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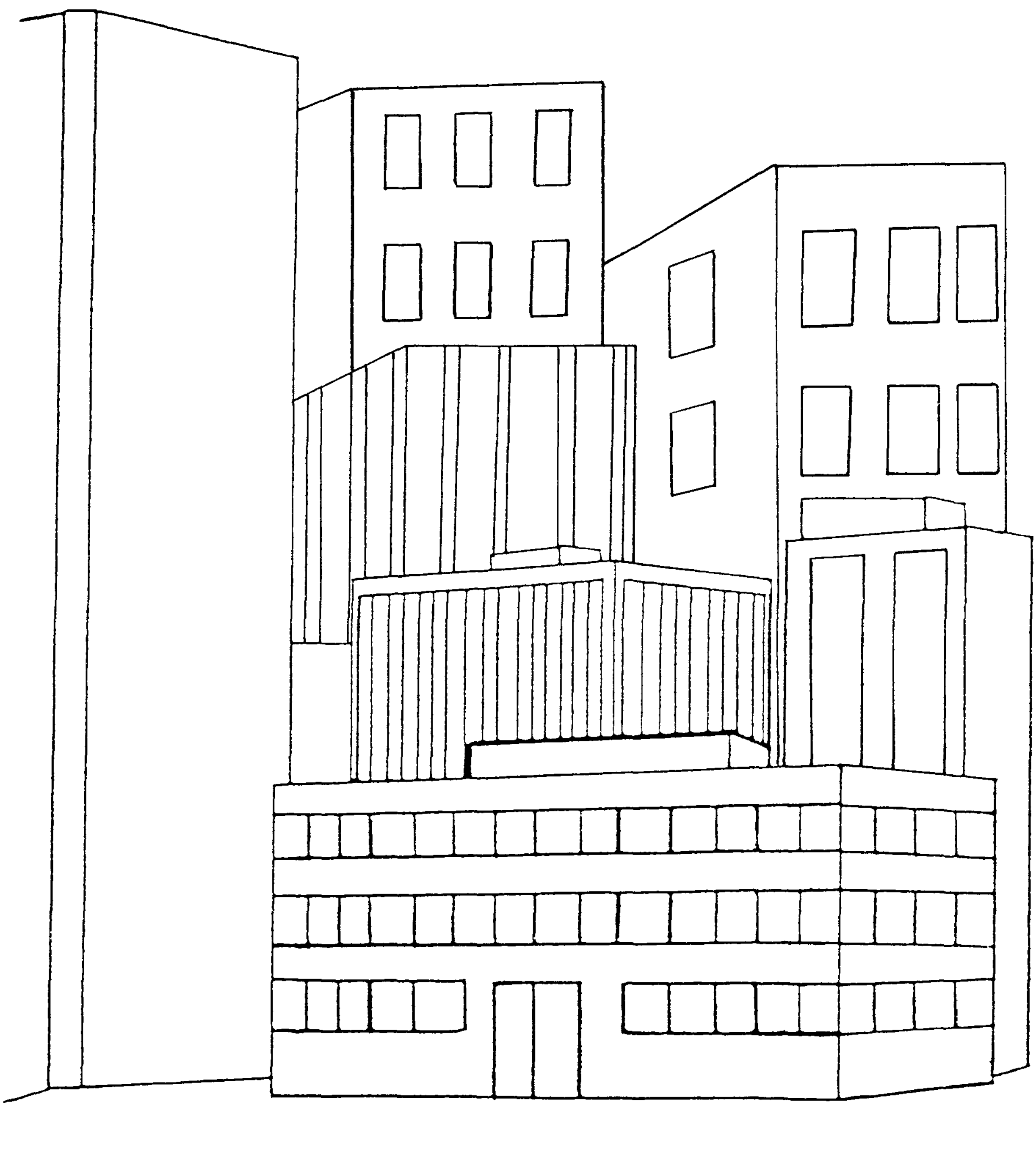
A Guide to Respiratory Protection for the Asbestos Abatement Industry



A GUIDE TO RESPIRATORY PROTECTION FOR THE ASBESTOS ABATEMENT INDUSTRY

A Technical Report by

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PREFACE

This guide is intended to provide practical guidance in the selection and use of respiratory protection to persons who work in asbestos abatement. The recommendations in this guide will also apply to other working activities, such as maintenance or repair, where exposure or the potential for exposure to asbestos exists. Because of the well documented risk to health associated with asbestos and uncertainties surrounding the level which can cause disease, exposures must be controlled to the lowest level possible as determined by the most sensitive and reliable monitoring methods. This guide is divided into five parts. Part I is an introduction to the hazards associated with airborne asbestos and to the issues involving respiratory protection against asbestos. Part II presents a model respiratory protection program for the asbestos abatement industry which both satisfies current Federal regulations and incorporates the most current information on appropriate respirators for use against airborne asbestos fibers. Part III contains a checklist for developing or evaluating a respiratory protection program. Part IV presents information on breathing air systems for supplied-air respirators. Part V lists sources of help for problems involving respirator use.

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Part I INTRODUCTION

Scientists and physicians generally agree that asbestos fibers cause human diseases. Research has proven that exposure to asbestos can cause cancers of the lung, stomach, rectum, intestines, and the linings of the lungs and inner abdominal wall. Asbestos enters the body when a person breathes or swallows airborne dust bearing microscopic asbestos fibers. When all feasible means of preventing asbestos fibers from becoming airborne are inadequate, the primary additional means of protecting people who must enter an asbestos-contaminated area to work is the use of respirators.

In the past, asbestos was widely used in surfacing and insulating materials, and in a variety of other products (such as ceiling and floor tile and wallboard) used to construct buildings. The effort to abate asbestos and asbestos-containing materials (ACM) from buildings has resulted in a rapidly growing asbestos abatement industry. Asbestos abatement or removal can disturb asbestos or ACM and release the very small fibers into the air. Workers do not always receive the maximum feasible level of protection against asbestos, primarily because:

- Employers and workers underestimate the hazards associated with asbestos exposure.

  Many employers and workers underestimate or ignore the health risks associated with exposure to asbestos because: (1) most asbestos fibers are invisible to the human eye; (2) breathing or swallowing asbestos fibers does not produce an immediate effects, such as pain or bleeding; and (3) the development of diseases caused by asbestos usually takes many years.

- Federal regulations which are now in effect were written years ago when scientists did not know as much as they do today about the harm asbestos can do and ways to protect against it.

  Currently, the Occupational Safety and Health Administration (OSHA) requires that the concentration of asbestos in air, that is the number of asbestos fibers in a measured amount of air, must be below a level that is known as the Permissible Exposure Limit (PEL).The PEL for asbestos is two million fibers (which are greater than 5 microns in length) per cubic meter of air, which is equivalent to 2 fibers per cubic centimeter of air (2f/cc). [Note: As of the date of publication of this guide, the OSHA standard establishing the PEL for abestos was under revision.] However, the National Institute for Occupational Safety and Health (NIOSH) and the Environmental Protection Agency (EPA) have concluded that there is no known threshold of exposure to asbestos below which there is no risk. OSHA's regulations also allow the use of respirators which NIOSH believes do not provide the best possible protection against asbestos. NIOSH, EPA, and OSHA agree that where exposures to asbestos can not be eliminated, they must be controlled to the lowest level possible. NIOSH and EPA believe this includes providing workers with the maximum feasible level of respiratory protection when measurable levels of asbestos are present in the air.

- To date, employers have not had a single source for the best and most current information on worker respiratory protection against asbestos.

The purpose of this guide is to provide employers with guidelines for developing effective respiratory protection programs, based on the best and most current information. This guide contains:

- a model respiratory protection program which covers the minimum requirements of the Federal regulations, incorporates additional NIOSH/EPA recommendations, and includes detailed discussion of the types of respirators appropriate for asbestos abatement (Part II)

- a checklist which can be used to develop or evaluate a respiratory protection program (Part III)

- a section on breathing air systems (Part IV)

- a listing of sources of help for respirator users (Part V)

- eight technical appendices, including current Federal regulatory requirements (Appendix A), respirator fit testing procedures (Appendix B), examples of NIOSH approval labels (Appendix C), NIOSH respirator user's notices (Appendix D), general safety considerations (Appendix E), heat stress considerations (Appendix F), breathing air systems (Appendix G), and the transcript of NIOSH testimony at a public hearing on occupational exposure to asbestos held in June 1984 (Appendix H).

Several important considerations, which the reader should bear in mind, form the basis for the guidelines contained in this manual. In making the recommendations in this guide for selecting respirators, NIOSH and EPA have determined the following:

- Asbestos is a known human carcinogen for which no level of exposure is known to be without risk. Single exposures may even present a health risk to some individuals.

- The maximum feasible level of respiratory protection should be provided to and used by workers engaged in either asbestos abatement operations - such as open surface removal, glove bag removal, or encapsulation or enclosure - or other work with or in close proximity to asbestos-containing material - such as maintenance or repair, **WHEN SUCH WORKERS ARE, OR COULD REASONABLY BE EXPECTED TO BE, OCCUPATIONALLY EXPOSED TO AIRBORNE ASBESTOS.** "Occupationally exposed" means exposed to any detectable level of airborne asbestos at or above the lowest limit of reliable quantitation as determined by phase contrast microscopy analysis (NIOSH Method 7400 or NIOSH P & CAM 239).

- Respirators which use filters to remove contaminants from the air do not provide as high a degree of protection for workers as respirators which supply clean pressurized air to the workers from a protected source.

In consideration of the above, NIOSH and EPA make the following recommendations as the best respiratory protection during any exposure or potential exposure to airborne asbestos:

- A combination respirator which includes a Type-C supplied-air respirator (SAR) with a full facepiece operated in the pressure-demand mode and with an auxiliary self-contained breathing apparatus (SCBA) operated in the pressure-demand mode (Photograph 1).

Photograph 1. Combination supplied-air respirator with auxiliary self-contained breathing apparatus (SAR/SCBA).

[CAUTION: The only "Type-C" supplied air respirator that NIOSH and EPA *recommend* for use against asbestos is a pressure-demand respirator. This type of respirator is not to be confused with <u>demand</u> or <u>continuous flow</u> Type C supplied air respirators, which are NOT recommended because they do not provide as much protection. Also, the provision of an escape SCBA *does NOT replace* the need for having a *reserve air system* for the SAR. See further discussion under Part IV. Breathing Air Systems and Appendix G.]

- Self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand mode (Photograph 2).

Photograph 2. Self-contained *breathing* apparatus (SCBA).

[NOTE: NIOSH and EPA realize that SCBA may not be practical for use in many asbestos abatement operations or tasks. However, where SCBA are practical for use, these respirators provide the maximum level of protection currently available.]

NIOSH and EPA *recommend* a combination pressure-demand SAR/SCBA instead of only a pressure-demand supplied air respirator primarily to provide continued protection in case the air supply is cut off. If the airline supplying a SAR were cut, crimped, or accidentally disconnected, the wearer would have no choice but to remove the facepiece.

In asbestos atmospheres which contain sufficient oxygen (at least 19.5%), a possible alternative to the recommended SCBA or combined SAR/SCBA would be a pressure-demand, supplied air respirator that is equipped with an emergency backup high efficiency particulate (HEPA) filter. The filter would be used when there was an *unanticipated interruption of air flow*, and would provide some degree of respiratory protection in emergency egress situations without requiring facepiece removal. The use of a full facepiece with such a device as well as a method of fit testing (see page 29) would be necessary to achieve the best possible facepiece seal. Although such devices are currently available in Type C continuous flow SAR models (not recommended by NIOSH or EPA for protection against asbestos), they are not currently available in a pressure-demand model. However, respirator manufacturers have indicated to NIOSH that such a device could be provided. The combination SAR/emergency backup HEPA might be appropriate where a backup auxiliary SCBA is not feasible, and where the backup system is clearly intended for **EMERGENCY EGRESS ONLY** due to SAR air supply disruption.

[Again, the provision of a HEPA filter as an emergency escape system would not replace the need for a reserve air system for the supplied air respirator. See Part IV. Breathing Air Systems for further discussion.]

Federal and State regulatory agencies may allow the use of a variety of other respiratory protective devices for protection against asbestos which do not provide the degree of protection afforded by the NIOSH/EPA recommended respirators. Therefore, NIOSH and EPA suggest that if employers choose not to follow the recommendations in this document, they should select the next best level of respiratory protection, in compliance with applicable Federal and/or State regulations. Respiratory protective devices which may be allowable under EPA regulations (40 Code of Federal Regulations (CFR) 763.120) and/or OSHA regulations (29 CFR 1910.1001) are listed later in this guide.

[IMPORTANT NOTE: At the time this document was being prepared, OSHA was considering a proposed revision to 29 CFR 1910.1001 and a construction-specific (including abatement) asbestos standard under 29 CFR 1926. Further, many states were developing and promulgating asbestos abatement requirements. Employers are cautioned to determine the regulatory requirements in effect at the time they are considering appropriate respiratory protection for their workers. Choosing respirators based upon the NIOSH/EPA recommendations, however, will ensure the highest level of respiratory protection available for workers exposed to asbestos.]

Like other construction work, asbestos abatement poses increased risks of injury to workers. NIOSH estimates that 10,000 workers throughout all industries are fatally injured on the job each year in the U.S. Falls and electrocutions account for 11% and 10% of these fatalities, respectively. Both falls and electrocutions represent risks which are more prevalent in abatement than in general industrial settings. In addition, workers required to wear protective clothing can face increased risk of heat stress. Appendix E and Appendix F of this document provide some general recommendations and references to guide an employer in ways to minimize safety and heat stress risks during asbestos abatement.

Part II A MODEL RESPIRATORY PROTECTION PROGRAM FOR ASBESTOS ABATEMENT OPERATIONS

Good engineering controls coupled with sound work practices can effectively reduce levels of airborne asbestos fibers during abatement or other activities. However, the known potency of asbestos as a cancer-causing substance dictates that workers engaged in abatement must receive the maximum level of protection feasible. Effective respiratory protection can be provided to workers only when employers develop, implement, and maintain effective respiratory programs.

Protecting workers from exposure is the responsibility of the employer (29 CFR 1910.1001, 29 CFR 1926.20, and 40 CFR 763.120). Employers are required by law (29 CFR 1910.134) to establish and maintain an effective respiratory protection program as outlined in American National Standards Institute (ANSI) Standard Z88.2-1969. (The more recent edition of ANSI Z88.2 (1980) contains more comprehensive requirements which are not yet incorporated in the OSHA regulation.) The intent of this part of the guide is to present a model respiratory protection program for asbestos abatement operations which meets or exceeds the requirements within the present OSHA standard.

The recommendations of this guide not only satisfy the current respiratory protection requirements of existing Federal regulations (29 CFR 1910.1001 and 40 CFR 763.121), but also include recommendations based on current information on respiratory protection.

An Effective Respirator Program should include:

A. **A written statement of company policy, including assignment of individual responsibility, accountability, and authority for required activities of the respiratory protection program**

B. **Written standard operating procedures governing the selection and use of respirators***

C. **Respirator selection (from NIOSH/MSHA approved and certified models) on the basis of hazards to which the worker is exposed***

D. **Medical examination of workers to determine whether or not they may be assigned an activity where respiratory protection is required***

E. **User training in the proper use and limitations of respirators* (as well as a way to evaluate the skill and knowledge obtained by the worker through training)**

F. **Respirator fit testing***

G. **Regular cleaning and disinfecting of respirators***

H. **Routine inspection of respirators during cleaning, and at least once a month and after each use for those respirators designated for emergency use***

I. **Storage of respirators in convenient, clean, and sanitary locations***

J. **Surveillance of work area conditions and degree of employee exposure (e.g., through air monitoring)***

K. **Regular inspection and evaluation of the continued effectiveness of the program***

L. **Recognition and resolution of special problems as they affect respirator use (e.g., facial hair, eye glasses, etc.)**

M. **Proper respirator use (procedures for donning and doffing respirators when entering and exiting the abatement area)**

*Elements presently required by OSHA for the use of respiratory protective equipment in asbestos abatement operations.

A. Written Statement of Company Policy

An important cornerstone to an effective respiratory protection program, and indeed to any worker protection program, is a written statement of the employer's intent to provide a safe and healthful workplace for workers. The employer's commitment to worker protection may be the single most important factor contributing to the success of workplace safety and health programs. The written statement should include assignment of individual responsibility, accountability, enforcement procedures, and authority for required activities of the respiratory protection program.

Program Responsibilities

The employer - Current Federal regulations assign the employer the responsibility to provide safe and healthful working conditions for workers. This responsibility can be accepted and met in part through the development and implementation of a respiratory protection program that meets the minimum requirements of the "American National Standard Practices for Respiratory Protection" (ANSI Z88.2-1969) as required by 29 CFR 1910.1001 and 40 CFR 763.120. However, because important parts of these regulations are outdated, the employer may not provide workers with the best respiratory protection possible by merely complying with existing regulatory requirements. NIOSH and EPA have determined that the best respiratory protection possible against airborne concentrations of asbestos is accomplished, within the context of an effective respiratory protection program, by the use of (1) a combination pressure-demand supplied air respirator with an auxiliary self-contained breathing apparatus (SAR/SCBA), or (2) a pressure-demand self-contained breathing apparatus (SCBA).

The employer may choose to delegate the responsibility for developing and implementing a respiratory protection program, but the employer is still legally responsible for ensuring compliance with the requirements set forth by OSHA and EPA.

The respirator program administrator - Responsibility and authority for administering the entire respiratory protection program should be assigned to one person. The designated administrator should write the operating procedures for the respiratory protection program. The American National Standards Institute offers some guidelines about selection of a suitable program administrator for companies that do not have organized industrial hygiene, health physics, or safety engineering departments, which is the case with most asbestos abatement contractors. In such cases, ANSI suggests that:

> . . . the respiratory program shall be administered by an upper-level superintendent, foreman, or other qualified person responsible to the principle manager. The administrator shall have sufficient knowledge of respiratory protection to properly supervise the respirator program.

The program administrator should meet the definition of "competent person" used in 29 CFR 1926.32 (f), which describes such an individual as ". . . one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous or dangerous to employees, and one who has authorization to take prompt corrective measures to eliminate them." It is necessary to provide this central authority and responsibility to ensure that there is coordination and direction of the program. This responsibility is usually designated to the first-line supervisor or site foreman of an asbestos abatement operation. Where other individuals are involved in the administration of the program, they should report directly to the one administrator with overall responsibility. Ultimately, however, the employer is responsible for ensuring compliance with applicable regulations.

In addition to the responsibility for managing the elements of the respiratory protection program outlined above, the program administrator should also be responsible for:

- purchasing approved respirators

- issuing respirators
- controlling inventory, to include, for example, a system of accounting and recordkeeping to track identification of users and to compile maintenance records for specific respirators.

Recordkeeping should include:

- a list of employees who are trained in respirator use
- medical records of each respirator user
- results of any pre- or post-training evaluations of workers' knowledge and hands-on skill
- documentation of respirator care and maintenance
- verification that respirators have been inspected for defects
- airborne concentrations of asbestos
- descriptions of any problems encountered during abatement.

Records of a worker's exposure, medical date, and air monitoring results are required by OSHA to be kept a minimum of 30 years.

The worker - It is the worker's responsibility to follow instructions and training in the use of respiratory protective equipment. The worker should avoid damaging the equipment, and report immediately to his/her supervisor when a respirator does not work properly or when something unusual happens to it.

B. Written Standard Operating Procedure

A minimally acceptable respiratory protection program must include written standard operating procedures for the selection and use of respirators.

The level of protection respirators provide may vary greatly, depending on the workplace conditions and the way they are used. In asbestos abatement, proper use of respirators is critical in protecting the health of the user. The potential for misuse can be reduced by written standard operating procedures, supported by strong management commitment and effective supervision of all aspects of the program.

Written procedures should contain all information needed to ensure protection for all workers employed in all phases of asbestos abatement. Federal regulations do not include guidelines regarding the format or content of written procedures. However, the general content of written procedures can be established from the information which follows, and can be adapted to meet the circumstances of a particular abatement operation.

The specific requirements and procedures for the program should be written clearly and simply so that they are easily understood and unambiguous. The person writing the procedures should be aware of who will be using the written procedures. In addition to the program administrator, persons who may need to refer to the written procedure might include: the supervisiors responsible for overseeing respirator use on the job; those responsible for fitting respirators and training the workers; respirator maintenance workers; contract, State and Federal inspectors; concerned local officials and individuals; and workers or their representatives.

C. Respirator Selection

(1) Respiratory Protection Against Asbestos

Because asbestos fibers are released during asbestos abatement work and are often released during other work in and around buildings such as construction, maintenance, and repair, the risk of breathing airborne asbestos fibers is high in areas where such work is done. The potential harm which can result from even minimal exposure to asbestos fibers has been well documented. Therefore, NIOSH and EPA recommend that employers provide workers with the maximum feasible level of respiratory protection. NIOSH and EPA have determined that the maximum level of respiratory protection can be achieved through use of either:

- A combination respirator which includes a Type-C supplied-air respirator with a full facepiece operated in the pressure-demand mode and with an auxiliary self-contained breathing apparatus (SAR/SCBA) operated in the pressure-demand mode; or
- A self-contained breathing apparatus (SCBA) with a full facepiece operated in the pressure-demand mode.

Respirators of these types should be selected by the program administrator from those approved and certified by the Mine Safety and Health Administration (MSHA) and NIOSH under the provisions of 30 CFR Part II. (See examples of approval labels in Appendix C.)

NIOSH and EPA recommend that pressure-demand SCBA with a full facepiece or combination pressure-demand SAR/SCBA with a full facepiece should be used by abatement workers and other workers who work with or in close proximity to asbestos-containing materials (such as maintenance or repair workers), when they are working in areas:

- where they are, or could reasonably be expected to be, occupationally exposed to airborne asbestos. "Occupationally exposed" means exposed to any detectable level of airborne asbestos at or above the lowest limit of reliable quantitation as determined by phase contrast microscopy analysis (NIOSH Method 7400 or NIOSH P & CAM 239), or
- where asbestos-containing debris has visibly accumulated.

Such situations can include asbestos abatement operations, such as open surface removal, glove bag removal, or encapsulation or enclosure. These recommendations also apply to workers involved in construction, maintenance, repair, or other work where exposure or the potential for exposure to asbestos exists.

Pressure-Demand SAR/SCBA

This device combines a short duration (as short as five minutes) SCBA with a supplied air respirator. The SCBA portion of the device is to be used only in an emergency situation to escape from a toxic atmosphere or to give the wearer time to connect to a different supply line and then escape. These units combine the advantage of use for long periods of time (SAR) with the ensurance of continued maximum protection should an emergency arise (SCBA).

Pressure-Demand SCBA

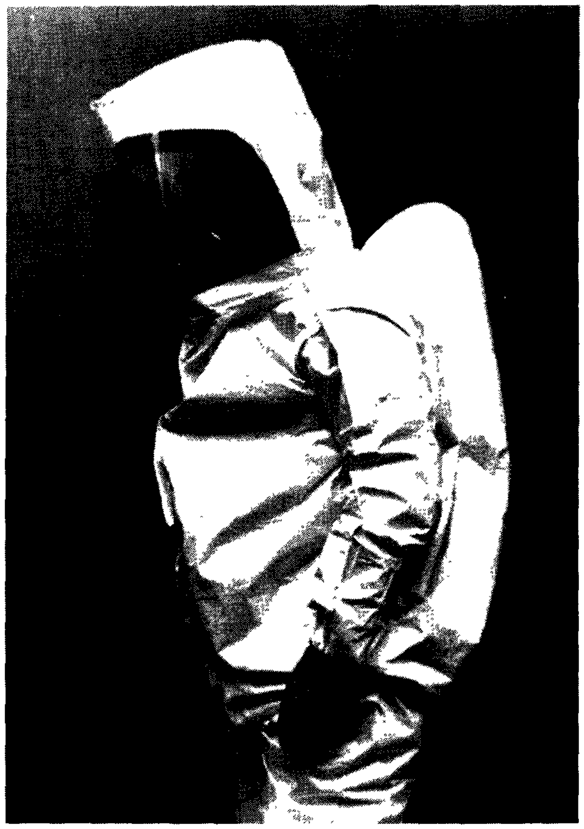
The pressure-demand SCBA has a regulator and valve design which maintains positive pressure in the facepiece at normal workrates. As such, the problem of contaminant leakage into the facepiece is minimized. The air supply is carried on the worker's back in a pressurized cylinder. Pressure-demand SCBA's consist of: (1) a full facepiece, (2) a regulator, (3) hoses and air lines, (4) a backpack assembly, and (5) a cylinder of compressed air. Gauges are located on the air cylinder, and in another location that is observable by the wearer. NIOSH and EPA recommend that, when SCBA's are used, they be worn under disposable suits with expandable backs. This will reduce contamination of the SCBA harness and tank assembly which are difficult to decontaminate.

Although SCBA's are recommended for use against respiratory exposure to asbestos, their size, weight and short service life usually relegate their practical use in asbestos abatement work to use by visitors and inspectors, and as stand-by units for rescue work, if necessary.

Headcoverings

Combination pressure-demand SAR/SCBA or pressure-demand SCBA should be equipped with full facepieces. Full facepieces should be worn with either a bonnet type disposable head cover/hood (Photograph 3) which covers the worker's head and the outside of the respirator facepiece, or with a full head cover/hood which covers the worker's head and the respirator facepiece (Photograph 4).

Photograph 3. Bonnet-type disposable head-cover.



Photograph 4. Fully encapsulating suit which incorporates full head cover.

When bonnet type head covers/hoods are used with full facepieces, the respirators should always be donned with the head straps located under the hoods. This allows removal of the headcovering prior to showering without disturbing the respirator (which is worn into the shower). This also provides greater stability and a better fit of the respirator facepiece and minimizes the possibility of asbestos-containing material accidentally falling into the respirator facepiece or into the face of the worker when the facepiece is removed during decontamination.

Reserve Air

OSHA regulations (29 CFR 1910.134) and good standard operating procedures require sufficient reserve air as part of any supplied air system used with any combination or supplied air respirator. This ensures that the worker has sufficient breathing air during escape from the abatement area and during decontamination in the event of compressor or air system failure. (Reserve air systems are discussed in detail in Appendix G.)

Auxiliary Backup System

As previously mentioned, in asbestos atmospheres which contain sufficient oxygen, a possible alternative to the recommended respirators may be a pressure-demand, full facepiece supplied air respirator that is equipped with an emergency backup HEPA filter. The filter would be used when air flow unexpectedly ceased and would provide some respiratory protection in emergency egress situations.

Respirators Allowable Under Existing Regulations for Protection Against Asbestos

Although only the first two of the following respiratory protective devices are recommended by NIOSH/EPA for use in asbestos abatement operations, the other respirator types (numbered 3 through 13) may be allowable under OSHA regulations (29 CFR 1910.1001) and/or EPA regulations (40 CFR 763.121).

[CAUTION: The Occupational Safety and Health Administration and many States are currently revising regulations pertaining to asbestos abatement. Some of the devices listed below may not be permitted in the future. Employers choosing not to follow the NIOSH/EPA recommendations in this document should verify existing regulatory requirements before selecting these respirators.]

These devices are listed in order of decreasing protection (the most protective devices are listed first).* Employers should note that regulatory requirements regarding specific respirator types may be dependent upon measured asbestos exposure levels which must, generally, be determined prior to selection.

Recommended by NIOSH/EPA:

1. A self-contained breathing apparatus with full facepiece operated in pressure-demand mode;

2. A combination Type C supplied air respirator with full facepiece operated in the pressure-demand mode, and with an emergency backup SCBA operated in the pressure-demand mode;

Not Recommended by NIOSH/EPA:

3. Any pressure-demand supplied-air respirator with full facepiece;

4. Any pressure-demand supplied-air respirator;

5. Any continuous-flow supplied-air respirator with full facepiece, hood, or helmet;

6. Any continuous-flow supplied-air respirator;

7. Any powered-air-purifying respirator with high-effiency filter and full facepiece, hood, or helmet;

8. Any dust, fume, and mist respirator with high-efficiency filter(s) and full facepiece;

9. Any powered-air-purifying respirator with high-efficiency filter;

10. Any demand supplied-air respirator or demand self-contained breathing apparatus;

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*The determination of relative protection provided by these respirator types is based upon A Guide to Industrial Respiratory Protection (DHEW (NIOSH) Publication No. 76-189) and recent respirator field studies by NIOSH and others.

11. Any dust, fume, and mist respirator with high-efficiency filter(s);

12. Any dust, mist, or asbestos-containing dust and mist respirator with full facepiece; or

13. Any dust, mist, or asbestos-containing dust and mist respirator.

[IMPORTANT: THE RESPIRATOR TYPES NUMBERED 3 THROUGH 13 ABOVE ARE NOT RECOMMENDED BY NIOSH OR EPA FOR USE AGAINST ASBESTOS. However, various existing regulations allow their use. In fact, the existing respirator certification regulations (30 CFR Part 11) require NIOSH to certify single-use or dust, mist, and asbestos respirators. However, as a matter of public health policy, NIOSH and EPA DO NOT RECOMMEND THEIR USE IN ASBESTOS ENVIRONMENTS.]

(2) Respiratory Protection for Non-Abatement Operations

Air-purifying respirators supplied with high-efficiency particulate/aerosol (HEPA) filters or respirators that offer higher protection are recommended for use ONLY in special situations such as during pre-abatement inspections, preparation of the abatement area, final cleaning, removal of the last layer of plastic, etc., when measurable concentrations of asbestos are not detectable. The use of air-purifying respirators is only a precaution in the event of an accidental disturbance of asbestos, and for exposures to other dusts and particulates which may be present in the workplace.

Glove Bag Removal

Air-purifying respirators may also be suitable for use by workers performing glove bag removal of asbestos from pipes, valves, etc., where the enviroment in which the glove bag abatement operation is to be conducted is free of any measurable concentration level of asbestos. The use of air-purifying respirators in this case is a precaution in the event of accidental puncture or rupture of the glove bag. Should puncture or rupture occur, workers should immediately leave the area of exposure and begin decontamination procedures in an appropriate designated area.

D. Medical Examinations

Employer requirements for providing medical examinations to workers are contained in OSHA 29 CFR 1910.1001 (j) and EPA 40 CFR 763.121 (see Appendix A). In addition to existing regulatory requirements, the initial examination should allow determination as to whether the worker is capable of wearing and using a respirator. Therefore, the worker's previous medical and employment history should also be considered.

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

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

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

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

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

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

E. Worker and Supervisor Training

Because asbestos is a carcinogen (a cancer-causing substance), the importance of proper training of workers and supervisors in the asbestos abatement industry cannot be overemphasized. It is imperative that those working with asbestos have a clear understanding of the hazards involved, and receive instruction in the proper selection, use, and maintenance of recommended respirators.

In abatement operations, two levels of training should be provided. One level is necessary for the abatement worker, and a second, additional level is necessary for the foreman or first-line supervisor (who will often provide training for the workers). Training needs will differ in that the supervisor needs a more comprehensive working knowledge of respirators and respiratory protection practices in addition to the basic worker training.

A STRONG MANAGEMENT COMMITMENT TO TRAINING IS ESSENTIAL TO THE SUCCESS OF AN EFFECTIVE RESPIRATORY PROTECTIVE PROGRAM.

(1) Worker Training

Formal instruction in the use of respiratory protective equipment is recommended for workers employed in asbestos abatement work. A basic respirator training program for workers should include:

- instruction in the nature of the hazards of asbestos and its potential health effects
- how asbestos enters the body and what happens when it does
- how cigarette smoking increases risk of adverse health effects
- explanation of why respirators are needed (e.g., where the use of engineering controls and other means of control have failed to eliminate exposures to asbestos)
- discussion of the consequences of not wearing respirators in exposure situations from legal, health, and disciplinary perspectives
- discussion of why the respirator selected is the proper type of respirator for use in asbestos abatement operations
- instruction, training and actual hands-on use of the respirator to include proper fitting, practice in wearing and adjusting the respirator, testing the facepiece-to-face seal, performing job functions, and limitations of respirator use (Close frequent supervision should be maintained during training to ensure that the respirator is used properly.)
- inspection and maintenance of the respirator

- classroom and field or simulated field training in recognizing and coping with medical and other emergencies

- respirator cleaning and decontamination procedures

- the purpose of medical evaluation.

The effectiveness of such training should be evaluated by testing to determine if the worker has acquired the knowledge and hands-on competency required. Test elements should correlate to actual job performance and respirator use requirements.

Wearing a respirator can cause discomfort and is inconvenient at best. A major emphasis should be made through training to convince the respirator user that respiratory protection is necessary, and that proper respirator use and maintenance are important. An example of a formal field training course for asbestos abatement workers is the one developed by the National Asbestos Council (NAC) in conjunction with OSHA.

(2) Supervisor Training

The training of supervisors who oversee the daily activities of workers wearing respirators and other personal protective equipment should include the basic worker training and the following:

- basic respiratory protection practices

- the selection and use of respirators to protect workers against airborne asbestos fibers

- the structure and operation of the respirator program

- the legal requirements pertaining to the use of the respirators.

Supervisor training should be acquired from a recognized training facility, such as Georgia Institute of Technology, the University of Kansas, Tufts University, the University of California at Berkeley, the University of Illinois at Chicago, or from other facilities or individuals which provide a comparable level of supervisory training. (Many State and other regulatory agencies have regulations specifying training requirements which must be followed by employers operating in their jurisdictions.)

In supervisor training, supervisors should be required to pass an examination to demonstrate their knowledge of the hazards associated with exposure to asbestos and the proper selection, use, and care of respirators.

F. Respirator Fit Test

The proper fitting of respiratory protective equipment requires the performance of a suitable fit test. The test is needed to determine a proper match between the facepiece of the respirator and face of the wearer.

NIOSH recommends that a quantitative (QNFT) fit test be done to determine the ability of each individual respirator wearer to obtain a satisfactory fit with any respirator which creates a negative pressure in the facepiece, such as negative-pressure air-purifying respirators or the SAR fitted with an emergency backup HEPA filter previously discussed. Fit tests have not been required by regulations for Type "C" pressure-demand supplied air (air line) respirators or for pressure-demand SCBA due to the positive pressure operation of these units. However, employers who choose not to use the NIOSH/EPA recommended positive-pressure respirators should be aware of the importance of fit testing to the protection level provided by air-purifying respirators. Appendix B contains procedures for both quantitative and qualitative fit testing.

(1) Quantitative Fit Test

The purpose of the quantitative fit test is to determine the proper fit of the respirator under simulated wearing conditions. It is intended to provide the best method of fitting the respirator to the individual, using sensitive methods of detection for leakage.

Quantitative respirator fit tests involve exposing the respirator wearer to a test atmosphere containing an easily detectable, nontoxic aerosol, vapor or gas as the test agent (Photograph 5). Instrumentation, which samples the test atmosphere and the air inside the facepiece of the respirator, is used to measure quantitatively the leakage into the respirator. There are a number of test atmospheres, test agents, and exercises to perform during the tests. Because of cost, employers may find it necessary to contract for quantitative fit testing services.

Photograph 5. Quantitative fit test chamber and instrument.

Fit testing may be conducted as part of the worker training described previously. Instruction in donning and adjusting the respirator facepiece and the effects of improper adjustment can be demonstrated to the trainee as part of the fit testing procedure.

(2) Qualitative Fit Test

Qualitative fit tests involve a test subject's responding (either voluntarily or involuntarily) to a chemical challenge outside the respirator facepiece. Three of the most popular methods are: (1) an irritant smoke test, (2) an odorous vapor test, and (3) a taste test. These tests are fast, easily performed, and use inexpensive equipment. Because these tests are based on the respirator wearer's subjective response to a test chemical, reproducibility and accuracy may vary.

[NOTE: When performing a quantitative or qualitative fit test, the wearer should carry out a series of exercises that simulate work movements. Exercises are listed in the American National Standard, Z88.2-1980, pp. 34-35.]

(3) Sealing Tests for Routine Donning of Respirators

To ensure proper protection, the wearer of a respirator equipped with a tight fitting facepiece must check the seal of the facepiece routinely prior to each entry into the abatement area. This may be done by using the sealing test procedures recommended by the manufacturer or (where the manufacturer does not provide such recommendations) by using the negative and positive pressure sealing tests described below. Sealing tests should NOT be substituted for the initial, required quantitative fit tests. Adequate training of respirator users is essential for satisfactory sealing tests.

(a) Negative Pressure Test

This test can be conducted on respirators equipped with tight fitting facepieces.

i. Respirator Types

- For self-contained breathing apparatus, combination SAR/SCBA, and supplied air respirators, the end of the breathing tube is blocked so that it will not allow the passage of air. (Photograph 6).

Photograph 6. Negative pressure test on SAR or SCBA.

- For negative-pressure air-purifying respirators, the inlet opening of the respirator's cartridge(s) or filter(s) is closed off by covering with the palm of the hand(s). (Photograph 7).

Photograph 7. Negative pressure test on air-purifying respirator.

ii. Wearers are instructed to inhale gently and hold their breath for at least 10 seconds.

iii. If the facepiece collapses slightly and no inward leakage of air into the facepiece is detected, it can be reasonably assumed that the respirator has been properly donned and the exhalation valve and facepiece are not leaking.

(b) Positive Pressure Test

This test can be conducted on respirators equipped with tight fitting facepieces which contain both inhalation and exhalation valves.

i. For self-contained breathing apparatus, combination SAR/SCBA, supplied air respirators, and for negative pressure air-purifying respirators, the exhalation valve is closed off so that it will not allow the passage of air. (Photograph 8).

Photograph 8. Positive pressure test; blocking exhalation valve.

ii. Wearers are instructed to exhale gently for at least 10 seconds.

iii. The respirator has been properly donned if a slight positive pressure can be built up inside the facepiece without the detection of any outward leakage of air between the sealing surface of the facepiece and the wearer's face.

[NOTE: *For some respirators* (negative-pressure air-purifying and supplied air), this test method requires that the respirator wearer first remove the exhalation valve cover (Photograph 9) from the respirator and replace it after completion of the test. This task is difficult to carry out without disturbing the fit of the respirator.]

Photograph 9. Positive pressure test with exhalation valve cover removed.

G. Cleaning and Disinfecting

Respirators should be cleaned after each use. This cleaning is usually done by the worker. In asbestos abatement operations, respirators should be collected on the clean side of the decontamination shower at the end of each shift for additional cleaning and inspection. (See section M for donning and doffing procedures.) It is best to have one individual responsible for the daily cleaning and inspection of respirators.

Every worker's respirator should bear identification, such as the worker's initials or employment number. When workers are assigned a respirator, they should be briefed on the cleaning procedure and assured (if practicable) that they will always get the same device.

If the respirators are serviced between shifts, only one respirator per worker is needed. If the cleaning is done during a work shift or if a worker will be entering and leaving the abatement area more than once during a shift, each worker requires two or more respirators depending on the number of exits and entries.

ALL RESPIRATORS SHOULD BE CLEANED AFTER EACH USE IN ACCORDANCE WITH THE MANUFACTURER'S INSTRUCTIONS.

H. Inspection and Repair

An important part of a respirator maintenance program is the continual inspection of the devices. If properly performed, inspections will identify damaged or malfunctioning respirators before they can be used.

Respirator cleaning presents a good opportunity to examine each respirator thoroughly. Respirators should be double checked after cleaning operations and reassembly have been accomplished.

ALL RESPIRATORS SHOULD BE INSPECTED IN ACCORDANCE WITH THE MANUFACTURER'S INSTRUCTIONS.

Continued usage of respiratory protective equipment may require periodic repair or replacement of component parts of the equipment. Such repairs and parts replacement must be done either by the manufacturer, by an individual(s) trained by the manufacturer, or by the user or supervisor in situations specified by the manufacturer.

Most, if not all, equipment manufacturers supply literature which lists the component parts of their respirators and includes information on servicing. Replacement parts for respirators must be those of the manufacturer of the equipment. SUBSTITUTION OF PARTS FROM A DIFFERENT BRAND OR TYPE OF RESPIRATOR, OR UNAUTHORIZED MODIFICATION, COULD DECREASE WORKER PROTECTION OR CAUSE A TOTAL LOSS OF WORKER PROTECTION. ALSO, SUCH SUBSTITUTION OF PARTS OR MODIFICATION WILL INVALIDATE THE APPROVAL OF THE RESPIRATOR, LEADING TO VIOLATION OF APPLICABLE REGULATIONS.

Maintenance of SCBA equipment is more difficult than supplied air or air-purifying respirators, primarily because of the complexity of the valve and regulator assembly. Because of this, all repairs or adjustments must be done by the manufacturer, by an authorized repair facility, or by a worker who has been trained and certified by the manufacturer.

I. Storage of Respirators

Respirators should be stored in a convenient, clean, and sanitary location. The purpose of good respirator storage is to ensure that the respirator will function properly when used.

Care must be taken to ensure that respirators are stored properly to protect against dust, harmful chemicals, sunlight, excessive heat or cold, moisture, and mechanical damage. Respirators should be stored in plastic bags which can be sealed, or in containers with tight-fitting lids.

[NOTE: Respirators should be thoroughly dried before being sealed in any container for storage.]

Respirators should be packed or stored so that the facepiece and exhalation valves will rest in the normal position. Respirators should not be hung by their straps. This will ensure that proper function is not impaired by distortion of the respirator or its straps.

J. Work Area Surveillance

As specified in 29 CFR 1910.1001 and in 40 CFR 763.121, a well designed air sampling and analytical program is an essential part of every asbestos abatement project and will help document the following:

- worker exposure levels
- compliance with regulations (Federal, state, local)
- building/area occupant exposure levels

- levels of asbestos after completion of abatement work
- compliance with contract specifications
- effectiveness of engineering controls and good work practices.

K. Regular Program Evaluation

The program administrator should periodically assess the effectiveness of the respiratory protection program during all phases of asbestos abatement operations. Frequent walk-through inspections during abatement activities should be conducted to monitor and document supervisor and worker compliance with requirements of the program. In addition to general assessment of the overall respiratory protection program, specific evaluations of the respirator cleaning, inspection, maintenance, repair, storage, and use procedures should be frequently conducted to ensure that the desired results of these operations are consistently achieved.

L. Special Problems

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

(1) Facial Hair

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

(2) Eye Glasses

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

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

(3) Contact Lenses

Workers should not, under any circumstances, be permitted to wear contact lenses when wearing any type of respiratory device. With full facepieces, incoming air directed toward the eye can cause discomfort from dirt, lint, or other debris lodging between the contact lens and the pupil.

(4) Facial Deformities

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

(5) Communications

Talking while wearing a respirator equipped with a facepiece can break the seal of the facepiece. Workers who must speak should be cautioned to keep jaw movement to a minimum. When communication is necessary within a contaminated area, it should be done with the help of special communicating equipment obtained from the manufacturer of the respirator.

(6) Temperature Extremes

In low temperatures, respirator lenses can become fogged. Fogging can be prevented by coating the inner surface of the lens with an anti-fogging compound. Satisfactory vision can be provided at temperatures down to -30°F. by supplying a full facepiece with a nose cup that directs the warm, moist exhaled air through the exhalation valve without its touching the lens. Airline respirators should provide dry, respirable air to the worker in cold temperatures.

High or low temperatures can make wearing a respirator uncomfortable. Under temperature extremes, a supplied air respirator may be equipped with a vortex tube to either warm or cool the air supply as needed, if such a device has been approved for use with the respirator. Also, air supply systems are now available which heat or cool the air supplied to the respirator facepiece or air hood.

M. Proper Respirator Use. (Procedures for Donning and Doffing Respirators When Entering and Exiting the Abatement Area.)

A well-defined procedure for donning and doffing respirators, as well as the disposal and/or decontamination of personal protective equipment when exiting the asbestos abatement area, is necessary for every abatement operation. An important part of this process is a decontamination unit through which workers must pass when entering and exiting the work area.

Figure 1 shows a typical abatement operation layout, including a decontamination unit fabricated on the abatement site. A typical unit consists of a clean room, a shower room, and an equipment room, each separated by air locks. Customized trailers, which can be readily moved from one location to the next, are also used as decontamination stations. The basic design should be the same, whether the decontamination unit is fabricated on-site or is in the form of a mobile trailer.

The decontamination unit consists of three rooms separated by air locks through which each worker must pass to enter and exit the abatement area:

Clean Room — a clean area. No asbestos-contaminated items should enter this room. This area is used for suiting up and donning respiratory protective devices prior to beginning work, and for dressing in clean clothes after work.

Shower Room — Workers pass through the shower room on their way to the abatement area, and use the showers on their way out after leaving their contaminated clothing in the equipment room. Respirators are always worn into the shower as part of the personal decontamination procedure.

Equipment Room — a contaminated area where equipment, boots or shoes, hardhats, and any other contaminated work articles are stored. This is the area in which contaminated clothing is removed and disposed as the workers exit the work area. Workers keep their respirators on (without disturbing the face fit) until after they have begun their showers.

All abatement workers and other authorized personnel should enter and exit the work area through the worker decontamination enclosure system. Clean respirators and other protective equipment must be provided in the clean room and utilized by each person for each separate entry into the abatement area.

All donning and removal of respiratory protective devices and work clothes should be accomplished using the "buddy" system, involving two employees assisting each other. Prior to entering a work area, each person should be examined by his "buddy" to ensure that all connections in the respirator system are properly made and that the disposable suits, booties, head covers/hoods, etc. are properly donned.

Systematic procedures for entry and exit of the abatement area with each of the recommended respiratory protection devices are given below. These procedures should be followed for each entry and exit of the work area, including lunch breaks, etc.

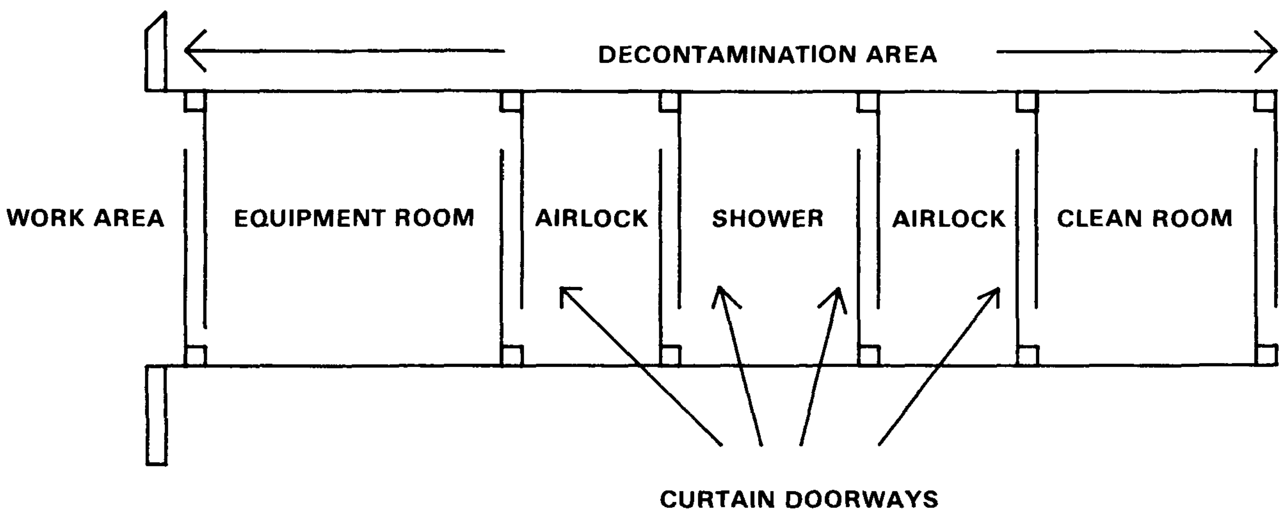


Figure 1. Typical Decontamination Area

Pressure-Demand SAR

Clean Room (Entry)

1. Remove all street clothing, including underwear and socks and don disposable briefs, suits, and booties if not attached to the suit.
2. Secure respirator belt assembly to the waist.
3. Proceed to shower room.

Pressure-Demand SCBA

Clean Room (Entry) — When SCBA's are used, complete donning of these units for entry into the abatement area should be done in the clean room.

1. Remove all street clothing, including underwear and socks, and don disposable briefs, suits and booties, if not attached to the suit.
2. Using the "buddy" system, fit the SCBA harness assembly on the worker with the air flow valve closed and the respirator facepiece hanging from the neck with the aid of a strap.
3. Don a disposable suit with an expandable back to cover the air tank to protect the unit from contamination.
4. Check the gauge pressure to ensure full service time and check the low pressure alarm, using the manufacturer's instructions, to ensure that it is working properly.
5. Press the facepiece to the face of the worker and open the air valve to provide air to the facepiece. Then fit the headstraps over the worker's head and tighten to a comfortable fit.
6. Check the seal of the facepiece as explained in the section on respirator fit testing (sealing tests).
7. If a bonnet type hood/headcover is used with the suit, fit it over the headstraps and firmly around the circumference of the respirator facepiece. If full head covers are used, simply fit them over the head and respirator facepiece.
8. Zip up the suit. The workers are ready to proceed directly to the Equipment Room.

Pressure-Demand SAR

Shower Room (Entry)*

1. Vigorously rinse the quick disconnect of the airline with fresh water to remove any foreign material that may have settled on the disconnect overnight.

2. Connect the Type "C" respirator system into the breathing air system (air line quick disconnect); then connect into the air system and adjust the air control valve for desired flow if applicable.

3. If half or full tight fitting respirator facepieces are used, secure the respirator facepiece comfortably to the face with the head straps.

4. Check the facepiece seal as explained in the section on respirator fit testing (sealing tests).

5. Don the bonnet hood/head cover or full head cover as explained in the respirator selection section above.

6. Proceed to the equipment room.

*It is not necessary to shower prior to entry into the asbestos abatement area.

Equipment Room (Entry)

1. Put on work shoes and other safety equipment as required by the job situation.

2. Proceed to the work area.

Pressure-Demand SCBA

Shower Room (Entry)*

1. Proceed to Equipment Room.

Equipment Room (Entry)

1. Put on work shoes and other safety equipment as required by the job situation.

2. Proceed to the work area.

Work Area

1. Do not remove the respirator facepiece for any reason while in the abatement area.

2. When working on scaffolding, tie the trailing airline off securely to the scaffold railing etc. as a safety precaution. This is to avoid entanglement or being pulled from the scaffolding.

* In the unusual circumstance when it is necessary to connect into a supplied air system in an asbestos laden atmosphere, the worker should always vigorously spray wash the outside and opening of both the male and female quick disconnect assembly with fresh water before connecting into the air system to ensure that both are free of any foreign material. Once the integrity of the air line has been contaminated with any foreign material, the entire length of air line should be examined and decontaminated where possible.

* When is is necessary to disconnect from the air supply system in the contaminated abatement environment, ensure that the ends of the air line (male and female) are capped. The female disconnect should be tied off on some stable object such as scaffolding cross braces, etc., so that the opening hangs vertically.

Before leaving the work area for exit to the clean room, the worker should vacuum all loose residue from the suit and wet the suit with a water spray to prevent asbestos from becoming airborne while removing the suit.

Pressure-Demand SAR

Equipment Room (Exit)

1. If wearing a tight fitting facepiece, carefully remove all protective clothing except the facepiece.

2. After the protective clothing has been removed, place it in the proper container for disposal.

3. Still connected to the air supply system, regardless of the type respirator system, proceed to the shower room.

Pressure-Demand SCBA

Equipment Room (Exit)

1. Remove all protective clothing except the SCBA.

2. After the protective clothing has been removed, place it in a proper container for disposal.

3. With the SCBA still in place, proceed to the shower room.

Pressure-Demand SAR

Shower Room (Exit)

1. If wearing a tight fitting facepiece, while standing under the shower, thoroughly clean the outside of the respirator facepiece and exposed area of the face prior to removal of the facepiece. Place the respirator on the floor outside the shower (dirty side), and finish primary showering.
2. Bring the respirator back into the shower and clean it. Disconnect from the air supply system and give the entire respirator breathing assembly to the outside man in the clean area.
3. After the respirator has been removed and primary cleaning has been accomplished in the shower, thoroughly wash the entire body with soap and water, and proceed to the clean room.

Clean Room (Exit)

1. Dress into street clothes.

Pressure-Demand SCBA

Shower Room (Exit)

1. Thoroughly shower down with the SCBA still on. Turn off the air supply valve, remove the respirator, and place the respirator unit on the floor outside the shower (dirty side), and finish showering.
2. Bring the respirator back into the shower and clean it. Hand the entire SCBA unit to the outside man in the clean room.
3. After the respirator has been removed and primary cleaning cleaning has been accomplished in the shower, thoroughly wash the entire body with soap and water, and proceed to the clean room.

Clean Room (Exit)

1. Dress into street clothes.

NOTE: **Before leaving the job site, ensure that the respirator worn is properly cleaned, repaired (if necessary), dried, and stored in a clean storage area for reuse the next work shift.**

Part III RESPIRATOR PROGRAM CHECKLIST

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

A. Program Administration

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

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

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

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

____ designation of an administrator;

____ respirator selection;

____ purchase of approved equipment;

____ medical aspects of respirator usage;

____ issuance of equipment;

____ fitting;

____ training;

____ maintenance, storage, and repair;

____ inspection;

____ use under special conditions; and

____ work area under surveillance?

B. Program Operation

(1) Respiratory protective equipment selection

____ Are work area conditions and worker exposures properly surveyed?

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

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

____ (2) Are only approved respirators purchased and used; do they provide adequate protection for the specific hazard and concentration of the contaminate?

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

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

(5) Respiratory protective equipment fitting

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

____ Is the fit tested at appropriate intervals?

____ Are those users who require corrective lenses properly fitted?

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

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

____ Are workers prohibited from entering contaminated work areas when they have facial hair or other characteristics which prohibit the use of tight-fitting facepieces?

(6) Respirator use in the work area

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

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

____ Are workers wearing respirators into the shower without disturbing the face fit?

(7) Maintenance of respiratory protective equipment

Cleaning and Disinfecting

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

____ Are proper methods of cleaning and disinfecting utilized?

Storage

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

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

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

Inspection

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

____ Are qualified individuals/users instructed in inspection techniques?

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

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

Repair

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

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

(8) Special use conditions

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

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

(9) Training

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

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

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

Part IV BREATHING AIR SYSTEMS

The NIOSH/MSHA approval certification requires that sufficient quantities of at least "Grade D" air must be supplied to the certified supplied-air respirators, at the pressures specified by the manufacturer for the length of hose that is being used. There has been some concern raised that this is not always the case under actual use conditions.

[NOTE: "Grade D" breathing air is air that meets certain criteria established by the Compressed Gas Association, Inc. (See Table 1 in Appendix G.]

The following information is offered for persons who select and operate breathing air systems for providing air to certified supplied-air respirators during asbestos abatement operations.

A breathing air system used in asbestos removal must accomplish the following:

- provide a continuous sufficient supply of "Grade D" or better breathing air
- provide adequate reserve or escape air

  [NOTE: This must be done even if using pressure-demand SAR/SCBA, or pressure-demand SAR with an emergency backup HEPA filter.]

- provide breathing air temperature control
- provide a continuous monitor and alarm against carbon monoxide (CO) in the airstream.

Four types of breathing air systems are generally available:

- low-pressure breathing air system
- high-pressure breathing air system
- high-pressure air storage cylinders
- ambient air pump (not recommended for use in asbestos abatement).

A. The Low-Pressure Breathing Air System

The typical low-pressure breathing air system (Figure 2) operates at pressures between 80 to 200 pounds per square inch gauge (psig). It consists of:

- a low-pressure air compressor
- an after cooler assembly with water removal traps
- a compressed air purifier assembly
- a standby high-pressure air reserve assembly
- a distribution hose and manifold with connections for the respirators.

The low-pressure air compressor must have sufficient capacity to provide the flow and pressure specified by the manufacturer for the selected respirator. Flow and pressure are measured at the point where the respirator is connected. The maximum length of hose that may be used on supplied air systems is 300 feet. The compressor should be equipped with sufficient interstage and aftercooling

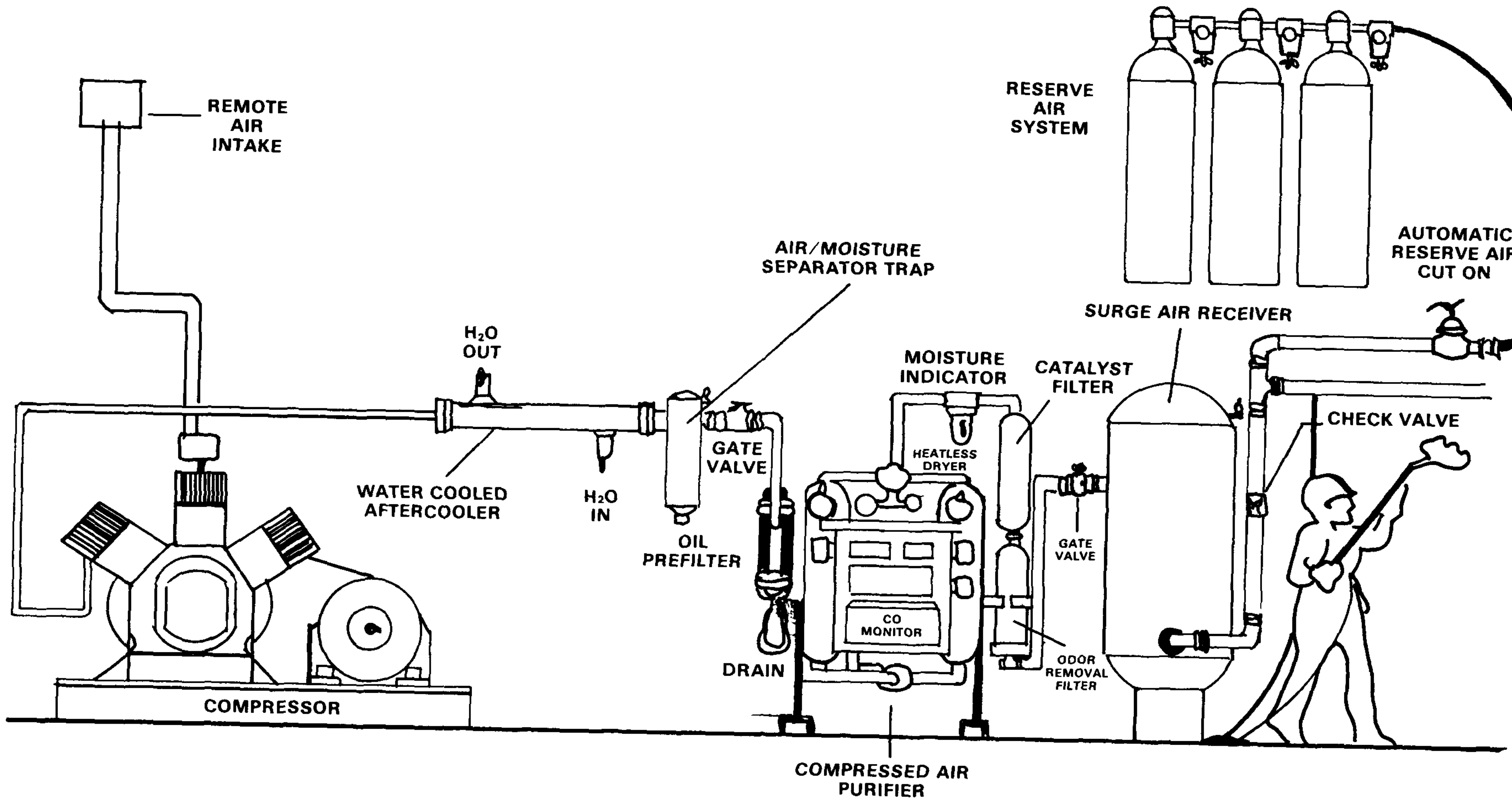


Figure 2. Typical Installation of Low Pressure Breathing Air System

capacity to reduce the output air temperature to within 10ºF of the ambient air temperature. (In hot environments, care should be taken to ensure that air supplied to the respirator will not result in additional heat stress burden to the user. See Appendices F and G for additional information regarding heat stress considerations and available methods of cooling air supplied by breathing air systems.) Sufficient moisture removal traps to remove all condensed water should be built in.

The low-pressure breathing air purifier assembly (Figure 3) must purify the air to at least "Grade D" quality. The typical low-pressure breathing air purifier assembly consists of:

- a process air cooler using either air or water to accomplish the cooling
- a water removal trap
- a sequenced set of adsorption canisters, oil removal filter, alternating air regenerative drying towers and a switching mechanism
- a catalytic canister to change carbon monoxide (CO) to carbon dioxide (CO_2)
- a continuous carbon monoxide monitor and alarm on the output air stream.

The required escape or reserve air supply is provided by a standby high-pressure reserve system. This system provides for uninterrupted airflow should the main compressor airflow cease. Typical escape times for an industrial crew of 5 to 25 workers can range from 30 to 60 minutes. Therefore, it is recommended that a minimum of 1 hour of reserve air be provided.

B. The High-Pressure Breathing Air System

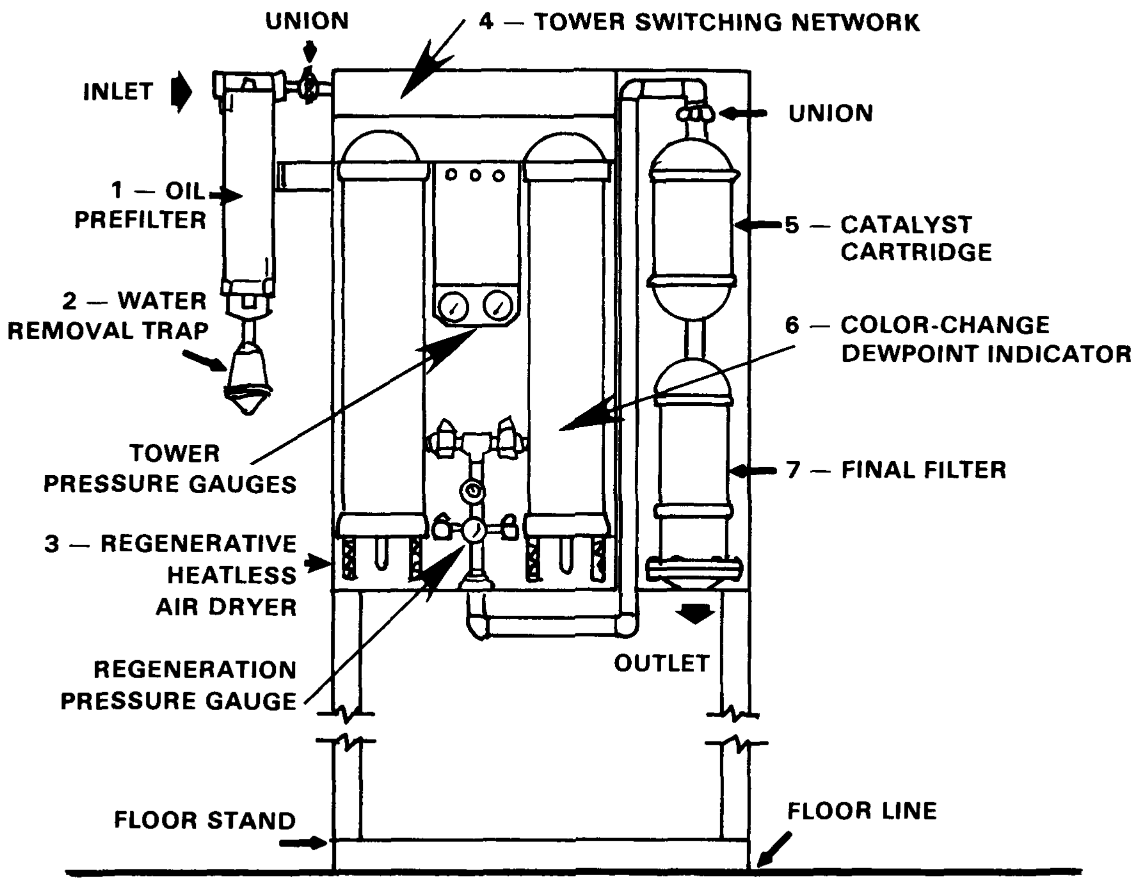
The typical high-pressure breathing air system (Figure 4) operates in the pressure range of 2000 to 4000 psig. It consists of:

- a high-pressure breathing air compressor
- an intercooler/aftercooler assembly with water removal traps
- a high-pressure air purifier assembly
- an in-line high-pressure air storage bank
- a high-pressure distribution line and control panel (with pressure reducer) with connections for respirator airlines.

The high-pressure breathing air compressor uses three to five successive stages of compression to produce pressures of 2000 to 4000 psig. Air temperature reduction and water removal is accomplished following each of the compression stages.

A high-pressure purifier assembly (Figure 5) must, just as the low pressure system must, purify the air to at least the required "Grade D" quality.

The typical high-pressure breathing air purifier assembly consists of a coalescing water removal trap and a sequenced set of adsorption canisters. The adsorption canisters remove oil, oil vapor, water vapor, and objectionable odors. They may also include a catalytic canister to change carbon monoxide (CO) to carbon dioxide (CO_2). Due to high pressures, the adsorber material can process more air and, therefore, less of it is needed.



1. Oil Prefilter — removes oil mist, particulates, and entrained water. Color-change replacement notice
2. Water Removal Draintrap — removes condensed water-oil mixtures
3. Dual Regenerative Heatless Air Drying Towers — reduce water vapor content; action is to regenerate its own adsorber material
4. Tower Switching Network — acts with plumbing to provide timed dryer tower switching to effect regeneration
5. Catalyst Cartridge — removes CO by catalytic conversion to CO_2
6. Color Change Dewpoint Indicator — Color change visually shows the performance of the drying towers
7. Final Filter - effects odor removal

Figure 3. Typical Low Pressure Breathing Air Purifier Assembly

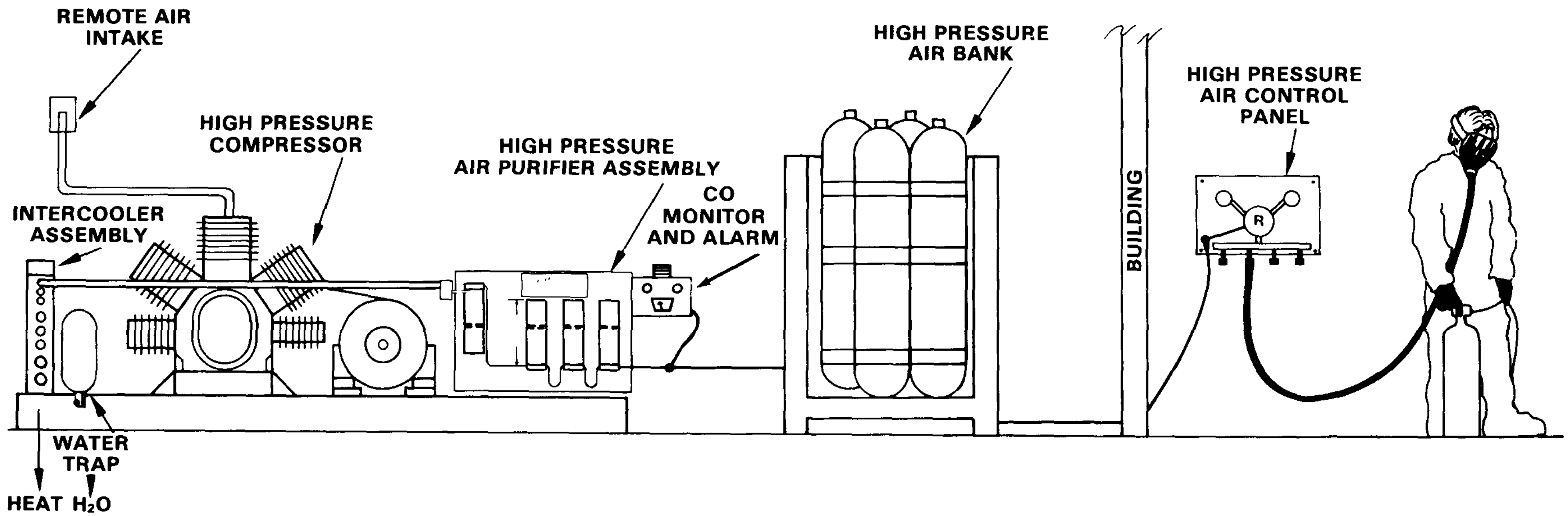


Figure 4. Typical High Pressure Breathing Air System

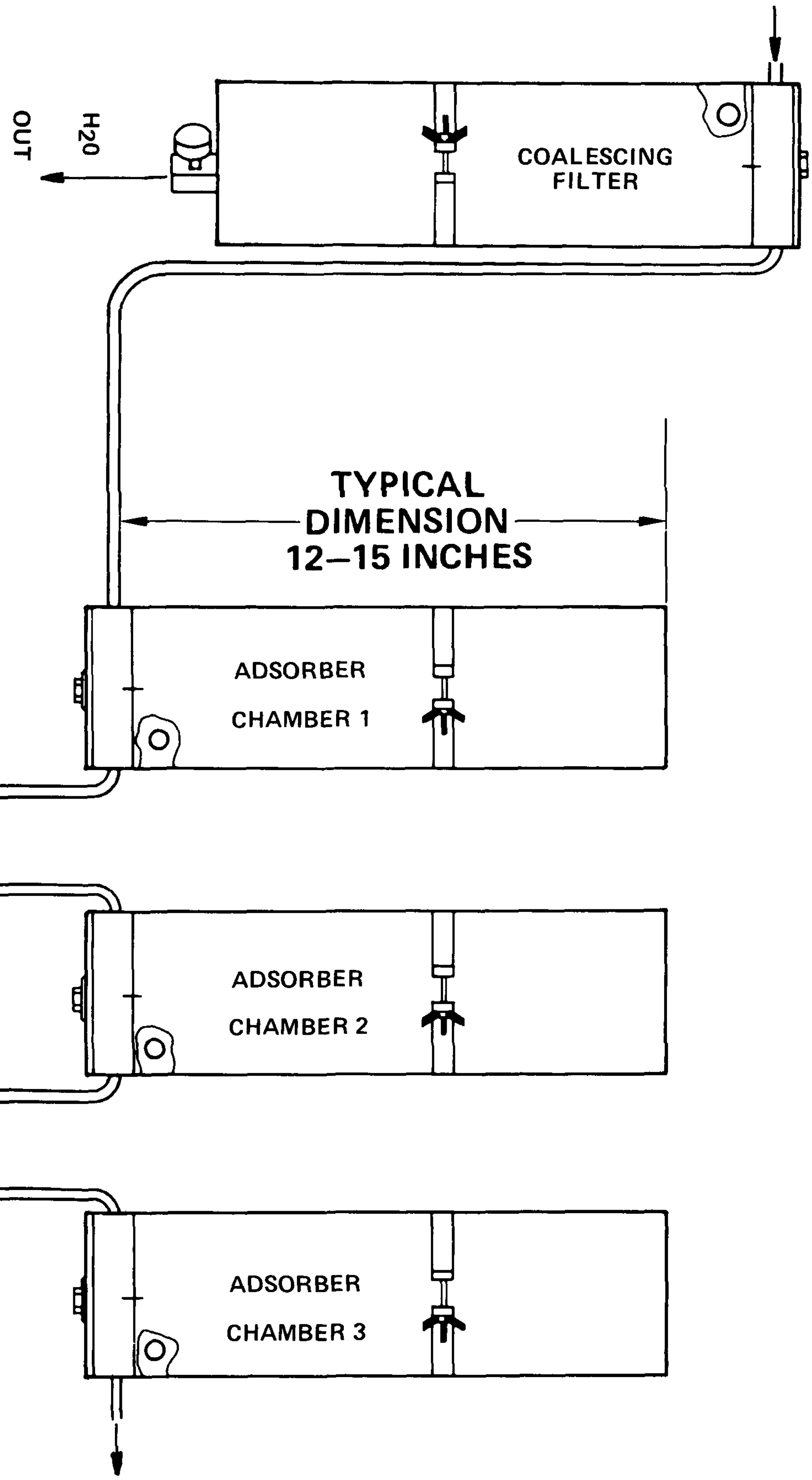


Figure 5. Typical High Pressure Purifier Assembly

A continuous carbon monoxide monitor and alarm is required on the output air stream. The required air for escape or reserve time, is provided by an in-line air bank pumped directly by the high-pressure compressor. A feedline comes from the air bank to an air control panel where the respirator airlines are attached. The air control panel contains an automatic pressure reducing valve which reduces the pressure to the correct respirator hose line pressure. Breathing air temperature is also reduced by the action of the valve. Escape or reserve time available from this air bank is typically much greater than what is required.

[CAUTION: No breathing air system will increase the oxygen content of the air being processed. Therefore, the air intake should be located in a clean air environment where the ambient atmospheric oxygen content is guaranteed. The intake system of any compressor operates at negative pressures. Therefore, no part of the intake system of any compressor should be located within the asbestos removal work zone.]

C. High-Pressure Prepumped Air Storage Cylinders

Sufficient breathing air for small jobs may be supplied by using prepumped high-pressure cylinders containing Grade D or better air. These cylinders may be obtained from many commercial suppliers, the same sources as for the standby reserve system in the low pressure system. The air source may also be the prepumped air bank obtained from the high-pressure breathing air system. Using such prepumped high-pressure air does not require an on-site compressor. Carbon monoxide (CO) monitoring is required when the cylinders are filled, and therefore no additional carbon monoxide monitoring is needed on the job site.

D. The Ambient Air Pump

The ambient air pump is a low-power (½ HP to 5 HP) pump. These pumps take ambient air and supply it to the respirator through the appropriate hose line. They are not intended to improve the quality of the air being pumped. Ambient air pumps provide output pressures between 8 to 30 psig. They do not provide sufficient pressure to operate any currently approved NIOSH/MSHA pressure-demand, combination SAR/SCBA respirators. Therefore, AMBIENT AIR PUMPS SHOULD **NOT** BE USED WITH THE RESPIRATORS RECOMMENDED BY NIOSH/EPA FOR USE IN ASBESTOS ABATEMENT OPERATIONS.

Appendix G of this guide contains a more detailed discussion of breathing air systems.

Part V SOURCES OF HELP FOR RESPIRATOR USER PROBLEMS

NIOSH recognizes that a respirator user may occasionally find a problem which is identified as a defect in the design and/or performance of a NIOSH/MSHA-approved respirator. The user should report these problems to the manufacturer of the respirator and send a copy to NIOSH. To assist the manufacturer and NIOSH in their investigations, the user should report the following information:

- name, address, and telephone number of reporter
- name of respirator manufacturer
- description and model number of respirator
- approval number of respirator
- name and part number (if known) of defective part
- lot number and/or serial number of respirator and/or defective part
- brief description of how respirator was used during discovery of defect
- description of defect
- description of how defect adversely affects performance of respirator.

The respirator user should report the defect to the manufacturer, with a copy or supplemental telephone call to NIOSH. The report to NIOSH should be addressed to:

Respirator Problem Coordinator
NIOSH Division of Safety Research
944 Chestnut Ridge Road
Morgantown, WV 26505-2888
Telephone: (304) 291-4595 or FTS 923-4595

The following is an up-to-date list of the names and addresses of persons who are responsible for investigation of problems with MSHA/NIOSH-certified respirators. Users may periodically contact NIOSH at the above address for updated information.

Mr. William Washburn
AGA Corportation
550 County Avenue
Secaucus, NJ 07094

Mr. Mark Theno
Air-Tek Company
6472 Flying Cloud Drive
Eden Prairie, MN 55344

Mr. Joseph Zdrok
American Optical Corp.
14 Mechanic Street
Southbridge, MA 01550

Mr. Raymond O. Day
Mr. Robert Meyer
Binks Manufacturing Co.
9201 W. Belmont Ave.
Franklin Park, IL 60131

Mr. W.F. Moon
H.S. Cover Co.
107 East Alexander St.
Buchanan, MI 49107

Mr. S.B. Shearer
CSE Corporation
600 Seco Road
Monroeville, PA 15146

Mr. Carl M. Fink
Defense Apparel
285 Murphy Road
Hartford, CT 06114

Dr. Helmut Siebar
Draegerwerk AG Lubeck
Postfach 1339
2400 Lubeck 1
Federal Republic of Germany

Mr. Steve Boro
E.D. Bullard Company
2680 Bridgeway
Sausalito, CA 94965

Mr. Marc Cooper
Cesco Safety Prod./Parmalee Ind.
U.S. Safety Service Co.
P.O. Box 1237
Kansas City, MO 64141

Mr. Martin Ziegler
Mr. Ronald J. DeMeo
Clifton Precision
Division of Litton Ind.
P.O. Box 305
Frederica, DE 19946

Mr. Donald M. Dawson
International Safety Instruments, Inc.
P.O. Box 846
Lawrenceville, GA 30246

Mr. Bengt Sjard
Interspiro AB
S-181 81 LIDINGO
SWEDEN

Mr. Ron Theerin
Lancs Industries
12704 N.E. 124th Street
Kirkland, WA 98033-4091

Mr. Robert E. Arroyo
Masprot Safety Products Corp.
2655 Le Jeune Road, Suite 302
Coral Gables, FL 33134

Mr. T.D. McConnell
Mine Safety Appliances Company
600 Penn Center Boulevard
Pittsburgh, PA 15235

Mr. Donald P. Wilmes
3M Company 3M Center
Building 230-B-06
St. Paul, MN 55144

Mr. Albert Mintz
Moldex/Metrics, Incorporated
4671 Leahy Street
Culver City, CA 90230

Mr. Les Boord
Mr. Wes Kenneweg
National Draeger, Inc.
P.O. Box 120
Pittsburgh, PA 15230

Mr. Willie Yung
Louis M. Gerson Company
15 Sproat Street
Middleboro, MA 02346

Mr. Joel Kaufman
Glendale Optical Co.
130 Crossways Park Drive
Woodbury, NY 11797

Mr. Stephen H. Bates
Globe Safety Equipment, Inc.
P.O. Box 7248
Dayton, OH 45407

Mr. Earl B. Jacobson
Nuclear Power Outfitters
P.O. Box 84
Crystal Lake, IL 60014

Mr. Pat Droppleman
Ocenco, Incorporated
400 Academy Drive
Northbrook, IL 60062

Mr. F. Levi-Senlgaglia
Pirelli Industrial Products
6 Ram Ridge Road
Spring Valley, NY 10977

Mr. Ing G. Cappa
Sekur S.P.A. — Pirelli Group
Via di Torrespaccata, 140
00169 Roma, ITALY

Mr. M.D. Shroff
Pradeep Raja Bahadur Motilai Mansion
1st Floor 11/43 Tamarind Street
Fort Bombay — 400023, INDIA

Mr. Jay Parker
Pulmosan Safety Equipment Corp.
30-48 Linden Place
Flushing, NY 11354

Mr. Donald Burd
Racal Airstream, Inc.
7309A Grove Road
Frederick, MD 21701

Mr. Justin Mills
Rexnord Safety Products
45 Great Valley Parkway
Malvaern, PA 19355

Mr. Stephen C. Smith
National Mine Service Company
600 N. Bell Ave., Bldg. 2, Suite 110
Carnegie, PA 15106

Mr. Ken Vaughn
Neoterik Health Tech., Inc.
P.O. Box 78
Mt. Airy, MD 21771

Ms. C.E. Chappron
North Safety Equipment
2000 Plainfield Pike
Cranston, RI 02920

Mr. Ian V. Maxwell
Sabre Safety, Ltd.
Ash Road, Alershot
Hampshire, GU12 4DD
England

Mr. Paul McConnaughey
Safety and Supply Co
5510 East Marginal Way South
Seattle, WA 98134

Mr. Robert Brennan
Scott Aviation
225 Erie Street
Lancaster, NY 14086

Mr. Larry Schaefer
Standard Safety Equipment Corp.
P.O. Box 188
Palatine, IL 60067

Mr. Walter Anderson
Robertshaw Controls Co.
33 North Euclid Way
Anaheim, CA 92803

Mr. Gerald S. Gilbert
Romiro Technology
3500 Carnegie Avenue
Cleveland, OH 44115

Ms. Antonette Bonfiglio
(Air-purifying respirators)
U.S.D. Corp.
3323 West Warner Ave.
Santa Ana, CA 92702

Dr. Richard Stein
(Atmosphere-supplying respirators)
U.S.D. Corp
3323 West Warner Ave.
Santa Ana, CA 92702

Mr. David Koch
Willson Safety Products
P.O. Box 622
Reading, PA 19603

Mr. Simon Kugler
Siebe Gorman, Ltd.
Avondale Way, Cwmbran, Gwent, Wales
NP4 1 YR, Great Britian

Mine Safety and Health Administration

Mr. Kenneth P. Klouse
MSHA Approval and Certification Center
P.O. Box 251, Route 1
Triadelphia, WV 26059

Appendix A.
Applicable Federal Regulations

Appendix A1. Occupational Health and Safety (OSHA) Asbestos Regulations (29 CFR 1910.1001)

1910.1001 ASBESTOS

(a) DEFINITIONS

For the purpose of this section,

(1) "Asbestos" includes chrysotile, amosite, crocidolite, tremolite, anthophyllite, and actinolite.

(2) "Asbestos fibers" means asbestos fibers longer than 5 micrometers.

(b) PERMISSIBLE EXPOSURE TO AIRBORNE CONCENTRATIONS OF ASBESTOS FIBERS

(1) *Standard effective July 7, 1972.* The 8-hour, time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed five fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(2) *Standard effective July 1, 1976.* The 8-hour, time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed two fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(3) *Ceiling concentation.* No employee shall be exposed at any time to airborne concentrations of asbestos fibers in excess of 10 fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(c) METHODS OF COMPLIANCE

(1) Engineering Methods

(i) Engineering controls. Engineering controls, such as, but not limited to, isolation, enclosure, exhaust ventilation, and dust collection, shall be used to meet the exposure limits prescribed in paragraph (b) of this section.

(ii) Local Exhaust Ventilation

(a) Local exhaust ventilation and dust collection systems shall be designed, constructed, installed, and maintained in accordance with the American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1971, which is incorporated by reference herein.

(b) See Section 1910.6 concerning the availability of ANSI-Z9.2-1971, and the maintenance of a historic file in connection therewith. The address of the American National Standards Institute is given in Section 1910.100.

(iii) Particular Tools

All hand-operated and power-operated tools which may produce or release asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, such as, but not limited to, saws, scorers, abrasive wheels, and drills, shall be provided with local exhaust ventilation systems in accordance with subdivision (ii) of this subparagraph.

(2) Work Practices

(i) Wet methods. Insofar as practicable, asbestos shall be handled, mixed, applied, removed, cut, scored, or otherwise worked in a wet state sufficient to prevent the emission of airborne fibers in excess of the exposure limits prescribed in paragraph (b) of this section, unless the usefulness of the product would be diminished thereby.

(ii) Particular products and operations. No asbestos cement, mortar, coating, grout, plaster, or similar material containing asbestos shall be removed from bags, cartons, or other

containers in which they are shipped, without being either wetted, or enclosed, or ventilated so as to prevent effectively the release of airborne asbestos fibers in excess of the the limits prescribed in paragraph (b) of this section.

(iii) Spraying, demolition, or removal. Employees engaged in the spraying of asbestos, the removal, or demolition of pipes, structures, or equipment covered or insulated with asbestos, and in the removal or demolition of asbestos insulation or coverings shall be provided with respiratory equipment in accordance with paragraph (d)(2)(iii) of this section and with special clothing in accordance with paragraph (d)(3) of this section.

(d) PERSONAL PROTECTIVE EQUIPMENT

(1) **Compliance with the exposure limits prescribed by paragraph (b) of this section may not be achieved by the use of respirators or shift rotation of employees, except:**

(i) During the time period necessary to install the engineering controls and to institute the work practices required by paragraph (c) of this section;

(ii) In work situations in which the methods prescribed in paragraph (c) of this section are either technically not feasible or feasible to an extent insufficient to reduce the airborne concentrations of asbestos fibers below the limits prescribed by paragraph (b) of this section; or

(iii) In emergencies.

(iv) Where both respirators and personal rotation are allowed by paragraphs (d)(1)(i), (ii), or (iii) of this section, and both are practicable, personnel rotation shall be preferred and used.

(2) **Where a respirator is permitted by paragraph (d)(1) of this section, it shall be selected from among those approved by the Bureau of Mines, Department of the Interior, or the National Institute for Occupational Safety and Health, Department of Health, Education, and Welfare, under the provisions of 30 CFR Part 11, Number II (37 FR 6244, March 25, 1972), and shall be used in accordance with subdivisions (i), (ii), (iii), and (iv) of this subparagraph.**

(i) Air purifying respirators. A reusable or single use air purifying respirator, or a respirator described in paragraph (d)(2)(ii) or (iii) of this section, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed no more than 10 times those limits.

(ii) Powered air purifying respirators. A full facepiece powered air purifying respirator, or a powered air purifying respirator, or a respirator described in paragraph (d)(2)(iii) of this section, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour time-weighted average concentrations of asbestos fibers are reasonably expected to exceed 10 times, but not 100 times, those limits.

(iii) Type "C" supplied-air respirators, continous flow or pressure-demand class. A type "C" continuous flow or pressure-demand, supplied air respirator shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed 100 times those limits.

(iv) Establishment of a Respirator Program

(a) The employer shall establish a respirator program in accordance with the requirements of the American National Standard Practices for Respiratory Protection, ANSI Z88.2-1969, which is incorporated by reference herein.

(b) See Section 1910.6 concerning the availability of ANSI Z88.2-1969 and the maintenance of an historic file in connection therewith. The address of the American

National Standards Institute is given in Section 1910.100.

(c) No employee shall be assigned to tasks requiring the use of respirators if, based upon his most recent examination, an examining physician determines that the employee will be unable to function normally wearing a respirator, or that the safety or health of the employee or other employees will be impaired by his use of the respirator. Such employee shall be rotated to another job or given the opportunity to transfer to a different position whose duties he is able to perform with the same employer, in the same geographical area and with the same seniority, status, and rate of pay he had just prior to such transfer, if such a different position is available.

(3) Special Clothing: **The employer shall provide, and require the use of, special clothing, such as coveralls or similar whole body clothing, head coverings, gloves, and foot coverings for any employee exposed to airborne concentrations of asbestos fibers, which exceed the ceiling level prescribed in paragraph (b) of this section.**

(4) Change rooms:

(i) At any fixed place of employment exposed to airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, the employer shall provide change rooms for employees working regularly at the place.

(ii) Clothes Lockers: The employer shall provide two separate lockers or containers for each employee, so separated or isolated as to prevent contamination of the employee's street clothes from his work clothes.

(iii) Laundering:

(a) Laundering of asbestos-contaminated clothing shall be done so as to prevent the release of air-borne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(b) Any employer who gives asbestos-contaminated clothing to another person for laundering shall inform such person of the requirement in paragraph (d)(4)(iii)(a) of this section to effectively prevent the release of airborne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(c) Contaminated clothing shall be transported in sealed impermeable bags, or other closed, impermeable containers, and labeled in accordance with paragraph (g) of this section.

(e) METHOD OF MEASUREMENT

All determinations of airborne concentrations of asbestos fibers shall be made by the membrane filter method at 400 - 450 x (magnification)(4 millimeter objective) with phase contrast illumination.

(f) MONITORING

(1) *Initial determinations.* **Within 6 months of the publication of this section, every employer shall cause every place of employment where asbestos fibers are released to be monitored in such a way as to determine whether every employee's exposure to asbestos fibers is below the limits prescribed in paragraph (b) of this section. If the limits are exceeded, the employer shall immediately undertake a compliance program in accordance with paragraph (c) of this section.**

(2) Personal Monitoring

(i) Samples shall be collected from within the breathing zone of the employees, on membrane filters of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(*ii*) Sampling frequency and patterns. After the initial determinations required by paragraph (f)(1) of this section, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of employees. In no case shall the sampling be done at intervals greater than 6 months for employees whose exposure to asbestos may reasonably be foreseen to exceed the limits prescribed by paragraph (b) of this section.

(3) Environmental Monitoring

(*i*) Samples shall be collected from areas of a work environment which are representative of the airborne concentrations of asbestos fibers which may reach the breathing zone of employees. Samples shall be collected on a membrane filter of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(*ii*) *Sampling frequency and patterns.* After the initial determinations required by paragraph (f)(1) of this section, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of the employees. In no case shall sampling be at intervals greater than 6 months for employees whose exposures to asbestos may reasonably be foreseen to exceed the exposure limits prescribed in paragraph (b) of this section.

(4) *Employee observation of monitoring.* Affected employees, or their representatives, shall be given a reasonable opportunity to observe any monitoring required by this paragraph and shall have access to the records thereof.

(g) CAUTION SIGNS AND LABELS

(1) Caution Signs

(*i*) *Posting.* Caution signs shall be provided and displayed at each location where airborne concentrations of asbestos fibers may be in excess of the exposure limits prescribed in paragraph (b) of this section. Signs shall be posted at such a distance from such a location so that an employee may read the signs and take necessary protective steps before entering the area marked by the signs. Signs shall be posted at all approaches to areas containing excessive concentrations of airborne asbestos fibers.

(*ii*) *Sign specifications.* The warning signs required by paragraph (g)(1)(i) of this section shall conform to the requirements of 20″ x 14″ vertical format signs specified in Section 1910.145(d)(4), and to this subdivision. The signs shall display the following legend in the lower panel, with letter sizes and styles of a visibility at least equal to that specified in this subdivision.

LEGEND	NOTATION
Asbestos	1″ Sans Serif, Gothic or Block
Dust Hazard..........................	¾″ Sans Serif, Gothic or Block
Avoid Breathing Dust	¼″ Gothic
Wear Assigned Protective Equipment......	¼″ Gothic
Do Not Remain in Area Unless Your Work Requires It	¼″ Gothic
Breathing Asbestos Dust May be Hazardous to Your Health	14 Point Gothic

Spacing between lines shall be at least equal to the height of the upper of any two lines.

(2) Caution Labels

(i) *Labeling.* Caution labels shall be affixed to all raw materials, mixtures, scrap, waste, debris, and other products containing asbestos fibers, or to their containers, except that no label is required where asbestos fibers have been modified by a bonding agent, coating, binder, or other material so that during any reasonably foreseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section will be released.

(ii) *Label specifications.* The caution labels required by paragraph (g)(2)(i) of this section shall be printed in letters of sufficient size and contrast as to be readily visible and legible. The label shall state:

CAUTION
Contains Asbestos Fibers
Avoid Creating Dust
Breathing Asbestos Dust May Cause
Serious Bodily Harm

(h) HOUSEKEEPING

(1) *Cleaning.* All external surfaces in any place of employment shall be maintained free of accumulations of asbestos fibers if, with their dispersion, there would be an excessive concentration.

(2) *Waste disposal.* Asbestos waste, scrap, debris, bags, containers, equipment, and asbestos-contaminated clothing, consigned for disposal, which may produce in any reasonably foreseeable use, handling, storage, processing, disposal, or transportation airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section shall be collected and disposed of in sealed impermeable bags, or other closed, impermeable containers.

(i) RECORDKEEPING

(1) *Exposure records.* Every employer shall maintain records of any personal or environmental monitoring required by this section. Records shall be maintained for a period of at least 20 years and shall be made available upon request to the Assistant Secretary of Labor for Occupational Safety and Health, the Director of the National Institute for Occupational Safety and Health, and to authorized representatives of either.

(2) *Access.* Employee exposure records required by this paragraph shall be provided upon request to employees, designated representatives, and the Assistant Secretary in accordance with 29 CFR 1910.20 (a)-(e) and (g)-(i).

(3) *Employee notification.* Any employee found to have been exposed at any time to airborne concentrations of asbestos fibers in excess of the limits prescribed in paragraph (b) of this section shall be notified in writing of the exposure as soon as practicable but not later than 5 days of the finding. The employee shall also be timely notified of the corrective action being taken.

(j) MEDICAL EXAMINATIONS

(1) *General.* The employer shall provide or make available at his cost, medical examinations relative to exposure to asbestos required by this paragraph.

(2) *Preplacement.* The employer shall provide or make available to each of his employees, within 30 calendar days following his first employment in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination, which shall include, as a minimum, a chest roetgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV 1.0).

(3) *Annual examinations.* On or before January 31, 1973, and at least annually thereafter, every employer shall provide, or make available, comprehensive medical examinations to each of his employees engaged in occupations exposed to airborne concentrations of asbestos fibers. Such annual examination shall include, as a minimum, a chest roetgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV 1.0).

(4) *Termination of employment.* The employer shall provide, or make available, within 30 calendar days before or after the termination of employment of any employee engaged in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination which shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second (FEV 1.0).

(5) *Recent examinations.* No medical examination is required of any employee, if adequate records show that the employee has been examined in accordance with this paragraph with the past 1-year period.

(6) Medical Records.

(i) *Maintenance.* Employers of employees examined pursuant to this paragraph shall cause to be maintained complete and accurate records of all such medical examinations. Records shall be retained by employers for at least 20 years.

(ii) *Access.* Records of the medical examinations required by this paragraph shall be provided upon request to employees, designated representatives, and the Assistant Secretary in accordance with 29 CFR 1910.20 (a)-(e) and (g)-(i). These records shall also be provided upon the request to the Director of NIOSH. Any physician who conducts a medical examination required by this paragraph shall furnish to the employer of the examined employee all the information specifically required by this paragraph, and any other medical information related to occupational exposure to asbestos fibers.

Appendix A2. Occupational Safety and Health Administration (OSHA) Respiratory Protection (29 CFR 1910.134)

1910.134 RESPIRATORY PROTECTION

(a) PERMISSIBLE PRACTICE

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

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

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

(b) REQUIREMENTS FOR A MINIMAL ACCEPTABLE PROGRAM

(1) Written standard operating procedures governing the selection and use of respirators shall be established.

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

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

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

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

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

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

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

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

(10) Persons should not be assigned to tasks requiring use of respirators unless it has been determined that they are physically able to perform the work and use the equipment. The local physician shall determine what health and physical conditions are pertinent. The respirator user's medical status should be reviewed periodically (for instance, annually).

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

(c) SELECTION OF RESPIRATORS

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

(d) AIR QUALITY

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

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

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

(ii) The compressor for supplying air shall be equipped with necessary safety and standby devices. A breathing air-type compressor shall be used. Compressors shall be constructed and situated so as to avoid entry of contaminated air into the system and suitable in-line air-purifying sorbent beds and filters installed to further assure breathing air quality. A receiver of sufficient capacity to enable the respirator wearer to escape from a contaminated atmosphere in event of compressor failure, and alarms to indicate compressor failure and overheating shall be installed in the system. If an oil-lubricated compressor is used, it shall have a high-temperature or carbon monoxide alarm, or both. If only a high-temperature alarm is used, the air from the compressor shall be frequently tested for carbon monoxide to insure that it meets the specifications in paragraph (d)(1) of this section.

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

(4) Breathing gas containers shall be marked in accordance with American National Standard Method of Marking Portable Compressed Gas Containers to Identify the Material Contained, Z48.1-1954; Federal Specification BB-A-1034a, June 21, 1968, Air, Compressed for Breathing Purposes; or Interim Federal Specification GG-B-00675b, April 27, 1965, Breathing Apparatus, Self-Contained.

(e) USE OF RESPIRATORS

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

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

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

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

the proper rescue equipment to be able to assist the other(s) in case of emergency.

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

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

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

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

(i) Every respirator wearer shall receive fitting instructions including demonstrations and practice in how the respirator should be worn, how to adjust it, and how to determine if it fits properly. Respirators shall not be worn when conditions prevent a good face seal. Such conditions may be a growth of beard, sideburns, a skull cap that projects under the face-piece, or temple pieces on glasses. Also, the absence of one or both dentures can seriously affect the fit of a facepiece. The worker's diligence in observing these factors shall be evaluated by periodic check. To assure proper protection, the facepiece fit shall be checked by the wearer each time he puts on the respirator. This may be done by following the manufacturer's facepiece fitting instructions.

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

(iii) If corrective spectacles or goggles are required, they shall be worn so as not to affect the fit of the facepiece. Proper selection of equipment will minimize or avoid this problem.

(f) MAINTENANCE AND CARE OF RESPIRATORS

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

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

(ii) Cleaning and disinfecting,

(iii) Repair,

(iv) Storage

Equipment shall be properly maintained to retain its original effectiveness.

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

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

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

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

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

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

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

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

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

(g) IDENTIFICATION OF GAS MASK CANISTERS

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

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

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

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

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

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

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

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

Table I-1.

ATMOSPHERIC CONTAMINANTS TO BE PROTECTED AGAINST	COLORS ASSIGNED*
Acid gases	White
Hydrocyanic acid gas	White with 1/2 inch green stripe completely around the canister near the bottom
Chlorine gas	White with 1/2 inch yellow stripe completely around the canister near the bottom
Organic vapors	Black
Ammonia Gas	Green
Acid gases and ammonia gas	Green with 1/2 inch white stripe completely around the canister near the bottom
Carbon monoxide	Blue
Acid gases and organic vapors	Yellow
Hydrocyanic acid gas and chloropicrin vapor	Yellow with 1/2 inch blue stripe completely around the canister near the bottom
Acid gases, organic vapors, and ammonia gases	Brown
Radioactive materials, excepting tritium and noble gases	Purple (Magenta)
Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors	Canister color for contaminant, as designated above, with 1/2 inch gray strip completely around the canister near the top.
All of the above atmospheric contaminants	Red with 1/2 inch gray stripe completely around the canister near the top.

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

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

(Secs. 4(b)(2), 6(b) and 8(c), 84 Stat. 1592, 1593, 1596, 29 U.S.C. 653, 655, 657; Secretary of Labor's Order No. 8-76 (41 FR 25059); 29 CFR Part 1911)
(39 FR 23502, June 27, 1974, as amended at 43 FR 49748, Oct. 24, 1978)

Appendix A3. Environmental Protection Agency Regulations Governing Asbestos Abatement Projects (40 CFR 763.120,121)

SUBPART G — ASBESTOS ABATEMENT PROJECTS

763.120 SCOPE

(a) This part extablishes requirements which must be followed during asbestos abatement projects, which include any activity involving the removal, enclosure, or encapsulation of any material containing more than 1 percent asbestos by weight which, when dry, may be crumbled, pulverized, or reduced to powder by hand pressure.

(b) This part applies to all employers of State and local government employees not covered by the Asbestos Standard of the Occupational Safety and Health Administration (OSHA), 29 CFR 1910.1001, or an Asbestos Standard adopted by a State as part of a State plan approved by OSHA under section 18 of the Occupational Safety and Health Act. The rule covers the employees of those employers. The employer is the public department, agency, or entity which hires the employee. This includes, but is not limited to the following examples of public entities: any State, County, City, or other local governmental entity which operates or administers schools, a department of health or human services, a library, a police department, a fire department, or similar public service agencies or offices.

763.121 REGULATORY REQUIREMENTS

(a) Definitions

For the purpose of this section:

(1) "Asbestos" means "the asbestiform varieties of chrysotile (serpentine); crocidolite (riebeckite); amosite (cummingtonite-grunerite); tremolite; anthophyllite, and actinolite."

(2) "Asbestos fibers" means asbestos fibers longer than 5 micrometers.

(b) Permissible exposure to airborne concentrations of asbestos fibers.

(1) Reserved

(2) ***Standard effective July 12, 1985.*** The 8-hour time-weighted average airborne concentrations of asbestos fibers to which any employee may be exposed shall not exceed two fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(3) ***Ceiling concentration.*** No employee shall be exposed at any time to airborne concentrations of asbestos fibers in excess of 10 fibers, longer than 5 micrometers, per cubic centimeter of air, as determined by the method prescribed in paragraph (e) of this section.

(c) Methods of compliance

(1) ***Engineering methods***

(i) *Engineering controls.* Engineering controls, such as, but not limited to, isolation, enclosure, exhaust ventilation, and dust collection, shall be used to meet the exposure limits prescribed in paragraph (b) of this section.

(ii) Local exhaust ventilation.

(A) Local exhaust ventilation and dust collection systems shall be designed, constructed, installed, and maintained in accordance with the American National Standard Fundamentals Governing the Design and Operation of Local Exhaust Systems, ANSI Z9.2-1979, (Revision of ANSI Z9.2-1971) which is incorporated by reference herein.

(B) ANSI Z9.2-1979 is available for inspection at the Office of the Federal Register Information Center, Rm. 8301, 1100 L St., NW., Washington, DC 20408. This incorporation by reference was approved by the Director of the Office of the Federal Register. This material is incorporated as it exists on the date of approval and a notice of any change in this material will be published in the **Federal Register.** Copies of the incorporated material may be obtained from the Document Control Officer (TS-793), Office of Toxic Substances, EPA, Rm. 107, 401 M St., SW., Washington, DC 20460, and from the American National Standards Institute, 1430 Broadway, New York, NY, 10018 (212-354-3473).

(*iii*) *Particular tools.* All hand-operated and power-operated tools which may produce or release asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, such as, but not limited to, saws, scorers, abrasive wheels, and drills, shall be provided with local exhaust ventilation systems in accordance with paragraph (c) (1) (ii) of this section.

(2) ***Work practices —***

(*i*) *Wet methods.* Insofar as practicable, asbestos shall be handled, mixed, applied, removed, cut, scored, or otherwise worked in a wet state sufficient to prevent the emission of airborne fibers in excess of the exposure limits prescribed in paragraph (b) of this section, unless the usefulness of the product would be diminished thereby.

(*ii*) *Particular products and operations.* No asbestos cement, mortar, coating, grout, plaster, or similar material containing asbestos shall be removed from bags, cartons, or other containers in which they are shipped, without being either wetted, or enclosed, or ventilated so as to prevent effectively the release of airborne asbestos fibers in excess of the limits prescribed in paragraph (b) of this section.

(*iii*) *Spraying, demolition, or removal.* Employees engaged in the spraying of asbestos, the removal, or demolition of pipes, structures, or equipment covered or insulated with asbestos, and in the removal or demolition of asbestos insulation or coverings shall be provided with respiratory equipment in accordance with paragraph (d) (2) (iii) of this section and with special clothing in accordance with paragraph (d) (3) of this section.

(d) Personal protective equipment

(1) Compliance with the exposure limits prescribed by paragraph (b) of this section may not be achieved by the use of respirators or shift rotation of employees, except:

(*i*) During the time period necessary to install the engineering controls and to institute the work practices required by paragraph (c) of this section;

(*ii*) In work situations in which the methods prescribed in paragraph (c) of this section are either technically not feasible or feasible to an extent insufficient to reduce the airborne concentrations of asbestos fibers below the limits prescribed by paragraph (b) of this section; or

(*iii*) In emergencies.

(2) Where a respirator is permitted by paragraph (d)(1) of this section, it shall be selected from among those approved by the Bureau of Mines, Department of the Interior, or the National Institute for Occupational Safety and Health, Department of Health, Education, and Welfare, under the provisions of 30 CFR Part 11 (37 FR 6244, Mar. 25, 1972), and shall be used in accordance with paragraph (d)(2)(i), (ii), (iii), and (iv) of this section.

(*i*) *Air purifying respirators.* A reusable or single use air purifying respirator, or a respirator described in paragraph (d)(2)(ii) or (iii) of this section, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed no more than 10 times those limits.

(ii) Powered air purifying respirators. A full facepiece powered air purifying respirator, or a powered air purifying respirator, or a respirator described in paragraph (d)(2)(iii) of this section, shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour time-weighted average concentrations of asbestos fibers are reasonably expected to exceed 10 times, but not 100 times, those limits.

(iii) Type "C" supplied-air respirators, continuous flow or pressure-demand class. A type "C" continuous flow or pressure-demand, supplied-air respirator shall be used to reduce the concentrations of airborne asbestos fibers in the respirator below the exposure limits prescribed in paragraph (b) of this section, when the ceiling or the 8-hour time-weighted average airborne concentrations of asbestos fibers are reasonably expected to exceed 100 times those limits.

(iv) Establishment of a respirator program.

(A) The employer shall establish a respirator program in accordance with the requirements of the American National Standard Practices for Respiratory Protection, ANSI Z88.2-1980 (Revision of ANSI Z88.2-1969), which is incorporated by reference herein.

(B) ANSI Z88.2-1980 is available for inspection at the Office of the Federal Register Information Center, Rm. 8301, 1100 L St., NW., Washington, DC 20408. This incorporation by reference was approved by the Director of the Office of the Federal Register. This material is incorporated as it exists on the date of approval and a notice of any change in this material will be published in the **Federal Register**. Copies of the incorporated material may be obtained from the Document Control Officer (TS-793), Office of Toxic Substances, EPA, Rm. 107, 401 M St., SW., Washington, DC 20460, and from the American National Standards Institute, 1430 Broadway, New York, NY 10018, (212-354-3473).

(C) No employee shall be assigned to tasks requiring the use of respirators if, based upon his most recent examination, an examining physician determines that the employee will be unable to function normally wearing a respirator, or that the safety or health of the employee or other employees will be impaired by his use of a respirator. Such employee shall be rotated to another job or given the opportunity to transfer to a different position whose duties he is able to perform with the same employer, in the same geographical area and with the same seniority, status, and rate of pay he had just prior to such transfer, if such a different position is available.

(3) ***Special Clothing.*** The employer shall provide, and require the use of, special clothing, such as coveralls or similar whole body clothing, head coverings, gloves and foot coverings for any employee exposed to airborne concentrations of asbestos fibers, which exceed the ceiling level prescribed in paragraph (b) of this section.

(4) ***Change rooms.***

(i) At any fixed place of employment exposed to airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section, the employer shall provide change rooms for employees working regularly at the place.

(ii) Clothes lockers. The employee shall provide two separate lockers or containers for each employee, so separated or isolated as to prevent contamination of the employee's street clothes from his work clothes.

(iii) Laundering.

(A) Laundering of asbestos contaminated clothing shall be done so as to prevent the release of airborne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(B) Any employer who gives asbestos contaminated clothing to another person for laundering shall inform such person of the requirement in paragraph (d)(4)(iii)(A) of this section to effectively prevent the release of airborne asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section.

(C) Contaminated clothing shall be transported in sealed impermeable bags, or other closed, impermeable containers, and labeled in accordance with paragraph (g) of this section.

(e) ***Method of measurement.*** **All determinations of airborne concentrations of asbestos fibers shall be made by the membrane filter method at 400 - 450 x (magnification)(4 millimeter objective) with phase contrast illumination.**

(f) ***Monitoring***

(1) *Initial determinations.* Every employer shall cause every place of employment where asbestos fibers are released to be monitored in such a way as to determine whether every employee's exposure to asbestos fibers is below the limits prescribed in paragraph (b) of this section. If the limits are exceeded, the employer shall immediately undertake a compliance program in accordance with paragraph (c) of this section.

(2) *Personal monitoring.*

(i) Samples shall be collected from within the breathing zone of the employees, on membrane filters of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(ii) Sampling frequency and patterns. After the initial determinations required by paragraph (f)(1) of this section, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of employees.

(3) *Environmental monitoring.*

(i) Samples shall be collected from areas of a work environment which are representative of the airborne concentrations of asbestos fibers which may reach the breathing zone of employees. Samples shall be collected on a membrane filter of 0.8 micrometer porosity mounted in an open-face filter holder. Samples shall be taken for the determination of the 8-hour time-weighted average airborne concentrations and of the ceiling concentrations of asbestos fibers.

(ii) Sampling frequency and patterns. After the initial determinations required by paragraph (f)(1) of this section, samples shall be of such frequency and pattern as to represent with reasonable accuracy the levels of exposure of the employees.

(4) ***Employee observation of monitoring.*** Affected employees, or their representatives, shall be given a reasonable opportunity to observe any monitoring required by this paragraph and shall have access to the records thereof.

(g) ***Caution signs and labels***

(1) *Caution signs.*

(i) Posting. Caution signs shall be provided and displayed at each location where airborne concentrations of asbestos fibers may in excess of the exposure limits prescribed in paragraph (b) of this section. Signs shall be posted at such a distance from such a location so than an employee may read the signs and take necessary protective steps before entering the area marked by the signs. Signs shall be posted at all approaches to areas containing excessive concentrations of airborne asbestos fibers.

(ii) Sign specifications. The warning signs required by paragraph (g)(1)(i) of this section shall conform to the requirements of 20" x 14" vertical format signs specified in 29 CFR 1910.145 (d)(4), and to this paragraph (g)(1)(ii). The signs shall display the following legend in the lower panel, with letter sizes and styles of a visibility at least equal to that specified in this paragraph (g)(1)(ii).

LEGEND	NOTATION
Asbestos	1" Sans Serif, Gothic or Block
Dust Hazard	¾" Sans Serif, Gothic or Block
Avoid Breathing Dust	¼" Gothic
Wear Assigned Protective Equipment	¼" Gothic
Do Not Remain in Area Unless Your Work Requires It	¼" Gothic
Breathing Asbestos Dust May be Hazardous to Your Health	14 Point Gothic

Spacing between lines shall be at least equal to the height of the upper of any two lines.

(2) ***Caution labels.***

(i) Labeling. Caution labels shall be affixed to all raw materials, mixtures, scrap, waste, debris, and other products containing asbestos fibers, or to their containers, except that no label is required where asbestos fibers have been modified by a bonding agent, coating, binder, or other material so that during any reasonably foreseeable use, handling, storage, disposal, processing, or transportation, no airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section will be released.

(ii) Label specifications. The caution labels required by paragraph (g)(2)(i) of this section shall be printed in letters of sufficient size and contrast to be readily visible and legible. The label shall state:

CONTAINS ASBESTOS FIBERS
AVOID CREATING DUST
BREATHING ASBESTOS DUST MAY CAUSE
SERIOUS BODILY HARM

(h) ***Housekeeping***

(1) ***Cleaning.*** All external surfaces in any place of employment shall be maintained free of accumulations of asbestos fibers if, with their dispersion, there would be an excessive concentration.

(2) ***Waste disposal.*** Asbestos waste, scrap, debris, bags, containers, equipment, and asbestos-contaminated clothing, consigned for disposal, which may produce in any reasonably foreseeable use, handling, storage, processing, disposal, or transportation airborne concentrations of asbestos fibers in excess of the exposure limits prescribed in paragraph (b) of this section shall be collected and dispose of in sealed impermeable bags, or other closed, impermeable containers.

(i) ***Recordkeeping***

(1) ***Exposure records.*** Every employer shall maintain records of any personal or environmental monitoring required by this section. Records shall be maintained for a period of at least 20 years and shall be made available upon request to the Environmental Protection Agency, the Assistant Secretary of Labor for Occupational Safety and Health, the Director of the National Institute for Occupational Safety and Health, and to authorized representatives of either.

(2) ***Employee access.*** Every employee and former employee shall have reasonable access to any record required to be maintained by paragraph (i)(1) of this section, which indicates the employee's own exposure to asbestos fibers.

(3) ***Employee notification.*** Any employee found to have been exposed at any time to airborne concentrations of asbestos fibers in excess of the limits prescribed in paragraph (b) of this section shall be notified in writing of the exposure as soon as practicable but not later than 5 days of the finding. The employee shall also be timely notified of the corrective action being taken.

(j) *Medical examinations*

(1) ***General.*** The employer shall provide or make available at his cost, medical examinations relative to exposure to asbestos required by this paragraph.

(2) ***Preplacement.*** The employer shall provide or make available to each of his employees, with 30 calendar days following his first employment in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination, which shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second ($FEV_{1.0}$).

(3) ***Annual examinations.*** On or before July 14, 1986, and at least annually thereafter, every employer shall provide, or make available, comprehensive medical examinations to each of his employees engaged in occupations exposed to airborne concentrations of asbestos fibers. Such annual examination shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomaltology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second ($FEV_{1.0}$).

(4) ***Termination of employment.*** The employer shall provide, or make available, within 30 calendar days before or after the termination of employment of any employee engaged in an occupation exposed to airborne concentrations of asbestos fibers, a comprehensive medical examination which shall include, as a minimum, a chest roentgenogram (posterior-anterior 14 x 17 inches), a history to elicit symptomatology of respiratory disease, and pulmonary function tests to include forced vital capacity (FVC) and forced expiratory volume at 1 second ($FEV_{1.0}$).

(5) ***Recent examinations.*** No medical examination is required of any employee, if adequate records show that the employee has been examined in accordance with this paragraph within the past 1-year period.

(6) *Medical records.*

(*i*) *Maintenance.* Employers of employees examined pursuant to this paragraph shall cause to be maintained complete and accurate records of all such medical examinations. Records shall be retained by employers for at least 20 years.

(*ii*) *Access.* The contents of the records of the medical examinations required by this paragraph shall be made available, for inspection and copying, to the Environmental Protection Agency, the Assistant Secretary of Labor for Occupational Safety and Health, the Director of NIOSH, to authorized physicians and medical consultants of either of them, and, upon the request of an employee or former employee, to this physician. Any physician who conducts a medical examination required by this paragraph shall furnish to the employer of the examined employee all the information specifically required by this paragraph, and any other medical information related to occupational exposure to asbestos fibers.

Appendix B.
Fit Testing Procedures

Appendix B1. Qualitative Fit Test Procedures

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

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

I. ISOAMYL ACETATE PROTOCOL

A. Odor Threshold Screening

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

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

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

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

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

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

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

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

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

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

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

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

B. Respirator Selection

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

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

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

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

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

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

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

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

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

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

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

C. **Fit test.**

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

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

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

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

   Test Exercises

   i. Normal breathing.

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

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

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

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

   Rainbow Passage

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

   vi. Normal breathing.

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

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

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

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

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

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

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

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

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

II. SACCHARIN SOLUTION AEROSOL PROTOCOL

A. Taste threshold screening.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

B. Respirator selection.

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

C. Fit test.

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

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

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

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

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

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

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

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

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

   i. Normal breathing.

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

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

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

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

   Rainbow Passage

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

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

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

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

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

III. IRRITANT FUME PROTOCOL

A. Respirator selection.

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

B. Fit test.

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

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

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

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

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

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

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

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

   i. Normal breathing.

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

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

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

   v. Talking—slowly and distinctly, count backwards from 100.

   vi. Normal breathing.

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

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

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

12. Respirators successfully tested by the protocol may be used in contaminated atmospheres up to ten times the PEL. In other words this protocol may be used to assign protection factors not exceeding ten. **[appendix D amended at 48 F.R. 9641, 3/8/83.]**

B2. Quantitative Fit Testing Procedures

[Note: The following procedures were adapted from A Guide to Industrial Respiratory Protection, DHEW (NIOSH) Publication No. 76-189. Further information can be obtained from this publication.]

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

I. PRELIMINARY CHECKOUT PROCEDURES

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

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

II. QUANTITATIVE FITTING TEST PROCEDURES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Normal Breathing	NB
Deep Breathing	DB
Turning Head From Side To Side	TH
Moving Head Up And Down	UD
Talking	T

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

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

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

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

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

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

24.00/8 = 3.00% peak average penetration.

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

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

1. VERY COMFORTABLE

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

2. COMFORTABLE

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

3. BARELY COMFORTABLE

   Mask can be worn for approximately ½ hour to 1 hour without intolerable discomfort. Some discomfort from pressure.

4. UNCOMFORTABLE

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

5. INTOLERABLE

   Mask cannot be worn at all without discomfort.

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

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

Appendix C.
Sample MSHA/NIOSH Approval Labels

Figure C1. Sample MSHA/NIOSH Approval Label for Pressure Demand SCBA.

PERMISSIBLE

30 Minute

Self Contained Pressure Demand

Compressed Air Breathing Apparatus

United States Department of Labor
MSHA
Mine Safety and Health Administration

U S Department of Health, Education, and Welfare
Center for Disease Control
NIOSH
National Institute
for Occupational Safety and Health

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

APPROVAL NO. TC-13F-000

ISSUED TO

ABC Company
Anywhere, USA

LIMITATIONS

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

CAUTION

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

MSHA — NIOSH Approval TC-13F-000

Issued to ABC Co., February 31, 2000

The approved assembly consists of the following part numbers:

000-000
000-000
etc.

Figure C2. Sample MSHA/NIOSH Approval Label for Pressure-Demand SAR

PERMISSIBLE

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

United States Department of Labor
MSHA
Mine Safety and Health Administration

U S Department of Health, Education, and Welfare
Center for Disease Control
NIOSH
National Institute for Occupational Safety and Health

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

APPROVAL NO. TC-13F-000

ISSUED TO

ABC Company
Anywhere, U.S.A.

SAMPLE

LIMITATIONS

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

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

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

CAUTION

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

SAMPLE

MSHA — NIOSH Approval TC-13F-000

Issued to ABC Company, February 31, 2000

The approval assembly consists of the following part numbers:

000-000
000-000
etc.

Appendix D.
Selected NIOSH Respirator User Notices

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

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

January 17, 1986

RESPIRATOR USERS NOTICE

Inspection of Certain Aluminum Cylinders for Breathing-gas Pressure

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

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

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

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

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

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

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

MORE

REMINDER

January 17, 1986

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

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

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

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

Change in Address of Manufacturer's Contact

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

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

John B. Moran
Director, Division of Safety Research

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

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

June 28, 1985

RESPIRATOR USERS NOTICE

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

John B. Moran
Director
Division of Safety Research

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

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

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

November 6, 1984

RESPIRATOR USERS' NOTICE

USE OF UNAPPROVED SUBASSEMBLIES

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

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

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

John B. Moran
Director
Division of Safety Research

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

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

December 16, 1983

RESPIRATOR USER'S NOTICE

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

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

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

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

Thomas C. Purcell

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

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

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

December 16, 1983

RESPIRATOR USER'S NOTICE

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

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

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

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

Thomas C. Purcell

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

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

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

March 3, 1983

RESPIRATOR INFORMATION NOTICE

ON

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

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

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

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

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

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

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

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

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

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

November 15, 1982

RESPIRATOR INFORMATION NOTICE ON MSA Powered Air Purifying Respirator

Mine Safety Appliance Company, Pittsburgh, PA
Model Numbers: 463354, 466607, 466608
Approval Number: TC-21C-186

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

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

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

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

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

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

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

Appendix E.
General Safety Considerations

Appendix E. General Safety Considerations

Ronald L. Stanevich
NIOSH Division of Safety Research

This guide was primarily developed to provide recommendations concerning worker respiratory protection within the asbestos abatement industry. However, employers must not lose sight of the safety hazards their employees are exposed to in performance of their work. Asbestos abatement operations can take place in a variety of industrial, commercial and public settings. Each has unique potential safety hazards that the employer must control. However, nearly all abatement operations have some common safety hazards. With proper job planning and supervision, the employer can control both the health hazards and the safety hazards faced by their workers. The more common safety hazards associated with abatement operations and general recommendations to control them are discussed below. Sources for more specific safety information are listed to supplement and support the applicable OSHA regulatory standards.

I. Elevated Work Surfaces

The nature of asbestos abatement tasks usually requires workers to work from ladders, scaffolds, manlifts, or other elevated surfaces, which creates the potential for fall injuries. Slips and falls from ladders, scaffolds, and other elevated surfaces result in a major portion of the construction industry injuries. Many of these can be prevented by implementing a few control measures:

A. General

(1) Avoid use of makeshift work platforms by providing portable ladders and scaffolds.

(2) Ensure that job-built elevated work surfaces are inspected by a competent person other than the individual who erects it.

(3) Avoid working from elevated surfaces where possible. Consider use of wands for spraying amended water or scrapers with extended handles.

B. Ladders

Eighty percent of ladder-related accidents result form improper use or application.

(1) Workers should face the ladder when climbing up, down, or working from it.

(2) Workers should not carrry objects in their hands while ascending or descending ladders. While working from a ladder they should hold on with at least one hand.

(3) Ladders should not be used as a substitute for planks, runways, or walkboards.

(4) Ladders should be maintained in good condition. Defective ladders should be destroyed so that no one uses them by mistake.

(5) Ladders should have safety feet in good condition to keep the ladder from slipping and cutting through polyethylene floor covers.

(6) Ladder rungs/steps should be kept free of contaminates such as amended water and buildup of asbestos waste.

(7) Employees should work no higher than the fourth step/rung from the top of the ladder.

(8) Employees should not attempt to "reach" distant objects from a ladder; other platforms should be used.

(9) Wood or fiberglass ladders should be provided to help control exposure to electrical hazards.

(10) Employees should not straddle the space between a ladder and another object.

(11) Employees should make a visual inspection of ladders before each shift.

Additional information sources:

"Ladders" — publication no. ISBN 0-919465-05-6

Construction Safety Association of Ontario
74 Victoria Street
Toronto, Ontario Canada M5C 2A5

"Safety Requirements for Portable Wood Ladders" — ANSI A14.1-1982

"Safety Requirements for Job-Made Ladders" — ANSI A14.4-1979

"Safety Requirements for Portable Reinforced Plastic Ladders" — ANSI A14.5-1982

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

"Portable Ladders" — Industrial Safety Data Sheet #665

National Safety Council
444 North Michigan Avenue
Chicago Illinois 60611

Environmental Health and Safety Division
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

C. Scaffolds

Falls from scaffolds result in about 2,000 injuries per month in the United States. These can be reduced by:

(1) providing guardrails around the perimeter of the work surface regardless of scaffold height

(2) securing scaffold decks against slippage

(3) keeping scaffold uprights vertical and pinned together when stacked

(4) ensuring vertical members are braced to keep the scaffold plumb and level

(5) decking the entire top portion of the work surface in lieu of using minimum planking dimensions

(6) extending planks at least 6" over their supports and cleating or restraining them from movement

(7) ensuring that manufacturer built-in ladders are in good condition

(8) maintaining mobile scaffold casters in good condition with position locking devices secured when employees are working from the scaffold

(9) keeping mobile scaffolding height less than four times the minimum base dimension and with adequate cross-bracing

(10) never interchanging scaffolding parts from different units

(11) never using defective scaffolding

(12) designating only "competent" persons to perform scaffolding repairs.

Additional information sources:

"Manually Propelled Mobile Ladder Stands and Scaffolds" — ANSI A92.1-1977

"Manually Propelled Elevating Work Platforms" — ANSI A92.3-1980

"Self-Propelled Elevating Work Platforms" — ANSI A92.6

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

II. Electrical Hazards

Asbestos abatement is often related to renovation or remodeling activities. Normally the equipment, machinery, overhead lighting fixtures, and auxiliary furnishings are removed to facilitate the abatement work. However, it is becoming more common that industrial and commercial buildings remain partially occupied while abatement operations are performed. In either situation, the abatement operator must take positive actions to protect employees from accidently coming into contact with energized electrical circuits.

A. General

(1) Perform a pre-work walk-through of the abatement area to look for pre-existing electrical hazards involved with the work.

(2) De-energize as many circuits as possible.

(3) Verify that the circuits have been de-energized with a "Field Current Sensing Device" circuit tester. Either lock out/tag out all de-energized circuits to prevent them from accidentally being energized.

(4) Use non-conductive tools such as scrapers and vacuum attachments made of wood, plastic, or rubber.

(5) Provide workers with non-conductive rubber boots and/or gloves when work must be done around energized wiring or equipment.

(6) Prohibit accumulation of puddles of water on the floor. Workers should be trained in the intelligent use of amended water. No water should be used around energized circuits.

B. Permanent Building Circuitry

(1) Ensure that all permanent circuits are provided with a grounding system. This can be determined with a portable ground tester.

(2) Ensure that electrical outlets are tightly sealed and taped to avoid water spray.

(3) Determine what equipment must remain energized during the abatement process.

(4) Insulate or guard energized equipment and wiring from employee contact and other conductive objects.

(5) Avoid damaging permanent building wiring during the work.

(6) Consider dry removal methods in the vicinity of electrical equipment which must remain energized.

C. Temporary Power

(1) All temporary circuits provided by the abatement operator must be provided with a grounding system and protected by ground fault circuit interrupters.

(2) Avoid stringing temporary wiring across floors.

(3) Elevated wiring should not be fastened with staples, nails, or wire.

(4) Use care not to damage the wiring insulation during installation or abatement work.

D. Electrical Cords and Tools

(1) Provide extension cords which have a ground conductor.

(2) Ensure that cords are not damaged, contain no splices, and that the groung lug on the male plug is intact.

(3) Position extension cords to eliminate stumbling/tripping hazards and to protect them from damage by moving scaffolds.

(4) Provide electrical tools which are either grounded or of the double-insulated type.

(5) Use shatterproof, guarded bulbs and heavy duty wiring for temporary lighting.

(6) Where plugs enter receptacles, ensure that the connection is protected by use of duct tape or by other means.

Additional information sources:

"National Electrical Safety Code" — ANSI C2-1984

"National Electrical Code" — ANSI/NFPA 70-1984

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

"Temporary Electric Wiring for Construction Sites" — Industrial Safety Data Sheet #515

National Safety Council
444 North Michigan Avenue
Chicago, Illinois 60611

III. Housekeeping

Asbestos abatement operations present continuous housekeeping problems. The accumulation of asbestos and other debris on polyethylene-covered floors create employee slipping and tripping hazards. It is essential that accumulation of such debris be bagged and removed from the floor as soon as possible. Even though this activity may initially require more effort, it will make final cleanup easier and the work area safer.

Additional information source:

"Supervisors Safety Manual"

National Safety Council
444 North Michigan Avenue
Chicago, Illinois 60611

IV. Emergency Planning

The abatement operator should develop emergency procedures for fires or severly injured employees. Since abatement work areas must be sealed off, thereby blocking normal exits, the operator must familiarize the workers with procedures for safe exit in case of fire. Furthermore, the operator should develop plans for obtaining emergency aid in case of severe employee injury. The plans should be compatible with decontamination procedures yet provide for quick medical aid.

Additional information source:

Environmental Health and Safety Division
Georgia Tech Research Institute
Georgia Institute of Technology
Atlanta, Georgia 30332

Appendix F.
Heat Stress Considerations

Appendix F. Heat Stress Considerations

Mary Kay White, Ed.D.
Donald F. Knowles
NIOSH Division of Safety Research

OSHA 1910.1001 — ASBESTOS, paragraph (d) (2) (iv) (3) states — "Special Clothing: The employer shall provide, and require the use of, special clothing, such as coveralls or similar whole body clothing, head coverings, gloves, and foot coverings for any employee exposed to airborne concentrations of asbestos fibers, which exceed the ceiling level prescribed in paragraph (b) of this section."[1]

NIOSH has recently published a document[2] which can be used for specific work site applications. Personal Protective Equipment for Hazardous Materials Incidents: A Selection Guide includes recommendations that can be applied to asbestos abatement procedures. Where the substance to be protected against has been clearly identified, "disposable" coveralls of nonwoven fabric may be recommended. These are generally one piece garments that fully cover the torso and extremities, and may or may not be coated with a plastic or rubberized barrier. These ensembles must be used with appropriate respiratory protection and include boots, boot coverings, and gloves. Helmets and/or hoods may be required as additional items.

Caution should be exercised when applying the recommended heat stress standard published by NIOSH in 1972. This document clearly states that "the provisions of this standard are applicable to all places of employment, indoors and outdoors, and to all employees except those who are required to wear impermeable protective clothing."[3]

While very little research on heat stress has been conducted to examine the specific protective clothing and respirator ensembles typically used by the asbestos abatement industry, several related studies may provide useful information for managing heat stress situations.[4-9] In general, this research indicates factors that contribute to worker heat stress: this includes ensemble weight (including the respiratory protective device), clothing permeability characteristics, individual work rates, and the environmental conditions.

NIOSH studies of workers wearing chemical protective clothing (CPC) and firefighters' ensembles have indicated that heat stress is a serious consideration.[10] Significant physiological stress was observed, even at low work intensities (30% of maximum work capacity — level walking at 3.4 miles per hour) in a neutral enviornment (73°F and 55% R.H.). With the chemical protective (CPC) ensemble, worker tolerance time was reduced by 56% as compared to light work clothing only. Elevated rectal temperatures (in excess of 39.0°C) were observed in three of the nine subjects. With heavier firefighters' ensemble, tolerance time was reduced by 84% as compared to light work clothing only. At higher work intensities (60% of maximum), tolerance time was decreased by as much as 96%.

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

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

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

(3) Reduce work rate by:

   (a) adjusting the work/rest schedules

   (b) using automated procedures and/or mechanical assistance where possible

   (c) minimizing the work intensity.

(4) Educate workers on the symtoms and prevention of heat illness and schedule periodic fluid replacement breaks.[11-12]

(5) Reduce heat stress by:

(a) providing external cooling, where possible (either through cooling garments and/or by providing cool respirable breathing air through pressure-demand air supplied respirators)

(b) providing multiple air changes per hour to provide negative air on asbestos abatement projects.

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

References

1. 29 CFR Part 1910.1001

2. NIOSH, Personal Protective Equipment for Hazardous Materials: A Selection Guide, DHHS (NIOSH) Publication No. 84-114

3. Criteria for a Recommended Standard . . . Occupational Exposure to Hot Environments. U.S. Department of Health, Education, and Welfare. National Institute for Occupational Safety and Health, U.S. Government Printing Office, HSM 72-10269, pg. 1-2 (1972).

4. Goldman, R.F., Tolerance Time for Work in the Heat Wearing CBR Protective Clothing. Military Medicine 128:776-786 (1963).

5. Mihal, C.P., Jr. Effect of Heat Stress on Physiological Factors for Industrial Workers Performing Routine Work and Wearing Impermeable Vapor-Barrier Clothing. Am. Ind. Hyg. Assoc. J. 42: 97-103 (1981).

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Appendix G.

Breathing Air Systems for Use with Pressure-Demand Supplied Air Respirators in Asbestos Abatement

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Breathing Air Systems for Use with Pressure-Demand Supplied Air Respirators in Asbestos Abatement

a Technical Report

by

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Appendix G. Breathing Air Systems for Use with Pressure-Demand Supplied Air Respirators in Asbestos Abatement

I. INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) and the Environmental Protection Agency (EPA) recommend that either self-contained breathing apparatus (SCBA) or combination pressure-demand supplied air respirators (SAR) with escape SCBA be used to protect workers from detectable airborne concentrations of asbestos. Since SCBA are often impractical for abatement due to their size and weight, the combined SAR/SCBA will probably offer the best protection for workers on abatement jobs. Only those respirators tested and certified by NIOSH (U.S. Department of Health and Human Services) and the Mine Safety and Health Administration (MSHA, U.S. Department of Labor) and therefore which bear the NIOSH/MSHA approval label (see Appendix C) are recommended.

As the term "supplied air" indicates, these respirators receive breathable air from an external source through a system that typically consists of compression, purification, storage, and distribution components. The subject of this Appendix is the system which produces breathable air and supplies it to the recommended respirators. The intent is to (1) acquaint employers with the characteristics of available types of breathing air systems (Part II), (2) emphasize the caution required in the use of such systems (Part III), and (3) examine the cost benefits of supplied air versus air-purifying respirator systems (Part IV). The names and addresses of suppliers of equipment used in and with breathing air systems are provided in the final section (Part V).

II. BREATHING AIR SYSTEMS

A. Performance Requirements

A breathing air system must accomplish the following:

(1) provide a continuous sufficient supply of Grade D breathing air

(2) provide adequate reserve or escape time

(3) provide breathing air temperature control

(4) provide a continuous monitor and alarm against carbon monoxide (CO) in the breathing airstream.

(1) Continuous Sufficient Supply of Grade D Breathing Air

A **continuous sufficient supply** of breathing air means that both the air pressure and air volume requirements necessary for respirator operation are supplied directly to each respirator. **Grade D breathing air** is air that meets certain criteria established by the Compressed Gas Association, Inc., and is required to be used in air supplied respirators (see Table 1). Producing and supplying a continuous sufficient supply of Grade D breathing air is accomplished by the combined effect of compression, purification, and delivery processes.

(a) Compression

Any person interested in specification of, purchasing, or operation of any breathing air system for use with pressure-demand supplied air respirators in asbestos removal should know the basics of air compression.

Theoretical Compression Process. For a moment, let us consider the compression process apart from compressors. Forget low or high pressure or any other type of mechanical compressor. Consider only a parcel of air, A, as in Figure 1. Parcel A has a spherical diameter of about 4.0 inches, and the air is at room or ambient conditions; its pressure is about 14.7 pounds per square inch atmospheric (psia), its temperature is about 70°F.

This air parcel, as do all air parcels, carries water vapor and contaminants. In atmospheric air, water vapor is not usually considered a contaminant. In compressed air for breathing purposes, however, water vapor should be considered as a major contaminant. In order to produce breathable air, water vapor must be properly processed out of the compressed air. Water in compressed air is itself a contaminant and it traps and carries other contaminants.

If this air parcel were suddenly compressed to 100 psi over and above it's ambient pressure of 14.7 psia, its absolute pressure would become 114.7 psia. The volume of the parcel of air is reduced by compression to about ⅛ of its original volume, or about one-half inch in spherical diameter.

Even with no outside heat added, because of compression the temperature of the compressed air parcel would jump to about 350°F. The water vapor and contaminants would also be compressed. Compressing air reduces its ability to hold water vapor. However, increasing the temperature increases the ability to hold water vapor. Because of these two opposite effects, the water vapor would not condense immediately upon compression, but most certainly would condense as the air temperature decreases. In a compressor, the compression itself increases contamination levels in the air. These increased contamination levels must be controlled so that they do not become a human hazard.

If the parcel of air were to be compressed to 1/300 of its initial volume, the 4-inch diameter spherical air parcel would be reduced to only 0.01 inches diameter. The air temperature in this high compression parcel would be very hot, 1500° to 2500°F. The water vapor and contaminants would also be equally highly compressed.

If either compressed air parcel in the above examples were held for a time at its higher pressure, the heat would eventually transfer out. Even in its compressed state, the initial high air temperature would decrease back toward the ambient temperature of 70°F. Once compressed air has cooled back to ambient temperature, a large amount of the water will have condensed. Condensed water can be mechanically collected and simply drained out of the air parcel. Even after all the condensation is removed, the air parcel is still saturated with the remaining water vapor. (Being saturated simply means that any further reduction in temperature of the air parcel below 70°F will also result in additional water condensation.)

After the air temperature has cooled back to 70°F, if we were then to expand the air back to its original spherical diameter of 4.0 inches, the air temperature would drop dramatically. Such a re-expansion of the air parcel would, in effect, dry the air enabling it to carry more moisture again.

There are several important things to remember about theoretical compression of air:

- Air temperature always rises with compression. The more compression, the greater the temperature rise. Even at low pressures, there are substantial temperature elevations.

- In theoretical compression, this temperature rise does not come from mechanical heating effects due to the action of pistons, vanes, compressor drive motors, etc., but only from compression.

- Compression always heats air, but the compression process can be designed to provide cooling effects in the air. This cooling is available only if sufficient heat exchanger design and time is available to remove the heat of compression from the air before delivery of the air to the workers.

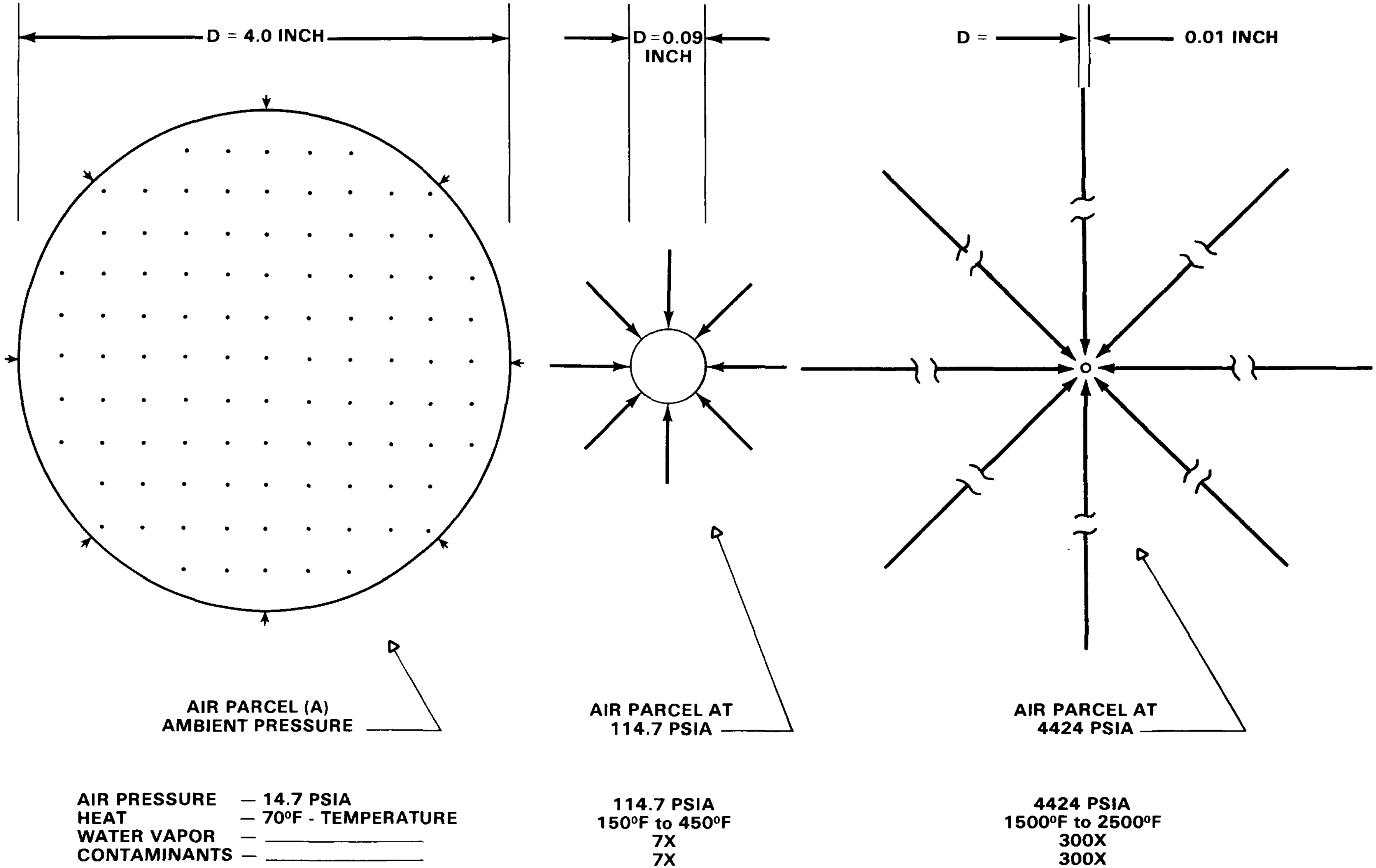


Figure G1. Theoretical Air Compression

Table I. Characteristics of Grade D and Better Breathing Air

Limiting Characteristics	GRADES D	E	F	G	H	I
% O_2 (v/v) Balance predominately N^2 (Note 1)	atm. 19.5-23.5	atm. 19.5-23.5	atm. 19.5-23.5	atm. 19.5-23.5	atm. 19.5-23.5	atm. 19.5-23.5
Water	note 2	note 2	note 2	note 2	note 2	1 -10.4°F
Hydrocarbons (condensed) in Mg/m^3 of gas at NTP (Note 3)	5	5				
CO	20	10	5	5	5	1
Odor	*	*	*	*	*	*
CO_2	1000	500	500	500	0.5	
Gaseous Hydrocarbons (as methane)			25	15	10	0.5
Nitrogen Dioxide				2.5	0.5	0.1
Nitrous Oxide						0.1
Sulfur Dioxide				2.5	1	0.1
Halogenated Solvents				10	1	0.1
Acetylene						0.05

*Adapted from Compressed Gas Association, Inc., Air Specification G-7.1

[Note 1: The term "atm" (atmospheric) denotes the normal oxygen content of atmospheric air numbers indicate oxygen limits for synthesized air.

Note 2: The water content of compressed air required for a particular grade can vary from saturated to dry depending upon the intended use. If a specific water limit is required, it should be specified as a limiting dewpoint (expressed in temperature °F at one atmosphere absolute pressure) or concentration in ppm (v/v).

Note 3: No limits are given for condensed hydrocarbons beyond Grade E since gaseous hydrocarbon limits could not be met if condensed hydrocarbons were present.]

- The water vapor is also compressed, and if high temperatures are lowered, will easily condense.

- Water vapor in compressed air is a major contaminant. Condensed water in compressed air is itself a contaminant and it traps and carries other contaminants.

- Concentrations of contaminants are increased and may become hazardous unless removed.

Practical Compression. Real compression requires a mechanical compressor of some type. Additional heat from the drive motor and frictional heat will be added in the real compression process. In addition, the compressor will add wear particles such as metal, carbon, etc. The compressor may also add lubricant oil as either liquid oil or oil vapor. If the compressor operates at excessive temperatures, it may actually form deadly carbon monoxide (CO) within the machine, although such CO formation is rare.

A compressor may be suited for only the tasks or types of jobs for which it was originally designed and built. For instance, a compressor built to power other industrial air machines may not need heat, water, and oil removal. In fact, some compressors actually have "oilers" in the output air to increase the oil being carried in the air. A compressor whose basic design was unsuitable could easily overpower the finest air purifier assembly. Operating with such an unsuitable machine would require more frequent filter and canister replacement than normal to maintain the required air quality. The cost of maintaining the air purifier in such a case would be prohibitive. The cost of redesigning and re-building such a compressor could be more than buying a compressor of a different design.

The real effect of water as a contaminant can be understood with an example: Consider a low pressure breathing air system with a normal piston or screw-type compressor and an air purifier assembly, such as depicted in Figure 1. This actual machine is pumping 100 standard cubic feet per minute (SCFM) of air on a day when the ambient temperature is 70°F and the relative humidity is 75%. This machine will take in about 16.5 gallons of water in vapor form every 24 hours. If the machine is properly designed for breathing air applications, it will have an aftercooler to cool the air and to condense most of this water. This breathing air compressor will also have water removal traps to drain the condensate out of the machine. If the air is being cooled in the compressor aftercooler back to near ambient temperature, then about 11.5 gallons of liquid water will condense. This condensing water has many of the other contaminants entrained. This contaminated liquid water can be mechanically removed from the aftercooler drain trap. This leaves about 5.0 gallons of water as water vapor still moving with the compressor output air. Most of this 5.0 gallons of water vapor will be removed along with any other contaminants by the air purifier assembly that is downstream of the compressor.

Proper design of the compressor with sufficient intercooling, aftercooling, and proper water removal traps can mechanically remove about 65% to 90% of all water and contaminants. Since mechanical removal methods are more or less permanent removal methods, the overall compressor design is important for final breathing air quality. The final polishing of the air quality to obtain Grade D or better will be accomplished by stages in the air purifier assembly.

(b) Purification

Ordinary compressed air cannot be used to supply breathing air to work crews working in hazardous atmospheres. Ambient breathing air, when pumped through an ordinary compressor, is not fit for human respiration. Even if the compressed air is filtered to remove dust and other particulates, it still contains the contaminants in ordinary atmospheric air, plus the localized contaminants near the compressor intake, plus any contaminants and wear particles added during compression. The compressor may add oil vapor, hydrocarbons, even carbon monoxide.

The compressor intake is especially vulnerable to all types of carbon monoxide sources. Sources of CO, such as transient vehicles and other mobile internal combustion engines, are especially hard to control on the typical asbestos abatement job.

Various contaminants are potentially present in air from ordinary compression. Where present, these contaminants are concentrated by the compression process. For these reasons, breathing apparatus will NOT provide protection unless the breathing air is purified.

Purification of air is a very precise technology which has developed over many years. Purification is considerably more than filtration. Filtration is simply capture and removal of particulates by a filter. Filtration is almost always included in the overall purification process, although it is a small part of the overall purifying process.

Adsorption. Purifiers are based primarily on the design and use of ADSORPTION. Adsorption of vapor and chemical contaminants is done by proper design and use of the class of materials known as adsorbers. The common adsorbers used in design of air purifier assemblies may include:

molecular sieves

silica gel

activated alumina (Al_2O_3)

activated charcoal

Adsorbers are porous type materials with large quantities of interconnected, submicroscopic internal voids, pores, or capillaries. This internal porous structure gives these adsorber materials very large surface areas in contact with the gases to which the adsorber is exposed. Adsorbers also have the property of being physiochemically "active" or can be "activated." This means that these adsorbers can hold onto, or adsorb onto their active surfaces, various physiologically active contaminants. The adsorbant thereby effectively removes the contaminants from the airstream and leaves the air pure and uncontaminated. These adsorbers are not all equally effective with all contaminants.

Water is an active contaminant for most adsorbers. Water is also processed in large quantities by air compression. Ninety percent of the water and entrained contaminants can regularly be removed by proper compression, cooling, and water traps, all of which are designed into the breathing air compressor section. Much of the remaining water must still be removed in order to allow adsorption of other vapor contaminants.

For the adsorber design to be effective, the appropriate types, quantities, and sequence of adsorbers materials must be selected.

Pressure Level and Adsorbers. The effectiveness of all adsorbers increases with increasing pressure. As the pressure of the air increases, the density of the air increases. More dense air exposed to any adsorber material simply means that more of the air is pushed into more intimate contact within the adsorber. Therefore, as air pressure increases, less adsorber is needed to do the same job.

Table 2 shows the typical operating pressure range and the relative density increase for both typical types of breathing air systems for use in asbestos removal work.

Table 2. Typical Pressure and Relative Adsorber Effectiveness

Type of Breathing Air System	Typical Pressure Range	Relative Air Density (and Adsorber Effectiveness)
Low Pressure	100-200 psi	6x to 12x
High Pressure	2000-4000 psi	150x to 300x

Adsorbers must be periodically replaced. Adsorber cartridges can be equipped with a color change reaction that will show the progress of adsorber use. Such cartridges can be changed based on coloration changes through a visual canister. Adsorption canisters may also be changed on a simple operational time basis.

The Carbon Monoxide Catalyst. The action of this catalyst, which is used to eliminate carbon monoxide, is unique. On the catalyst surface, carbon monoxide, in the low concentration ranges of 10 ppm to 600 ppm, is brought into contact with oxygen in the air. These conditions cause the chemical reaction $2CO + O_2 = 2\ CO_2$. The end result is that dangerous CO is changed to CO_2, which is not harmful in these low concentrations. Theoretically, catalysts last forever, but in practice they permanently adsorb trace chemicals and become "inactive." Most manufacturers recommend yearly replacement of their catalyst-type filters.

Even very small amounts of water vapor contamination on the catalytic adsorber "poison" the catalyst and reduce its activity. For such a catalyst to operate for a reasonable period of time, the air entering the catalyst must be very dry, below 5% relative humidity.

The most effective way to dry air to these conditions is to use drying adsorbents before the air reaches the catalyst. If a drying adsorber of the throwaway type were considered for use in a low pressure purifier assembly, enormous quantities of this disposable adsorber material would be required for each 8-hour shift. In order to avoid having to use such quantities of water adsorber material in the low pressure purifiers, a different design solution has been used.

The Regenerative Water Adsorber Dryer. The heatless air regenerated dryer has evolved as the simplest and most rugged method to continously regenerate the required adsorber material. It consists of airline plumbing, two central air dryer towers, and a tower switching system. In action, this system has one tower drying the process airstream while the other tower is "off-cycle." From 10% to 20% of the dry air output of the "on-cycle" tower (depending on system operating pressure) is split off and sent back down in reverse through the "off-cycle" tower. This regeneration air removes the water previously adsorbed in the "off-cycle" tower and is vented to the atmosphere. In this way the off-cycle adsorber material is renewed or regenerated. Every few minutes on a regular basis, the cycle switches, alternating between the two towers.

A typical adsorber design for 100 SCFM process air flow, which has 50 pounds of activated alumina in each tower, can be expected to run regeneratively for several years before this activated alumina stops being regenerated. Replacement of 100 pounds of activated alumina only one time every 5 to 7 years is inexpensive. In comparison, a single column of activated alumina in a throwaway canister design would need about 100 pounds of new activated alumina every 8 hours.

If the activated alumina regenerated dryer were the first step in the purifying process just following the breathing air compressor, it would "see" significant amounts of oil and oil vapor as well as water vapor. The regenerative dryer is based on the alternate adsorption and desorption of water from the adsorber. In these cycling towers oil will not desorb. The regenerative dryer will operate only a few days if no oil adsorption media is placed in front of the regenerative drying section. An oil adsorption prefilter must precede the dryer towers.

The Oil Adsorption Prefilter. The active media in the oil adsorption prefilter is chosen for its ability to selectively retain oil and oil vapor. It can be formulated with a color change reaction and placed into a visual canister for visual determination of the filter media remaining. The oil vapor adsorption prefilter may quickly be saturated if "slugs" of oil and water come from the compressor. Removal of liquid "slugs" just prior to the oil prefilter is accomplished by the coalescing filter and drain trap.

The Coalescing Filter and Drain Trap. Compressors used for breathing air need great attention paid to removal of heat, which causes condensed liquids to be formed. These breathing air machines also provide special liquid removal devices called "liquid traps." Liquids are retained in the traps and can be drained from them.

Heat exchangers and drain traps do not remove vapors. Water vapor and oil vapor move through liquid traps. Also, microscopic drops of both liquid water and liquid oil (aerosols) act similar to vapor and move through ordinary liquid traps. The coalescing element is designed to cause these aerosols to impact on a myriad of mechanical elements within the coalescing filter. This action makes big drops out of the aerosols so they can be removed.

Summary of Important Points About Adsorption Purification:

- Purification of air requires adsorption as well as filtration.
- Purification and adsorber design is a highly developed science. Proper design of adsorber must include:
  - proper choice of adsorber material
  - sufficient quantities of adsorber
  - proper sequencing of the correct adsorbers.
- All adsorbers must be changed periodically.
- Systems with higher working pressures will require less adsorber material to do the same job.
- A low pressure adsorber should include a regenerative dryer or enormous quantities of adsorber material will need to be replaced every eight (8) hours.

Grade D breathing air is specified by OSHA 29 CFR 1910.134(d)(1) as that listed by the Compressed Gas Association Specification G-7.1. Table 1 shows the criteria for Grade D and better breathing air. Most established American manufacturers of both high and low pressure breathing air purifying systems design and test their systems to produce Grade D or better breathing air.

(c) Distribution

Breathing air must be delivered to the respirators in a continuous and sufficient supply, which means that both air pressure and air volume requirements must be maintained through the purification and delivery processes. Required air pressure can be ensured:

- by measuring and controlling the air pressure within the air delivery system at the entrance to the respirator hoses

(Air pressure is adjusted to the required pressure specified by the manufacturer for each respirator.)

- by maintaining the required pressure under all flow conditions when all the respirators are being used.

Two factors which affect the respirator pressure during air flow are (1) the inside diameters of hoses and their connectors, and (2) the overall length of air supply hose. Respirator hose-line pressures must typically be maintained in the 65-100 pounds per square inch gauge (psig) range. The Occupational Safety and Health Administration (OSHA) and NIOSH regulations prohibit the actual hose length from the respirator manifold to exceed 300 feet in length.

In order to add low pressure supply hose beyond 300 feet, the respirator input pressure should be maintained at the required and specified value for the respirators being used. Extra large diameter supply hose from the compressor to the respirator hose manifold may allow some length increases beyond the 300 feet. The simplest method to add some extra length to the low pressure supply line is to provide a compressor with output pressure higher than the pressure required by the respirators, and to provide a regulator at the respirator manifold. This regulator functions to reduce, control, and maintain the correct respirator pressure at the inlet to the respirator hoses. An accurate pressure gauge should be located at the inlet to the respirator hoses. For increases in hose length to be acceptable, this respirator inlet pressure gauge must read the correct and required value specified for the respirators being used when under maximum flow conditions (i.e., with all available respirators in use).

An easy test of the low pressure distribution system can be conducted by:

(1) laying out the required length of air transfer hoses

(2) connecting all respirator manifolds

(3) attaching the maximum number of respirator hoses and respirators to be used (up to 300 feet if needed)

(4) pressurizing the system

(5) with all respirators in use, then check the pressure at the respirator manifolds.

Should the pressure at the manifolds be less than the specified respirator pressure, increasing the pressure may be accomplished by using extra-large diameter supply hoses, or increasing compressor pressure combined with use of a control regulator at the respirator manifolds. If one of these methods will allow the required respirator pressure to be maintained, the extra length is acceptable for use. If the required respirator pressure cannot be maintained, the hose lengths must be shortened until the specified respirator hose pressure can be maintained.

Remember: providing a continuous and sufficient supply of breathing air is accomplished by maintaining the correct and specified respirator inlet air pressure under all airflow conditions.

(2) Adequate Reserve Air or Escape Time

Providing for adequate reserve air or escape time is a necessary and required function of the breathing air system. The OSHA Safety and Health Manual 29 CFR 1910.134 (d)(2)(ii) states, "A receiver of sufficient capacity to enable the respirator wearer to escape from a contaminated atmosphere in event of compressor failure and alarms to indicate compressor failure shall be installed in the system."

This poses the question of how much reserve time, and therefore how much stored air, is necessary. If a work crew were told an escape test was going to be conducted at a specified time, such a test might show that only 10 to 20 minutes were required. The escape time required under actual workplace conditions could be considerably longer. Complex airline routing and even tangling, work on scaffolding or in restricted access areas, and the requirement for the entire work crew to take showers can all lengthen escape time. For a crew size of ten workers, actual egress times have been measured at 30 to 50 minutes and more. Therefore, for most asbestos jobs a reserve time specification of 50 minutes to one hour is needed. Certain special asbestos jobs with more complicated egress conditions may need escape time of more than one hour.

Prepumped air or air stored in a pressure container is used as the method to obtain the required escape time. However, it should be noted here that low pressure systems, with pressures up to 200 psi, are not capable of storing any appreciable escape time in any practical tank volume size. However, high pressure air storage in the 2000 psi to 4000 psi range is easily capable of meeting the required escape time and more. When high pressure tanks are used to provide one hour and more escape time, the overall tank size, weight and cost are within practical limits.

The requirement to use high pressure (2000 to 4000 psi) as the only practical reserve air storage method does not adversely affect specification, choice, or the use of low pressure breathing air systems. The cost for providing a high-pressure standby reserve system with Grade D air on a low pressure breathing air system is minimal. The high pressure breathing air tanks for this standby air reserve do not need to be purchased; rental is the normal arrangement for suppliers of such high pressure tanks. High pressure tanks are routinely available from many sources nationwide. The rental cost for such tanks is usually minimal. Suppliers can be found by search of the Yellow Pages of a local telephone book under the heading, "Gas - Industrial and Medical." Since this high pressure standby reserve should be used only for the occasional emergency compressor stoppage, the actual cost of the air used from such a standby reserve system on a jobsite should also be minimal.

Cost considerations for the in-line reserve or escape air on a high pressure breathing air system are even lower. The in-line air storage bank provides more than sufficient escape time.

(3) Temperature Control of the Breathing Air

Asbestos removal during warm weather can create extremely hot working environments for abatement workers. Typically, the heating, ventilation, and air conditioning is shut down, and the building is then sealed off with plastic sheeting on all wall, overhead, and floor surfaces. This increases the retention of heat in the workplace. Then, water sprays are introduced into this hot workplace in order to minimize the airborne fibers. Such sprays create high humidities that reduce or eliminate the normal external body heat removal method of sweat evaporation. It is not at all unusual to see workplace ambient temperatures of 120° to 130°F with relative humidities in the 90% - 100% range.

The worker has other additional adverse personal circumstances. The asbestos worker is clothed with disposable garments which are very hot to wear. Although these garments are light in weight, they are made of material which is of low permeability. Such garments restrict local body air movement and, therefore, the transfer of heat from the body.

Asbestos removal work is hard physical labor. In many instances, this labor is performed from precarious or dangerous work positions, such as high up on movable scaffolding, or in the crawl space above lightweight ceiling grids where temporary flooring is placed.

It is in this hot and difficult workplace that the respiratory protective system must be used. If a low quality supplied air system is introduced, it typically may bring hot, humid, foul-smelling air, or even air that is dangerous to breathe. In such a case, it is no wonder that the worker may dislike the respiratory protective device and remove it whenever possible.

However, a supplied air system which delivers cooled, high quality breathing air, can provide the worker with relief against body heat buildup in such hot environments. Under these circumstances the respirator may even become equipment preferred by the worker.

Where hot environmental conditions exist, the asbestos worker should be provided with some type of personal cooling. The available choices of personal cooling depend on which type of breathing air system is being used. Hot air is produced in the compression process of all three basic types of breathing air systems--low pressure, high pressure, and prepumped high pressure tank systems. The already hot general working conditions of the asbestos workplace make it intolerable to deliver hot breathing air to the worker. Unless some temperature control is placed within the breathing air system to reduce and control the compressed air temperature and remove all condensables before the air is admitted to the air purifier, the air quality will also be unreliable. Reduction of temperature and removal of condensate before the air enters the purifier system are vital to ensure air quality, even if expensive and otherwise adequate purification systems are used.

Three methods of personal cooling that are in breathing air systems are the aftercooler (air-cooled or water-cooled), the Vortex tube, and adiabatic cooling.

The Aftercooler. Hot compressed air exiting a compressor may be cooled by using an aftercooler or heat exchanger. These heat exchangers may transfer the heat either to the ambient air (air-cooled) or to locally available cold water (water-cooled). Figure 2 shows the correct location of such aftercoolers within the overall breathing air processing system. For the downstream air purifier assembly to function properly and give good control to process high quality breathing air, excess heat, condensates, water, and oil must be removed. This is accomplished by first removing heat, and then removing the condensed water and oil. These are two vital sequential steps that must be taken before air is admitted to any purifier assembly or supplied to any worker.

The efficiency of the air-cooled aftercooler will be affected by the ambient air temperature. Because of this fact, the air-cooled aftercooler will not function as efficiently on the hottest days, when worker cooling is most needed. Therefore, the best type of aftercooler choice to ensure that worker cooling is available when needed may be the water-cooled aftercooler.

The Vortex Tube. The Vortex Tube (for cooling or heating) is another available method of worker temperature control (See Figure 3). The Vortex Tube is a very simple device. It is a tube of approximately ½ to 1 inch diameter and perhaps 6 to 12 inches in length. The Vortex tube is simple, lightweight, and inexpensive. Air is admitted into the side of the tube and split into two separate airstreams, each exiting at opposite ends of the tube. One airstream is hot, the other is cold. Either of these two airstreams may be directed into the worker's disposable suit or hood to provide external temperature control to the worker.

The only disadvantage of the Vortex tube is that it uses a comparatively high volume of air, approximately 15 to 20 cfm per worker. Compared to the air used by a pressure-demand type respirator, each vortex tube will use as much air as would be needed to supply 4 or 5 pressure-demand respirators. Therefore, the use of vortex worker cooling will increase the size and cost of both the compressor and the breathing air purifier.

Adiabatic Cooling. Adiabatic cooling is available when sufficient cooling capacity has been designed into each of the multistage compression steps found internally in the high pressure compressor. Provided that the high pressure compressor cooling design is adequate, cool or ambient temperature air will be produced at the high pressure compressor outlet. This air is carried into the in-line air reserve tanks and then into the asbestos work area via high pressure lines to an air control panel. The air pressure regulator on this panel reduces the high pressure air from pressures of 1000 to 4000 psig down to the required respirator line pressure (typically in the 65 to 100 psig range). The air temperature also drops dramatically with this air expansion at the control panel and the resulting cold air is directed into the respirator lines at the panel.

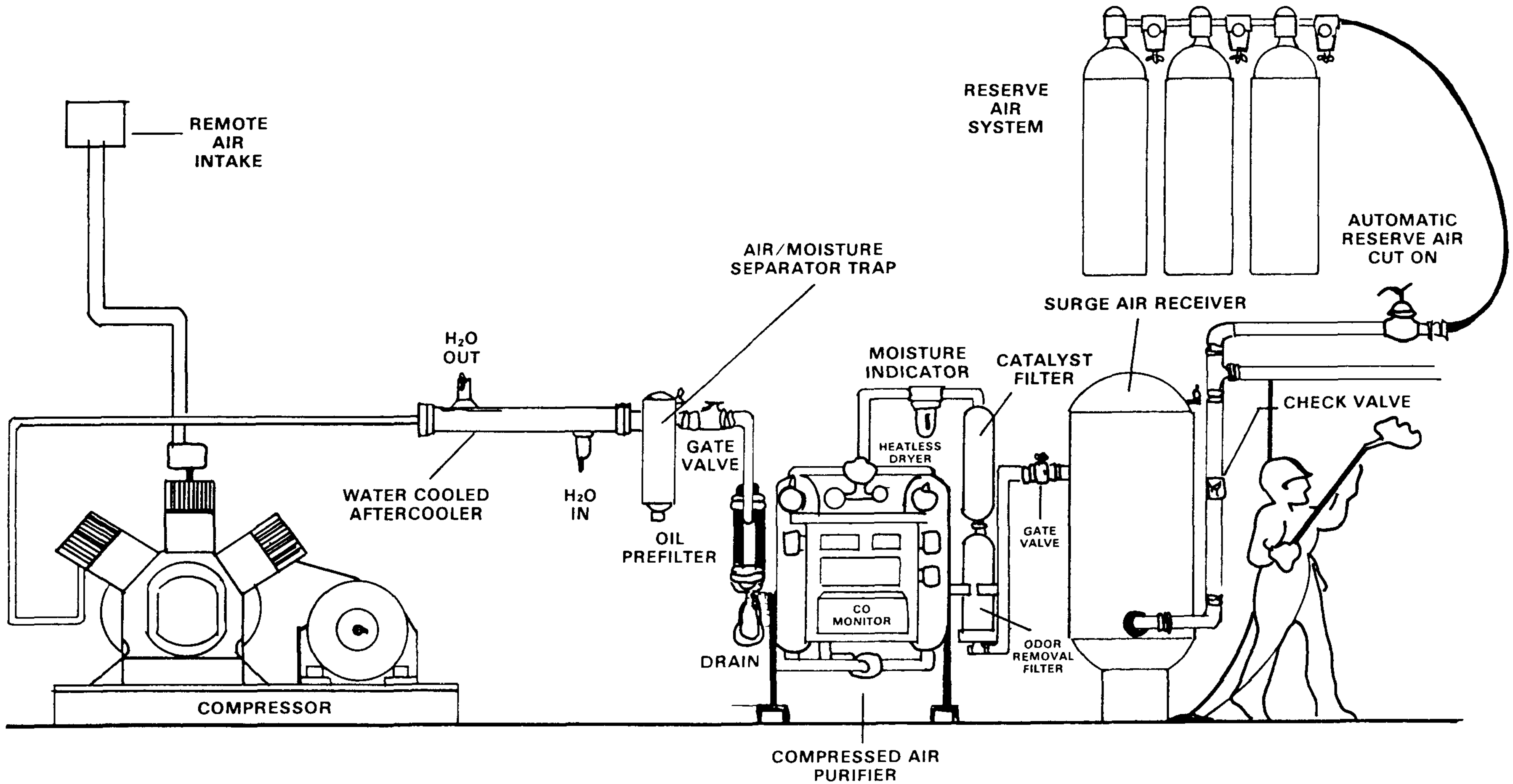
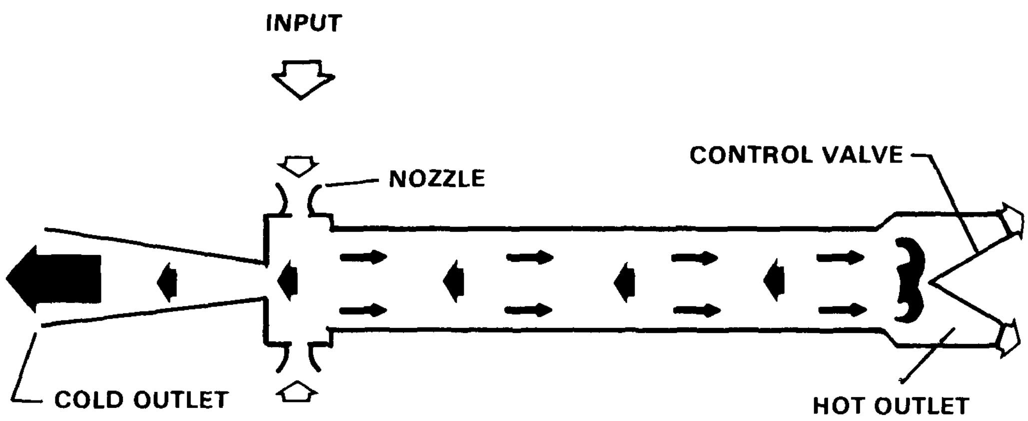


Figure G2. Typical Installation of Low Pressure Breathing Air System



SCHEMATIC DRAWING OF A VORTEX TUBE

WHAT IS A VORTEX TUBE?

The Vortex tube is a device capable of converting an ordinary supply of compressed air into two streams, one hot and one cold. The proportions of hot and cold flow and their temperatures can be varied over a wide range. All of this is accomplished without moving parts using only compressed air as a source of power.

The temperature differences in the hot and cold outputs can be striking. With a 100 psig compressed air source, the Vortex tube can be adjusted to cool the air as much as 100° below inlet air temperature.

HOW DOES IT WORK?

The compressed air first enters nozzles which inject it at sonic speed circumferentially into the vortex generation chamber. Spinning as fast as one million revolutions per minute, the vortex moves through the tube toward the hot outlet. Air near the surface of the tube becomes hot and some of it leaves through the control valve at the hot end. The control valve imposes enough pressure on the vortex to force some of the air to the center and back through the tube to the cold end. This air becomes very cold in the process and leaves the tube through the cold outlet.

Figure G3. The Vortex Tube, Its Construction and Performance

Adiabatic cooling is very simple, lightweight, and reliable provided the compressor has been initially designed to be adequate for such cooling.

In the typical asbestos worksite, cold breathing air will aid in cooling the asbestos worker. Normal external body cooling methods have been reduced due to the previously described working conditions, while body core cooling effects of breathing cool air have not been changed. Cooling methods using cool or cold breathing air can also be used incidentally to provide cool air externally to the worker. This can be accomplished simply by directing the cool exhaust from the respirator exhalation valve down inside the asbestos worker's disposable garment. Workers generally are observed to accomplish this added cooling without special instruction or added personal equipment. With a high pressure breathing air system, a single user of a pressure-demand full facepiece type respirator (with built-in adiabatic cooling) may use a total of only 4 standard cubic feet per minute (SCFM).

When asbestos abatement is accomplished in extremely cold environments, there may be a need to provide heat to the breathing air. Heat exchangers with a warm water heat source can be used to heat and control the breathing air being delivered to the respirator hoses. Supplemental heating or cooling may be used with any type breathing air system.

(4) Continuous Carbon Monoxide (CO) Monitor and Alarm

Providing a continous CO monitor and alarm is a requirement of law and of common sense. Carbon monoxide monitors and alarms are available from many sources. A list of sources is included in Part V of this Appendix. The CO monitor should be purchased as a part of the overall breathing air system or breathing air purifier assembly. Proper choice of CO monitor and correct installation in the system are aided by the system manufacturer. Since CO monitor and alarm systems can malfunction, employers may find it prudent to install two such systems to ensure continued protection in case of failure.

Manufacturers of carbon monoxide monitors have available two basic types of sensors. One sensor type is specific or sensitive only to carbon monoxide. This sensor will ignore all other trace chemicals and alarm only in the presence of CO. The monitors based on a CO-specific sensor are usually more expensive. The other type of sensor also will alarm in the presence of carbon monoxide, but it is a non-specific sensor and may also give alarms in the presence of trace chemicals when carbon monoxide is not actually present. Non-specific systems are usually less expensive.

Some manufacturers tend to recommend the non-specific type sensor for inclusion in the asbestos removal air system. Non-specific sensors may give more alarms. The reasoning behind recommending the non-specific type is that other potentially harmful chemicals are being detected when this system gives such an alarm. For instance, off-gassing of certain synthetic compressor lubricants not recommended for use as lubricants in breathing air compressors may cause such non-CO alarms. The breathing air system would be protected against an "unfamiliar" rental compressor in which such adverse synthetic lubricants had been used by the action of such alarms.

On the other hand, the occurrence of numerous alarms will disrupt the asbestos worksite and could significantly increase the cost of removal or make job completion difficult. Such excessive alarms also create a "cry wolf" attitude in the workforce, leading to a disregard for the alarm. Disregard for the CO alarm is a very dangerous practice and MUST be avoided. Therefore, the CO monitor must be kept in calibration and all alarms equally respected. Immediate air quality samples may be taken during the alarm to verify the absense or presence of CO. Should numerous alarms be experienced, the possible sources for other chemicals being detected by the alarm should be found and eliminated.

If CO alarms continue after efforts at finding a local fix, contact the CO monitor manufacturer for aid. In this case, consider with the manufacturer or supplier of the carbon monoxide monitor either (1) obtaining a new CO monitor of the same type, to eliminate the possibility of a mechanically or electrically malfunctioning alarm, or (2) obtaining a CO monitor and alarm from a different manufacturer.

IF A LOW PRESSURE BREATHING AIR SYSTEM IS BEING USED WHEN THE ALARM SOUNDS:

When the alarm sounds, the breathing air system should immediately be switched to the high pressure standby air reserve system. Depending on the capacity of the reserve system, the workers should exit the toxic removal zone. Typically, one 220 standard cubic foot tank will provide one man equipped with a 4.0 SCFM pressure-demand respirator with fifty-five minutes of escape time.

The outside supervisors should check and make certain all workers are exiting. All respirators should be accounted for and verified as no longer in use.

With sufficent high pressure reserve or when using a high pressure breathing air system with sufficient in-line reserve capacity, CO alarms and unexpected compressor shutdown can often be handled without disruptions in the asbestos removal work.

Remember, air being processed in a low pressure air system is almost immediately being delivered to and breathed by the workers. Therefore, when using the low pressure system, there is an immediate need for switchover to the high-pressure reserve air when the CO alarm sounds. If only the minimum high pressure reserve is available, the workers should exit the area. If additional reserve air capacity is available, the workers should exit when the reserve supply approaches the minimum acceptable amount.

When using a high pressure breathing air system with an in-line high pressure air storage bank, the compressed air from the compressor is delayed and diluted by the action of the in-line storage bank before being delivered to the workers. When the CO alarm sounds in a high pressure breathing air system, the stored air at the moment of the alarm has previously been processed through the CO monitor, and is already guaranteed to be Grade D quality. The air in the in-line air bank therefore remains available for the workers' continued use.

IF A HIGH PRESSURE BREATHING AIR SYSTEM IS BEING USED WHEN THE ALARM SOUNDS:

Immediately stop the air flow from the compressor into the in-line reserve air bank by shutting the output air valve. **[Note: If so arranged, this step may be automatically accomplished through relays in the CO monitor.]**

Immediately provide a gas sample test for CO in the supply output from the air bank to the workers. (See discussion of the gas detection method which follows).

If the sample test shows no carbon monoxide in the air from the air bank going to the workers, then the workers may continue to work. They may work as long as no further air from the compressor is being admitted into the air bank, and provided more air time is stored in the bank than the required one hour reserve time. When and if the one hour reserve level is reached, the workers should be removed.

A study of formation of carbon monoxide in breathing air compressors was done by Lawrence Livermore Laboratory in 1978*. Two separate conclusions from this study which are of particular signifiance for breathing air systems used in asbestos removal are as follows:

- "Exhaust gases from combustion engines are the major threat to the quality of compressed air." *(p. 6)*

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*Formation of Carbon Monoxide in Air Compressors, Lawrence Livermore Laboratory, T.M. Distler, July 26, 1978, 94550 Contract No. W-7405-Eng-48

- "The preceding observations [of the study] indicate that a high temperature shut-off or alarm, as one of the options specified by OSHA, does not significantly protect against CO contamination of compressed air. In the event of local overheating in a compressor, the effectiveness of a temperature sensor would depend on its placement near the hot spot. The oil reservoir, because of its much lower temperature, is unreliable as an indicator of overheating. Therefore, a high-temperature alarm or shut-off device should not be considered as a substitute for CO monitoring." (p. 7)

Gas Detector Tubes. As previously noted, when a CO alarm sounds in a high pressure system, a gas sample test for CO in the supply output from the air back to workers should be done immediately. Whether a low pressure or a high pressure breathing air system is in use, after all workers have exited, and all respirators have been accounted for, air testing should be conducted to determine if CO was present or not.

Although direct reading CO monitors are available, a less expensive and simple to use on-site air analysis method can be used to provide a positive backup analysis method in case a CO alarm is activated. This method uses preset chemical color change analysis. The analysis chemicals are precharged and sealed into small glass tubes. Different tubes are available for many different gases. A small case contains several sets of tubes and the constant volume sampling pump. Other tubes useful on an asbestos jobsite include those which indicate oxygen and carbon dioxide. These tubes are simple to use. The ends are broken off a tube and the tube is inserted into the pump. Operating the hand pump draws a measured volume of air sample through the tube. The results are read directly on a scale on the tube.

Practice samples taken on two known CO sources can be used to verify the detection of CO using detector tubes. Cigarette smoke can be used as a common type of low-level carbon monoxide sample test. Exhaust from an idling, non-catalytic-equipped automobile, truck, or other engine is a second example, this time of high CO content. Taking these two known CO-content samples on a CO tube will educate the crew as to what the abnormal CO reading actually looks like on the tube. The usual CO sample results on a high quality breathing air is zero CO.

Periodic gas tube sampling results should be permanently logged. This provides an additional record of the air quality on the job site.

B. Types of Breathing Air Systems

There are three (3) general types of breathing air systems potentially available for use in asbestos removal. These general types are categorized according to the pressure levels at which they are designed to operate:

(1) the low pressure system

(2) the high pressure system

(3) high pressure pre-pumped tanks

(1) The Low Pressure System

The typical low pressure system is shown in Figure 2. This system consists of:

(a) a low pressure compressor

(b) an aftercooler assembly with water removal traps

(c) an air purifier assembly

(d) a standby high pressure air reserve assembly

(e) a surge-tank or in-line air volume tank

(f) a distribution hose and distribution manifold with connections for respirator hose lines.

(a) A Low Pressure Breathing Air Compressor

The low pressure breathing air compressor produces pressures between 100 and 200 psi. It has sufficient flow capacity to provide the flow needed for the respirators being used. The compressor should also be equipped with sufficient interstage and aftercooling capacity to reduce the air temperature to within 10°F of the ambient air temperature. The low pressure compressor should be equipped with suitable moisture removal traps to be able to remove 60% to 85% of the water/oil condensed within the machine. Water removal may be either automatic and continuous or manual and periodic.

(b) An Aftercooler Assembly with Water Removal Traps

The aftercooler assembly is used immediately following the low pressure breathing air compressor. The aftercooler and its water trap may be incorporated physically in the compressor. The purpose of the aftercooler assembly is to guarantee that the air temperature is reduced to within 10°F of ambient air temperature. Such a reduction in temperature forces condensation of water/oil in the airstream. The cyclone-type water separator or water trap is also a part of the aftercooler. This separator or water trap is used to allow removal of the water/oil mixtures condensed by the action of the aftercooler in the airstream.

Aftercoolers may either be ambient air-cooled or water-cooled. Ambient air aftercoolers will not function as well on the hottest days, when the most worker cooling is needed. Water-cooled aftercoolers may work best on the low pressure system.

(c) An Air Purifier Assembly

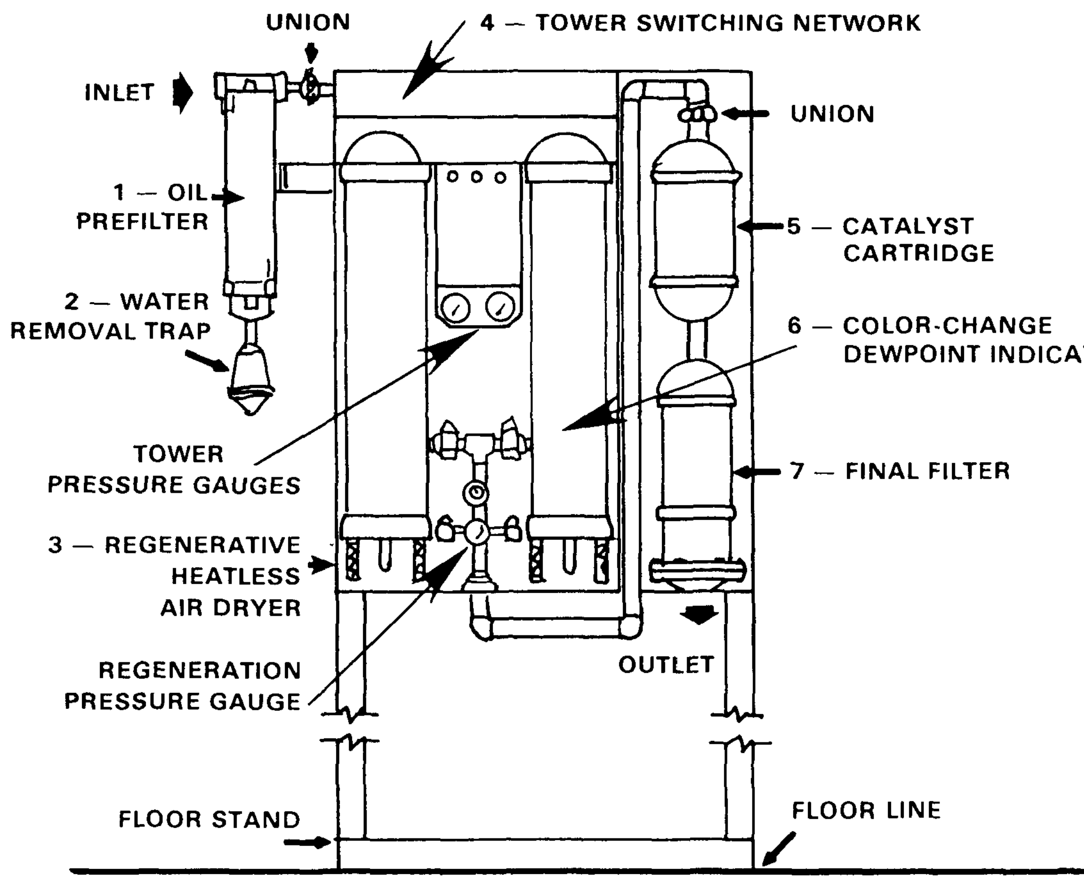
The purpose of this purifier network (see Figure 4) is to polish the air to at least the required Grade D air quality.

The air inlet is on the upper left of the diagram. The air path is actually downward into the prefilter, and the first active element encountered by the air is an added water coalescing element in the down tubes and bottom of this prefilter. Water is mechanically collected on this coalescing section of the prefilter and drains downward into the water removal trap. Water can be drained automatically or through a manual valve added to the bottom of this trap.

[IMPORTANT NOTE: ALL CONDENSED WATER AND OIL MUST BE DRAINED AND REMOVED FROM THE AIR ADMITTED INTO THIS PREFILTER. If proper reduction of air temperature and proper removal of condensate is not accomplished at the entrance to the prefilter, the breathing air purifier may not function as well as expected and may require more filter replacements.]

The air continues moving upward through the prefilter and into the oil removal section of the prefilter. At the lowest visual level in the prefilter there is a red color-match band. Oil vapors are adsorbed by the filter media, beginning just above the red band. Oil adsorption causes a red color change in the originally white filter material above the red color-match band. As additional air quantities are passed through the prefilter, this color change will progress upward inside the prefilter material as the filter material adsorbs the oil from the airstream. When the color change approaches the top of the prefilter material, the prefilter should be changed. The above description is typical of the visual or color-change method of notice of need for filter change, which is used by several manufacturers in many types of adsorption filters.

[IMPORTANT NOTE: Some low pressure compressors that may be available for local rental may be built and set up to power industrial machines. Industrial machines such as air tools, jack-hammers, roadwork earth drills, and other such machines have very different



1. Oil Prefilter — removes oil mist, particulates, and entrained water. Color-change replacement notice
2. Water Removal Draintrap — removes condensed water-oil mixtures
3. Dual Regenerative Heatless Air Drying Towers — reduce water vapor content; action is to regenerate its own adsorber material
4. Tower Switching Network — acts with plumbing to provide timed dryer tower switching to effect regeneration
5. Catalyst Cartridge — removes CO by catalytic conversion to CO_2
6. Color Change Dewpoint Indicator — Color change visually shows the performance of the drying towers
7. Final Filter - effects odor removal

Figure G4. Typical Low Pressure Breathing Air Purifier Assembly

requirements from a compressor required to produce breathing air. Industrial machines may require a high oil content in the airstream. Industrial oiling requirements may be designed to be met directly in the compressor output or may be met by the addition of airline oilers. In such cases where a high oil content is found in the air, the solution is to either remove airline oilers downstream of the compressor outlet, or change to a different and suitable compressor that has low oil output.]

Air processed through the active prefilter passes into the dual dryer tower assembly, into the air-switching plumbing circuit assembly. This air-switching circuit simply directs the air into the heatless air dryer assembly. There are two of these drying towers. Each tower is alternately either on-line, drying the air, or off-line being regenerated.

The regeneration of the off-duty tower is accomplished by taking a percentage of the dry air from the output of the on-duty drying tower and running it in a reverse direction through the off-duty tower. The dewpoint of the drying air and also the amount of air to be diverted to drying the off-cycle tower is determined by the setting of the regeneration pressure gauge.

The breathing air purifier shown in Figure 4 has visual moisture indicators in each drying tower. These indicators change color in the presence of moisture. Observation of these color-change indicators allows the operator to observe the functioning of the drying operation. During operation the on-cycle tower will begin to absorb water. After approximately 2½ minutes the system will switch, the now dry off-cycle tower will become the functioning tower, and the on-cycle tower will go over to off-cycle as it begins to be de-adsorbed or regenerated.

Over a period of years in normal operation the ability of the towers to be regenerated decreases. Colorimetric indicators are available to indicate when the adsorber material in these towers must be replaced.

[<u>IMPORTANT NOTE:</u> The drying action of these towers depends on water adsorption and water de-adsorption. If the system is operated with a depleted prefilter, oil may be passed into the drying towers. The activated alumina in the drying towers will adsorb oil and therefore will provide a backup to the function of oil removal normally accomplished by the prefilter. However, oil adsorbed in the drying towers will not be desorbed in the towers. Therefore oil passing through a saturated prefilter will effectively ruin the water drying function of part or all of the tower and result in shorter-than-expected drying media lifetime and more frequent tower media replacement.]

Air from the dryer towers now enters the CO catalyst. This catalyst changes harmful CO to CO_2. The catalyst can process up to 400 ppm inlet CO and still keep the output air below the required 20 ppm limit.

[<u>Note</u>: A carbon monoxide continuous monitor and alarm is required on all breathing air systems used in asbestos removal work, even if a CO catalyst is also used.]

Periodic replacement of the CO catalyst is recommended by all purifier manufacturers.

Air now flows to the final adsorber canister where odors are removed by activated charcoal. This canister is usually replaced on a recommended interval basis. This final canister may also contain a particle filter which prevents adsorber particles from passing downstream.

The low pressure breathing air compressor plus the described breathing air purifier is time-proven and will deliver high quality breathing air.

(d) A Standby High Pressure Reserve System

The only effective method to store sufficient air for an industrial sized asbestos removal work crew is through the use of high pressure storage tanks. Such tanks are available for rental at low rates, and they can be delivered directly to the asbestos abatement worksite.

The standby reserve system functions by sensing both the line air pressure and the air quality provided by the compressor and breathing air system. Should the compressor fail and the line air pressure begin to drop or should CO levels exceed 20 ppm, the standby reserve sensing system detects dropping pressure or presence of CO and starts to supply pressure from the reserve air system. This pressure supply is automatic and immediate, and functions to continuously provide sufficient air to operate the respirators.

There are two operational notes that must be included in the startup and shutdown checklist for the operator of this system:

On Startup of the Low Pressure Breathing Air System:

(1) Start the low pressure breathing air compressor and verify air delivery at full pressure.

(2) Only then turn each reserve air tank on.

On Shutdown after workers have exited:

(1) Turn OFF each reserve air tank valve.

(2) Only then go through the procedures to shut down the breathing air compressor.

Operating any standby reserve air system without including the directions listed above could cause inadvertent loss of air from the reserve system. This could result in low or zero reserve air in the standby reserve air tanks when it is really needed.

(e) A Surge Tank or In-line Air Volume Tank

A surge tank provides air storage capacity so that peak flow conditions will not deplete the air supply.

(f) A Distribution Hose and Manifold with Connections for Respirator Hose Lines

Once air is processed through the low pressure air purifier it is directed into the delivery air line and is immediately available to the worker.

(2) The High Pressure System

The high pressure breathing air system (Figure 5) is composed of four major components:

(a) a high pressure compressor

(b) an air purifier assembly

(c) a high pressure air storage bank

(d) a high pressure control and distribution panel

(a) A High Pressure Compressor

The function of the high pressure compressor is the same as that in the low pressure system. The low pressure compressor utilized one or two successive compression steps or stages to compress the air up to 100 to 200 psi. The high pressure machine pumps the air to pressures of 2000 to 4000 psi utilizing from 3 to 5 successive stages of compression.

Each time the air is processed through a compression stage, its density and its pressure are increased, and its volume is decreased. The air temperature increases sharply through each

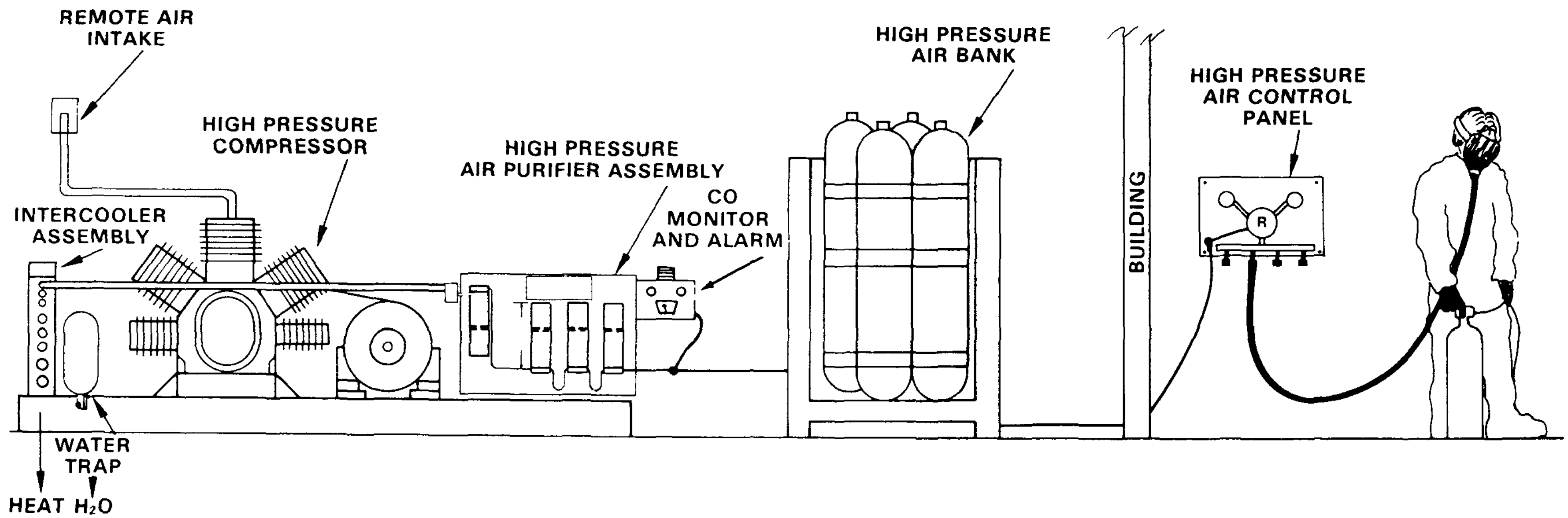


Figure G5. Typical High Pressure Breathing Air System

compression stage due to the adiabatic process. Following each stage of compression, the air is put through an intercooler that transfers considerable heat out of the air. Once the compressed air temperature is brought down, it cannot hold the moisture that it carried before that stage of compression, and the water vapor and other vapors condense. Following each intercooler stage is a cyclone-type liquid trap. The liquid trap is a vertical cylinder with a drain valve in the bottom. The air is introduced tangentially near the top of the trap, and creates a spinning vortex within the trap. The higher density condensed liquids are thrown against the cylinder walls of the trap. They drain down along the walls of the trap and can be removed from the compressor through the drain valve in the bottom. Even though water has been condensed and removed, the air is saturated. In this state, further compression or cooling will be able to remove additional water. This will be done in the following stages.

The air from the preceding compressor stage is now carried into the intake of the next compressor state. Here it is again compressed, cooled, and water is again extracted. This process of compression, cooling, and condensate removal is repeated for every succeeding state within the high pressure compressor. High pressure makes it possible to take out considerably more heat from the air than could be extracted by low pressure compression. The same is true for moisture removal within the high pressure machine. It is capable of removing much more of the water vapor that was originally being carried by the air than if the air were only compressed to a lower pressure in a single or dual state compressor.

Heat and water removal inside the compressor, by intercoolers and drain traps, is done by mechanical methods. Mechanical removal methods are more or less permanent removal methods. These methods do not require replacement adsorber cartridges nor the maintenance associated with such cartridge changes. Very high percentages of condensates are capable of being mechanically removed in high pressure processing. The result of such processing is to reduce the water vapor and other contaminants that must be removed by the following adsorber purifier.

Therefore, one of the major effects of high pressure mechnanical processing in the breathing air compressor is to reduce the required size and weight of adsorbent material needed in the follow-on high pressure purifier assembly.

(b) The Air Purifier Assembly

The high pressure purifier assembly is made up of an aftercooler, a combination coalescing filter/drain trap, and a number of successive purifier containers that hold adsorber materials.

The function of the aftercooler is similar to that of the intercoolers. Following the aftercooler, the air is put through a combination mechanical coalescing filter element/drain trap. Vapor is not removed in mechanical drain traps. There are some very tiny drops of condensed materials, called aerosols (water, oil, etc.) which act almost like vapor and also move through ordinary drain traps. In order to mechanically remove these aerosols, they are forced, in the coalescing element, to impact or squeeze together and to form big drops out of the aerosols. These coalesced liquid drops can now be drained from the air stream.

The air now moves into the adsorber section of the purifier.

Adsorber materials to be used in high pressure adsorber chambers are the same as used in low pressure designs:

molecular sieves

silica gel

activated alumina (Al_2O_3)

activated charcoal.

At this point the engineer or designer of the high pressure purifier assembly has two major advantages over designing for low pressure air purification: (1) more condensate and contaminates have already been mechanically removed within the high pressure compressor section, and (2) the density of the air is much higher. Higher density air means that any given amount of adsorber will be more effective and will process more air. Both of these facts add to a reduction in the required adsorber needed.

There is a third factor in the overall high pressure design which also allows for a reduction in the required adsorber material. One major action of the in-line high pressure storage bank is to allow a smaller compressor to be used. The high-pressure in-line air bank allows the designer to reduce compressor output, size, weight, and horsepower. Therefore overall cost of this system is reduced. Costs for the high pressure system are lower both in initial purchase and in operating costs, than if the designer were operating without the in-line high pressure air storage bank.

The combination of:

- *more condensate mechanically removed by the high pressure compressor*
- increased adsorber effectiveness due to higher density of air
- lower air flowrates needed because of the combination of the high pressure compressor and in-line air storage bank

make possible the use of simpler, smaller, and less costly adsorber purifiers to process the high pressure air.

As with low pressure breathing air systems, high pressure regenerative adsorber systems are available, but their high initial cost make them unattractive to the engineer/designer. They are generally not included in high pressure assemblies processing breathing air for asbestos work crews.

Following the coalescing filter trap, there are usually two (2) to four (4) successive additional disposable adsorber containers. These are usually replaced on a machine time basis, but color change or other indicators are available. Since cartridges cannot regenerate themselves it is especially important that they are changed on a regular and scheduled basis. Failure to do so could allow desiccants to reach saturation and permit contaminants to enter and contaminate the high pressure storage bank system. A typical high pressure purifier assembly, consisting of an inlet coalescing drain trap and three successive replaceable adsorber containers, is shown in Figure 6.

Continous CO Monitor and Alarm. Air passing from the high pressure purifier should be continuously monitored by an electric carbon monoxide alarm. Should any carbon monoxide be produced in the compressor or induced into the compressor air intake, it will be detected by the CO monitor. The CO alarm will visually and/or audibly warn if the CO level goes above 20 ppm. Visual warning is accomplished by meter and by a green/red system of lights. High decibel audible alarms are also available.

CO monitors can be adjusted to alarm at different levels of CO present. In order to meet the requirements of "Grade D" air, no more than 20 ppm are allowed.

(c) The High Pressure In-line Air Storage Bank

High quality air, Grade D or better, is now pumped directly into the high pressure storage bank. The function of this high pressure storage bank is to act as an air reservoir, so that:

- the peak air flow demands can be met without concern for or limitation by the maximum compressor output

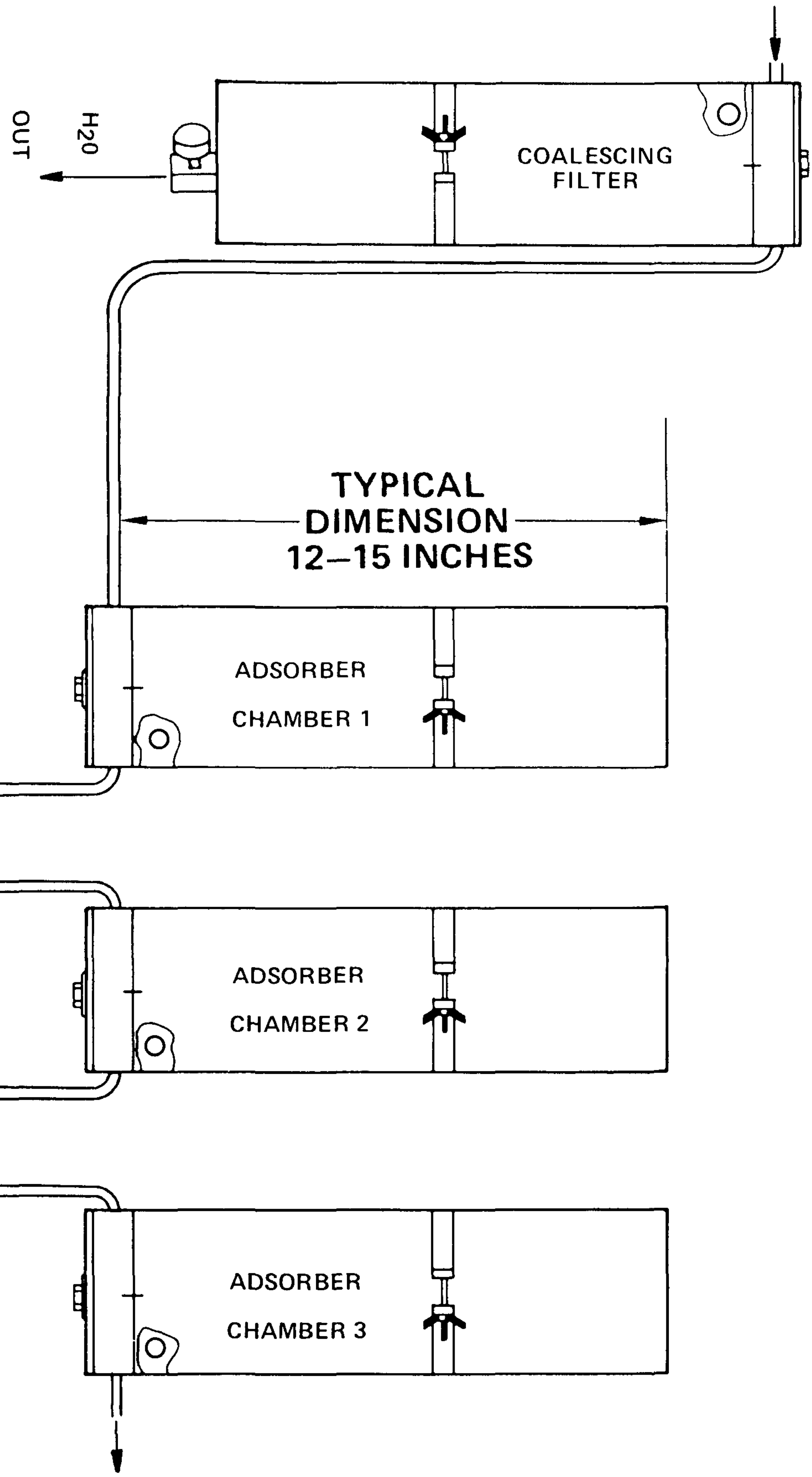


Figure G.6. Typical High Pressure Purifier Assembly

- the compressor and purifier can be sized for lower flowrates than the peak flowrates required

- in emergency compressor conditions, such as power failure, compressor stoppage, etc. the work crew air supply remains uninterrupted for at least one hour

- greater capacity (typically three to six hours) than the minimum required for escape (one hour) can be used to allow routine or emergency maintenance of the system to be accomplished without interrupting the work crew.

Air Reservoir for Peak Flow. A compressor pumping directly to a large work crew is analogous to a water pump pumping without a water reservoir. The direct supply water pump must be sized to meet the peak flow demands. Water systems include a water storage reservoir so that the peak flows are supplied by the reservoir, while the water pump operates over longer periods of lower flow to maintain the reservoir level. This pump/storage design method is done more than just for convenience; it is done also for cost reasons. Even small community water systems would require prohibitively sized water pumps, if only direct supply from the water pump was used. Therefore the function of large storage capacities is included in all municipal water systems. We see large water tanks located strategically around cities.

Air Reservoir to Lower Costs. Air storage is different from storage of water. Water density is the same for all water pumps, while air density is a function of air pressure. Low pressures simply do not have enough density to store air effectively. Therefore low pressure air compressors must deliver and use the air almost immediately, since no effective storage is available. Higher pressure increases air density. Increased air density makes possible the compressor/storage combination which can more effectively accomplish the air supply to large crews. Therefore smaller, lighter weight, lower horsepower and lower cost high pressure air compressors can compress air into and maintain the high pressure reservoir. The high pressure reservoir can supply peak flowrates without being limited by lower maximum compressor flowrates.

The major reason for the use of in-line high pressure air storage is economic. The in-line high pressure air storage bank allows a lower cost of smaller high pressure compressor to provide breathing air to a large asbestos removal work crew. Without the in-line air storage bank, a larger and more costly air compressor and larger and more costly air purifier assembly would be needed to support the same crew.

Reserve air time in excess of one to one and a half hours is also available from the high pressure system. Extra time above the one hour escape time may be called the working reserve. Working reserve time, stored in a high pressure storage bank, is very valuable in that unscheduled or scheduled maintenance can be done without interupting the work crew.

Air Reservoir for Emergency Conditions. The working reserve allows the severity of emergency conditions to be lessened. For instance, an inadvertent compressor stoppage with a low pressure system requires an immediate switchover to the high pressure air reserve. A normally open air valve is held closed until switchover is required to provide adequate egress time. The reserve air tanks must be fully charged. It is recommended that a low pressure sensor and alarm be used to monitor the standby reserve. In the high pressure system with in-line storage and reserve, the worker does not enter the toxic zone in the first place unless he is drawing air from the reserve air bank. Both outside and inside toxic zone pressure gauges show at all times the number of hours of reserve time for any crew size. Should the power fail and the high pressure compressor stop, there is no requirement for a switch to operate in order for the "reserve air" to be brought on line.

The working reserve also decreases the severity of the other conditions which might constitute real emergency conditions in other systems. For instance, consider that the CO alarm sounds. The CO alarm has auxiliary relays which can be used in the high pressure system to protect the air previously stored in the air bank. (Likewise, such relays can switch the low pressure system over to the reserve air bank.) It does this by providing power to close the air valve on the compressor output (high pressure system) or open the air valve to the backup reserve bottles (low pressure system). At the first moment of alarm, this valve is shut. Also, for both high and low pressure systems, manual valving on the compressor output can be used to shut off flow upon CO alarm. With Grade D air stored in the air bank, there is no CO emergency for the inside workers. The outside supervisors and outside workers can deal with this alarm as a potential CO problem. The inside workers are using the previously processed air stored in the bank, which will supply them for the next several hours. The problem can be identified and the condition corrected.

(d) A High Pressure Control and Distribution Panel

Air is delivered into the toxic zone from the high pressure air bank through small high pressure lines. These lines may be flexible or solid high pressure lines and may be several hundred feet in length. This high pressure line is led into the building to a lightweight air control and air distribution panel. The panel has a high pressure guage that may be marked off in pressure units or it may be rated in time units (hours) for any size work crew. Each worker attached by respirator hose to this panel can at all times see exactly how much working reserve time (and escape time) is available.

As with the low pressure breathing air system manifold, this panel also contains a regulator and low pressure gauge. The regulator sets, controls and maintains the respirator hose-line pressure to a precise value. Momentary fluctuations in the low pressure hose lines are removed by the action of the regulator. The regulator holds the respirator hose-line pressure at a constant value, which allows for more consistent respirator performance.

Respirator low pressure hose-line lengths are still limited to not more than 300 feet.

Filling SCBA Tanks. If equipped with filling devices, high pressure SCBA tanks can be filled from any part of a high pressure system.

Worker Cooling with the High Pressure Breathing Air System. Providing worker cooling is a consistent problem in asbestos removal work. Both the high and low pressure breathing air systems have built-in worker cooling. Because of its higher working pressures, high pressure cooling is more noticeable. The air supplied to the air panel is at high pressure and is also at ambient temperature (2000 to 4000 psi and about 70° - 85°F). The air panel regulator reduces this pressure to 80 to 100 psi. When this pressure reduction takes place, the air temperature drops 25° to 40°F or more. This cold low pressure air is supplied to the respirator hose lines. These hose lines may moderate the air temperature somewhat, but the result is that very desirable cold air is available for the worker to breathe. This adiabatic method of cooling is reliable, lightweight, and requires no added heat exchanger or other worker or work area equipment. It does not increase airflow requirements, and adds no cooling air burden to the compressor designer's air supply requirements.

(3) High Pressure Pre-Pumped Tanks

Sufficient breathing air for small jobs may be supplied by using pre-pumped high pressure air. There are two different choices of supply:

- rental cylinders from commercial speciality gas suppliers (This is the same source used to provide the high pressure standby air reserve.)

- the pre-pumped in-line reserve air bank from a high pressure breathing air system.

Either of these air sources can supply a small crew of one to four workers with enough air for one to three days. Operating in this manner, no electrical, gasoline, or diesel power is required at the jobsite. The pre-pumped air has already been processed through a CO monitor; therefore, job-site monitoring is not required. Special designs of larger air storage banks are possible so that this simple method of operation can be extended for larger crews and for longer times. A single high pressure air source located either at a major job site or at home base can function effectively to support one or more additional off-site jobs.

(4) Other

The Non-Lubricated Compressor. There are certain models of industrial-crew sized compressors which use solid state lubrication, rather than liquid lubrication. These machines, if recommended by the manufacturer, can be used to pump air for human consumption. Most of these special machines are more expensive than their oil-lubricated equivalents. They generally have to be rebuilt with less running time than the oil lubricated models.

The majority of breathing air around the world is pumped from oil-lubricated machines, and purified to Grade D air using the adsorber technology described in this report. Whether high or low pressure air, whether commercial divers, sport divers, industrial plant breathing apparatus, fire and rescue crews, all use Grade D air produced from adsorption-based air purifiers.

Unless there is a very special reason, and unless the extra cost can be justified, there is no need to operate the special class of non-lubricated compressor.

The Ambient Air Pump. The ambient air pump is a low power (½ h.p. to 5 h.p.) pump. These pumps take ambient air and supply it to the respirator through the appropriate hose line. They are not intended to improve the quality of the air being pumped.

Ambient air pumps provide an output air pressure in a range from 8 psig to 30 psig. They do not provide sufficient pressure to operate any currently approved NIOSH/MSHA pressure-demand combination SAR/SCBA respirator. Therefore, ambient air pumps cannot be used with the respirator recommended by NIOSH for use in asbestos abatement operations.

III. CAUTIONS IN THE USE OF BREATHING AIR SYSTEMS

1. Gross contaminations of the inlet air to the air compressor will adversely affect purifier performance. Therefore,

   CAUTION: **The compressor intake should be properly located to intake ordinary uncontaminated ambient air.**

2. Inlet air must not be oxygen deficient. No breathing air system will increase the oxygen content of the intake air being processed. Therefore,

   CAUTION: **The compressor intake should be located to ensure that air with normal ambient air oxygen content (19.5% - 23.5%) is always available.**

3. The inlet to the compressor should be located away from known or mobile (transient) sources of carbon monoxide. That is, it should be located away from and protected from the engine exhaust of any diesel or gasoline drive compressor, or away from the exhaust from automobiles, trucks, lawnmowers, and other mobile (transient) internal combustion engines. Therefore,

   CAUTION: **The compressor intake should be remotely located from the compressor and all possible mobile exhausts to ensure that carbon monoxide (CO) is excluded from the intake. The intake should be remotely plumbed to a safe position at each worksite.**

4. The potential for carbon monoxide poisoning through the intake of the compressor of the breathing air system is high enough so that further protection from carbon monoxide is required by OSHA regulation. Such additional CO protection should be part of any breathing air system at any asbestos removal worksite.

The General Industry OSHA Safety and Health Standards (29 CFR 1910.134), states "If an oil lubricated compressor is used, it shall have a high-temperature or carbon monoxide alarm, or both. If only a high-temperature alarm is used, the air from the compressor shall be frequently tested for carbon monoxide to insure that it meets the specifications."

Since the asbestos removal workplace is usually a temporary worksite, the expectation is that mobile sources of carbon monoxide may pose more hazard than in a permanent worksite. If carbon monoxide is introduced into the intake it will NOT be detected by a high temperature alarm. Therefore, due to the conditions at the asbestos removal worksite, the recommendation is made that additional protection from carbon monoxide be provided by a continuous carbon monoxide monitor with alarm. This choice of a continuous carbon monoxide monitor and alarm is the preferred choice rather than using a high temperature alarm on the compressor.

Catalysts that under ideal conditions can cause oxidation of carbon monoxide to the less dangerous carbon dioxide (CO_2) are a feature to help protect against carbon monoxide in breathing air. However, OSHA requires the protection of a monitor and alarm against CO in the breathing air. Therefore,

CAUTION: **A continuous carbon monoxide monitor and alarm should be installed and functioning in the compressor output breathing air stream.**

5. When operating a diesel or gasoline driven compressor, addition precautions should be taken to plumb both compressor intake and exhaust away from the compressor and into a safe location. Therefore,

CAUTION: **Any internal combustion engine-driven compressor should also have the exhaust line plumbed to a safe location, as well as having the intake line plumbed to a safe (separate) location.**

6. An open-ended or broken pneumatic line or hose may create a hose "whipping" or moving hose hazard. Therefore all pneumatic lines, low or high pressure, should be restrained. Simple and inexpensive restraints such as sandbags are usually sufficient. Therefore,

CAUTION: **Air supply hose or lines should be restrained every 15 feet of their length. (This does not include the length of hose from the distribution manifold to the respirator.)**

7. Asbestos removal worksites create the possible hazard of airborne toxic fibers. Therefore standard practices to contain these fibers must be used. The compressor is a concentrator of any airborne contaminants. The compressor intake inlet and the entire length of intake hose should be free of airborne asbestos fiber contamination. Therefore,

CAUTION: **The compressor intake point and intake hose should never be operated in air contaminated with asbestos fibers. The compressor and air intake hose should be located in a clean air environment outside the asbestos work zone.**

8. Compressor oil suitable for use in breathing air applications should be used. The only proper source for such oil type recommendation is the manufacturer of the breathing air compressor or breathing air system. Therefore,

CAUTION: **Use only compressor oil suitable for use in breathing air applications.**

and

CAUTION: The recommendation for oil suitable for use in compressors for breathing air applications should only be made by the compressor or breathing air system manufacturer.

9. The user of any breathing air system should recognize the importance of running the system at the correct design conditions. The heat, moisture and oil removal abilities designed within the compressor are important. If the high air temperatures generated by compression are not reduced, the water/oil vapors will not be condensed and therefore may pass through the water traps without being removed. This circumstance may present an overload of water/oil to any breathing air purification assembly that follows the compressor and aftercooler. Such purifier assembly overload will cause the adsorber assemblies within the purifier assembly to be replaced on a more frequent than normal schedule. Unnecessary canister replacement increases the expense of maintaining the breathing air purifier. Therefore,

CAUTION: Compressors equipped with breathing air purifier assemblies should be used. Breathing air purifier assemblies should be used as designed and not overloaded.

10. Pure oxygen gas must not be pumped by or utilized in a breathing air system for use with air supplied respirators. Only air is pumped by these systems. Pure oxygen gas is never to be used in the standby escape time or reserve air system. Only compressed air is used in the standby reserve air system. Pure oxygen is not to be supplied from any source into the respirator systems used in asbestos removal. Therefore,

CAUTION: Never use pure oxygen gas in any part of the gas supply system supplying the air supplied respirators. Respirators are supplied only with Grade D air.

11. High pressure air reserve bottles are, and all compressed air systems have, pressurized vessels. Therefore, an explosive hazard potential exists.

CAUTION: Before starting and operating a compressor and purifier system, inspect all system components for structural damage which could result in an explosion. Inspect safety relief valves carefully, and verify that they are in good working order.

IV. Cost Analysis: Supplied Air Versus Air-Purifying Respirator Systems

This part of the Appendix presents an analysis of the comparative cost of equipping equal sized crews with supplied air respirator/breathing air systems versus air-purifying respirators.

Some important conclusions of this cost comparison, which follows in detail, are:

(1) A breathing air supply system used with pressure-demand, supplied air respirators, is considerably lower in cost than an air-purifying respirator system.

(2) The *initial* cost of outfitting an asbestos removal crew is lower when equipped with air-purifying respirators than the initial cost of obtaining a breathing air system and equipping the same crew with pressure demand supplied air respirators.

(3) The yearly cost for the asbestos removal crew equipped with air-purifying respirators is much higher than the same size crew equipped with the breathing air system and supplied air respirators. This higher yearly cost is the result of the recurring daily costs of the required replacement filters for the air-purifying respirators.

(4) The higher initial cost of the pressure-demand supplied air respirators and breathing air system over the cost of the air-purifying respirators is usually returned to the owner of the breathing air system within only 6 months to one year of *operational* use.

(5) Following this short time of operational use, the pressure-demand supplied air respirators with the breathing air system continue to save the owner the cost of the entire system approximately every 6 months to one year throughout its subsequent operational lifetime.

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*Based on the average yearly cost of $20,504.00 of the Supplied Air System.

RESULTS COMPARATIVE INITIAL COSTS

Crew Size 15 Workers All Cases

I.	Initial cost full facepiece PAPR-HEPA (15 each)	$8,895.00
II.	Initial cost full facepiece negative pressure	1,425.00
III.	Initial cost breathing air system with 15 pressure demand respirators	25,985.00 to 37,985.00

[NOTE: Low pressure rental breathing air compressors have not been calculated; however, they are sometimes locally available. If rental compressors were calculated, it would reduce the initial purchase cost and increase the yearly costs of the low pressure breathing air system in this comparative study. High pressure breathing air compressors are not generally available for rent.]

RESULTS COMPARATIVE YEARLY COSTS*

I.	Full facepiece positive pressure air purifying powered air high efficiency particulate filtration respirator (PAPR-HEPA)	$57,030.00 to $110,168.00/yr.
II.	Full facepiece negative pressure air purifying respirator	30,617.00 to 60,617.00/yr.
III.	Breathing air system with full facepiece pressure demand respirators	18,704.00 to 22,304.00/yr.

Conclusion:

On a yearly cost basis, breathing air systems cost considerably less than air purifying replaceable filter respirators. The higher yearly costs of the replaceable filter air purifying respirators are due almost entirely to the recurring daily costs of replacement filter canisters.

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*The cost figures given above and on subsequent pages respresent "worst case" estimates because they are based on 24-hour day, 365-day year operations (8760 hours/yr). Actual costs will be proportionately less depending upon actual use.

COSTS OF FULL FACEPIECE POSITIVE PRESSURE DEMAND AIR-PURIFYING HIGH EFFICIENCY PARTICULATE FILTER TYPE RESPIRATORS (PAPR-HEPA)

Initial Purchase:

15 each PAPR-HEPA at $599.00 each	$8,985.00
Yearly cost:	
Amortize in three years	$2,995.00/yr.
Unscheduled maintenance at 10% per year	898.00/yr.
Scheduled maintenance for HEPA cartridge replacement at $14.17/day or $28.35/day based on one shift per day, 5 days per week, for 50 weeks per year or 250 days per year	53,137.00/yr. to 106,275.00/yr.
TOTAL COSTS YEARLY	**$57,030.00 to $110,168.00**

[NOTE: Inclusion of the air purifying respirator types in this comparative cost study should not be inferred as a recommendation for their suitability for use in any given asbestos removal circumstance. Breathing air systems, either low pressure (100 to 200 psi) or high pressure (2000 psi or more), used with pressure-demand full-facepiece respirators, or pressure-demand self-contained breathing apparatus provide higher levels of protection and the high reliability needed for asbestos removal.]

COSTS OF FULL FACEPIECE NEGATIVE PRESSURE AIR-PURIFYING RESPIRATORS

Initial purchase:

15 each negative pressure full facepiece respirators at $95.00	$1,425.00
Yearly cost:	
Amortize in three years	$475.00/yr.
Unscheduled maintenance at 10% per year	142.00/yr.
Scheduled maintenance for daily replacement of filter canisters averaging either $8.00 or $16.00 per man per pay day for 250 days	30,000.00/yr. to 60,000.00/yr.
TOTAL COSTS YEARLY	**$30,617.00 to $60,617.00**

[NOTE: Inclusion of the air purifying respirator types in this comparative cost study should not be inferred as a recommendation for their suitability for use in any given asbestos removal circumstance. Breathing air systems, either low pressure (100 to 200 psi) or high pressure (2000 psi or more), used with pressure-demand full-facepiece respirators, or pressure-demand self-contained breathing apparatus provide higher levels of protection and the high reliablility needed for asbestos removal.]

COSTS OF BREATHING AIR SYSTEM WITH FULL FACEPIECE PRESSURE DEMAND RESPIRATORS

Initial purchase:	
Breathing air compressor	\$8,000.00 to \$12,000.00
Air purifier system	\$9,000.00 to \$17,000.00
15 each airline respirators complete with fittings and hoses at \$500.00 each	\$8,985.00
Yearly costs:	
Cost of compressor operation at 21¢/1000 SCFM	\$6,623.00/yr.
Purge air costs at 21¢/1000 SCFM	\$1,325.00/yr.
Amortize breathing air system in five years	\$3,400.00 to \$5,800.00/yr.
Unscheduled maintenance at 10% per year	\$2,598.00 to \$3,798.00/yr.
Scheduled maintenance for breathing air purifying canister replacement* (see below)	\$1,763.00/yr.
Amortize respirators three years	\$2,995.00/yr.
TOTAL COSTS YEARLY:	**\$18,704.00/yr. to \$22,304.00/yr.**

*Scheduled maintenance:

Oil purifier prefilter 6x per year at \$60.00 - 80.00	\$480.00/yr.
Al_2O_3 dryer towers 1x every 3 years at \$100.00	\$33.00/yr.
CO catalyst filter 1x per year at \$750.00 - \$1,800.00	1,800.00/yr.
Odor removal charcoal filter 2x per year at \$90.00 - 120.00	240.00/yr.
Total scheduled maintenance per year	**\$1,763.00 yr.**

V. SUPPLIERS OF BREATHING AIR EQUIPMENT

INCLUDING SUPPLIERS OF

High and Low Pressure Breathing Air Compressors
High and Low Pressure Breathing Air Purifiers
Carbon Monoxide Monitors
Gas Detection Tubes
Heat Exchangers
Particle Filters
Vortex Tubes

American Bristol Industries
1600 West 240th Street
Harbor City, California 90710

Asbestos Control Technology
P.O. Box 183
Maple Shade, New Jersey 08052

Atlas Copco Turbonetics
20 School Road
Voorheesville, New York 12186

Bauer
1328 Azalea Garden Drive
Norfolk, Virginia 23502

E. D. Bullard Co.
2680 Bridgeway
Sausalito, California 94965

Consumer Fuels, Inc.
7250 Governors Drive West
Huntsville, Alambama 35805

Critical Services, Inc.
2828 Broad
Houston, Texas 77087

Control Resource Systems, Inc.
670 Mariner Drive
Michigan City, Indiana 46360

Ingersol Rand
11 Greenway Plaza
Houston, Texas 77046

Joy Manufacturing Company
Montgomery Industrial Park
Montgomeryville, Pennsylvania 18936

3M Company
3M Center Building 230-B
St. Paul, Minnesota 55101

Daboco, Inc.
3319 E. Ten Mile
Warren, Michigan 48091

Davey Compressor Company
11060 Kenwood Road
Cincinnati, Ohio 45242

Deltech Engineering, Inc.
Century Park, P.O. Box 667
New Castle, DE 19720

Dynamation, Inc.
3748 Plaza Drive
Ann Arbor, Michigan 48104

Dynatech Frontier, Inc.
5655 Kircher Blvd. NE
Albuquerque, New Mexico 87109

Enmet Corporation
2307 South Industrial Highway
Ann Arbor, Michigan 48104

Hankison Corporation
1000 Philadelphia Street
Cannonsburg, Pennsylvania 15317

Industrial Pump & Compressor
12014 Chain Lake Road
Snohomish, Washington 98290

Industrial Safety Products
1502 Telegraph Road
Mobile, Alambama 36611

Rix Industries
6460 Hollis Street
Emeryville, California 94608

Sullair Corporation
3700 East Michigan Blvd.
Michigan City, Indiana 46360-9990

Mine Safety Appliances Company
600 Penn Center Blvd.
Pittsburgh, Pennsylavania 15235

National Draeger
101 Technology Drive
Pittsburgh, Pennsylvania 15235

North Safety Equipment
2000 Plainfield Pike
Cranston, Rhode Island 02816

RhineAir, Inc.
8402 Magnolia Avenue
Santee, California 92071

Racal Airstream Inc.
7209A Grove Road
Frederick, Maryland 21701

Vortec Corporation
10125 Carver Road
Cincinnati, Ohio 45242

Willson Safety Products
2nd and Washington Streets
P.O. Box 622
Reading, Pennsylvania 19603

Appendix H.

Transcript of NIOSH Testimony Given to the U.S. Department of Labor at a Public Hearing on Occupational Exposure to Asbestos held on June 21, 1984

Appendix H. Statement of The National Institute for Occupational Safety and Health The Public Hearing on Occupational Exposure to Asbestos June 21, 1984

I am Richard A. Lemen, Director of the Division of Standards Development and Technology Transfer (DSDTT) of the National Institute for Occupational Safety and Health (NIOSH). With me today are senior staff from NIOSH research Divisions; each of whom has expertise in various aspects of the asbestos problem. Our purpose for appearing at this hearing is to support OSHA's efforts to promulgate a new standard for asbestos.

The United States Public Health Service first published a study describing the adverse effects of exposure to asbestos in the asbestos textile industry in 1938 and recommended a guidance concentration to protect workers from adverse effects of asbestos. This concentration was 5 million particles per cubic foot of air (mppcf). This recommendation was not officially adopted until 1960, under the Longshoremen's Act, administrated by the Department of Labor. This standard remained in effect until 1969 when the Department of Labor lowered it to 2 mppcf or 12 fibers/ml under the Walsh-Healey Act.

In November 1971, the Director of the newly created NIOSH, an agency of the USPHS, in a letter to the Assistant Secretary of Labor for OSHA recommended a reduction of the then current asbestos standard from 12,000,000 to 5,000,000 fibers greater than 5 microns in length per cubic meter of air (12 fibers/ml to 5 fibers/ml) as an 8-hour time weighted average (TWA). In December of 1971 OSHA issued an emergency temporary standard specifying an 8-hour TWA permissible exposure limit (PEL) of 5,000,000 fibers per cubic meter greater than 5 microns in length per cubic meter of air. Concentrations above 5,000,000 fibers per cubic meter but not to exceed 10,000,000 fibers per cubic meter were permitted for up to 15 minutes in an hour for as many as 5 hours in an 8-hour day. That standard specified respirator use where engineering controls were not feasible (36 FR 23207).

Subsequently, on February 25, 1972 NIOSH submitted a Criteria for a Recommended Standard . . . Occupational Exposure to Asbestos to OSHA. This NIOSH criteria document recommended an 8 hour TWA of 2,000,000 fibers per cubic meter based on a count of fibers greater than 5 microns in length as determined by the phase contrast microscope. Peak exposures for any 15 minute sampling period at greater than 10,000,000 fibers greater than 5 microns per cubic meter of air would not be permitted. Periodic medical examinations were also required, and respirator types were specified for various concentrations in excess of the TWA. Under the NIOSH recommended standard, it was also required that workers be informed of the hazards of working with asbestos, symptoms of diseases, and precautions to be taken to reduce the risk of adverse effects. On June 7, 1972, OSHA issued a final asbestos standard having an initial PEL of 5,000,000 fibers per cubic meter to take effect immediately and a reduced PEL of 2,000,000 fibers per cubic meter to take effect on July 1, 1976. In this OSHA standard, engineering controls were required to meet the PEL and only limited use of respirators was permitted during installation of engineering controls or when engineering controls were not feasible or during emergencies. Labels were also required.

In December 1976, NIOSH submitted a revised recommended asbestos standard to OSHA recommending that the current 2,000,000 fibers per cubic meter standard was inadequate to protect against asbestos-related disease. Since phase contrast microscopy was the only generally available and practical analytical technique at that time, the concentration recommended by NIOSH was 100,000 fibers |5um in length/m^3 (0.1 fibers/cc) as an 8-hour TWA with peak concentrations not exceeding 500,000 fibers |5um in length/m^3 (0.5 fibers/cc) as determined in a 15 minute sampling period. This new recommendation was intended to protect against the non-carcinogenic effects of asbestos and to lower the carcinogenic risk since cancer risks had been demonstrated at all fiber concentrations studied to that date. The available data at that time provided no evidence for a threshold of response or for a "safe" level of asbestos exposure. To date no new evidence would disprove this.

In the fall of 1979, at the request of the Assistant Secretary of Labor for Occupational Safety and Health and the Director of NIOSH, a joint NIOSH/OSHA working group on asbestos was established. In

November 1980 the committee's report was released. The working group was requested to review the existing scientific information concerning asbestos-related disease and assess the adequacy of the current OSHA standard of 2,000,000 fibers greater than 5 microns in length per cubic meter of air. This NIOSH/OSHA committee reviewed previous NIOSH criteria documents, the report of the British Advisory Committee on Asbestos (completed in 1979), and the 1977 International Agency for Research on Cancer (IARC) monograph on the carcinogenic hazards of asbestos. Among the recommendations made by the joint committee was a recommended definition of asbestos for regulatory purposes.

> Asbestos is defined to be chrysolite, crocidolite, and fibrous cummingtonite-grunerite incuding amosite, fibrous tremolite, fibrous actinolite, and fibrous anthophylite. The fibrosity of the above minerals is ascertained on a microscopic level with fibers defined to be particles with an aspect ratio of 3 to 1 or larger.

At present, NIOSH knows of no compelling scientific argument upon which to change this definition.

The committee also recommended sampling and analytical techniques for airborne asbestos and concluded that using these techniques would permit airborne asbestos to be accurately quantitated to 100,000 fibers greater than 5 um in length per cubic meter averaged over an 8-hour workday; the joint committee recommended that this be the occupational standard for asbestos exposure in the workplace. A modification to this recommendation will be presented in the final recommendations of this testimony.

In addition, the joint committee stated that "Regardless of the choice of a permissible exposure limit, the best engineering controls and work practices should be instituted, and protective clothing and hygiene facilities should be provided, and their use required of all workers exposed to asbestos." The committee further emphasized that "Respirators are not a suitable substitute for these control measures." The joint committee also concluded that ". . . even where exposure is controlled to levels below 100,000 fibers, [sic] there is no scientific basis for concluding that all asbestos-related cancers would be prevented." In addition, the joint committee also recommended provisions for medical surveillance. Because of the widespread current and past uses of asbestos products in the maritime and construction industries, the joint committee stated that ". . . it is vital that any new asbestos standard address these industry sectors as well as other workplaces with employees exposed to asbestos." The joint committee further recommended that:

> ". . . manufacturers of asbestos-containing products such as construction materials should perform detailed monitoring of exposures which could result from all foreseeable uses of their products, including misuse. This monitoring should include electron microscopy to identify fiber type, mix and exposures to fibers less than 5 um in length. This monitoring data should accompany these products downstream so the users not only know that asbestos exposures may occur, but also know the nature of potential exposures. This monitoring data could, if appropriate, avoid the need for small employers who use asbestos-containing products to have to conduct monitoring on their own." NIOSH supports the OSHA position that any excursion about the PEL should verify the fiber type by electron microscopy.

Also, the joint committee urged that ". . . because cigarette smoking enhances the carcinogenic effect of asbestos exposure on the lung, particular emphasis should be placed on this in any educational program developed under a new standard."

NIOSH continues to believe that both asbestos and smoking are independently capable of increasing the risk of lung cancer mortality. When exposure to both occurs, the combined effect with respect to lung cancer appears to be multiplicative rather than additive. From the evidence presented, we may conclude that asbestos is a carcinogen capable of causing, independent of smoking, lung cancer and mesothelioma.

Finally, the joint committee stated that ". . . due to the fact that other agencies regulate occupational exposures to asbestos (such as the Mine Safety and Health Administration), these agencies should be urged to participate in the development of a new standard and adopt this new standard."

NIOSH continues to recommend a revised asbestos standard. It is our contention that there is no safe concentration of exposure to asbestos. Any standard, no matter how low the concentration, will not ensure absolute protection for all workers from developing cancer as a result of their occupational exposure; however, lower concentrations of exposure carry lower risks. This is consistent with the conclusions of the NIOSH 1976 criteria document and the joint NIOSH/OSHA report of 1980. This is also consistent with the conclusion of the Consumer Product Safety Commission (CPSC) Chronic Hazard Advisory Panel on Asbestos in 1983. They concluded that "on scientific grounds and as a matter of public health prudence, the Commission should regard asbestos at all levels of exposure as a potential human carcinogen." The CPSC report all concluded that:

> All major fiber types studied (i.e., chrysotile, amosite, crocidolite) appear to be capable of causing lung cancer and all except anthophyllite, pleural mesothelioma in humans.

This is consistent with the joint NIOSH/OSHA report which stated that:

> "On the basis of available information, the committee concludes that there is no scientific basis for differentiating between asbestos fiber types for regulatory purposes."

This statement by the joint NIOSH/OSHA committee continues to be NIOSH policy today and is supported in our written comments to the docket.

DOSE-RESPONSE RELATIONSHIPS

The available evidence indicates that larger doses of asbestos will produce greater biological effects than smaller doses. Although there appears to be little dispute that a larger dose of asbestos poses a health risk, the exact nature of the dose-response relationship for lung cancer mortality is subject to considerable debate. This is primarily because of the uncertainty of exposure estimation. Methods of measuring asbestos concentrations have changed over time. Sampling instrument (thermal precipitation versus midget impinger versus membrane filter), location of sampling (personal versus area), dust counting (particles versus actual fibers), and evaluation techniques (whole fields versus eyepiece graticule) have all changed. As a result, conversion of asbestos concentrations obtained by one method to those obtained by another is far from simple and is subject to considerable error. Another factor which may lead to differences of opinion on the exact shape of the dose-response curve is the measure of the dose. The commonly used measures are cumulative dose and the duration of employment. Since using cumulative dose as a measure of exposure gives equal weight to the concentrations of asbestos experienced in each year of exposure, exposures that occured many years ago are implicitly considered to be as important as recent exposure. This assumption is unrealistic for the chronic diseases having a long latency period. Duration of employment has also been used as a measure of exposure with the assumption that increasing the exposure duration approximates increasing the dose. This procedure has the same problem as using the cumulative dose. Furthermore, in the absence of reliable past exposure data, the duration of employment may not be directly proportional to the total dose of asbestos.

Data available to date provide no evidence for the existence of a threshold level. Virtually all levels of asbestos exposure studied to date demonstrated an excess of asbestos-related disease.

ASBESTOS SAMPLING AND ANALYSIS AND RECOMMENDED EXPOSURE LIMIT

In the 1980 NIOSH/OSHA publication Workplace Exposure to Asbestos; Review and Recommendations we presented and evaluated several methods for sampling and analysis of asbestos that had been developed since the publication of the NIOSH criteria document on asbestos. Based upon that evaluation, it was concluded that: "The phase contrast method is clearly capable of measuring airborne fiber levels down to 0.1 fibers/cc . . ."

We also recognized that phase contrast microscopy lacked specificity when asbestos and non-asbestos fibers occurred in the same environment. To cope with the problem of specificity we concluded: "The most likely choice for fiber identification in airborne dust samples is electron microscopy where both electron diffraction and microchemical analysists may be used to identify fibers."

We also concluded that it is reasonable that such determinations only need be made for a sample which is statistically significantly above the blank with subsequent determinations made only upon process or product modifications.

In making a recommendation for an occupational exposure limit for asbestos, NIOSH's ultimate goal is to eliminate asbestos exposures. However, we realize that at this point in time such a recommendation is neither feasible nor practicable due in part to limitations imposed by currently accepted methods of sampling and analysis.

Since 1980, NIOSH has developed modifications to our existing phase contrast method for asbestos determination. By employing this modified method (NIOSH Method 7400), it is possible to measure personal asbestos exposure at concentrations as low as 20,000 fibers per cubic meter of air (when a 2 cubic meter air sample is collected). However, in some sampling locations the filter may become so loaded with non-asbestos particulates that accurate counting may not be possible.

It is assumed that NIOSH Method 7400 will be used for monitoring, which requires a minimum fiber loading of 100 f/mm^2. This method is able to achieve precision which meets the established NIOSH accuracy standard of 12.8% RSD, at an exposure limit of 100,000 fibers/m^3 determined as an 8 hour TWA in a 400 liter sample. Using the new method 7400 it is also possible to measure 50,000 fibers per cubic meter with an overall precision of 20% RSD and to measure 20,000 fiber per cubic meter at 30% RSD using a 400-L air sample.

NIOSH and others have recommended exposure limits for asbestos based on 8-hour time weighted average concentrations. While this is a well understood practice, we cannot find compelling arguments to prevent a recommendation based on alternative sampling periods. In fact, such an approach may provide more protection than an 8-hour based sampling period that allows short term exposures 6 or 10 times greater than the 8-hour exposure limits being considered by OSHA. Furthermore, since there is uncertainty regarding the cumulative dose required to initiate disease, it seems reasonable to make every attempt to control exposures to as narrow a range of concentrations as possible. We believe that one way to accomplish this may be by restricting the period over which workplace concentrations can be averaged. Four liter per minute personal sampling pumps are presently available which would allow a sampling time of 100 minutes. NIOSH is currently evaluating this information.

We recognize that there will be certain situations in which overloading of the filter at this flow rate may be of concern. In those situations, the judgement of the professional taking the sample must be applied to determine a more appropriate sampling time keeping in mind the requirement that a minimum fiber density of 100 fibers per square millimeter is required to achieve the NIOSH acceptable precision at a concentration of 100,000 fibers/cubic meter of air.

Finally, we still believe that there are occasions such as mixed fiber exposures where fiber specificity is necessary. Therefore, we recommend the use of electron microscopy in the event of process or product modification, in mixed fiber exposures or when there are other reasons for characterization of fiber type.

Control of Exposures:

Effective control involves a system of engineering, work practice, personal protection, and monitoring/ feedback measures, with engineering as the preferred control measure by professional occupational safety and health professionals. There are clear advantages to using engineering measures to prevent or contain emissions at the source. Effective containment prevents problems associated with housekeeping and with secondary workplace emissions from settled dust; it also prevents the prospect of emitting asbestos into the environment outside of the workplace. Thus, it addresses both occupational and public health concerns simultaneously.

The proposed OSHA requirement that engineering and work practice measures be used to meet a 2,000,000 fibers/m^3 level is consistent with effective containment. However, the additional proposed provision of compliance by respiratory protection below this level is not consistent with source containment, especially since engineering measures may in fact be able to control to well below 2,000,000 fibers/m^3 (as discussed below). Proposed blanket exemptions for intermittent exposures without regard to feasibility are also no consistent with source containment. Worker rotation as a compliance measure must be forbidden given the lack of a safe threshold for lung cancer caused by asbestos.

Potential asbestos exposures can be divided into two broad categories. The first involves the inclusion of asbestos in products which are currently being developed or manufactured (e.g., brake shoes, thermal insulation, floor tile, cement pipe) and additional handling of these products (e.g., replacement of brake shoes). The second involves construction activities, which consist principally of tearout or maintenance of previously installed asbestos in buildings or factories, and demolition of these buildings.

In the first case (currently manufactured products) the recommended control strategy is to modify the product so that asbestos or a substitute is not required at all. The continued use of large quantities of asbestos presents the prospect of large scale introduction of asbestos into the workplace, and ultimately into the environment as these products are used and disposed of. Rajhans and Bragg discuss substitutes such as: alkaline resistant glass fiber for asbestos in cement; iron or plastic pipe for cement pipe; steel and glass fiber composites (still under development) for brakes; fibrous glass and various refractories for thermal insulation. The Royal Commission Report for Ontario Canada states that, "in 1980, semi-metallic disc pads were used on the front brakes of approximately half of all new North American vehicles, and it is expected that this fraction will approach 100 percent by 1985." Further, they report that, for packing materials, "New packing materials appear to be more than viable alternatives (to asbetos), offering less abrasion and thus lower operating and maintenance costs. It appears that only sales and engineering resistance stand in the way of a total switchover to non-asbestos packings." For asbestos-cement pipe, they report that, "for most applications at least one alternative to asbestos-cement pipe will offer satisfactory performance, and main factor of choice is economics." For plastic fillers, they report that, "substitutes are economically competitive with asbestos and yield satisfactory product qualities." They report that more work may be necessary to provide completely acceptable non-asbestos substitutes for floor tile and roof coatings or paints.

Where asbestos is used, rigorous engineering source controls should be employed. Bragg stated that "Emptying asbestos out of bags, or debagging, is one of the most difficult processes to control." Bragg indicates that even if substitutes are not available, engineering containment measures should generally suffice to keep exposures at or below 500,000 fibers per cubic meter for most manufacturing operations using asbestos. NIOSH has studied controls for two of the most difficult operations involving asbestos processing. NIOSH found exposure levels around 200,000 fiber per cubic meter at an asbestos debagging operation which used an automated debagger. Furthermore, the exposures that did occur in the NIOSH study seemed to be from contaminated incoming bags rather than from the debagger itself. Newly available automated debaggers with improved bag disposal combined with improved cleaning of incoming bags may offer even further exposure reductions.

NIOSH also found exposurers of 100,000 fibers per cubic meter at a well controlled asbestos bag filling operation. Therefore, the blanket OSHA exemption of engineering measures for control below 2,000,000 fibers per cubic meter is not warranted for the manufacture of asbestos-containing products.

In the second case (tearout and maintenance), rigorous engineering and work practice containment measurers are available. Techniques such as wetting, local exhaust, and HEPA filtration are appropriate. Workforce mobility and rapidly changing worksites in construction activities complicate both engineering and environmental/medical monitoring activities and may justify a seperate standard for this industry. In general, NIOSH feels that there is a need for a validation, specification and uniform enforcement of specific engineering and work practice controls in asbestos-related construction activities. It is important that competing bidders be required to address a minimum level of safe performance, since the growth and highly competitive nature of the asbestos removal industry has resulted in strong incentives to cut costs.

RESPIRATORS

Respirators can effectively reduce employee exposures to asbestos. However, a number of problems must be overcome before any confidence can be given to using respirators as a solution to preventing excessive exposures. Some of the problems include:

- Whether or not single-use or dust and mist respirators can provide adequate protection for cancer-causing agents such as asbestos.
- Discomfort associated with wearing respirators including dermatitis, heat, difficulty in breathing, callouses, and feelings of claustrophobia.
- Need for adequate fit testing and addressing fit problems with workers who are not clean-shaven.
- Physiologic stress and drying of breathing passages and sinuses associated with wearing respiratory protective devices.

These problems can exist even when the proper respirator has been selected and an adequate respiratory protection program including training is in place. If a respirator training program does not exist, the chances of respirators providing adequate protection are much less.

NIOSH has stressed that worker exposures to airborne contaminants should be controlled through permanent engineering controls. However, prior to the installation of or during the malfunction or maintenance of engineering controls, for certain short-term intermittent exposures, and for certain operations that are performed at constantly changing locations, a need for respirators does exist. Because respirators are and will be selected and used in industry, NIOSH wants to ensure that the respirators will be used correctly and that the quality of each respirator produced will meet certain criteria. Proposed blanket exemptions for intermittent exposures without regard to feasibility of engineering controls are also not consistent with source containment.

The position of the Institute with respect to the following specific concerns is as follows:

- <u>Use of single-use or dust and mist respirators for protection against asbestos</u>

  Under Title 30, Code of Federal Regulations, Part 11 (30 CFR 11), NIOSH is required to test and certify respirators within the categories specified therein when such devices are submitted to NIOSH by applicants. Curently, 30 CFR 11, Subpart K defines a number of dust, fume, and mist respirators which may be used for protection against certain hazardous particulate atmospheres. Among the respirators defined in Subpart K are single-use dust respirators designed as respiratory protection against pneumoconiosis - producing and fibrosis-producing dusts, or dusts and mists. The Subpart goes on to list asbestos as one of the dusts against which the single-use dust respirator is designed to protect [Subpart K, sec. 11.130(h)]. Though at the time of the promulgation of Subpart K, it may have been assumed appropriate to list asbestos as a fibrosis-producing particulate against which the single-use disposable respirator could be reasonably expected to provide adequate protection, NIOSH is no longer confident that such an assumption is reasonable because asbestos is also potent carcinogen. The Current requirements of 30 CFR 11 for approval of a single-use dust respirator or dust and mist respirator do not include any tests with a fibrous challenge.

  NIOSH is currently in the process of undertaking a comprehensive revision of 30 CFR 11 and intends to address the issue of appropriate respiratory protection for use against asbestos and to require that any respirator for which such approval is sought be proven to provide effective protection against asbestos. NIOSH may change the regulations included in 30 CFR 11 only in accordance with procedures set forth in the Administrative Procedures Act. In the interim, NIOSH will continue to approve single-use and replaceable dust/mist respirators for use against asbestos when such approvals are applied for only because of the legal requirement in the current approval regulations. However, NIOSH does not recommend the use of such respirators where exposurers to asbestos may occur on the basis that such is not a prudent occupational health risk.

- Finally, we want to reiterate our position that we recommend a quantitative respirator fit testing program as previously stated in comments on the proposed lead standard

MEDICAL SURVEILLANCE PROGRAMS FOR ASBESTOS EXPOSED WORKERS

One of the principal questions of considerable public health importance is "Can we develop valid and reliable medical screening and biological monitoring tests to recognize the early effects of exposures to occupational hazards at reversible or treatable stages in order to complement and evaluate the effectiveness of environmental monitoring and control measures?" (Orchard, 1980; Becklane, 1982).

Recent reviews of available epidemiological literature indicate that withdrawal from asbestos exposure will not ensure protection against progression of existing or development of asbestos-related disease (Becklake, 1982; NIOSH/College of American Pathologists Pneumoconiosis Committee, 1982; Craighead et al., 1982). Few would disagree with the view expressed by Dr. Hans Weill that radiographic evidence of diffuse pulmonary fibrosis should lead to the prudent course of avoiding further exposure (to asbestos) (Weill, 1980). However, it is uncertain whether medical removal protection should also be recommended for workers who exhibit only limited "benign" pleural abnormalities. Nor is it known whether removal from exposure will also favorably influence the risk of developing bronchogenic lung cancer or pleural mesothelioma (Orchard, 1980; Becklake, 1982; NIOSH/College of American Pathologists Pneumoconiosis Committee, 1982; American Thoracic Society 1983).

Exposure rate and cumulative dose appear to be the relevant parameters governing development of asbestosis and bronchogenic carcinoma. Therefore, while medical removal may not diminish the worker's lifetime risk of development of nononcogenic or oncogenic asbestos-related diseases, continued exposure will surely increase the risk (Becklake, 1982). For a worker who has evidence of asbestos exposure related pleural or interstitial abnormalities with or without associated impairment or disability, the effectiveness of medical removal as a method of reducing that worker's lifetime risk of pleural mesothelioma is even less certain since the risk of developing mesothelioma is related to the time since first exposure, even for brief low level exposures (Day et al., 1980; National Research Council, 1984). In addition, the lifetime risk of developing pleural mesothelioma among asbestos exposed workers who smoke cigarettes is not diminished by cessation of cigarette smoking (National Research Council, 1984).

Recent updates have been published concerning the principles and criteria which should underlie the design, conduct, interpretation, and evaluation of screening an surveillance programs for respiratory disease and cancer (American Thoracic Society, 1982; American Thoracic Society, 1983; Ferris, 1978; Coles et al., 1980; Halperin et al., 1984). Given the current state of knowledge, routine periodic chest X-rays and spirometric lung function tests do not meet the most crucial criteria for determining the suitability of screening tests for early recognition and primary prevention of any asbestos-related diseases.

Although these diseases are eminently preventable by eliminating or limiting exposures to asbestos, they are not curable nor amenable to secondary preventive measures in affected individuals (Becklake, 1982; NIOSH/College of American Pathologists Pneumoconiosis Committee, 1982; Craighead et al., 1982). By the time these diseases are clinically detected among individual members of an asbestos exposed workforce by routine periodic screening, it is unlikely that the affected worker, or that worker's similarly exposed co-workers, will derive any primary preventive benefits. It may be of little consolation that recently hired workers may benefit from the resulting reductions in their future exposures.

While currently available screening tests may detect asbestos-related abnormalities among asymptomatic asbestos exposed workers years before pulmonary impairment, disability, or death occur, medical removal of these workers for exposure to asbestos may not be effective in preventing development of cancer or non-carcinogen disease. However, cessation of cigarette smoking among asbestos exposed workers with or without detectable evidence of asbestos-related pulmonary abnormalities does appear to effectively lower the overall risk of premature disability and death in these individuals (Becklake, 1982; NIOSH/College of American Pathologists Pneuoconiosis Committee, 1982; Craighead et al., 1982; Weill, 1980; Day et al., 1980).

RECOMMENDATIONS FOR SURVEILLANCE

The existing OSHA standard for occupational exposures to asbestos was not designed to protect all exposed workers from the risks of developing asbestos-related cancer diseases (NIOSH/OSHA Asbestos Work Group, 1980). In fact, it may not have been adequate to protect all workers from developing nononcogenic asbestos-related diseases (Becklake, 1982; NIOSH/College of American Pathologists Pneuoconiosis Committee, 1982; Craighead et al., 1982; NIOSH/OSHA Asbestos Work Group, 1980).

The proposed OSHA standard is intended to reduce the risk to workers of developing asbestos-related disease based on consideration of (a) the estimated probability of developing significant disease following a given cumulative exposure; (b) a comparison of the risk estimate with the health and safety risks experienced among workers in a variety of non-asbestos producing or using industries; (c) the technical limits of reliable sampling and analysis; (d) the technical feasibility of measures to reduce asbestos exposure.

Thus, some proportion of asbestos exposed workers may still develop asbestos-related cancer diseases even if all workplaces are in compliance with the proposed standard. As with all extrapolative estimates of risk, we know there is a great deal of uncertainity regarding the true risk among asbestos exposed workers. Ideally, a well designed medical surveillance program would help quantify the risk and, therefore, reduce the uncertainity of the estimate. Unfortunately, we cannot find any medical evidence that the medical surveillance provision of the proposed rule will provide additional protection to asbestos exposed workers.

OSHA's reason for requiring periodic chest X-rays and pulmonary function testing for asbestos exposed workers is to:

1. Detect early pleural or interstitial effects of asbestos exposure

2. Prevent the progression of non-oncogenic disease or the development of oncogenic disease by removing the affected worker from further exposure or by reducing that worker's future exposure.

While we believe that these goals are highly desirable, we do not believe that they can be accomplished using the medical surveillance program being considered by OSHA.

If in the final rule OSHA maintains its requirement for employers to obtain routine periodic chest X-rays and pulmonary function tests for asbestos exposed workers; it seems appropriate that the following should then also be required:

1. Both screening tests should be conducted, at initiation of employment and thereafter every 5 years for the first 15 years, and thereafter every 2 years, using the standardized guidelines for instrumentation, training, and interpretation of recognized expert authorities (American Thoracic Society, 1982; American Thoracic Society, 1983; Feris, 1978; International Labour Office, 1980; Guidotti et al., 1983).

2. Cigarette smoking should not be permitted at worksites because of the known synergistic effects of cigarette smoking and lung cancer.

3. The results of required screening tests should be reported to OSHA without personal identification within 2 months of the performance of the tests in order to enable OSHA to evaluate over time the effectiveness of the medical surveillance and environmental control provisions of this standard.

4. Some consideration must be given to mandatory followup of all workers with any asbestos exposure. This is necessary because of the prolonged latency period of most asbestos-related diseases and the uncertainty surrounding the cumulative dose needed to initiate the disease process.

5. Routine periodic stool guaiac, sputum cytology, and bronchoalveolar lavage tests are not recommended as screening procedures based on the current state of knowledge concerning their diagnostic value in massive screening programs. However, their use on an individual basis should be left to the discretion of the examining physician.

SUMMARY OF NIOSH RECOMMENDATIONS

NIOSH urges that the objective or goal is to eliminate asbestos exposures. Where asbestos exposures cannot be eliminated, they must be controlled to the lowest level possible. A significant consideration in establishing a permissible exposure limit should be the lowest level of exposure which can be accurately measured using curently available analytical techniques. At present this level would be 100,000 fibers greater than 5 microns in length per cubic meter, as determined in a sample collected over any 100 minute period at a flow rate of 4L/min using the NIOSH analytical method 7400. However, the presence of background dust in high sample volumes may be the limiting factor which may complicate the analysis under these sampling conditions. In making a recommendation for an occupational exposure limit for asbestos, NIOSH's ultimate goal is to eliminate asbestos exposures. However, we realize that at this point in time such a recommendation is neither feasible nor practicable due in part to limitations imposed by currently accepted methods of sampling and analysis. At this time in order to achieve precision which meets the established NIOSH accuracy standard of 12.8% RSD an exposure limit of 100,000 fibers/m^3 determined as an 8 hour TWA in a 400 liter sample is maintained. Since asbestos is a recognized carcinogen, NIOSH does not recommend the use of air purifying respirators for protection against asbestos.

The position OSHA is considering of permitting only the use of high efficiency air-purifying respirators, although an improvement over the old standard, may not adequately protect exposed workers.

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16. Abstract (Limit: 200 words)

This guide provides practical guidance for selection and use of respiratory protection to persons who work in asbestos abatement operations or other activities, such as maintenance or repair, where exposure or the potential for exposure to asbestos exists. This guide recommends controlling exposures to the lowest level possible as determined by the most sensitive and reliable monitoring methods. The guide has five parts. Part I is an introduction to the hazards associated with airborne asbestos and to the issues involving respiratory protection against asbestos. Part II presents a model respiratory protection program for the asbestos industry which both satisfies current Federal regulations and incorporates the most current information on appropriate respirators for use against airborne asbestos fibers. Part III contains a checklist for developing or evaluating a respiratory protection program. Part IV presents information on breathing air systems for supplied-air respirators. Part V lists sources of help for problems involving respirator use.

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