated or impregnated fabric that is maintained under positive pressure by an air-line supply (Figure 5-4). In general, the air is distributed within the suit by a system of ducts to the head, trunk, and extremities, exiting either through the suit closures or through special exhaust valves. Sufficient air must be provided both for breathing and cooling to avoid heat exhaustion. Cooling equipment, such as a vortex tube or a refrigerated air supply may also be required at high ambient temperatures.

The need for an adequate continuous supply of respirable air to such suits is more important than with other air-line respirators. Such a need stems from the potential lack of adequate warning in case of loss of air supply and the difficulties that would be encountered by the wearer in extricating himself from the suit while carbon dioxide, moisture, and heat build up, and oxygen becomes deficient inside the suit. A loss of a continuous air supply and a consequent deficiency of oxygen as a result of rebreathing can cause rapid onset of unconsciousness and death (Ref. 16).

For this reason, and because circumstances in which rescue is required might include extreme respiratory hazards, a second individual equipped with self-contained breathing apparatus shall be stationed in respirable air outside the contaminated area. This individual shall be prepared and trained to render emergency assistance to the individual in the suit in case of failure of the air supply. He shall be in visual, voice, or signal line communication at all times.

ONE-PIECE SUPPLIED-AIR SUIT

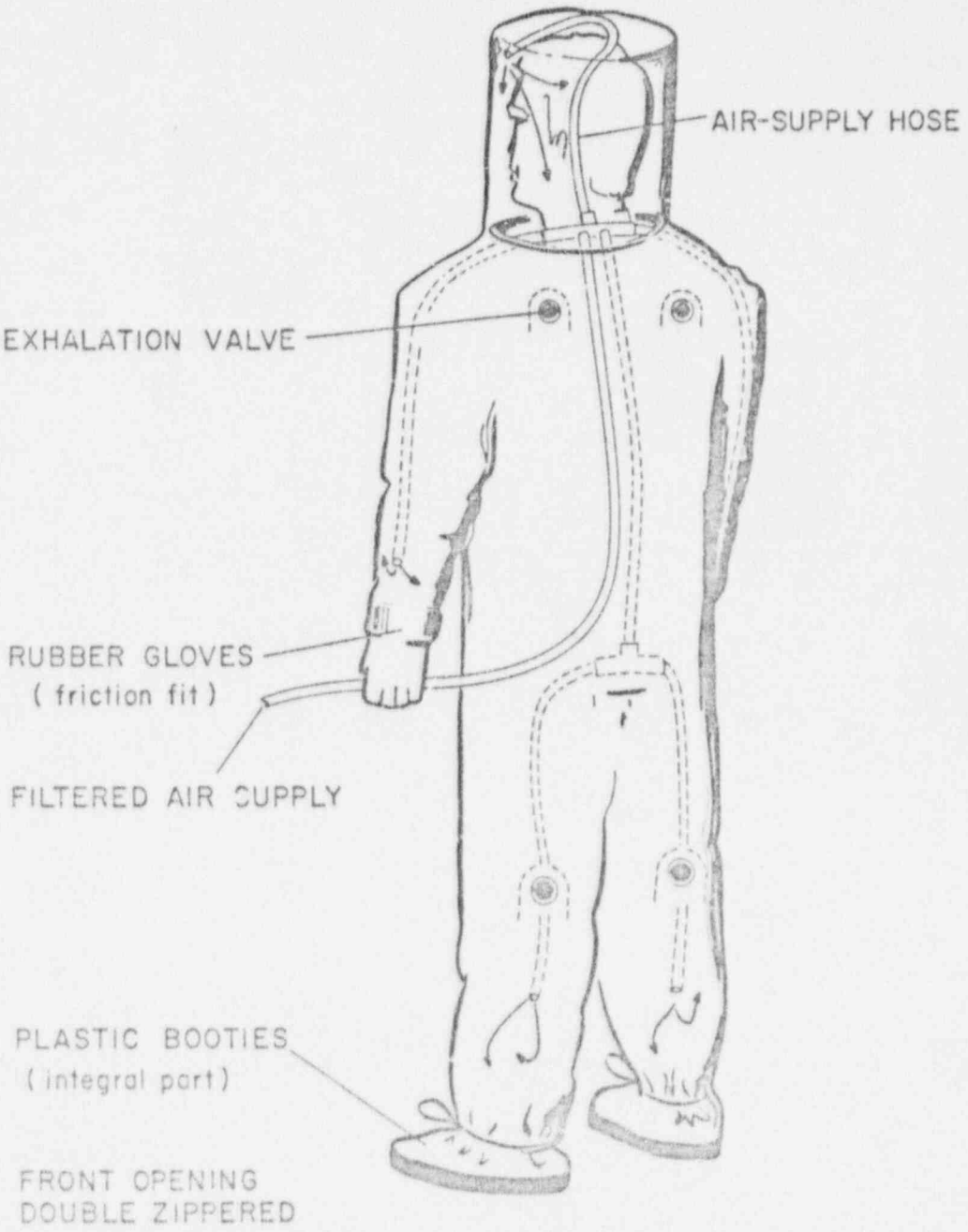

FIGURE 5-4

It should also be recognized that suit materials may have some permeability to chemicals and an associated retention of toxic materials. Such permeability may ultimately result in the exposure of the wearer to a contaminant, even though the suit is continuously maintained at positive pressure (Refs. 17-25).

5.2 RESPIRATOR TYPES, DESCRIPTIONS, AND LIMITATIONS

5.2.1 Air-Purifying Respirators

An air-purifying respirator is one that removes contaminants from the ambient air. The purification of the air is accomplished by mechanically filtering out particulate contaminants with fibrous media or by removing contaminating gases and vapors by chemical means. Cartridges and canisters are available that are capable of removing both types of contaminants. Throughout this manual, "cartridges" refers to the smaller types of air-purifying filters used generally on half-mask respirators, "canisters" refers to the larger capacity devices used on full-facepiece respirators, either attached to the respirator facepiece (chin style) or carried on the chest or back and attached to the facepiece with a flexible hose (Type N or industrial size). The word "filter" generally refers to a mechanical device used to remove particulate contaminants.

Air-purifying respirators generally operate in the negative pressure (NP) mode; that is, a negative pressure is created in the facepiece during inhalation. An exception is a special type of powered air-purifying

respirator that operates continuously in the positive pressure (PP) mode by using a motor-driven blower to drive the contaminated air through an air-purifying filter and/or sorbent cartridge.

5.2.1.1 Air-Purifying Respirator - Negative Pressure Mode

This common type of air-purifying respirator is used with a tight-fitting facepiece. The motive force for passage of contaminated air through the air-purifying media is provided by the wearer's breathing. During inhalation, the facepiece is under negative pressure. This negative pressure results in various degrees of penetration of contaminants by inward leakage through the seal area between the facepiece and the wearer's face (assuming there are no other potential sources of leakage). Full facepieces generally have less penetration through the seal area than half-mask facepieces. During exhalation, the mask interior is at positive pressure. Since the leakage through the filters is generally much less than the potential leakage around the facial seal, the limitations placed upon the several types of air-purifying respirators are based primarily upon the ability to obtain an initial fit of the facepiece and to maintain the quality of the fit during wearing.

5.2.1.2 Air-Purifying Respirator - Positive Pressure Mode

This special type of air-purifying respirator may be used either with a tight-fitting facepiece or with a hood or helmet. The motive force for passage of the contaminated air through air-purifying media is provided by a blower. The blower may be driven by a battery or by a line-powered motor. The interior of the facepiece or hood is

maintained at pressures positive with respect to the ambient atmosphere at all times during blower operation. Thus, inward leakage around the facial seal area is minimized. Respirators of this type, furnished with a tight-fitting facepiece, may be designed to be operated in the negative pressure mode in the event of a power failure.

5.2.2 Filters and Sorbents (Air-Purifying Media)

Air-purifying media consist of fiber filters or sorbents used individually or in combination and contained in a suitable protective casing that is designed for attachment to the respirator facepiece or breathing tube. *Since the efficiencies of sorbents are generally not well established, no credit may be taken for the use of sorbent canisters or cartridges for protection against radioactive gases or vapors.* (See Sections 5.2.2.2 and 5.6.6.)

5.2.2.1 Filters

A filter is a fibrous medium used for the removal of airborne solid or liquid particulates from the airstream entering the respirator enclosure. It may be designed for a single type of particulate or for various combinations of particulates such as dust, fumes, and mists. Filter media used for protection against radioactive particulate contaminants shall be of the high-efficiency type (greater than 99.97% effective by thermally generated 0.3 micrometer dioctyl phthalate (DOP) test). They are not effective against gases and vapors.

5.2.2.2 Sorbents

Sorbents are used for chemically removing toxic gases and vapors from the airstream entering the respirator enclosure. They consist of chemicals that attract and hold the gas molecules.

Sorbents may be used singly or in mixture and multiple layers to give protection against a single gaseous contaminant, a class of contaminants (e.g., organic vapors or acid gases), or combinations of gases and vapors. They are *not*, of themselves, effective against particulates. They are not approved for use for protection against radioactive gases or vapors unless their efficiency against the gas or vapor of interest has been well established. Note: If the odor or other warning threshold is above the MPC, as is generally the case for radioactive materials, *sorbent cartridges or canisters may not be used.*

5.2.2.3 Combination Filter - Sorbent Canisters

Canisters used for protection against particulates as well as gases and vapors consist of various combinations of filters and sorbents appropriate to the hazards for which protection is desired. For radioactive particulate contaminants, the filter media shall be of the high-efficiency type.

5.2.3 Limitations on Air-Purifying Respirators

The application of air-purifying respirators for protection against airborne radioactive contamination is subject to the following additional limitations:

5.2.3.1 Oxygen Deficiency

Air-purifying respirators remove a specified contaminant from the inhaled air. These devices *do not* supply oxygen; therefore, they may not be used in atmospheres deficient in oxygen.

5.2.3.2 Nature of Contaminant

Air-purifying respirators offer protection to the wearer by removing a specific contaminant from the inhaled air by means of a particulate filter or sorbent, or both, contained in a canister. The canister media are designed for removal of specified vapor(s) or gas(es), and the components of the canister are chosen to fulfill this purpose. The canister media are, therefore, not universal sorbents and it is vital to ensure that the canister selected is appropriate to the hazard.

Unless a particulate filter element is added, as in the case of the combination filter-sorbent canister, protection against particulates is not provided by a canister designed for gases and vapors. Only a high-efficiency-type canister shall be used for protection against airborne radioactive particulates.

When air-purifying respirators are worn in atmospheres containing substances such as hydrocyanic acid that may be absorbed through the unbroken skin, adequate skin protection must be provided.

5.2.3.3 Physical and Chemical State of Contaminant

The chemical and physical state of the contaminant must be considered in the selection of an air-purifying respirator canister (see Chapter 6 for details on selection). For example, the radionuclide

chlorine-36 may be present as airborne radioactivity in any of the following forms: gaseous (as chlorine gas), vapor (as a chlorinated hydrocarbon vapor), or particulate (as a hydrochloric acid mist or fume or as a dust of a chlorine salt).

A canister containing only a particulate filter may be inappropriate for use with radionuclides that decay from a particulate to a gaseous state or from a gaseous to a particulate state. For example, a filter used to protect against fresh fission products might allow the decay product iodine-131 to pass as a gas through the filter into the lungs.

5.2.3.4 Concentration of Contaminant

Experience has shown that there are maximum concentrations above which a person may not be safely exposed while wearing an air-purifying respirator. *Air-purifying respirators shall not be used in atmospheres immediately hazardous to life or health.* As defined in American National Standards Institute recommendations, conditions "immediately dangerous to life and health" include "...conditions that pose an immediate threat to life or health and conditions that pose an immediate threat of severe exposure to contaminants such as radioactive materials which are likely to have adverse delayed effects on health." This limitation on the use of air-purifying respirators is effectively provided for radioactive materials by limiting the use of such respirators to within peak concentrations that do not exceed specified multiples of the MPC (see Chapter 6 and footnote f to Table 6-1).

The limiting concentration for many particulates would be the one that causes rapid plugging of filter media with resultant increase in breathing resistance. However, for airborne radioactivity, rapid plugging is not generally a problem unless other hazards (e.g., chemicals, dust) are also present.

5.2.3.5 Service Life

Service lives of the filter media of air-purifying respirators are directly related to the capacity of the filter for the contaminant, the concentration of the contaminant in the air, and the respiratory minute volume (amount of air breathed in per minute) of the wearer, as determined by his work rate.

The service life of a particulate filter is limited by the amount of material that can be retained before the resistance to inhalation increases significantly. A second limitation results from the radiation and potential contamination hazard due to the material deposited on the filter.

Sorbent cartridges and canisters may be used only for nonradioactive gases and vapors and should always be kept sealed until installed on the respirator because exposure to high humidities might shorten their useful lifetimes. Unsealed, unused cartridges and canisters may be kept for use for 1 year if attached to a respirator and sealed in a plastic bag. Unsealed cartridges or canisters not so stored shall be

discarded even though unused. The date of removal of the seal should be clearly marked on the cartridge or canister.

Particulate filters used for protection against radioactive particulates may be reused if a quality assurance program (see Chapter 10) is in effect to ensure that the filters meet the requirements for efficiency and resistance to breathing specified for unused filters and that a means is available to determine the extent of radioactive contamination of the filters. *If these criteria are not met, particulate filters shall not be reused.*

Sorbent cartridges and canisters that might have been used for nonradioactive gases and vapors in circumstances in which the sorbent capacity might be diminished shall never be reused, since there is no way of determining the useful service life remaining after use.

5.2.3.6 Knitted Cloth Covers (Facelets)

Knitted cloth covers (facelets) have been used on half-mask respirators for sanitary purposes. *They shall not be used since they cause significant leakage with submicron aerosols.*

5.2.4 Atmosphere-Supplying Respirators, Descriptions, and Limitations

An atmosphere-supplying respirator is one that furnishes respirable air or oxygen to the wearer from an uncontaminated supply such as a compressed-breathing air or oxygen cylinder, an oxygen-generating canister, or a breathing-air compressor that draws its supply from an uncontaminated ambient atmosphere. This type includes air-line respirators and self-contained breathing apparatus.

5.2.4.1 Air-Line Respirators: Continuous Flow, Demand, Pressure Demand

An air-line respirator provides protection against contaminants by providing an adequate supply of respirable air by any of the following three modes of operation:

a. Continuous flow

b. Demand

c. Pressure demand.

Air is supplied in an air-line respirator through a hose to a facepiece, hood, helmet, or suit. The source of respirable air may be either a cylinder of compressed pure breathing air, or a breathing-air compressor located so that the air supplied is uncontaminated and respirable. If the air-supply system pressure for demand-type air-line respirators at the hose connection exceeds 125 psig, a pressure-reduction stage must be used with a pressure-relief device in case of valve failure.

For continuous-flow units additional pressure reduction under the wearer's control may be provided with an air-regulating valve worn at some conveniently reached position. Under current Bureau of Mines/ NIOSH approvals, such an air-regulating valve, at any setting, must not reduce the flow of air to less than 4 cfm for tight-fitting facepieces or to less than 6 cfm for loose-fitting hoods or helmets with the maximum specified length of hose and the minimum specified air-supply pressure.

Detailed requirements on air-supply lines, lengths of hose, airflows, and other components may be found in Table 8 of 30 CFR Part 11, Subpart J., §11.124-7.

While the American National Standards Institute's "Standard Practices for Respiratory Protection" (Ref. 2) recommends that breathing air meet at least the requirements for the specification for Grade D air as described in Compressed Gas Association (CGA) "Commodity Specification for Air," G-7.1-1966, (Ref. 25), it is good practice to supply breathing quality air that meets the requirements for Grade E air in the CGA specification. Grade D specifications should be considered as the limits for air of deteriorating quality. The following are the limiting characteristics for Grade E and Grade D air:

	Grade E	Grade D
% O_2 (v/v) (balance mainly N_2)	Atmospheric (~21%)	Atmospheric
O_2 limits for synthesized air	19-23%[a]	19-23%[a]
Condensed hydrocarbons in mg/m^3 of gas @NTP (Max.)	5	5
Carbon monoxide, ppm (v/v) (Max.),	10	20
Carbon dioxide, ppm (v/v) (Max.)	500	1000

The CGA specifies that breathing air must have no pronounced odor.

Compressed oxygen shall never be used in supplied-air or open-circuit self-contained breathing apparatus in which compressed air has previously been used. Oxygen shall never be used with air-line respirators.

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[a]Bureau of Mines/NIOSH approvals require a minimum of 19.5% oxygen by volume.

5.2.4.1.1 Continuous Flow Type. The continuous-flow air-line respirator may be used with a half-mask facepiece, full facepiece, hood, helmet, or suit. The minimum airflow for a person doing moderate work is 4 cfm for tight-fitting facepieces, such as the half masks and full-face masks, and 6 cfm for a person wearing a hood as specified in the Bureau of Mines/ NIOSH approvals. A suit requires a flow of 6 cfm, or more, depending on the suit design.

5.2.4.1.2 Demand Types. The demand regulator is usually located between the breathing tubes leading to the facepiece and the small-diameter pressure line from a high-pressure air source, such as a compressor (~100 psi) or a breathing-air cylinder (~2400 psi). Sometimes this regulator is mounted directly on the mask. The regulator has a diaphragm-actuated valve that opens on inhalation and permits air to flow into the facepiece only as long as a negative pressure exists. The negative pressure can cause leakage of contaminants into the facepiece where it seals to the face. Therefore, a demand-type device provides no higher degree of protection against contaminants than does an air-purifying respirator with the same facepiece.

During exhalation, the regulator valve shuts off the air supply and the pressure in the facepiece returns to that present in an air-purifying respirator facepiece during exhalation. This pressure condition creates the added hazard of possible inward leakage during inhalation that is not present in the pressure-demand types.

5.2.4.1.3 Pressure-Demand Types. In a pressure-demand air-line respirator, a spring-loaded regulator and exhalation valve combination provides a flow of air into the facepiece which maintains a slight positive pressure at all times. Any outward leakage around the facepiece seal results in a greater air consumption than for the demand types. However, if the facepiece fits properly, there is no increase in air consumption.

Some pressure-demand regulators are supplied with a control so that the respirator may be operated in either the pressure-demand or demand mode. Where such a control is provided, care must be exercised to ensure that the regulator is operating in the appropriate mode.

A pressure-demand device requires a special exhalation valve that is available only on full facepieces. A facepiece fitted with a demand-type exhalation valve cannot be used with a pressure-demand regulator.

5.2.4.1.4 Limitations on Air-Line Respirators. Although most atmosphere-supplying respirators are capable of providing protection against high concentrations of many toxicants, no device is 100% efficient. Some leakage into the facepiece may occur, particularly with apparatus operated in the demand mode where there is negative pressure in the mask during part of the breathing cycle. Many of the air-line devices employing a tight-fitting facepiece use the same facepieces as many of the air-purifying half-mask and full facepiece respirators. Limitations on their

use by persons with beards, eyeglasses, etc., are identical to the limitations on similar use of air-purifying facepieces of the same design (see Chapter 13). Also, respiratory protection fails if the oxygen or air supply fails, unless an auxiliary supply is available.

Air-line respirators generally furnish no protection, other than to the face, against contaminants irritating to the skin or mucous membranes, nor any protection against materials such as tritium oxide vapor or hydrocyanic acid gas that can be absorbed through the unbroken skin. Even supplied-air suits, which may afford more protection against the latter hazards, are permeable to varying degrees, depending on factors such as concentration of contaminant, time of exposure, and the properties of the suit material.

Air-line respirators that rely on an external air source connected by a length of hose or similar device to the facepiece, hood, or suit shall not be used for emergency rescue or escape. The restriction to movement imposed by the hose and the possibility of physical damage to the hose if used in an area where there might be sharp objects (for example, after an explosion or fire) would make the use of an air-line respirator a dangerous procedure. A positive-pressure self-contained breathing apparatus shall be used instead.

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 unless an auxiliary air

tank is provided for escape. Air-line respirators must be used within the limits set by the manufacturer and approved in 30 CFR Part 11 for air-supply hose length, type, and range for pressure applied.

Air-line respirators provide no protection if the air supply fails; therefore, they shall not be used in atmospheres immediately dangerous to life or health. This limitation precludes their use as emergency escape and rescue devices.

5.2.4.2 Self-Contained Breathing Apparatus Description and Limitations

A self-contained breathing apparatus (SCBA) consists of a respirator with the supply of air, oxygen, or oxygen-generating material carried by the wearer. These devices can be either open circuit, such that the exhaled breath passes to the ambient atmosphere through the facepiece exhaust valve, or closed circuit (re-breathing), wherein the carbon dioxide is removed from the exhaled air, oxygen is added, and the recycled air is rebreathed. An open-circuit SCBA operates on compressed air, compressed oxygen, liquid air, or liquid oxygen. A closed-circuit SCBA uses compressed, liquid, or chemically generated oxygen.

Compressed air and oxygen *may not* be used interchangeably in the same apparatus. Compressed air might contain slight amounts of oil that might coat orifice housings; oxygen passing through such an orifice under high pressure could cause an explosion or fire (Ref. 2).

5.2.4.2.1 Demand Type, Open Circuit. The demand-type, open-circuit, self-contained breathing apparatus is similar to the demand-type air-line respirator, except that the source of respirable air is a cylinder of compressed air or oxygen carried by the wearer. This apparatus usually consists of a full facepiece equipped with a demand valve and a pressure-reducing valve connected by a cylinder of compressed air, compressed oxygen, or liquid oxygen. A pressure gauge is located near the demand valve to indicate the pressure in the gas cylinder. An alarm device indicates when the reservoir pressure has dropped below a predetermined point, allowing enough reserve time for the wearer to exit from a contaminated area.

A demand-type SCBA does not provide any higher degree of protection against airborne contaminants than an air-purifying respirator with the same facepiece, but it does provide protection against oxygen deficiency. *A demand type SCBA must never be used as a standby emergency rescue device* because the possibility of facepiece seal leakage does not warrant its use where contaminant concentration is unknown, but potentially high.

5.2.4.2.2 Pressure-Demand Type, Open Circuit. A pressure-demand self-contained breathing apparatus is an open-circuit apparatus similar to the pressure-demand air-line respirator, except that the supply of respirable air is a cylinder of compressed air carried by the wearer.

A loaded regulator and exhalation valve combination maintains a positive pressure in the facepiece slightly above atmospheric pressure at all times. Therefore, any leakage is outward.

Because of the high degree of protection provided by the pressure-demand SCBA, this type of unit is recommended for emergency use, escape, and rescue.

5.2.4.2.3 Recirculating, Closed Circuit. In the recirculating or closed-circuit self-contained breathing apparatus, conservation of oxygen or air supply is obtained by recirculation between the facepiece and a breathing bag or reservoir. Carbon dioxide in the exhaled breath is removed by an absorber. Oxygen is added to the closed circuit as needed from a cylinder of compressed or liquid oxygen. Units of this type can be obtained that have useful lifetimes up to 4 hours.

5.2.4.2.4 Limitations of Self-Contained Breathing Apparatus. The lengths of time that these devices may be used are limited by the air or oxygen supply that the wearer can carry. Units are given nominal ratings for the length of time they would protect an average person doing moderately heavy work. However, these ratings are only a guide; and oxygen or air may be used more rapidly than a rating indicates, particularly under the stress of an emergency. Thus, these units must be provided with a warning device that indicates to the wearer when the remaining service life has been reduced to the point that he should leave the area or replace the supply.

The Bureau of Mines has published information (Table 5-1) on factors affecting the service life of a 30-minute self-contained compressed-air breathing apparatus approved under its schedules.

The demand types of self-contained breathing apparatus rely on a negative pressure being created in the facepiece to actuate the air or oxygen supply. Although these types of apparatus do supply respirable air to the facepiece, thereby protecting against oxygen deficiency, they are no more efficient than an air-purifying respirator employing the same facepiece. Therefore, they should not be used as emergency devices. Concentrations of airborne contaminants can become unpredictably high in an emergency situation.

Further limitations on the use of these devices may result from their size and weight when work is to be done in a very confined space.

5.3 COMBINATION RESPIRATORS

A combination respirator is any respirator that affords the wearer the option of changing from one basic type of respirator operation to another, either by operation of a selector valve or by disconnecting a source of respirable air supply. The degree of protection afforded by the combination respirator is determined by its operating characteristics for the mode being used and the type of facepiece being used. Combination respirators may be categorized in one of the following three classes described in Sections 5.3.1 through 5.3.3.

TABLE 5-1

SERVICE LIFE OF

THIRTY-MINUTE SELF-CONTAINED COMPRESSED-AIR BREATHING APPARATUS[a]

This equipment is approved by the U.S. Bureau of Mines as a "1/2-hour duration" unit, based on the fact that the equipment, when tested by the Bureau on men performing moderate-to-heavy work, was found to last 30 minutes or more in each of the different types of work tests.

The user should not expect to obtain exactly 30 minutes service life from this apparatus on each use. The work being performed may be more or less strenuous than that used in the Bureau of Mines tests. Where work is more strenuous, the duration may be shorter, possibly as short as 15 minutes.

The duration of the unit will depend on factors such as:

(a) the degree of physical activity of the user;

(b) the physical condition of the user;

(c) the degree to which the user's breathing is increased by excitement, fear, or other emotional factors;

(d) the degree of training or experience that the user has had with this or similar equipment;

(e) whether or not the cylinder is fully charged at the start of the work period;

(f) the possible presence in the compressed air of carbon dioxide concentrations greater than the .04% normally found in atmospheric air;

(g) the atmospheric pressure; if used in a pressurized tunnel or caisson at 2 atmospheres (15 psi gage), the duration will be one-half as long as when used at 1 atmosphere; and at 3 atmospheres will be one-third as long.

(h) the condition of the apparatus.

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[a] From the U.S. Bureau of Mines.

5.3.1 Air-Line Respirator - Air-Purifying Respirator

This type of combination respirator is designed to be operated either (1) as a continuous-flow or as a demand air-line respirator, or (2) as an air-purifying respirator, negative pressure (NP). The selector switch may be manually operated or may operate automatically if there is a failure of the air-line supply.

5.3.2 Self-Contained Breathing Apparatus - Air-Purifying Respirator

This type of combination respirator utilizes a full facepiece and consists of a self-contained breathing apparatus of the demand or pressure-demand type with appropriate valving so that the respirator may be operated in the air-purifying (NP) mode. The operation of the selector switch may be manual or automatic.

5.3.3 Self-Contained Breathing Apparatus - Air-Line Respirator

This type of combination respirator uses a full or half-mask facepiece. It generally consists of a demand- or constant-flow air-line respirator with additional valving so that a small cylinder of compressed air, attached to the unit, may be used to supply respirable air if the air-line supply is interrupted. Generally, the small cylinder (5 to 7 ft^3) is suitable only for escape purposes.

5.4 HOSE MASKS WITH AND WITHOUT BLOWER

This type of mask consists of a full facepiece connected by one or more flexible breathing tubes to a large-diameter hose (approximately 1 inch inside diameter). In a hose mask with blower, the large-diameter hose is connected to a blower operated in respirable air; in the hose mask without blower, the inlet end of the large diameter hose has a filter screen and is anchored in respirable air. Hose masks are generally unsuitable for

protection against radioactive materials owing to the difficulty of keeping the inlet ends of the short hoses in uncontaminated air.

5.5 EMERGENCY USE, ESCAPE, AND RESCUE DEVICES

Because an emergency is an unplanned event (see Section 2.1.3), it must be assumed when contaminant air concentrations can not be evaluated that they may be "immediately dangerous to life" (ANSI Z88.2-1969, Section 4, Table I). Therefore, devices for use during escape, firefighting, rescue, and emergency re-entry should provide a high level of protection (Figure 5-5).

5.5.1 Self-Contained Breathing Apparatus

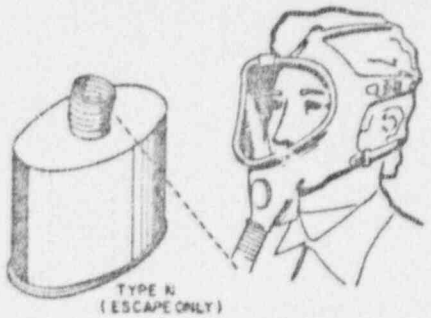
Generally, only the pressure-demand type SCBA should be selected for emergency use, rescue, and re-entry into a contaminated area to perform emergency shutdown or maintenance of equipment. The pressure-demand type with a positive pressure in the facepiece provides a much higher level of protection (protection factor = 10,000+) than the demand type with a negative pressure in the facepiece during inhalation.

The Bureau of Mines/NIOSH approves a 5- or 10-minute SCBA for emergency escape only. These devices are lighter and may be donned rapidly with proper training.

5.5.2 Air-Purifying Respirator

A Type N gas mask is approved for emergency use; however, the protection factor (see Chapter 6) for radioactive particulates is no greater than the protection factor of a full facepiece equipped with a high-efficiency filter. Comparison of the half-mask with the full-facepiece

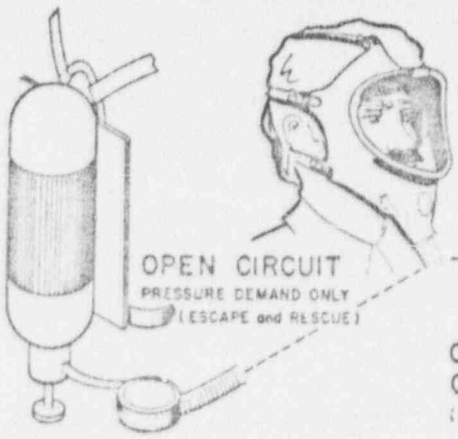
EMERGENCY ESCAPE & RESCUE



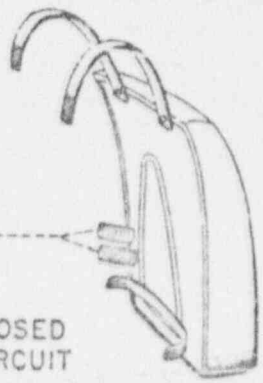
TYPE N
(ESCAPE ONLY)

AIR PURIFYING

MOUTHPIECE
(ESCAPE ONLY)



OPEN CIRCUIT
PRESSURE DEMAND ONLY
(ESCAPE and RESCUE)



CLOSED
CIRCUIT
(RESCUE IN O_2 DEFICIENT ATMOSPHERES ONLY)

SELF CONTAINED
5 MIN. ESCAPE DEVICE

8 MIN. ESCAPE DEVICE
WITH HALF MASK AND
AIR CYLINDER

FIGURE 5-5

respirator shows that the half-mask respirator (with high-efficiency filter) protection factor is only one-fifth (PF = 10) that of the full-facepiece respirator and obviously provides the least protection of any approved device for escape from radioactive particulates.

5.5.2.1 Mouthpiece Respirators

A mouthpiece respirator is a compact device designed for quick application when the atmosphere unexpectedly is contaminated with a hazardous material. It normally consists of a housing with a mouthpiece and a single canister or cartridge, a nose clamp, exhalation and inhalation valves, and a neckband. These devices can be carried on the belt, in a laboratory coat pocket, or around the neck. When properly used, there is little inward leakage when breathing through the mouthpiece with the nose clamp in place. These devices are available with high-efficiency filters and various types of sorbent cartridges.

Mouthpiece respirators shall never be used as a routine means of protection against radioactive contamination or for re-entry into a contaminated area during an emergency.

5.5.3 Combination Respirators

There are combination air-line respirators with an auxiliary self-contained air supply that are recommended for atmospheres immediately dangerous to life. The degree of protection provided depends on the mode of operation. Because of its air-line hose, such a device is not satisfactory for emergency escape.

A combination pressure-demand, or continuous-flow-type, air-line respirator with an auxiliary self-contained air supply provides a high degree of protection. The combination demand-type air-line respirator with an auxiliary self-contained air supply provides a much lower level of protection owing to the negative pressure in the facepiece.

5.6 SELECTION OF APPROVED OR ACCEPTED EQUIPMENT

5.6.1 Subpart K, 30 CFR Part 11, and Bureau of Mines Schedule 21B

Respirators that are specifically certified under Subpart K of 30 CFR Part 11 for use against radioactive particulates are listed, along with devices that are certified under other Subparts of 30 CFR Part 11, in "NIOSH Certified Personal Protective Equipment" (NIOSH) 75-119 (Ref. 26). Supplements to (NIOSH) 75-119 are issued periodically to keep the list updated. Respirators that were formerly approved under Bureau of Mines Schedule 21B, and other Bureau of Mines Schedules, are listed in Bureau of Mines Circular 8559 (Ref. 27). Equipment is referred to as "approved" under older Bureau of Mines regulations and as "certified" under 30 CFR Part 11. (See Section 3.1.3 for terminal dates of approval under the older schedules.)

When a negative-pressure, air-purifying device is used, it shall have been certified under Subpart K specifically for radionuclides, including the separate certifications for use against radon daughters. (A device offering a greater protection factor may be selected; see Chapter 6.) The air-purifying devices used must have a high-efficiency (99.97% efficient

for 0.3 micrometer DOP aerosol) particulate filter. Devices with a less efficient filter shall never be used for radioactive particulates.

5.6.2 Other Subparts and Schedules

Four additional Bureau of Mines Schedules (Refs. 28-31) and five Bureau of Mines/NIOSH Subparts cover self-contained breathing apparatus, gas masks, supplied air respirators, chemical cartridge respirators, and pesticide respirators. These additional schedules and subparts can be used for guidance, provided that an evaluation has not shown that the radiological characteristics of the hazard present a circumstance for which the particular respirator is inappropriate. Such circumstances could occur, for example, where airborne radioactive concentrations present submersion or absorption problems or where a short-lived radioactive particulate may decay into a gas.

5.6.3 NRC Testing Programs

An extensive amount of field testing of respirators has been performed by various NRC contractor laboratories and other laboratories. Most of these testing programs, including the tests in the field, have been reported in the public literature and may be used for guidance in the selection of respirators (Refs. 16-23, 32-37).

5.6.4 Selection Guidance From Other Resources

The recommendations of competent groups such as the American Industrial Hygiene Association, the American Conference of Governmental Industrial Hygienists, the American Society of Safety Engineers, and

American National Standards Institute, who have applied the use of respirators towards protecting against chemotoxic agents, should also be considered in respirator selection (Ref. 24).

5.6.5 "Accepted" Devices

The NRC permits use of other than approved or certified devices for use against airborne radioactive materials only in the following circumstances (Refs. 1, 38):

a. Where no equipment of a particular type has been approved or certified or where there is no existing schedule for approval of certain equipment, and

b. When the licensee has demonstrated to the Commission by testing or on the basis of reliable test information that the material and performance characteristics of the equipment are capable of providing an acceptable degree of protection under proposed conditions of use.

5.6.6 Sorbent Cartridges and Canisters

Sorbent cartridges and canisters shall not be used for protection against radioactive gases or vapors for the following reasons:

a. The efficiencies of the various sorbents for most radioactive gases and vapors are not known.

b. The length of time that a particular sorbent cartridge or canister offers protection against a given radioactive gas or vapor concentration is unknown in most instances.

c. The threshold of odor for most radioactive gases and vapors is above the MPCs, often by several orders of magnitude. Thus, when a breakthrough through the sorbent occurs there is no warning.

Studies are planned to test sorbent cartridge efficiencies against some radioactive gases and vapors. As results become available, it may be possible to assign protection factors in some instances and to permit the use of sorbents in certain cases. Studies conducted at Lawrence Livermore Laboratory (Ref. 39) indicate that organic cartridge breakthrough may occur in less than a minute, even at low concentrations of some non-radioactive organics (e.g., methyl alcohol). When efficiencies and breakthrough times are unknown, extreme caution must be exercised when using any sorbent cartridge or canister device.

CHAPTER 6

SELECTION GUIDES (PROTECTION FACTORS)

The overall protection afforded by a given respirator design is defined in terms of its protection factor (PF). The PF is a measure of the degree of protection afforded by a respirator and is defined as the ratio of the concentration of contaminant in the ambient atmosphere to that inside the equipment (usually inside the facepiece) under conditions of use. Respirators are to be selected so that the concentration inhaled by the wearer does not exceed the appropriate limit.

Table 6-1 lists protection factors for the various classifications of respirators. The protection factors are based on laboratory leakage studies and field experience in the use of the devices.

When using Table 6-1, it is important to keep in mind that the values given are intended for selection of respirators to protect against radionuclides in the absence of practicable engineering controls. The values are not intended as a device to maximize the potential exposure of workers in areas of airborne radioactivity, nor are they intended for planning the use of respirators to avoid adequate containment and other engineering controls in the designing of installations and process equipment. The indiscriminate and uncritical use of this table where it does not apply might result in undue hazards. Scrupulous attention must be paid to the limiting and qualifying notes.

The protection factors in the table may not be appropriate where chemical or other respiratory hazards exist in addition to radioactive hazards. The selection and use of respirators for such circumstances should take into account recommendations and requirements of the National Institute for Occupational Safety and Health and the Occupational Safety and Health Administration.

Respiratory protective equipment is to be selected to provide a protection factor greater than the multiple by which peak concentrations of radioactive materials are expected to exceed the values specified in Appendix B, Table I, Column 1 of 10 CFR Part 20. The equipment selected is to be used so that the average concentration of radioactive material inhaled during any period of uninterrupted use in an airborne radioactivity area, on any day, by any individual using the equipment, will not exceed the values specified in Appendix B, Table I, Column 1 of 10 CFR Part 20. For the purposes of this manual the concentration of radioactive material that is inhaled when respirators are worn may be initially estimated by dividing the ambient concentration in air by the protection factor specified in Table 6-1.

TABLE 6-1
PROTECTION FACTORS FOR RESPIRATORS[a]

DESCRIPTION[b]	MODES[c]	PROTECTION FACTORS[d] PARTICULATES ONLY	PROTECTION FACTORS[d] PARTICULATES, GASES & VAPORS[e]	SELECTION OF TESTED & CERTIFIED EQUIPMENT BUREAU OF MINES/NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH APPROVALS
I. AIR-PURIFYING RESPIRATORS				
Facepiece, half-mask[f]	NP	10		30 CFR Part 11 Subpart K
Facepiece, full	NP	50		
Facepiece, half-mask, full, or hood	PP	1000		
II. ATMOSPHERE-SUPPLYING RESPIRATORS				
1. Air-line respirator				
Facepiece, half-mask	CF		1000	30 CFR Part 11 Subpart J
Facepiece, half-mask	D		10	
Facepiece, full	CF		2000	
Facepiece, full	D		50	
Facepiece, full	PD		2000	
Hood	CF		2000[g]	
Suit	CF		h	i
2. Self-contained breathing apparatus (SCBA)				
Facepiece, full	D		50	30 CFR Part 11 Subpart H
Facepiece, full	PD		10,000	
Facepiece, full	R		50	
III. COMBINATION RESPIRATOR				
Any combination of air-purifying and atmosphere-supplying respirators		Protection factor for type and mode of operation as listed above		30 CFR Part 11 § 11.63(b)

[a]For use in the selection of respiratory protective devices to be used where the contaminant has been identified and the concentration (or possible concentration) is known.

[b]Only for shaven faces and where nothing interferes with the seal of tight-fitting facepieces against the skin. (Hoods and suits are excepted.)

[c]The mode symbols are defined as follows:

- CF = continuous flow
- D = demand
- NP = negative pressure (i.e., negative phase during inhalation)
- PD = pressure demand (i.e., always positive pressure)
- PP = positive pressure
- R = demand, recirculating (closed circuit)

[d]1. The protection factor is a measure of the degree of protection afforded by a respirator, defined as the ratio of the concentration of airborne radioactive material outside the respirator's protective equipment to that inside the equipment (usually inside the facepiece) under conditions of use. It is applied to the ambient airborne concentration to estimate the concentration inhaled by the wearer according to the following formula:

$$\text{Concentration Inhaled} = \frac{\text{Ambient Airborne Concentration}}{\text{Protection Factor}}$$

2. The protection factors apply:

(a) Only for trained individuals wearing properly fitted respirators used and maintained under supervision in a well-planned respiratory protective program.

(b) For air-purifying respirators only when high efficiency particulate filters [above 99.97% removal efficiency by thermally generated 0.3 μm dioctyl phthalate (DOP) test] are used in atmospheres not deficient in oxygen and not containing radioactive gas or vapor respiratory hazards.

(c) For atmosphere-supplying respirators only when supplied with adequate respirable air.

[e]Excluding radioactive contaminants that present an absorption or submersion hazard. For tritium oxide, approximately one half of the intake occurs by absorption through the skin so that an overall protection factor of less than 2 is appropriate when atmosphere-supplying respirators are used to protect against tritium oxide, for example:

If the protection factor for a device is	PF overall for tritium oxide is
10	1.82
100	1.98
1,000	1.99

(Continued)

(Continued)

Air-purifying respirators are not suitable for protection against tritium oxide. See also footnote g concerning supplied-air suits.

[f]Under-chin type only. This type of respirator is not satisfactory for use where it might be possible (e.g., if an accident or emergency were to occur) for the ambient airborne concentration to reach instantaneous values greater than 10 times the pertinent values in Table I, Column 1 of Appendix B to 10 CFR Part 20, "Standards for Protection Against Radiation." This type of respirator is not suitable for protection against plutonium or other high-toxicity materials. The mask is to be tested for fit with irritant smoke, prior to use, each time it is donned.

[g]The design of the supplied-air hood or helmet (with a minimum flow of 6 cfm of air) may determine its overall efficiency and the protection it provides. For example, some hoods aspirate contaminated air into the breathing zone when the wearer works with hands-over-head. Such aspiration may be overcome if a short cape-like extention to the hood is worn under a coat or coveralls. Other limitations specified by the approval agency must be considered before using a hood in certain types of atmospheres (see footnote h). Manufacturers' recommended pressure settings for the air supply cannot always be relied on to ensure a minimum 6 cfm air flow. Equipment must be operated in a manner that ensures proper flow rates are maintained.

[h]Appropriate protection factors must be determined, taking into account the design of the suit and its permeability to the contaminant under conditions of use.

[i]No approval schedules are currently available for this equipment. Equipment is to be evaluated by testing or on the basis of reliable test information.

[j]This type of respirator may provide greater protection and be used as an emergency device in unknown concentrations for protection against inhalation hazards. External radiation hazards and other limitations to permitted exposure such as skin absorption must be taken into account in such circumstances.

Note 1: Protection factors for respirators, as may be approved by the U.S. Bureau of Mines/National Institute for Occupational Safety and Health (NIOSH) according to applicable approvals for respirators to protect against airborne radionuclides, may be used to the extent that they do not exceed the protection factors listed in this table. The protection factors listed in this table may not be appropriate to circumstances where chemical or other respiratory hazards exist in addition to radioactive hazards. The selection and use of respirators for such circumstances should take into account applicable approvals of the U.S. Bureau of Mines/NIOSH.

Note 2: Radioactive contaminants for which the concentration values in Table I of Appendix B to 10 CFR Part 20 are based on internal dose due to inhalation may, in addition, present external exposure hazards at higher concentrations. Under such circumstances, limitations on occupancy may have to be governed by external dose limits.

CHAPTER 7

WEARER REQUIREMENTS AND LIMITATIONS

7.1 ACTIVITIES OF THE WEARER

An important element to be considered in the selection of respirators is the degree to which the device selected will meet the physical and physiological requirements of the work to be done without causing undue stress to the wearer or imposing restraints that lead to unsafe practices (Refs. 17, 40).

It should be recognized that the wearing of respirators usually results in some additional stress and, therefore, an additional risk to the wearer. Thus, respirators should be selected so that any specific job can be performed with a minimum of stress compatible with the job requirements and the degree of respiratory protection needed.

The work rate of the wearer determines his respiratory minute volume, peak respiratory airflow rate, and the inhalation and exhalation breathing resistance associated with the respirator. The minute volume is significant when self-contained and air-line respirators are operated from cylinders because it determines the useful duration of the air supply. The useful life of the air supply at moderate work rates may be only one-third that at sedentary use.

Peak respiratory airflow rate is of importance since to maintain a continuous-flow, air-line respirator or a positive-pressure, air-purifying respirator under positive pressure at all times, the supply rate must be

greater than the peak respiratory airflow rate. The 4 cfm air supply (minimum) recommended for tight-fitting facepieces is 115 liters per minute or approximately the peak airflow rate for a normal person working at a moderate work rate of 622 kg-m/min. Similar considerations apply to the 6 cfm air supply (minimum) recommended for hoods.

The resistance to breathing associated with air-purifying and demand-type SCBA and air-line respirators of the negative pressure (NP) type used by a person working at a moderate work rate or at higher elevations can result in worker fatigue and discomfort. This is especially true for the Type N gas mask.

Visual and communications limitations of respirators and other special problems must not be neglected (see Chapter 13). Appropriate equipment with proper visual and communications capabilities must be provided where the work to be done demands it. Otherwise, hazardous situations may arise; for example, the wearer might remove the respirator in a hazardous area in order to see (lens fogging) or to be heard.

7.2 FIT

The most significant individual requirement of the wearer is proper respirator fit. Each commercial half-mask and full-face respirator normally manufactured in the U.S. to date has been available only in one size. Since a given respirator in a single size will not fit all of the population, it is necessary that several models be available in order that each person may know which models provide him with an adequate fit. (A few individuals of

unusual facial size or contour may be encountered who cannot be fitted adequately and should therefore not be permitted to use negative pressure respirators of the facepiece type.) An adequate fit is of importance with any facepiece operating in the negative pressure mode (NP type) when a high degree of protection is required. (See Chapter 8 for fitting methods.)

7.3 ANTHROPOMETRIC CRITERION

Although there is a wide variety of facial sizes and shapes in the general population, commercial respirators are available in only one size, i.e., each manufacturer produces only one size of each of his respirator models. In addition, all masks are presently designed for men. Most women have faces that are both narrower and shorter than men's. Consequently, it is expected that the fitting of women is more difficult.

Many factors affect the fit of a mask. Even different commercial masks of the same length may accommodate different faces if there are differences in the design of sealing edge, shape, and materials of manufacture. An effective way to have the capability of fitting a large percentage of the population at the present time is to stock the products of three or four different manufacturers. Because the different brands of commercial masks differ considerably in design, the availability of different brands and the use of a fitting test is the most effective way to provide adequate protection for most of those people who wear respirators.

The 1956-1958 AEC Ad Hoc Committee on Respiratory Protection Equipment suggested that respirators be designed so that 95% of the population could

obtain an adequate fit with any specific respirator or size series of masks (Ref. 4). Table 7-1 shows the 95% limits used in determining protection factors for both half- and full-facepiece masks for men and women for face length, face width, and lip width. Persons whose facial dimensions are outside these limits should be identified since they might have more difficulty in obtaining a good seal with a respirator.

TABLE 7-1

95% LIMITS OF FACIAL MEASUREMENT (in mm)

	Men	Women
Face Length	108-133	94-119
Face Width	132-153	117-141
Lip Width	45-60	35-52

These ranges encompass ± 2.0 standard deviations of the mean values from surveys of military populations: for men, the 1967 USAF Anthropometric Survey of Flying Personnel, for women, the 1968 Anthropometric Survey of Air Force Women.

The proposed Bureau of Mines/NIOSH amendments for 30 CFR Part 11 specify that the certifying test panel be representative of 95% of the male-female working population. Thus, the protection factors given in Chapter 6 will apply *only* to 95% of the population. Therefore, it will be necessary for licensees to identify the 5% of the working population not covered by the approval tests.

7.3.1 Anthropometric Facial Measurements and Characteristics Relating to Facepiece Fit

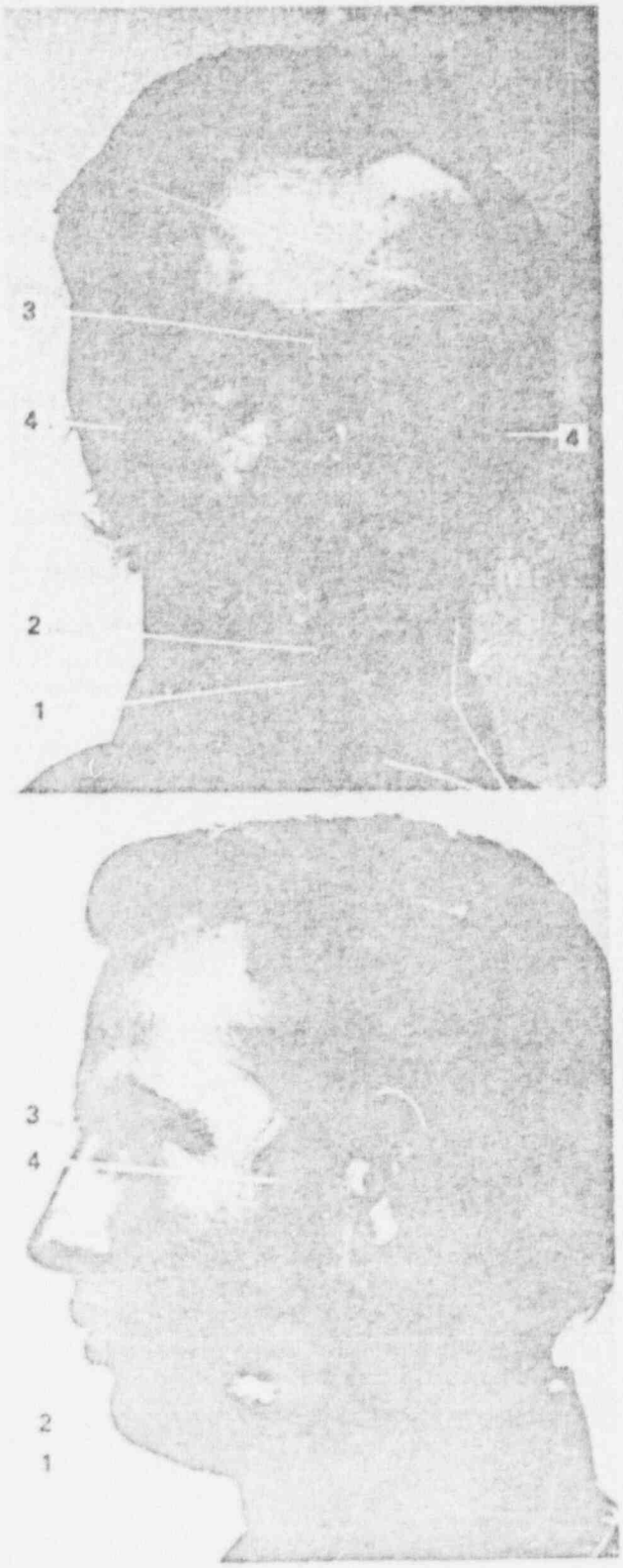
Standard anthropometric techniques consist of measuring between selected points on the face with anthropometric calipers. These points, called landmarks, refer to either visible features on the face, such as the corners of the mouth, or to points on the underlying skull. The latter must be located by palpating the skin and marking the correct location with a pencil. Then the actual measurements can be taken using the indicated landmarks. An example of a landmark located by palpation is the menton, which is the point of the chin in the center of the jaw. A few key facial dimensions of importance in respirator fitting are shown in Figure 7-1.

Face length is perhaps the most important single dimension in respirator design and fitting. Face length is measured from the menton, described above, to the nasal root depression, defined as the area of greatest indentation where the bridge of the nose meets the forehead. This distance is shown in Figure 7-2. It might be noted that although a full face mask covers the distance from under the chin to above the eyebrows, this distance is closely related to the face length.

An appropriate breadth measurement for a full-facepiece mask is face width. It is defined as the maximum horizontal breadth of the face across the zygomatic arches, where the bony arches extend horizontally along the side of the head from the cheekbone to the ear. Figure 7-3 illustrates the measurement of face width.

Figure 7-1 ANTHROPOMETRIC LANDMARKS

1. Menton- The tip at the bottom surface of the chin
2. Anterior Chin Projection- The maximum anterior projection of the fleshy chin with face viewed in profile.
3. Nasal Root Depression- With subject viewed in profile the point of maximum depression (posterior) of the nasal root.
4. Bizygomatic Breadth- The maximum horizontal breadth of the face across the most laterally projecting bones of the cheek.



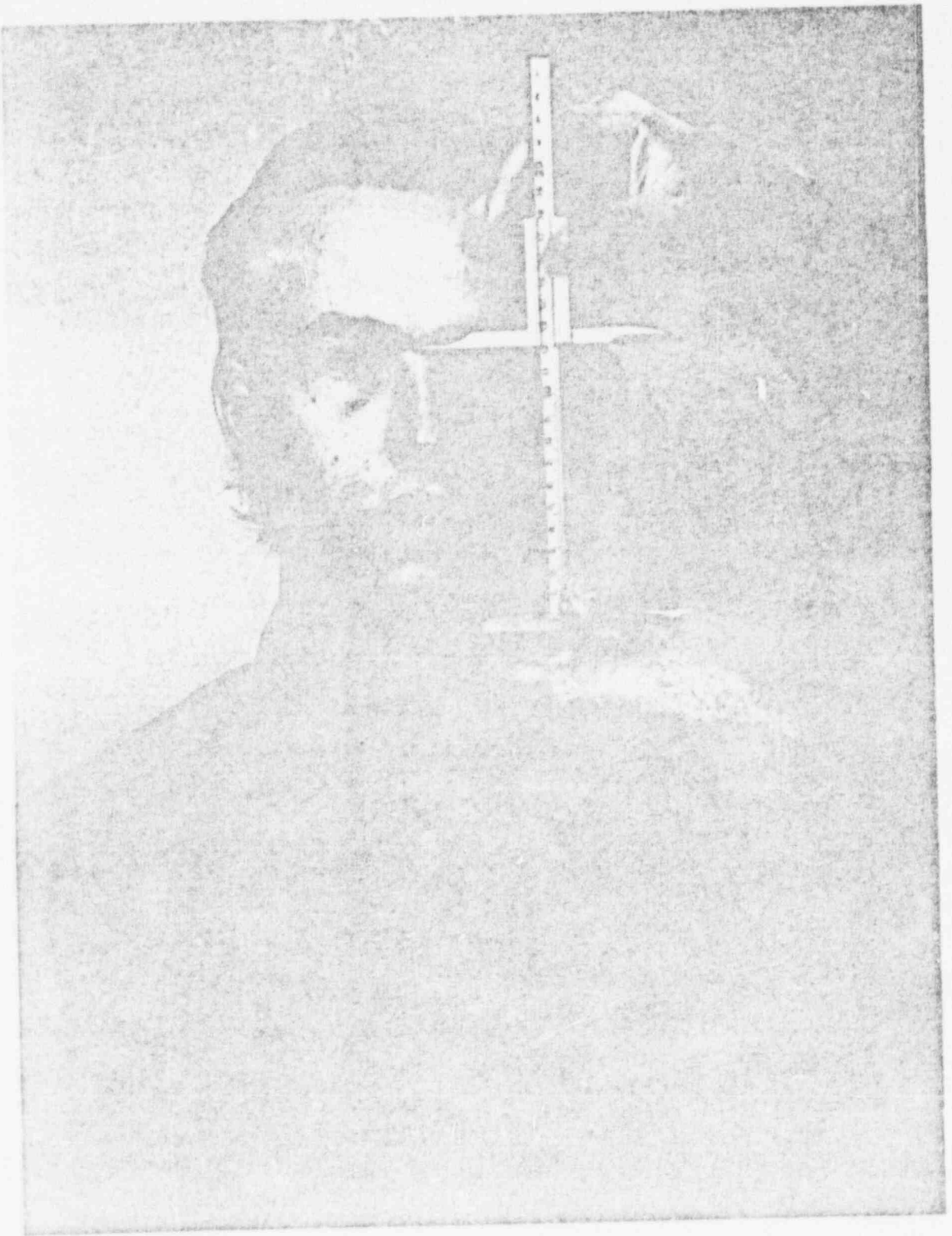


FIGURE 7-2 MEASUREMENT OF FACIAL LENGTH

FIGURE 7-3 MEASUREMENT OF FACIAL WIDTH

Other factors of possible importance in fitting a full-facepiece mask include the shape of the jaw and the width across the eyebrows.

The correlation between face length and face width is low, as it is for most facial dimensions. Therefore, subjects with a long face do not necessarily have a wide face.

For half-mask fitting, face length is important and is used, but a different width is more appropriate. Lip width, shown in Figure 7-4, is measured from one corner of the mouth to the other. This width is related to the ability of a half mask or quarter mask to seal around the mouth, although the mouth width can change while the subject is talking or moving his jaw. Other measurements may be important in evaluating the fit of a half mask, such as the width of the nasal bridge, and studies are being carried out to find what their significance may be.

Anthropologists employ standard measuring calipers which are not in general use outside the profession but are commercially available.

7.3.2 Facial Abnormalities

Many characteristics of the face can adversely affect the seal of a respirator facepiece. Some of the features that should be obvious to and carefully checked by the individual doing the respirator fitting are:

a. The effect of facial hair.

b. For half masks, the shape and size of the nose. (A nose that is skewed to one side, broken, or exceedingly broad or thin may prevent a good seal.)

FIGURE 7-4 MEASUREMENT OF LIP WIDTH

c. A weak jaw without a clearly defined menton.

d. Hollow temples or cheeks, scars, or excessive wrinkles that may provide a channel for contaminated air to enter the breathing zone.

e. Missing dentures.

7.4 MEDICAL LIMITATIONS

Workers must be evaluated by competent medical personnel to ensure that they are physically and mentally able to wear respirators under simulated and actual working conditions. These evaluations should be an important part of the employee's periodic physical examinations routinely given in most industrial medical facilities.

Adequate medical supervision of respirator users is indispensable in determining the extent of individual stress tolerance and in preventing potential physiological derangements.

7.4.1 Physiological Factors

The "Respiratory Protective Devices Manual" (Ref. 4) devotes an entire chapter to the physiology of respiration and the effects of respiratory equipment on respiration. However, research that must still be done on the effects of stress caused by breathing against some resistance while performing various types of work includes studies of energy expenditure, pulmonary ventilation-perfusion, cardiovascular physiology, and potential for precipitating asthmatic attacks.

Because of the additional stress placed on the cardiopulmonary system, some pathological conditions (expecially those associated with hypoxemia) should preclude the use of respiratory protective devices. The presence of other cardiovascular or systemic diseases that might be aggravated also may limit the use of respiratory devices.

The following clinical conditions are among those most likely to be investigated by the examining physician in determining an individual's fitness for respirator use:

a. Chronic obstructive and restrictive lung disease: chronic bronchitis, emphysema, pneumoconioses, fibrothorax, asthma, etc;

b. Ischemic heart disease: coronary insufficiency and myocardial infarction;

c. Benign and accelerated hypertension;

d. Hemorrhagic disorders: vascular hemophilia, hypersplenism, thrombocytopenia, purpura, etc;

e. Thyroid disorders or cystic fibrosis;

f. Epilepsy: grandmal, focal, etc;

g. Diabetes mellitus;

h. Cerebrovascular accidents;

i. Facial abnormalities;

j. Kidney diseases;

k. Conductive and sensorineural hearing loss;

l. Serious defects in visual acuity;

m. Ruptured eardrum; or

n. Other disabilities.

7.4.2 Psychological Factors

It is generally very difficult to evaluate a wearer's psychological limitations by means of a routine medical examination. The examining medical doctor should investigate any mental illness thoroughly to ascertain that the wearing of respiratory protective equipment will not aggravate an existing condition. Under the best conditions, a degree of anxiety is often encountered when wearing a respirator; such anxiety may become exaggerated in emergency situations. Experienced personnel who fit and train respirator users might sometimes have the opportunity to note unusual behavior patterns.

7.4.2.1 Wearer Acceptance

Wearer acceptance of respirators can best be accomplished through proper training. Knowledge of the reason for using a device, the possible consequences of not wearing it, the capabilities of the device, and the reasons that engineering controls are not feasible may relieve any "fear of the unknown," "only sissies use them" concepts and any other preconceived notions and will improve wearer acceptance.

7.4.2.2 Claustrophobia

Some people may experience claustrophobia when wearing respirators. Claustrophobic reactions might not be detected when a device is first tried on or during the fitting phase. It usually does not appear until the wearer actually goes into an atmosphere that is either hazardous or irritating. Use of a room, chamber, or "smoke house" filled with irritating

smoke, such as that from burning wet straw, may assist greatly in identifying individuals who tend to develop claustrophobia.

7.4.2.3 Stress

Stress conditions generated in an emergency may completely incapacitate an individual, endangering him and others around him. People who may be used in an emergency, such as a standby man whose task will be to observe a worker in a tank or a rescue team member, should be trained, if possible, using simulated conditions. Because there is no way to predict how a person might react under actual stress conditions, respirator users should be conditioned physically, mentally, and psychologically for the situations they might have to deal with. Such preparation can only be accomplished by repeated and sufficient training.

7.4.3 Periodic Medical Examinations

A physical examination is required for each user before he wears any device and at least annually thereafter. A physician is to determine whether health and physical conditions are pertinent and will make necessary recommendations for each situation.

7.4.4 Medical Approval Forms

It is recommended that each licensee use a medical approval form for every individual who might use a respirator. These forms are to be completed by the examining physician for the person in charge of the respirator program. The assessment of medical restrictions facilitates the planning of training activities and the types of job assignments.

7.5 WEARER COMFORT

Comfort relates to the degree of physical distress to the respirator wearer. Everyone who wears a respirator may be expected to experience some discomfort. Distress associated with the job environment tends to be accentuated by wearing a respirator: vision is restricted; breathing is more difficult; ventilation across the face is limited; equipment may be cumbersome and restrict movement; and wearing the respirator may add to adverse effects of temperature extremes. Other factors also militate against wearer acceptance. An improperly fitted mask may create intolerable pain spots. Improperly designed or malfunctioning valves may cause uncomfortable restrictions to breathing or an irritating flicking and popping. Limitations on communications may be unpleasant and add to the hazards. All these factors contribute to the physical discomfort that affects the willingness to wear and make proper use of respirators. However, if proper attention is paid to these factors in selecting equipment, most people may be provided with respirators that do not cause undue distress and that effectively protect the wearer.

CHAPTER 8

TRAINING

8.1 QUALIFICATIONS OF TRAINING PERSONNEL

Training in the use of respiratory protective devices is to be given by a qualified and experienced instructor, such as a health physicist, industrial hygienist, or safety engineer. The instructor must have a thorough knowledge of the application and use of respiratory protective equipment and of the hazards associated with radioactive airborne contaminants. He also must have had considerable experience in the practical selection and use of respirators for protection against radioactive airborne contaminants.

8.2 EXTENT OF TRAINING

The instructor is to develop an adequate training program based on the hazards to be encountered and the types of respirators to be worn. Training must be given not only to the persons who will perform the work using the respirators but also to those individuals who will direct the work. It is important, especially in establishments where respirators are used only occasionally, that periodic retraining be performed with sufficient frequency and at appropriate times so that a high degree of proficiency will be retained when respiratory equipment is actually used.

8.3 CONTENTS OF TRAINING PROGRAM

Training in the use of any respirator must cover the following, as a minimum:

a. Discussion of the airborne contaminants against which the wearer is to be protected, including their physical properties, MPCs, physiological action, toxicity, and means of detection;

b. Discussion of the construction, operating principles, and *limitations* of the respirator and the reasons the respirator is the proper type for the particular purpose;

c. Discussion of the reasons for using the respirator and explanation of why more positive control is not immediately feasible, including recognition that every reasonable effort is being made to reduce or eliminate the need for respirators;

d. Instruction in procedures for ensuring that the respirator is in proper working condition;

e. Instruction in fitting the respirator properly and checking for adequacy of fit;

f. Instruction in the proper use and maintenance of the respirator;

g. Discussion of the application of various cartridges and canisters available for air-purifying respirators;

h. Instruction in emergency action to be taken in the event of malfunction of the respiratory protective devices;

i. Review of radiation and contamination hazards, including the use of other protective equipment that may be used with respirators;

j. Classroom and field training to recognize and cope with emergency situations; and

k. Other special training as needed for special use.

8.4 DRILLS

Training must include the use of the respirator under simulated conditions of exposure so that the wearer will develop a sense of confidence in his ability to use the device properly. Performance in these drills is to be reviewed with the trainees by a qualified observer.

8.5 FITTING OF RESPIRATORS

Fitting of respirators can be accomplished either with quantitative man-tests or qualitative tests. In any sizable respirator program or a program that uses respirators for highly hazardous conditions or materials, quantitative tests should be used for selecting the best-performing mask for each individual during training. Qualitative field-fitting tests should be used prior to each entrance into a hazardous atmosphere to ascertain that an adequate fit has been obtained.

As a minimum, a qualitative fitting program employing a challenge atmosphere is to be used to determine which models of masks give each wearer the best protection.

8.5.1 Quantitative Man-Tests

Quantitative man-tests employ a challenge atmosphere, at a known concentration, in a chamber of some type. The wearer is first given a qualitative test while he is wearing an appropriate device for protection against the challenge atmosphere (Section 8.5.2). Once an adequate fit is obtained qualitatively, the wearer enters the chamber. A sampling tube

extends from the inside of the specially modified test respirator and is connected outside the chamber to an appropriate instrument for sampling and quantitatively measuring the atmosphere within the mask. A technician can then measure leakage into the respirator while the wearer performs various exercises.

8.5.1.1 Fitting Chambers

The following types of chambers can be used for quantitative tests:

a. Test Room. Provided there is sufficient window space in a room to allow the technician to observe the wearer in case of problems, the use of a room as a fitting chamber works well. A means of communication is also required. Although the large size of a room permits more vigorous exercise, allowing the technician to check for leakage from mask slippage due to perspiration and movement, greater volumes of the challenge atmosphere are required to achieve adequate concentrations (see Figure 8-1).

b. Test Booth. A booth may be easily converted for use as a fitting chamber. An audiometric booth or telephone-style booth could work quite well. Vigorous exercise is less practicable, however, in the smaller space than in a test room.

c. Plastic Hood. Plastic hoods work very well, particularly when used in combination with a treadmill to simulate work stress. Figure 8-2 shows a small hood, good for use with cartridge or canister masks.

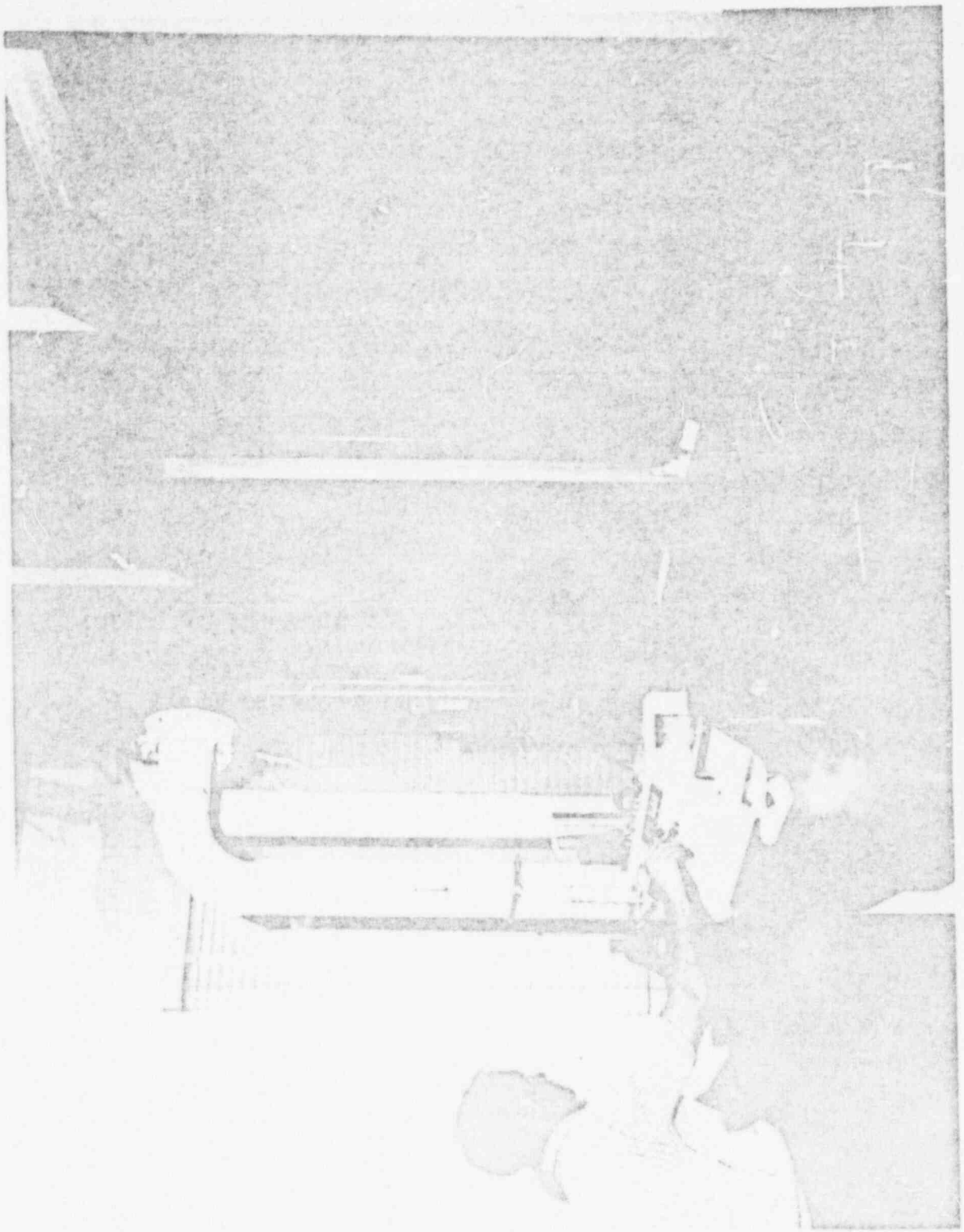


FIGURE 8-1 RESPIRATOR-FITTING TEST ROOM

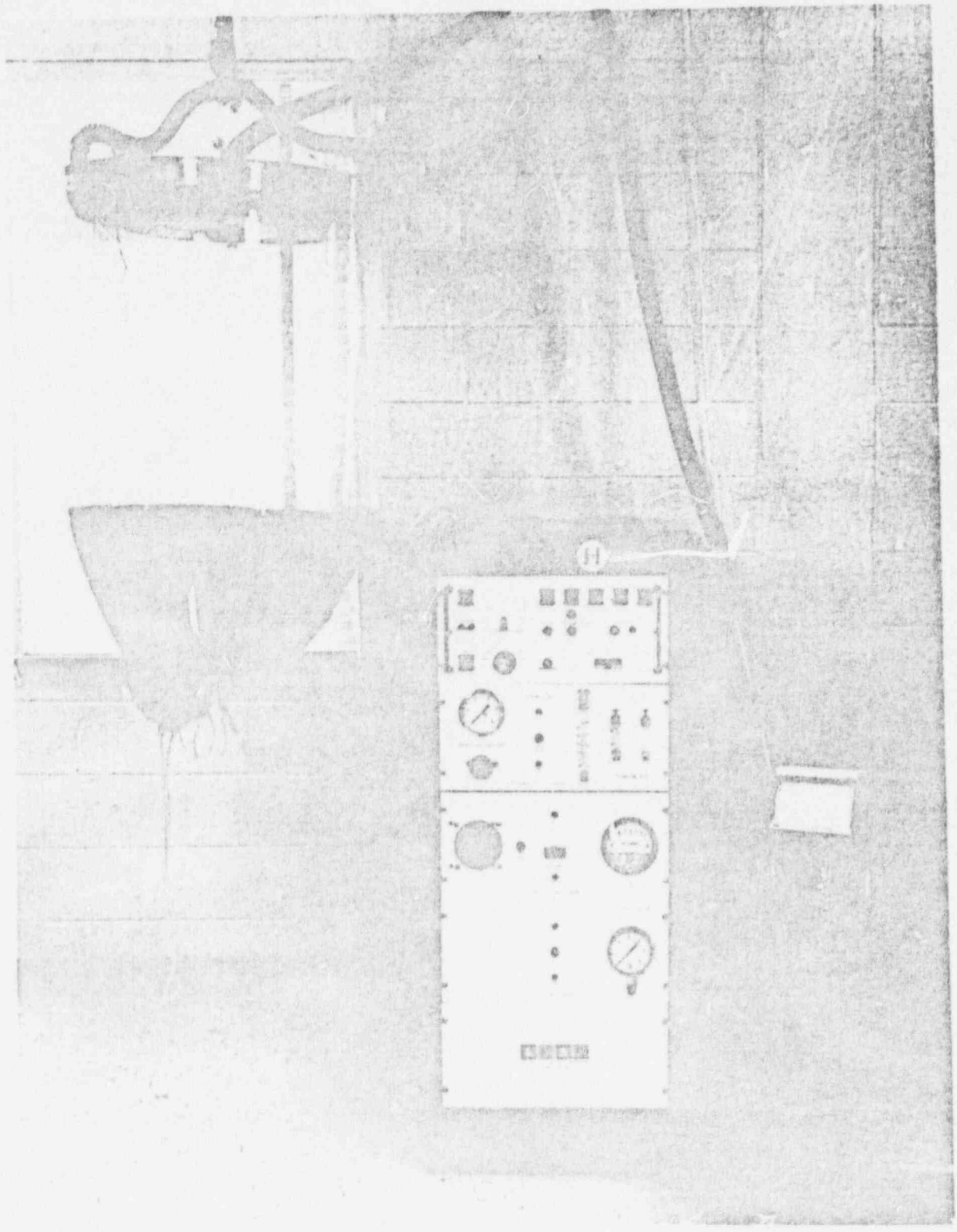


FIGURE 8-2 POLYDISPERSE DOP MAN-TEST SYSTEM WITH SMALL HOOD

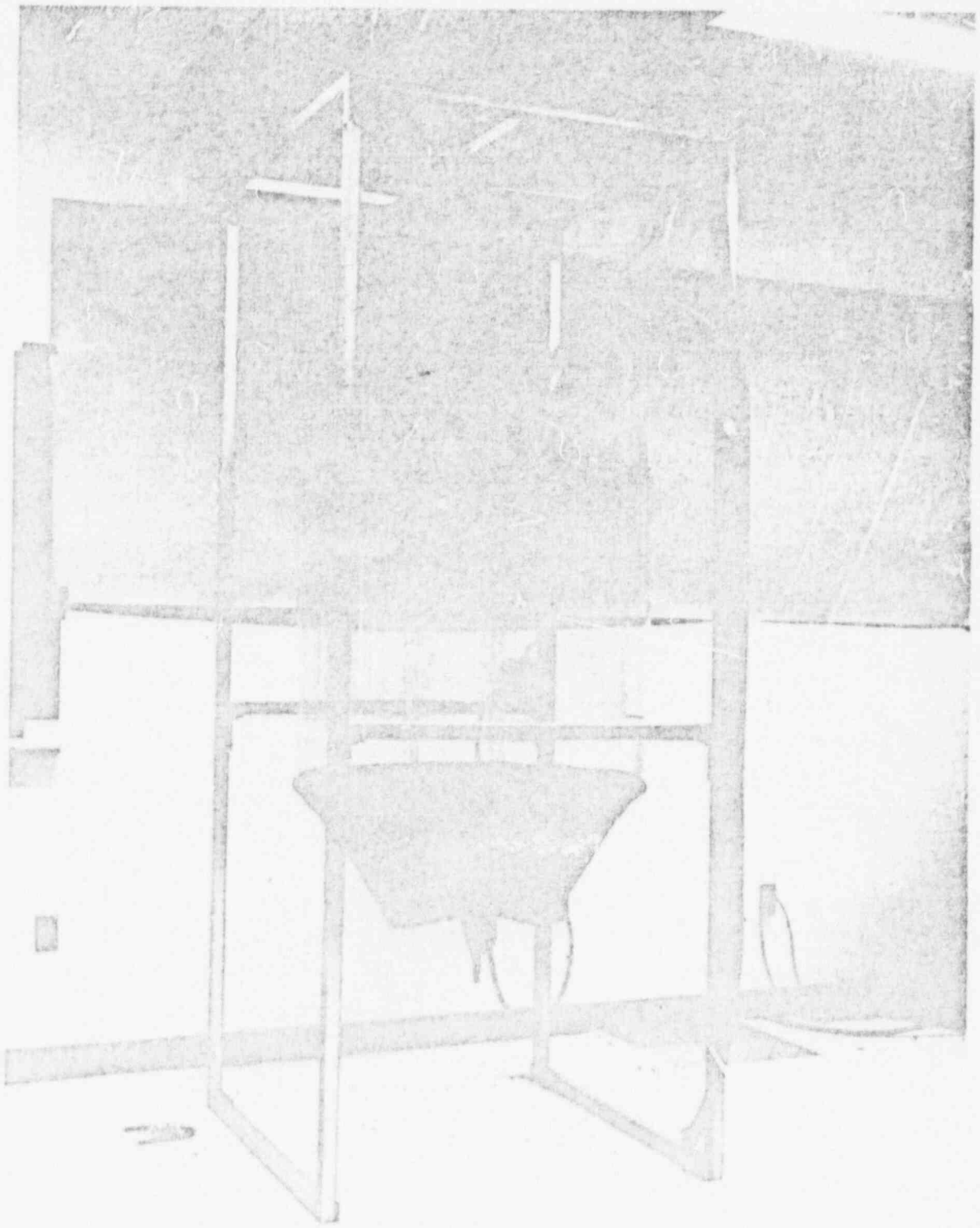


FIGURE 8-3 LARGE HOOD FOR RESPIRATOR FITTING TESTS

Figure 8-3 shows a larger hood, which can be used even for testing a self-contained breathing apparatus. A hood can be raised or lowered with an electric motor for entering and leaving. A treadmill could be used with either hood.

8.5.1.2 Simulated Work Conditions

The more closely working conditions are simulated during fitting tests, the more useful the test results are. If a person stands perfectly still during the fitting test, those leaks that can occur from moving the head or from mask slippage due to perspiration do not show up.

The following are minimum movements that should be performed during testing of a respirator:

a. Normal breathing,

b. Deep breathing,

c. Moving head from side to side (slowly),

d. Moving head up and down (slowly),

e. Frown (for full face masks only),

f. Talking (e.g., reading a short passage aloud),

g. Running in place, and

h. Normal breathing to recheck seal after movements.

Use of a treadmill to simulate work stress may also be beneficial during fitting tests. In lieu of the treadmill, running in place or a brisk walk through an obstacle course might be used, followed immediately by another test to measure facepiece-to-face fit with hard breathing and perspiration on the face.

People who are being fitted with respirators and trained in their use should be cautioned to avoid movements of the head or face that might cause leakage at the respirator facepiece-to-face seal area. For example, extreme up-and-down or side-to-side head movements can be a source of such leaks. Extreme facial movements should also be avoided; for example, smiling is known to cause serious leakage, particularly with half-mask facepieces.

8.5.1.3 Instrumentation

8.5.1.3.1 Polydisperse DOP Man-Test System. A mobile, quantitative, polydisperse DOP respirator man-test system developed at LASL is illustrated in Figure 8-2.

The major component, the "Polydisperse DOP Aerosol System," contains an air-generated DOP aerosol system, a 5-decade, forward light-scattering photometer, air supply, and sampling vacuum system. This unit operates on 115V, 60 cycle AC current and may be moved without difficulty and operated at any location where electrical power is available.

The test chamber is a Harvard School of Public Health design that features an annular exhaust system to prevent aerosol contamination of the area outside the hood. This unit can be hung from the ceiling or from a portable frame. Flexible hose from the main unit delivers the DOP aerosol to the hood, and exhaust lines return the dynamic flow of aerosol to a high-efficiency filter. A strip chart recorder is connected to the photometer output signal for a permanent record of test results. A flow diagram of this system is shown in Figure 8-4.

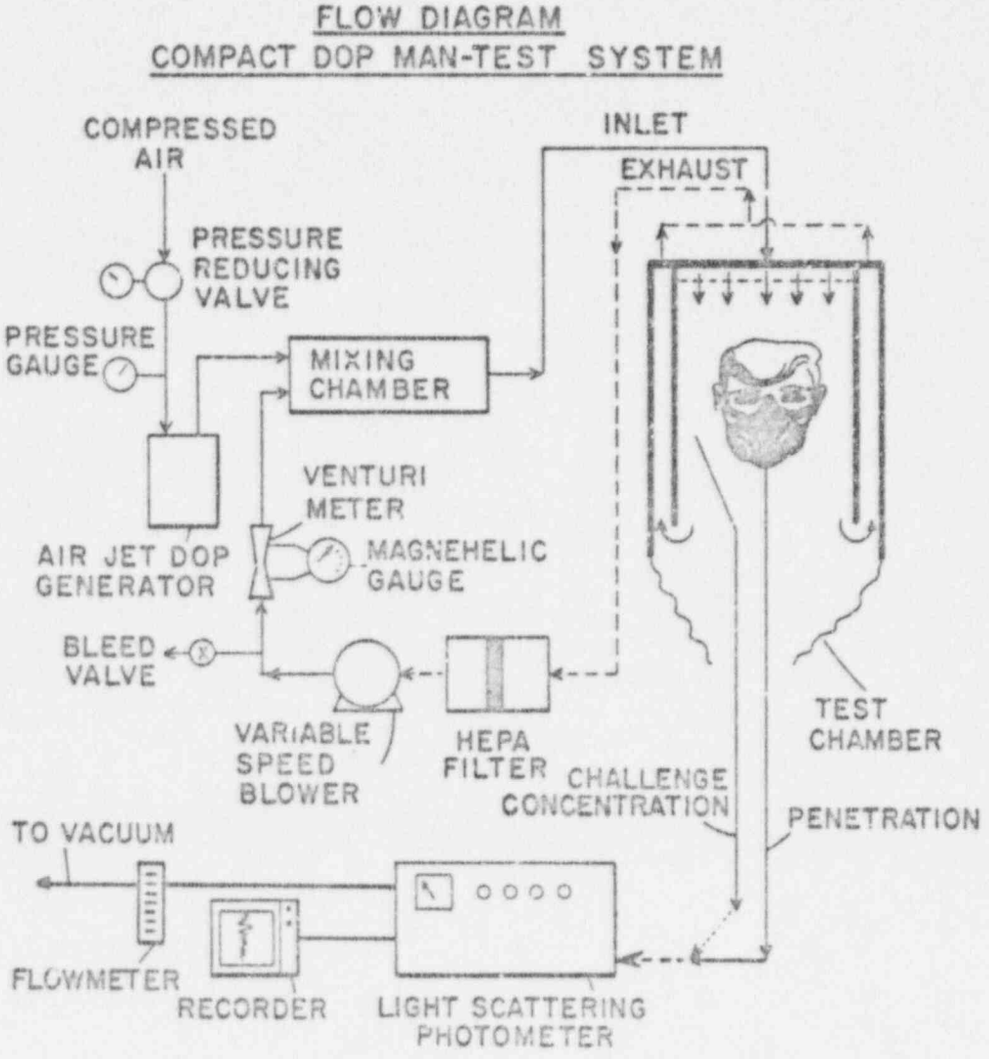


FIGURE 8-4 RESPIRATOR-FITTING TEST SYSTEM

The main advantages of this system are (a) relatively low initial cost, (b) mobility, and (c) versatility. The air-pressure-generated, polydisperse DOP aerosol is not heated[a] and therefore does not contain decomposition products of DOP. It is virtually odorless. The DOP aerosol concentration maintained in the test chamber for man-testing is 25 ± 5 mg/m^3 for air-purifying respirators and may be increased to 100 mg/m^3 for testing respiratory protective devices offering a higher degree of protection.

Air-generated, polydisperse DOP man-test systems with configurations similar to that illustrated in Figure 8-2 are commercially available from two sources.

8.5.1.3.2 Sodium Chloride Test. In the United Kingdom and Canada, sodium chloride respirator man-tests for all types of air-purifying respirators for removal of particles have been accepted as a standard procedure. In the U.S., development of an NaCl respirator man-test system has been pursued by LASL at the request of the National Institute for Occupational Safety and Health. The mobile system designed by LASL was influenced by the experience and techniques developed in the United Kingdom and Canada. The LASL-designed, polydisperse NaCl respirator man-test system is shown in Figure 8-5. Commercial models of this unit are available.

The LASL Model 1 NaCl-aerosol system is designed to generate an aerosol with reproducible particle size distribution and concentration. The NaCl-aerosol concentration is measured by the response of a photomultiplier tube to a propane flame exposed to air drawn from either the test

[a] Monodisperse DOP is not recommended for man-tests because of the toxicity of the thermal decomposition products.

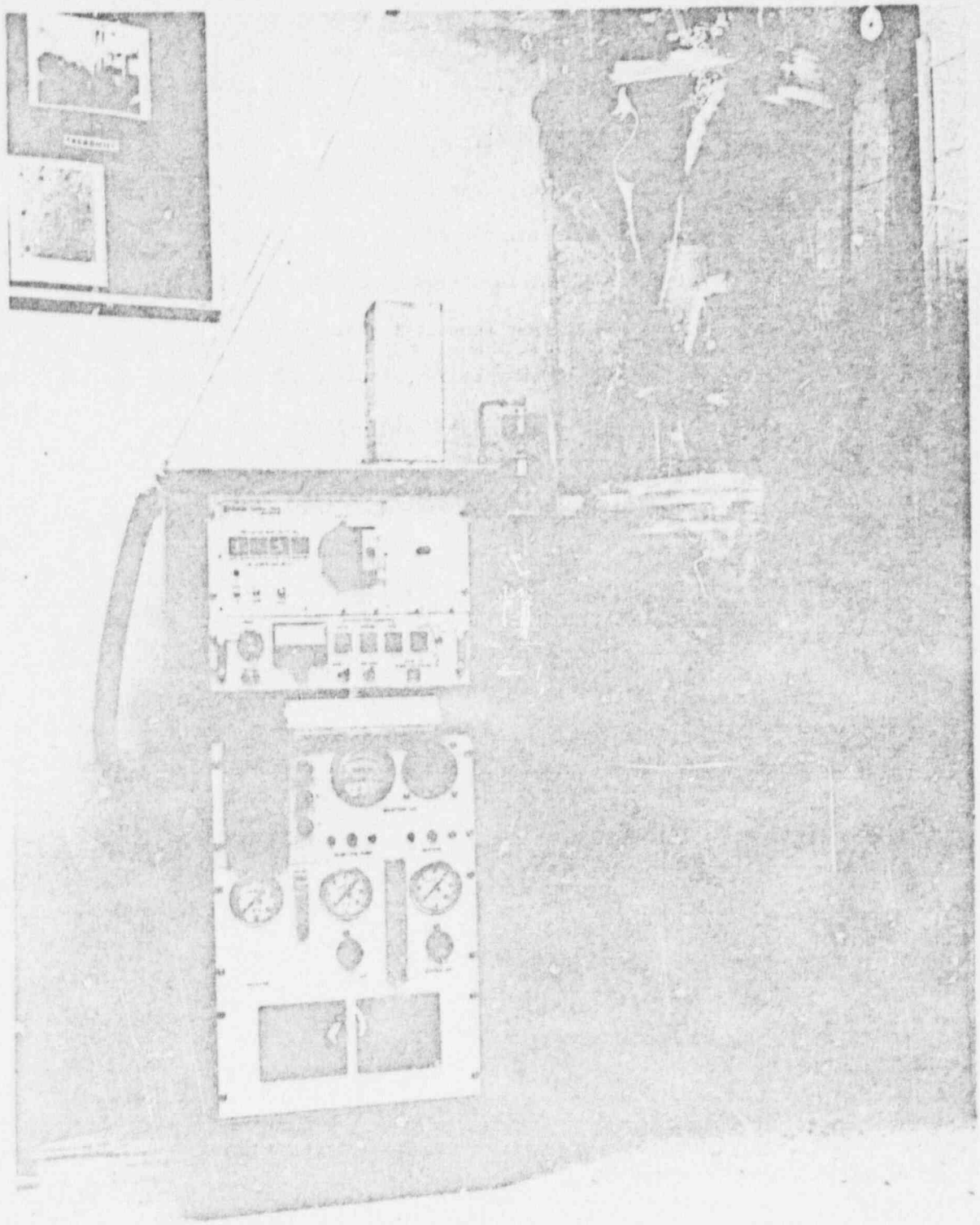


FIGURE 8-5 SODIUM CHLORIDE AEROSOL MAN- AND FILTER-TEST SYSTEM

chamber or the facepiece. The ratio of the response to the test chamber NaCl-aerosol concentration and the aerosol concentration leaking into the facepiece is monitored by a recorder built into the electronics cabinet. The test chamber is identical with that described in Section 8.5.1.3 on the polydisperse DOP man-test system. This unit can measure facepiece leakage as low as 0.02%.

The principal advantage of an NaCl respirator man-test system is the use of low concentrations (12 ± 2 mg/m^3) of a nontoxic, odor-free aerosol. The rapid response of the flame photometer to facepiece leakage is equal to that of DOP systems at much lower sampling rates (8 liters per minute for DOP to 1 liter per minute for NaCl) causing less interference with the normal functioning of the respirator. The compatible NaCl aerosol may be used for respirator man-tests with dust, fume, or high-efficiency filters without concern for overexposure of the test subject.

8.5.1.3.3 Freon-12 Test. A Freon-12 man-test system has been developed and used successfully by F. E. Adley (Ref. 16) at the Hanford Atomic Products Operation (now the Hanford Environmental Health Foundation).

Freon-12 has a TLV (Section 4.1.2.1) of 1000 ppm, is non-flammable, highly inert, and relatively nontoxic. Particle size is not a problem with a gas such as Freon-12; and it is easy to control the concentration.

For a man-test, the respirator must be equipped with pre-tested organic vapor (OV) sorbent cartridges or an external supply of clean

air. The low (~1350 cc/min) sampling rate does not interfere with the functioning of the respirator but does not provide sufficiently rapid response time for the instrument to record either the breathing cycle (inhalation-exhalation) or facepiece leakage caused by head and facial movements. The man-test data output can be recorded on a strip chart for a permanent test file and analyzed to determine an overall integrated test average.

A major difficulty with the Freon-12 respirator man-test system is in testing a respirator for facepiece fit in its Bureau of Mines approved configuration. The OV cartridges deteriorate during the test and must be tested before and after the test to determine any penetrations caused by filter deterioration or leakage (Ref. 16).

8.5.2 Qualitative Tests

When quantitative fitting test equipment is not available, some form of qualitative test is required. It is preferable to use a chamber containing a challenge atmosphere, such as isoamyl acetate, in order to perform the exercises as described in Section 8.5.2.2. If a chamber is not available, a minimum test using at least isoamyl acetate or an irritant smoke tube is required.

The major disadvantage of a qualitative test is that the wearer must determine mask leakage. The threshold of odor detection for various challenge atmospheres varies among different people. Thus, some wearers may not

detect a significant leak. Also, a wearer not properly trained to understand the reasons for wearing respirator equipment may tend to claim a leak on a less comfortable mask when no leak exists and claim no leak on a "preferred" device that is actually not sealing properly.

8.5.2.1 Fitting Chambers

As with quantitative tests, various kinds of chambers can be used. Rooms or booths are very suitable. One manufacturer makes a plastic hood and aerosol generator that fit into a suitcase for easy portability.

One of the best qualitative fitting chambers for SCBA is located in a boxcar at Lawrence Livermore Laboratory in California. The challenge atmosphere is supplied from a pot-bellied stove in which wet straw is burned to create smoke that is piped into the boxcar. The trainees, wearing SCBAs, first exercise outside the boxcar trotting and rolling barrels that are half-filled with sand. They then enter the boxcar and are asked to read various dials that display gas concentrations in the boxcar. The dials are located above platforms and under low overheads so that climbing and crawling are required. Oxygen and carbon monoxide readings are taken by each trainee so that he is aware of the gas concentrations present. Emergency conditions can be further simulated with dummy victims needing first aid.

8.5.2.2 Challenge Atmospheres

8.5.2.2.1 Isoamyl Acetate. Isoamyl acetate has been used by the Bureau of Mines/NIOSH as a qualitative means of evaluating half-face and

full-facepiece fit on air-purifying respirators. Such respirators must be fitted with appropriate organic vapor canisters or cartridges for this test. Isoamyl acetate, commonly known as banana oil, can be detected by odor in very low vapor concentrations. An air concentration of 100 parts per million (ppm) of isoamyl acetate is recommended for testing half masks and a concentration of 1000 ppm for full-facepiece masks. (See Refs. 2 and 4 for details.) If a person wearing a respirator enters and remains in the test atmosphere while simulating work activities without detecting the odor of isoamyl acetate, the respirator is properly fitted. If he detects the odor of isoamyl acetate, he should retreat to fresh air, readjust the facepiece, and then repeat the test. If leakage is still noted, he should retreat to fresh air and recheck the respirator as previously outlined. Organic vapor cartridges must, of course, be replaced with high-efficiency filters for use against radioactive particulates.

8.5.2.2.2 Irritant Smoke. A qualitative method for checking facial fit of air-purifying respirators using high-efficiency particulate filters (Ref. 41) involves exposing the wearer to an irritating aerosol of stannic chloride (titanium tetrachloride has also been used) generated with a commercially available smoke tube. This procedure is said to provide the same sensitivity as the isoamyl acetate method.

When these smoke generators are used, the worker should be cautioned to keep his eyes closed and to breathe very shallowly at the

beginning of the test since the smoke is highly irritant. The tube should be brought no closer than 2 inches from the eyes, canister, or facepiece at any time.

This method is to be used each time a half-mask respirator is donned since it is more difficult to achieve and maintain an adequate fit with half masks than it is with other facepieces.

8.5.2.2.3 Other Challenge Atmospheres. Other challenge atmospheres, such as tear gas, have been used. However, their use is not recommended because of their toxicity and other problems associated with use of most of these materials (e.g., clinging to clothing, insensitivity or extreme sensitivity of the respirator wearer to odor, etc.).

8.5.2.3 Field Testing of Respirator Operation

There are many occasions where it is necessary to conduct fitting tests in the field. One of the following field-fit tests should be performed before each use of a respirator.

8.5.2.3.1 Isoamyl Acetate. For chemical cartridge respirators with organic vapor cartridges or canisters, the reliability of the face fit is checked by filling a stencil brush with isoamyl acetate or by pouring a few drops of isoamyl acetate onto a piece of cotton and waving the brush or the cotton gently near the periphery of the facepiece or cartridge (spray cans of isoamyl acetate are also available).

8.5.2.3.2 Irritant Smoke. The stannic chloride or titanium tetrachloride (smoke tube) technique can also be used in the field in a similar manner (Ref. 41).

Where it is impossible to perform the field tests using isoamyl acetate or stannic chloride, either of the following less satisfactory tests should be performed just prior to actual use of the equipment. These negative pressure and positive pressure tests should be used with considerable caution since small leakages that may be significant (e.g., around eyepieces, lens frames, speaking diaphragms, etc.) may remain undetected. Furthermore, pushing on the facepiece as described below may also close off a facepiece-to-face seal leak.

8.5.2.3.3 Negative Pressure Test. Close off the inlet opening of the canister or the breathing tube by covering it with the palm of the hand or by replacing the tape seal, gently inhale so that the facepiece collapses slightly, and hold the breath for 10 seconds. If the facepiece remains in its slightly collapsed condition and no inward leakage of air is detected, the tightness of the respirator is satisfactory.

8.5.2.3.4 Positive Pressure Test. If necessary, remove the exhalation valve cover, close off the exhalation valve with the palm of the hand, and exhale gently so that a slight positive pressure is built up in the facepiece. If no outward leakage of air is detected at the periphery of the facepiece, the face fit is satisfactory. (Note: With certain devices, removal of the exhaust valve cover is very difficult, making this test almost impossible to perform.)

CHAPTER 9

MAINTENANCE

9.1 MINIMUM ACCEPTABLE MAINTENANCE PROGRAM

The primary purpose of the maintenance program is to ensure that respiratory protective equipment is kept in a state of readiness for use. An ongoing program of continuing maintenance and inspection is imperative.

The minimum acceptable maintenance program shall include the following operations: inspection, testing, and repair; storage; inventory; issuance of devices; surveys for contamination of respirators; decontamination; cleaning and disinfection; provision of a pure, uncontaminated air or oxygen supply; and maintenance of auxiliary equipment.

9.2 INSPECTION, TESTING, AND REPAIR

An inspection, testing and repair program must be established to ensure the operability of respiratory protective equipment. The program is to include the following elements:

a. All respirators must be inspected routinely before and after each use. Devices stored for emergency use must be inspected after each use and at least monthly to ensure that they are in satisfactory working condition. A record of inspection dates and findings is to be kept on all emergency-use devices. Routinely used and personal-issue devices are to be inspected before and after each use and at least monthly. Inspection is to include a check of the tightness of connections and the condition of the

facepiece, headbands, valves, connecting tube, and canisters. Special attention is to be given to rubber or elastomer parts to ensure that they are pliable and flexible and not deteriorating or taking a set during storage.

Self-contained breathing apparatus must be inspected at least once a month to ascertain that air and oxygen cylinders are fully charged, facepiece assemblies are totally functional and properly stored, harness assemblies are in good condition, and regulators and warning devices are functioning properly.

b. Portions of respiratory protective devices such as regulators, valves, warning devices, and cylinders, are to be tested periodically for proper function in accordance with the manufacturer's instructions or applicable standards.

c. Inspection and testing are to be carefully supervised and performed only by responsible and thoroughly trained individuals.

d. Repair of any component of a respiratory protective device may be undertaken only by persons thoroughly familiar with the device who have been instructed in the type of repair to be performed. No attempt shall be made to replace components or to make adjustments or repairs beyond the manufacturer's recommendations. No attempt shall be made to repair or adjust reducing valves or regulators. For adjustment or repair, these items are to be returned to the manufacturer or to a mechanic trained by the manufacturer.

e. Components of respiratory protective devices must be changed on a replacement schedule as required by conditions of use. In no case may replacement time exceed the time recommended by the manufacturer.

9.3 STORAGE

After cleaning, inspection, testing, and repair, the respiratory protective equipment is to be placed in storage in plastic or paper bags or storage cases. Care must be taken that the equipment is not exposed to direct sunlight, heat, extreme cold, excessive moisture, or other physicochemical environments likely to cause damage. Emergency-use devices placed at stations and work areas shall be clearly marked and shall be placed so as to be quickly accessible at all times. Devices in proper condition for re-use shall be clearly identified and separated from units needing repair. The respirators are to be packed or stored so that they are not damaged by adjacent equipment or twisted out of their normal configuration by improper storage.

9.4 INVENTORY AND CONTROL

Inventory and control procedures have to be established as a means of identifying the stock level of all respiratory protective devices and the replacement parts of any respirator. Such a procedure ensures that parts subject to deterioration can be replaced on the schedules recommended by the manufacturer. It also enables the individual supervising the respiratory protective equipment program to determine those areas where large numbers of respirators are stockpiled.

9.5 ISSUANCE OF RESPIRATORS

Procedures for issuance of respiratory protective equipment are to be established so as to ensure that only the correct respirator is obtained for a job. Proper issuance is usually accomplished by having the respirator type specified either in the work procedures or by the qualified individual supervising the respiratory protective equipment program. It is essential that the individuals issuing or supervising the use and issuance of respirators be adequately trained to ensure that the correct respiratory equipment is issued for each job and that it meets the special needs of individual workers.

Where feasible, individuals should have a permanently assigned respirator that should be durably marked indicating to whom it is assigned. This marking must not affect the respirator performance in any way.

9.6 CONTAMINATION SURVEYS/DECONTAMINATION

All respiratory protective equipment should be surveyed for radioactive contamination prior to cleaning and disinfection. Respirator facepieces or hoods may be reused by the same individual on the same working day, provided that (1) the beta-gamma contamination level on any surface of the facepiece or hood does not exceed 0.2 millirad per hour above background at contact or (2) the alpha contamination level does not exceed 100 disintegrations per minute (d/m) per 100 cm^2. The monitoring done must, of course, be appropriate for measurements of the contamination present in the area in which the respirator was used.

Respirators made available for reissuance or reuse must show no contamination (as determined by standard swipe or smear techniques) in excess of 100 d/m per 100 cm^2 fixed alpha or 1000 d/m per 100 cm^2 of beta-gamma above background at contact on any accessible surface.

9.7 CLEANING AND DISINFECTION

Respirators must be exchanged periodically for cleaning and inspection. In a large program in which respirators are used frequently, cleaning and inspection could be done daily; in small programs with only occasional use, the period might be weekly or monthly. Preferably, respirators are individually assigned; they should be durably marked to ensure that a worker receives the same device on reissuance.

Frequently used repirators are to be cleaned and disinfected as often as necessary to ensure that proper protection is provided for the user. Each worker should be briefed on the cleaning procedure and 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. Emergency devices must be cleaned after each use.

A generally accepted sound cleaning procedure is to wash the respirator with a good detergent in warm water (by hand brushing or by use of a specially adapted washing machine), rinse, and air dry in a clean place. Care should be taken not to damage the respirator by excessive heating or by agitation in the washing solution. This procedure need not be followed by disinfection for respirators issued on an individual basis.

The following procedure may be followed in cleaning air-purifying respirators:

a. Remove the filters, cartridges, or canister.

b. Wash the respirator in cleaner-sanitizer solution at 120-140°F (see the following paragraph).

c. Rinse completely in clean, warm or hot water (140°F maximum).

d. Air dry in a clean area.

e. Inspect valves, headbands, and other parts; replace with new parts, if defective.

f. Insert new or retested filters and cartridges; make sure the seal is tight.

g. Place in a plastic bag for storage.

Cleaner-sanitizer solutions that effectively clean the respirator and contain a bactericidal agent are available. The bactericidal agent is generally a quaternary ammonium compound. The respirator may be immersed in the cleaner-sanitizer solution (120-140°F), rinsed well in clean, warm water (140°F maximum) to remove all sanitizer solution, and air or machine dried.

It is good practice to disinfect respirators in addition to washing them before they are reissued, especially if a respirator will be used by different individuals. In addition to commercial cleaner-sanitizers, other compounds considered reliable for disinfecting respirators are (1) a hypochlorite solution (50 ppm of chlorine; 2 minutes immersion)

or (2) an aqueous solution of iodine (50 ppm iodine; 2 minutes immersion). A concentration of 200 ppm of quaternary ammonium compounds in water with less than 500 ppm total hardness is generally an effective disinfecting solution. The disadvantages of the quaternary ammonium compounds are (1) for waters of different compositions, different concentrations of salts are required to achieve a disinfecting solution and (2) the possibility of dermatitis of the respirator user if the quaternary ammonium salts are not completely rinsed from the respirator.

Cleaning and disinfecting agents or solvents that can damage parts of a respiratory protective device shall not be used.

9.8 MAINTENANCE OF AIR OR OXYGEN SUPPLIES

Procedures for the maintenance of a supply of respirable air or oxygen are to be included as part of the respiratory protective equipment program. Both compressed gas cylinder supplies and compressor supplies shall be maintained and used in accord with appropriate standards and recommendations. The compressed-air and oxygen-cylinder supply shall be inventoried periodically to ensure that an adequate supply is available.

All fittings and components shall be standardized so that the introduction of gases other than pure breathing air or pure breathing oxygen into a respirator system is impossible. Every compressed-gas cylinder shall have a *label* indicating that it contains pure breathing air or pure breathing oxygen, as appropriate. When a compressor is used, it must be properly monitored and attended to ensure that the air intake remains in

an uncontaminated atmosphere. A separate breathing air supply and distribution system shall be used. The ordinary plant supply of compressed air in any building shall not be used for breathing purposes (due to possible presence of carbon monoxide, oil vapor, and other contaminants) unless it has been specially modified and properly adapted for such use and specifically approved for this purpose by the qualified person supervising the respiratory protective equipment program. The maintenance of a breathing air or oxygen supply shall be performed by capable, thoroughly trained individuals. Adequate numbers of personnel must be assigned to attend and monitor air supplies, hoses, and communication lines and to keep workers using the respiratory equipment under precautionary surveillance by signal, verbal, or line-of-sight communication.

CHAPTER 10

QUALITY ASSURANCE

The purpose of a quality assurance (QA) program is to prevent the use of defective or faulty devices. A proper and complete QA program must encompass inspection and testing of both new and used devices. Written procedures must be established to maintain uniformity of the program.

10.1 NEW EQUIPMENT

Quality assurance inspection and testing of new equipment is not intended to dispute the design but to find any instances of human error in the manufacture and assembly of the devices. Manufacturers of Bureau of Mines/NIOSH-approved devices maintain rigid quality assurance programs for testing of newly manufactured devices and parts, but human error in testing may permit distribution of defective equipment. Thus, a QA program covering new equipment is needed.

10.1.1 Air-Purifying Devices

The air-purifying device, which is the least complex of respiratory protective devices, should not be slighted in inspection and testing because of its simplicity.

10.1.1.1 Facepieces

Half-mask facepieces should be inspected to ascertain the following:

a. Four-point strap suspension is to be specified on the order. Only 4-point suspension is acceptable.

b. Rubber or elastic strap material. Elastic straps are recommended and should be specified on the order.

c. Single or dual cartridge facepiece should be specified on the order.

d. Integrity of valves and seats.

e. Presence and integrity of cartridge gasket or gaskets (as required).

f. Integrity of facepiece (absence of tears, mold defects, etc.).

Full facepieces require more attention than the half-mask facepieces owing to the intricacy of the valves and speaking diaphragm assembly available on most. Inspection of full facepieces should include the following:

a. Straps and suspension.

b. Facepiece material (i.e., neoprene, silicone, etc.) should be specified on the order.

c. Integrity of facepiece (absence of tears, mold defects, etc.).

d. Canister or cartridge mounts (cheek, chin, etc.) should be specified on the order.

e. Canister or cartridge gaskets (where applicable).

f. Integrity of inhalation and exhalation valves and seals.

g. Speaking diaphragm assembly (Mylar diaphragm, diaphragm gasket, assembly tightness). A simple vacuum test on the assembly is quite effective.

h. Lens (absence of scratches, cracks, blemishes).

i. All clamps and connections (check for tightness).

Where leak-test equipment is available, it is advisable to test the complete facepiece assembly for leaks.

10.1.1.2 Cartridges, Canisters, and Filters

Cartridges, canisters, and filters should be visually inspected for damage created by handling and shipping. The presence of proper labels should be checked and the protection afforded checked against the label on the storage container. (Note: High-efficiency particulate filters, by definition, must be at least 99.97% efficient as determined by the manufacturer by testing with a monodisperse 0.3μm dioctyl phthalate (DOP) aerosol.) If possible, arrangements should be made to check some portion of each filter shipment for efficiency. (It should be noted that a fraction of the high-efficiency filters from each manufacturer has been found defective.)

For air-purifying respirators with chest- or back-mounted canisters, the canister harness assembly and corrugated breathing tube or tubes should be inspected for possible defects.

10.1.1.3 Powered Air-Purifying Units

A powered air-purifying respirator consists of a battery-operated blower fitted with an air-purifying filter connected to a facepiece by means of a corrugated breathing tube. The facepieces on the units must be inspected and tested, the blower must be checked for adequate airflow, and the tubing must be inspected for cracks or other defects and for tightness of connections.

10.1.2 Air-line Respirators

10.1.2.1 Facepieces, Hoods, and Suits

Facepieces of supplied air devices should be inspected and tested as outlined in Section 10.1.1. An additional step must be added: checking of the corrugated breathing tube for holes or defects in the rubber and for tightness of the connections at each end.

Hoods and suits should be checked for tears and defects in fabrication material, presence of zippers and snaps as required, and integrity of air distribution and exhaust systems.

10.1.2.2 Regulators

Supplied-air regulators shall be visually inspected for damage, attached to an appropriate air supply, and tested for proper function.

If a factory-trained repair technician and factory-approved test equipment are available, it is advisable to test the regulator function. Otherwise, the regulator is to be returned to the factory at least every 3 years for repair and inspection.

10.1.2.3 Compressors

Compressors used to provide air for atmosphere-supplying respirators should be inspected and tested to ascertain the following:

a. Proper and adequate intake filters.

b. Presence of moisture trap.

c. Sufficient reserve air storage (where required).

d. Carbon monoxide alarm presence and proper function (for oil-type compressors).

e. Adequate air output and presence of proper connectors for equipment to be used.

f. Heat alarm function (for oil-type compressors).

Oil-type compressors may only be used if fitted with either a continuous carbon monoxide monitor or high-temperature alarm. Diaphragm and water-seal pumps are recommended since they do not create an air supply contaminated with oil mist or carbon monoxide.

10.1.2.4 Air-Line Hose

Air-line hose should be inspected for the following:

a. Contaminants (mold powder, ground rubber, etc.) inside the hose.

b. Proper fittings and connections (i.e., not compatible with other gas systems).

c. Cuts, leaks, or weak spots in hose.

10.1.3 Self-Contained Breathing Apparatus

The self-contained breathing apparatus (SCBA), the most complicated of respiratory protective devices, requires more extensive inspection and testing than other types of devices. Owing to the intricacy of the parts of the SCBA, simple visual inspection is not sufficient to identify defective units. Inspection and testing of a SCBA must be done by individuals totally familiar with the particular device.

10.1.3.1 Facepiece Assemblies

Facepiece assemblies should be inspected as outlined in Section 10.1.1; and the corrugated breathing tube and the facepiece-to-regulator connector should also be inspected. Special attention should be given to the exhalation valves of those devices having a pressure-demand mode of operation.

10.1.3.2 Regulators and Alarms

Regulators and alarms of SCBA are to be visually inspected and a simple test performed to ascertain proper regulator function and integrity of the regulatory diaphragm. The alarm should be activated to ascertain that it functions properly.

A method for testing regulator function and disphragm integrity is as follows:

a. Demand-Only Units

(1) Open the cylinder valve.

(2) Suck on the regulator outlet (air should flow).

(3) Blow gently on outlet (no air should pass through).

b. Combined Demand/Pressure-Demand Units.

(1) Select the demand mode of operation.

(2) Follow steps (1), (2), and (3) of a, above.

(3) Cover the outlet of the regulator with a hand.

(4) Select the pressure-demand mode of operation (no air should flow).

(5) Remove hand from outlet (air should flow freely).

c. Pressure-Demand-Only Units.

(1) Blow gently on the outlet (no air should pass through).

(2) Open the cylinder valve.

(3) Cover the regulator outlet with a hand.

(4) Open the main line valve on the regulator (no air should flow).

(5) Remove the hand from the outlet (air should flow freely).

10.1.3.3 Other Associated Equipment

The following other parts of SCBA must be checked:

a. Cylinder - check the pressure; check the cylinder valve for leaks; and inspect the cylinder valve lock for presence and function.

b. Backpack and harness assembly - Inspect the integrity of straps, buckles, and fasteners; and check the backpack cylinder lock assembly for function.

10.1.3.4 Recirculating Devices (Closed-Circuit Apparatus)

The following parts of recirculating devices must be checked:

a. Breathing Bags - Visually inspect for tears and defects; then inflate and check for leaks.

b. CO_2 Sorbent - Make certain that used sorbent is removed from the unit before storage. (Do not refill with sorbent until immediately prior to use of unit.) Ensure that seals on sorbent containers are in place.

c. O_2-Generating Canister - Never store an oxygen-generating unit with the O_2-generating canister in place. Place the canister in the unit immediately prior to use. Make certain that canisters are properly sealed.

d. Check the rubber canister seals on the unit.

It is virtually impossible to inspect and test self-contained breathing apparatus properly without actually donning the unit. When factory-approved test equipment and factory-trained personnel are available, it is strongly advised that new units be tested before they are placed in use.

Although complete test and inspection procedures for each device available cannot be given in this guide, such tests and inspections should be made. Complete instructions for inspection procedures are packed with most devices or are available from the manufacturer.

10.2 INSPECTION AND TESTS AFTER CLEANING AND MAINTENANCE

The procedures for inspecting and testing cleaned and repaired devices are the same as those outlined in the preceding new equipment section except that a leak test shall be performed on all cleaned or repaired devices. This leak check may vary from a simple field test of the device (a test using irritant smoke or isoamyl acetate to check the device prior to its use) to a very sophisticated leak check employing test heads on which the device is mounted and probe tested using a specially generated aerosol or gas with the appropriate readout equipment. The following are examples of this aerosol-generating and readout equipment:

a. Dioctyl phthalate aerosol with light-scattering photometric readout equipment.

b. Sodium chloride aerosol with flame photometer readout.

All of the above equipment is commercially available.

Maintenance and repair of respiratory protective devices shall be performed only by qualified individuals who are totally familiar with the function of each part of the device in question. Only factory-trained individuals shall repair or adjust regulators, timers, alarms, or other such parts of respiratory protective devices.

10.3 PERIODIC CHECKS OF ITEMS IN STORAGE

Periodic checks of items in storage should be performed to ensure that the facepiece rubber is not taking a set, that rubber parts are not hardening or deteriorating, that sorbent canisters have not exceeded their shelf life, and that breathing-air or oxygen cylinders contain sufficient pressure. Other checks relevant to the equipment in storage should be made as necessary.

These checks should be designed to ensure that if the devices in storage are needed, they will be ready for immediate use.

CHAPTER 11

BIOASSAY PROGRAMS

Bioassay programs are used to evaluate the amounts of radioactive materials in the body as a result of inhalation, ingestion, absorption, or injection. From such a program, the intake of the material may be estimated. A bioassay program performed by a laboratory that provides accurate analyses is essential to verify the effectiveness of respiratory protection programs.

11.1 BIOASSAY TECHNIQUES

Details on techniques for bioassay and subsequent determination of the intake by the body constitute a separate field of study and are not included in this manual. A brief summary of the techniques is given below.

11.1.1 Sampling

11.1.1.1 Urine

Urine samples are collected according to the metabolite identity and mode of metabolism. Materials metabolized and excreted in the urine at analytically significant levels may, when determined, be an index to uncontrolled exposure.

11.1.1.2 Fecal

Materials that are insoluble or known not to be absorbed, either from inhalation or ingestion, are best estimated by analysis of fecal samples.

Although the presence and amounts of radionuclides may be determined, interpretation of the data to estimate lung burden and time of exposure may be difficult.

11.1.1.3 Breath

Materials excreted via the lungs may often be determined by breath analysis. The breath sample may serve as an index to exposure shortly after cessation of exposure. Collection of a series of samples in an atmosphere free of contaminating material simplifies the interpretation of exposure.

11.1.1.4 Nasal and Throat Swabs or Washings

Nasal and throat swabs or washings may serve as indicators of particulate exposures. These samples serve as a qualitative exposure index for radionuclides. From baseline data, the radionuclides may be determined simply and may be semiquantitatively related to exposure.

11.1.1.5 External Wholebody Counting (X-ray or γ-ray) and Individual Organ Scanning

Employees exposed to radionuclides may be examined by various external X-ray or gamma-ray counting techniques. Where analytically significant results can be determined, the exposure or intake may be easily evaluated.

11.1.1.6 Hair

Analysis of hair samples is not normally employed to verify the effectiveness of a respiratory protection program. However, properly

selected and prepared samples may serve as an indicator of past performance of the program for a number of metals or compounds. The hair strand or bundles can be cut into sections and analyzed for the metabolite or metal. Correlations of the analyzed sections with growth rate can be an exposure profile for the effectiveness of the respiratory protection program.

11.1.1.7 Summary

The choice of monitoring techniques to be used for an adequate bioassay program depends mainly on the characteristics of the material to which personnel might be exposed. The frequency of respiratory protection usage and duration of exposure also dictates the bioassay program. Table 11-1 indicates the types of samples that should be assayed in relation to the type of material to which employees might have been exposed in order to evaluate the effectiveness of a respiratory protection program.

11.1.2 Analysis

All analyses must be performed by a qualified laboratory. The limits of the analytical technique must be known and the mechanism of detoxification or excretion must be thoroughly understood.

11.2 BIOASSAY SAMPLING

It is desirable to obtain baseline measurements on each individual prior to work assignment in potentially contaminated atmospheres. Subsequent sampling must be frequent enough to account for all potential hazards; i.e., sample collection following exposure must be appropriately timed to permit accurate evaluation of the total intake and the resultant dose.

Additional bioassay should be performed if, on the basis of air sampling data, accident, equipment failure, etc., there is reason to believe that an individual might have taken into his body an appreciable quantity of material.

Processing of bioassay samples and evaluation of bioassay data must be performed by or under the direct supervision of persons qualified in such techniques.

TABLE 11-1

SELECTION OF TYPES OF BIOASSAY SAMPLES FOR EVALUATION OF RESPIRATORY PROTECTION PROGRAMS

Type of Material to Which Exposure is Possible	Urine	Fecal	Breath	Nose or Throat Swab	Whole Body Counting	Hair Sections
Actinides	C	C		I	I-C	C
Fission Products	C	C		I	I-C	
Acid Gases[a]			I			
Most Metals	C	C		C		C
Inert Organic Cases			I			
Metabolizable Organic Compounds	C		I			C (few)
Biohazards[b]				C		
Radium	C	C	I(Rn)	I		C

[a] Special: CO, HCN, NO_2, other (Blood Metabolite)

[b] Special: Biohazards (Blood Culture)

Code (The individual compound dictates the sampling selection; these are generalities):

I = Immediate evaluation of single exposure or delayed multiple exposures.

C = Continuous evaluation or reconstruction of exposure.

CHAPTER 12

ADMINISTRATION

An effective respirator program must be based on well-conceived administrative and supervisory practices and guides. Although detailed formats for such practices and guides vary from one installation to another, certain important broad administrative areas, briefly discussed below, should be included.

12.1 QUALIFICATIONS OF RESPONSIBLE PERSON IN CHARGE

Responsibility for the respirator program is to be vested in one individual. The respirator program may be under the direction of a health physicist, industrial hygienist, safety engineer, or other person similarly qualified. Regardless of his organizational position, the responsible individual in charge of the respirator program must have the ability, training, and experience to (1) evaluate the total hazard and the job, (2) recommend engineering controls if appropriate, (3) specify respiratory protection if control cannot be otherwise obtained, and (4) forbid the use of respirators if conditions warrant. The responsible person should have, in addition to his other qualifications, at least 1 year's field experience in the use of respirators.

12.2 PROCEDURES AND STANDARDS

Procedures are to be prepared in writing regarding all phases of the respirator program, including: descriptions of equipment; information regarding issuance, maintenance, selection, use, and return of equipment;

and training techniques. Information regarding air-sampling and bioassay programs is to be included or referenced.

12.3 EVALUATION OF PROGRAM EFFECTIVENESS

Continuous feedback of a respirator program's effectiveness is necessary in order to evaluate its value. The following are suggested methods to obtain such feedback:

12.3.1 Wearer Acceptance

Comfort, ability to breathe without objectionable effort, adequate visibility, ability to communicate, ability to perform all tasks without undue interference, and confidence in the facepiece fit (Ref. 2), all contribute to acceptance of the devices by the wearers. Discussions with users at plant safety committee meetings, on inspections, on tours through the plant, and at training sessions can bring to light complaints that should be investigated.

12.3.2 Evaluation of Protection

Bioassay results, correlated with air-sampling results, are an effective means of program evaluation. Any evidence of a rise in exposure levels that could be linked to inhalation should be investigated immediately, even if within permissible exposure limits.

Any positive facepiece interior smear results should be investigated. The investigation should include immediate bioassay sampling of the worker who used the facepiece.

12.4 RECORDS

Records systems are to be established for the four main purposes described in the following sections:

12.4.1 Analysis of Adequacy of Respirator Program

The adequacy of a respirator program can only be determined by periodic review of respirator usage, including identification of the hazard, specification and use of the respirators, and analysis of the results of bioassay and air-sampling programs. These latter programs should include records of accurate and continuous monitoring of spaces whenever work is performed as well as records of the internal exposures of individual workers.

12.4.2 Procurement Information

Periodic review of respirator usage is needed to provide information for reordering canisters and other replacement parts and to establish a replacement table for respirator components.

12.4.3 Maintenance Information

Maintenance records are needed to provide knowledge of the out-of-service time for respirators, common failure modes of particular respirator types, and personnel complaints on respirator design.

12.4.4 Training and Fitting Records

Training and fitting records are necessary for all workers who might use respiratory protective equipment as a basis for scheduling refresher courses and refitting and to have a record of what makes of masks each person can wear. In addition, it is desirable that each person be issued a wallet-sized card listing those devices that adequately fit

him. The wallet cards can save time in the field, particularly in the event of an emergency, by making it unnecessary to check files for issuance of acceptable masks.

12.5 METHODS OF STAYING ABREAST OF NEW DEVELOPMENTS IN THE FIELD

Since rapid advancements are occurring in the respirator field in both equipment and regulations, it is essential for the program administrator to stay up to date. Some sources of current information are:

a. The *Federal Register* prints all changes in Federal regulations. Various periodic health and safety newsletters and abstracting services report on the changes directly affecting industrial health and safety regulations (Ref. 42).

b. Health and safety professional societies, such as the American Industrial Hygiene Association, Health Physics Society, National Fire Protection Association, American Society of Safety Engineers and others, notify their members in newsletters and journals of new developments. Membership in one or more of these societies is recommended to those in charge of the respirator programs.

c. The NRC, Bureau of Mines, NIOSH, and OSHA frequently publish documents on aspects of respirators. For example, every criteria document published by NIOSH has a section on recommended respiratory protective devices for the substance about which the document was written.

CHAPTER 13

SPECIAL PROBLEMS

In addition to the normal problems associated with properly fitting a group of workers with respiratory protection, there are some specific hazards that can be avoided by following a few basic guidelines. Among the topics of particular interest are facial hair, dentures, prescription glasses, the wearing of other types of protective headgear such as surgeon's caps, bumpcaps, hardhats, goggles, and faceshields, and the use of respirators in extreme temperatures.

13.1 COMMUNICATIONS

Although conventional respirators distort the human voice to some extent, adequate communications can be maintained in relatively quiet areas. In noisy areas, modifications and special attachments for facepieces are available to improve the quality of the communications. A description of the various options is available in ANSI Standard Z88.2-1969, Section 9.5 (Ref. 2).

13.2 PRESCRIPTION GLASSES

Prescription or safety glasses may be worn with half-mask respirators although there is likely to be some interference with the mask at the bridge of the nose. This interference can be minimized by careful choice of mask and proper fitting and training.

Glasses with standard temple bars shall not be worn with full-facepiece respirators since extension of the temple bars through the

sealing surface of the facepiece causes leakage. If prescription glasses must be worn, it is required that all Bureau of Mines/NIOSH-approved full facepieces be provided with means for optional use of corrective spectacles or lenses without temple bars that break the facepiece-to-face seal and that shall not otherwise reduce the respiratory protective qualities of the facepiece.

Contact lenses shall not be worn with full-facepiece respirators. These devices present a distinct hazard to the individual owing to the possibility of the lenses slipping because of pressure on the outside corners of the eyes from a full face mask or a speck of dirt getting under them while the respirator is being worn. Corrective action would entail removing the respirator, which would mean that the individual would either have to leave the contaminated atmosphere or run the risk of exposure if he removed the respirator in the contaminated area.

13.3 FACIAL HAIR

Persons using tight-fitting (facepiece) respirators shall not have any facial hair that interferes with the sealing surface of the respirator. Any intrusion of facial hair into the sealing surface of the respirator results in an increase in leakage (Ref. 43). Problem areas, in addition to full facial hair, are beards and moustaches if half-mask facepieces are used, and long, wide sideburns if full facepieces are used.

Close supervision must be maintained of individuals who do have facial hair styles that might interfere with the sealing surface of a respirator. Over a short period of time (7 days), the facial hair

can extend into the critical seal area. *Any worker who has facial hair that intrudes into the area where the respirator seals against the face shall not be fitted with a respirator. Additionally, any worker who is not clean-shaven shall not be allowed to wear a respirator, even though he has previously obtained a satisfactory fit with the particular device.* These proscriptions do not apply to loose-fitting enclosures such as hoods, blouses, or suits.

The above precautions do *not* mean that all facial hair must be forbidden when respirators are worn, since a moustache or sideburn may be permitted if it does not interfere with the sealing surface of the respirator. Each case must be considered individually, but it is incumbent upon the supervisor to ensure that the respirator is sealing properly while, at the same time, having regard for the personal feelings of the individual wherever possible. Good relations can be maintained if time is taken to carefully explain the danger of increased facepiece leakage due to facial hair. If a means is available for quantitatively assessing the amount of leakage, it should be used. A demonstration of this type can be quite convincing.

13.4 DENTURES

Dentures, either partial or full, can be worn with respirators subject to certain restrictions. Full dentures generally present few problems other than some possible discomfort to the individual when wearing half-mask or full-facepiece respirators. In fact, full dentures

should not be removed because the jaw becomes distorted without them. This causes leakage in the chin area.

Partial dentures may or may not be worn with a respirator, depending upon the configuration. If there is a possibility that the partial dentures could be swallowed, they should be removed. The wearing of dentures with hoods, suits, and blouses is not a problem.

13.5 PROTECTIVE HEADGEAR

Use of other types of protective headgear is permitted with respirators, but certain precautions shall be observed. *There shall be no interference between the additional headgear and the normal method of wearing the respirator.* This means that the respirator head straps or headharness should lie next to the head in their normal position, and any other protective headgear should go over them. Surgeon's caps used for protection against contamination may be worn under the head straps or harness, but care must be exercised to ensure that the front of the cap does not intrude under the sealing surface of a full facepiece in the forehead area.

Goggles may be worn with half masks only if they do not interfere with the normal sealing of the mask in the nasal bridge area. *Goggles shall never be worn with full-facepiece respirators* because the strap holding the goggles to the face would of necessity pass under the sealing edge in the temple area and cause leakage. In any case, only full facepieces that have an impact-resistant, shatterproof lens or eyepieces are granted a Bureau of Mines/NIOSH approval.

Faceshields can be worn with half-mask or full-facepiece respirators, depending on the individual design. The shield must not interfere with the normal position of the respirator on the face.

13.6 USE IN EXTREMES OF TEMPERATURES

The use of respirators at temperatures below 32°F can result in freezing of exhalation valves and fogging of the lenses in full facepieces. Use at high temperatures causes added stress on the individual.

ANSI Standard Z88.2-1969, Section 9.3, describes steps that can be taken to minimize the effect of both low and high temperatures on respirators. These steps include:

a. Antifog compounds to coat the inside of the lens.

b. Nose cups to direct exhaled air directly through the exhalation valve.

c. Use of dry breathing air with SCBA or air-line equipment. (The dew point of the breathing air shall be appropriate to the ambient temperature.)

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