

THE NEEDS FOR FUTURE RESPIRATOR RESEARCH

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INTRODUCTION

The primary means of protecting workers against respiratory hazards are engineering controls, administrative rules, and proper work practices. However, whenever emergencies occur or whenever the primary means of protection are infeasible, while they are being put into effect, or if they are inadequate, then respirators must be utilized to protect workers against inhalation of harmful atmospheres.

Millions of respirators are in use in industry today. The utilization of respirators by employers to protect employees against inhalation of contaminants in workplace atmospheres is increasing rapidly. As medical research on air contaminants progresses, evidence frequently demonstrates that many contaminants occurring in workplace atmospheres are hazardous to the health of workers when present in very low concentrations. This evidence requires government agencies, which are responsible for promulgating and enforcing occupational health and safety regulations, to issue occupational exposure standards for these contaminants which contain very low permissible exposure limits. Many employers are required to provide respirators to employees for protection against inhalation of these air contaminants because they often find that it is not possible to utilize engineering controls, administrative rules, and proper work practices to insure that employees are not exposed to concentrations of these air contaminants above the very low permissible exposure limits. Therefore, the importance of respirators as a means of protecting workers is increasing at a rapid pace and will continue to do so in the future.

The investigation of the facts involving the complaints of respirator wearers concerning the stress placed on wearers by respirators, a study of alleged inadequacy of protection provided by respirators, and examination of product liability lawsuits which allege failure of respirators to provide proper protection frequently demonstrate that these problems are due to the failure of employers to establish and implement proper respirator programs. However, the results of laboratory studies and field investigations of the performance of respirators do indicate that much research is necessary to improve the levels of protection provided by the various types of respirators to workers and to improve the acceptability of the wearing of respirators by workers. Research is needed to establish improved test procedures and performance criteria for use in approving respirators since many current test procedures and performance criteria are obsolete, inadequate, or do not cover new innovative types of respirators. There is a great necessity for research to develop sound methods for evaluating the performance of respirators in workplaces. Much research must be carried out to result in commercially available respirators which are acceptable to workers and which provide very high levels of protection.

There are a multitude of research projects which should be carried out to improve the technology of respiratory protection. However, it will not be possible to cover all of these projects in this presentation. An attempt will be made to discuss only major respirator research needs.

STUDIES OF PHYSIOLOGICAL AND PSYCHOLOGICAL STRESSES APPLIED BY RESPIRATORS ON WEARERS

There is a great need to study the physiological and psychological stresses applied by respirators on workers. Information on these stresses is needed to establish medical limitations for respirator wearers, to develop meaningful respirator performance criteria, to design respirators acceptable to wearers, and for use in selecting the proper types of respirators for specific applications involving various workplace conditions.

Stresses exerted by respirator on wearers involving resistance to breathing, temperature of inhaled air, oxygen and carbon dioxide concentrations of inspired air, fatigue caused by excessive respirator mass, vision restriction, limitation of movement of wearer, a feeling of claustrophobia or isolation, and a belief that respiration is adversely affected should be investigated.

INVESTIGATION OF EFFECTIVENESS OF RESPIRATORS IN WORKPLACES

Many studies have been carried out to determine the performance of the various types of respirators in the laboratory and reports presenting the results of these studies have been published. This laboratory work has included investigations of the function of specific respirator components and complete respirators and has included tests where persons wear respirators in test atmospheres to permit the measurement of protection factors. Unfortunately, relatively few investigations have been carried out in the field to determine the effectiveness of the various types of respirators in providing protection to workers in actual workplaces and very few reports giving the results of these investigations have been published.

There is a great need for more studies to be made to determine how effective the various types of respirators are in offering protection to workers against a wide variety of respiratory hazards under actual conditions that exist in workplaces. The results of such investigations will have many uses. These results will be helpful in determining the proper types of respirators for application in protecting workers against various types of respiratory hazards. These results are needed to determine whether or not current laboratory test procedures and performance criteria are adequate or should be modified. A comparison of the respirators protection factors measured in the workplace with respirator protection factors measured in the laboratory will indicate whether or not the results of quantitative respirator fitting tests carried out in the laboratory have validity in the real world. The results of workplace studies are useful in pointing out if constructional changes are needed in respirators.

RESPIRATOR FIT TESTING

In qualitative respirator fit testing, the respirator wearer is exposed to an irritant smoke, an odorous vapor, or other suitable test agent which can be detected by a person by sensing irritation, odor, or taste. When an air-purifying respirator is used in qualitative fit testing, it must be equipped with an air-purifying element(s) which effectively removes the test agent from the inspired air. During a qualitative respirator fitting test, if the respirator wearer is unable to detect the penetration of the test agent into the respirator, then it is assumed that the wearer has obtained a satisfactory fit with the respirator.

During a quantitative respirator **fitting** test, the respirator wearer is exposed to a test atmosphere containing a test agent in the form of an aerosol, vapor, or gas. When an air-purifying respirator is used in quantitative fit testing, it must be equipped with an air-purifying element(s) which effectively removes the test atmosphere and the air inside the respiratory-inlet covering the respirator, is utilized to measure quantitatively the penetration of the test agent into the respiratory-inlet **covering**.

Respirator fit testing should be used by an employer in selecting specific makes and models of the proper type of respirator for a given respiratory hazard for assignment to particular employees. This is especially true for negative pressure type respirators which permit a negative air pressure to exist inside the respiratory-inlet covering during inhalation. However, up until recently, few employers have utilized respirator fit testing, qualitative or **quantitative**, for respirator selection. Now, OSHA is attempting to mandate that employers utilize fit testing in selecting specific makes and models of negative pressure respirators for assignment to particular employees.

There has been much controversy concerning the validity of the results of qualitative respirator fit testing. A few investigations have been carried out to correlate the results of qualitative respirator fitting tests with the results of quantitative respirator fitting tests. Most of these studies indicate that qualitative respirator fit testing is safe to use if conservative values are selected for maximum respirator protection factors for the application of respirators selected by means of qualitative respirator fitting tests. However, more studies are needed to prove conclusively whether or not qualitative respirator fit testing is safe for use in respirator selection.

During a respirator fitting test, qualitative or quantitative, the respirator wearer carries out a series of exercises which are supposed to simulate the movements of workers engaged in performing tasks in the workplace. Although certain exercises have been more or less accepted for use in carrying out respirator fitting tests, very little has been done to determine if these exercises have statistical **significance**. Studies should be carried out to select a set of exercises for use in fit testing of respirators equipped with **tight-fitting** respiratory-inlet coverings and to select a set of exercises for use in fit testing of respirators equipped with **loose-fitting** respiratory-inlet coverings which have statistical **significance**. Quantitative respirator fit testing is preferable to qualitative respirator fit testing since it gives numerical results concerning the adequacy or inadequacy of the fit of a specific make and model respirator on a particular person while qualitative respirator fit testing only provides a yes or no answer on whether a specific make and model respirator fits a particular person. However, quantitative respirator fit testing is not a panacea because of the many problems encountered in carrying out this testing. Problems of quantitative respirator fit testing include non-reproducible test results, complex test apparatus requiring extensive training of operators, frequent calibration and extensive maintenance of instrumentation, and the high costs of purchasing the apparatus, training persons to operate the test apparatus, and carrying out the tests. At the present time, several OSHA occupational exposure standards

mandate that employers use quantitative respirator fit testing for selection of specific makes and models of negative pressure respirators for assignment to particular employees. Various OSHA officials have stated that it would be desirable to require that all employers who provide negative pressure respirators to employees utilize quantitative respirator fit testing in respirator selection. However, the problems pointed out concerning quantitative respirator fit testing make such testing to be feasible only for large employers. Research is needed to develop quantitative respirator fit testing apparatus that is simpler to operate, calibrate, and maintain than present apparatus and also which is lower in cost than current apparatus in order to permit medium size and small size employers to make use of quantitative respirator fit testing.

Several years ago NIOSH funded a project to establish the requirements for a panel of persons having anthropometric measurements representing the adult work population, male and female, for use in carrying out quantitative fitting tests on respirators to insure that approved respirators would adequately fit most workers. However, NIOSH has never used an anthropometrically selected panel for quantitative fit testing of respirators submitted to NIOSH for approval. Currently, NIOSH carries out qualitative fit testing on some types of respirators using small numbers of human test subjects selected at random when approving certain types of respirators, and NIOSH presently approves some respirators without performing any fit testing. There has been some criticism that the requirements for the anthropometric panel for use in respirators fit testing established by the mentioned NIOSH-sponsored project does not truly represent the adult work population since the project utilized anthropometric data for military personnel who mostly are young and healthy persons. It is recommended that a study be made of the adult work population in the United States to permit the establishment of requirements for a panel of persons truly representative of this population for use in respirator fit testing. If the requirements for such a panel of persons are established, then perhaps NIOSH would perform quantitative respirator fit testing using a panel of persons meeting these requirements as part of the respirator approval program. Undoubtedly, if NIOSH carried out quantitative respirator fit testing using appropriate fitting criteria for various types of respirator as a standard procedure when approving respirators, the manufacturers of respirators would have incentive to improve the fitting characteristics of respirators which they manufacture and market.

POSITIVE PRESSURE RESPIRATORS

A positive pressure respirator is a respirator in which the air pressure inside the respiratory-inlet covering during both exhalation and inhalation is positive relative to the air pressure of the atmosphere surrounding the respirator wearer. Positive pressure respirators include: pressure-demand open-circuit self-contained breathing apparatus, some models of closed-circuit self-contained breathing apparatus, some models of hose masks with blowers, continuous flow airline respirators, pressure-demand airline respirators, and powered air-purifying respirators. It is assumed that this type of respirator will prevent leakage of contaminated atmospheric air into the respiratory-inlet covering of the respirator and assure a wearer of a very high protection factor. Unfortunately, the current respirator test and approval requirements for positive pressure respirators do not insure that a

positive air pressure always exists inside the **respiratory-inlet** coverings of these devices under all use conditions. Tests have shown that some approved so-called positive pressure respirators provide low protection factors under certain use conditions which are far below the values of protection factors which have been listed for these respirators in various published documents. **Unfortunately**, both OSHA and NIOSH have utilized these high protection factor values in recommending the use of positive pressure respirators for protection of workers against inhalation of very hazardous atmospheres.

Research should be carried out to develop test procedures and performance criteria for positive pressure respirators which assures that these respirators provide high protection factors under all possible use conditions. The results of this research should be used by NIOSH in establishing test procedures and performance criteria for positive pressure respirators which are more realistic than current test procedures and performance criteria listed in the respirator test and approval document. The manufacturers of positive pressure respirators should make use of such research results in the design of new positive pressure respirators which offer higher levels of protection to wearers under actual use conditions than products presently produced and marketed.

FACEPIECES

Workers have complained about respirator facepieces for many years. Complaints include wearing **discomfort**, poor fit, difficulty of donning and removing, unsatisfactory means of adjusting tension in headharness straps, excessive perspiration, dermatitis, restriction of speech transmission, fatigue, and deterioration of the face-sealing surface by body oil and perspiration. These complaints are the symptoms of the poor acceptance of facepiece-equipped respirators by workers and they are indications that respirator facepieces frequently fail to function properly. These complaints often result in the refusal of workers to wear facepiece-equipped respirators. **Unfortunately**, when workers who complain about respirator facepieces are forced to wear such respirators, these workers frequently wear the respirators improperly and this has detrimental effects on the health of these workers. Since most respirators used in industry today are equipped with facepieces, these complaints are very serious. Respirator manufacturers have the obligation to carry out research to result in the design of respirator facepieces which would eliminate the mentioned complaints. Such facepieces would increase the acceptance of wearing facepiece-equipped respirators by workers and would improve the wearing of these respirators by workers. The final results to this research would be improved protection attained by the wearers of facepiece-equipped respirators.

RELIABILITY OF RESPIRATOR PERFORMANCE DURING CONTINUED WEARING

The present respirator test and approval program does not take into account the reliability of the proper functioning of most types of respirators when worn continuously for long periods of time. The consequences of this lack of required reliability of the performance of approved respirators worn continuously for long periods of time occasionally results in the availability of approved respirators which perform well when first worn but which deteriorate in performance as wearing continues. Sometimes when this

happens, the marketplace will mandate that changes be made in the construction of respirators to improve their reliability in providing proper protection when worn continuously for long periods of time. However, there is no guarantee that such correctional action will occur since respirator wearers may not be aware that the performance of respirators may be decreasing as they are being worn.

There is a need for an investigation of how respirators perform when worn continuously for long periods of time. The results of this work should be used to establish test procedures and performance criteria for incorporation into the respirator test and approval program to assure that approved respirators function properly when worn continuously for long periods of time. Respirator manufacturers can utilize the results of such an investigation to improve respirator designs.

DURABILITY OF REUSABLE RESPIRATORS

The durability of a reusable type respirator to withstand repeated use and function properly is not covered by the current respirator test and approval program. A study should be undertaken to determine how well approved reusable type respirators perform when used repeatedly. The results of this study should be employed to set up durability test procedures and performance criteria as part of the respirator test and approval program.

EFFECTS OF SHIPMENT AND STORAGE ON RESPIRATOR AIR-PURIFYING ELEMENTS

Respirator air-purifying elements may be exposed to conditions during shipment and storage which adversely affect the performance of these devices. Sometimes respirator users have become aware that the function of respirator air-purifying respirators has been impaired by various conditions of shipment and storage and these users have taken action to insure that the affected products are not used. Unfortunately, some respirator users may not be cognizant that certain conditions of shipment and storage may reduce the performance of respirator air-purifying elements and this can result in the wearing of air-purifying respirators by workers that are not providing proper protection. The present respirator test and approval program does not contain requirements which insure that respirator air-purifying elements are adequately protected during shipment and storage.

Work should be carried out to determine the effects of various conditions of shipment and storage on the performance of respirator air-purifying elements. The findings of this work should be used to establish test procedures and performance requirements for respirator air-purifying elements which insure that approved products are properly protected during shipment and storage.

SCRATCHING OF LENS IN RESPIRATOR USED IN ABRASIVE BLASTING

Excessive scratching of the lens in a respirator used for protection in an abrasive blasting operation can be hazardous to the respirator wearer since such scratching may impair the wearer's vision. The present respirator test and approval program does not contain a test procedure and a quantitative performance criterion concerning the resistance of the lens in a respirator

approved for use by a person engaged in abrasive blasting to scratching by rebounding abrasive particulate matter. Research should be carried out to establish the mentioned test procedure and quantitative performance criterion.

SELF-CONTAINED BREATHING APPARATUS

At a public meeting held three years ago concerning the respirator test and approval program and at a public meeting held several weeks ago concerning this program, a number of persons representing fire fighting organizations pointed out the need for special test procedures and performance criteria for self-contained breathing apparatus used by fire fighters. These people gave evidence why such test procedures and performance criteria are needed. Subjects mentioned by these people included poor operation of the apparatus at high and low temperature extremes, the flammability of material used in the apparatus, the permeation of elastomeric material used in the apparatus by various chemicals, the malfunction of regulators caused by high velocity water streams, the corrosion of metal components of the apparatus, and inadequate performance of end of service life alarms.

Fire fighters routinely are exposed to extremely dangerous atmospheres. Their lives and their health depend upon the proper functioning of self-contained breathing apparatus. Ample evidence exists that approved self-contained breathing apparatus may not always provide adequate protection to fire fighters. Thus, there is an urgent need to carry out research to result in the development of special test procedures and performance criteria for self-contained breathing apparatus for use by fire fighters.

AIR-PURIFYING RESPIRATORS

Most of the performance tests listed in the current respirator test and approval document for particulate-filtering respirators involve the use of aerosols having high concentrations of particulate matter which rapidly plug the fibrous particulate-filtering elements employed in respirators and involve the measurement of the integrated penetration of these fibrous particulate-filtering elements over long periods of time. These performance tests were developed many years ago when high concentrations of airborne particulate matter in workplace atmospheres were common. Today, most particulate-filtering respirators are used where conditions do not result in rapid plugging of fibrous particulate-filtering elements by retained particles. It is possible that under present workplace conditions, significant penetration of fibrous particulate-filtering elements by airborne particles may occur. Certain storage and use conditions may adversely affect the functioning of some types of fibrous particulate-filtering material, but such conditions are not taken into account by the present respirator test and approval program. Particulate-filtering respirators sometimes are used for protection of persons against inhalation of airborne fibrous particulate matter such as asbestos fibers, but the current respirator test and approval document does not list any test procedures and performance criteria which assure that particulate-filtering respirators provide adequate protection to wearers against airborne fibrous particulate matter. Research should be carried out to develop test procedures and performance requirements involving the instantaneous penetration of particulate-filtering respirators by

respirable size particles during the use periods **of** these respirators, to insure that **particulate-filtering** respirators offer adequate protection against airborne **fibrous** particulate matter, and to assure that **particulate-filtering** respirators do not contain fibrous **particulate-filtering** materials adversely affected in regard to function by various storage and use **conditions**.

Although published test reports have shown that the service lives of organic vapor-removing cartridges and canisters vary widely depending on the organic vapors used in the tests, the present respirator test and approval document lists only a single organic vapors which is readily adsorbed by the sorbent material used in these cartridges and canisters as the sole representative of the many thousands of volatile organic substances. **Research** should be carried out with the purpose of establishing a set of organic vapors as representatives of the various classes of organic compounds for use in the performance testing of organic vapor-removing cartridges and canisters. The respirator test and approval document should be amended to list this set of organic vapors for use in approving air-purifying respirators for protection of persons against inhalation of organic vapors.

Medical research is producing evidence that exposure of persons to low concentrations of vapors and gases of specific substances results in serious health hazards. Testing of standard **vapor-/gas-removing** cartridges and canisters used in various approved air-purifying respirators against several of these vapors and gases indicates that these cartridges and canisters readily permit penetration of these vapors and gases. If **OSHA** promulgates occupational exposure standards for these vapors and gases which list extremely low permissible exposure limits there will be an increasing need for air-purifying respirators for protection of workers exposed to low concentrations of these vapors and gases. Thus, there will be a great need for research to be **carried** out by respirator manufacturers and sorbent manufacturers aimed at the development of special sorbent materials for use in **vapor-/gas-removing** cartridges and canisters that will effectively remove these vapors and gases from air. Also, research should be carried out to establish test procedures and performance criteria for **vapor-/gas-removing** cartridges and canisters for use in air-purifying respirators for protection of persons against inhalation of these vapors and gases and these procedures and criteria should be added to the respirator test and approval document.

The present respirator test and approval document lists carbon tetrachloride vapor, lead oxide **fume**, and silica dust as the test agents for use in evaluating the performance of air-purifying respirators which are approved for protection of persons against inhalation of airborne pesticides. Persons are exposed to airborne pesticides that vary widely in chemical composition and these airborne pesticides may be in the form of vapor and particulate **matter**, both solid and liquid. It is not known if currently approved pesticide air-purifying respirators provide adequate protection to persons exposed to airborne pesticides which vary in composition and form. Since many thousands of persons exposed to toxic airborne pesticides must depend upon the use of air-purifying respirators for protection of their health, it is urgent that research be performed to develop test procedures and performance criteria for use in approval testing of pesticide air-purifying respirators which are more realistic than the test procedures and performance criteria presently listed in the respirator test and approval document.

ESTABLISHMENT OF AN IMMEDIATE RESPONSE **RESPORATOR** RESEARCH LABORATORY

The level of research in occupational health now is much greater than it has been in the **past**. This activity has led to the discovery that many substances present in the air at very low concentrations are hazardous to the health of exposed persons. It should be expected that many additional discoveries of this type will be made in the future.

Industrial technology is constantly changing. Industrial research and development continues to result in new **materials**, products, and processes. Many of these new materials, products, and processes generate new respiratory hazards. This situation will continue in the future.

Occupational safety and health standards issued by **OSHA** are required to cover the use of personal protective equipment including respirators for protection of workers against hazards which may occur in workplaces. Often, it is not known if the various types of approved respirators offer adequate protection against air contaminants covered by these new OSHA standards. Sometimes, it is known that new test procedures and performance criteria are needed for use in approving respirators for protection of persons exposed to air contaminants covered by new OSHA standards.

Unfortunately, a respirator research laboratory which can respond immediately to cope with the mentioned problems does not exist. It is proposed that **NIOSH** establish a respirator research laboratory which has adequate equipment and staff to respond immediately whenever new problems arise concerning respiratory protection.