

Keynote Address

Terrorism in the Twenty-First Century: Threats and Responses

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Terrorism-the calculated employment of the threat of violence by individuals, subnational groups, and state actors to attain political, social, and economic objectives in the violation of law, intended to create an overwhelming fear in a target area larger than the victims attacked or threatened-is as old as civilization itself. Yet unlike their historical counterparts, present day terrorists have introduced into contemporary life a new scale of violence in terms of conventional and unconventional threats. The internationalization and brutalization of modern terrorism make it clear that we have entered into an "Age of Terrorism" with all of its serious implications to national, regional and global security concerns. This alarming and dangerous trend increases the potential for "Super Terrorism"-biological, chemical or nuclear violence-as well as the advent of information warfare and cyber terrorism. Perhaps the most significant dangers are those relating to: the safety, welfare, and rights of ordinary people; the stability of the state system; the health of economic development; the expansion of democracy; and perhaps even the survival of civilization itself.

Thus, despite the end of the Cold War and evolving era of the "New World Order," terrorism remains as threatening as ever. Undoubtedly, the conflicts emerging from ideological, religious, and national animosities will continue to make terrorism a global problem well into the twenty-first century. Ensuring the safety of its citizens at home and abroad will therefore continue to be every government's paramount responsibility in the coming months and years. Thus far, at least, many governments and people have failed to appreciate the magnitude and implications of the terrorist threat. Some countries tend to regard terrorism as a minor nuisance or irritant. As a result, a large number of countries have not yet developed a strong commitment to deal effectively with the problem of terrorism.

On the other hand, some states, such the U.S. have taken a variety of effective counter terrorism measures. Most notably, they have given greater public attention to terrorism; improved intelligence gathering resources against terrorist; enacted appropriate legislation; apprehended, prosecuted, and punished terrorists; provided greater protection to government facilities and officials; and developed various programs to help train those who must respond to unconventional attacks such as police officers, firefighters, and emergency medical personnel.

In sum, the vulnerability of modern society and its infrastructure, coupled with the opportunities for the utilization of sophisticated high-leverage conventional and unconventional weaponry, requires states both unilaterally, and in concert, to develop credible responses and capabilities to minimize future threats. Moreover, the public in general, including the International Society for Respiratory Protection, has both a moral and practical responsibility to participate in the international effort to arrest the virus of terrorism.

Dead Space Measurement in RPE-European Test House Results, Problems and Solutions

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Respiratory protective equipment (RPE) from sources throughout the world is now in use in Europe because it has undergone a certification procedure and hence carries the "CE" mark. Part of this process can involve passing tests in harmonized European standards. It is thus important that the standards are written in an unambiguous manner and that test houses can carry out tests to give reproducible results both on an inter-, and intra-laboratory basis.

One method of assessing this reproducibility is to carry out inter-laboratory trials (termed "round robin" testing) doing a specific test on the same example of RPE. This can throw light on both the different interpretations of the test procedure and the methodology used by test houses. It is also useful for laboratories who are newly on-stream and are on a learning curve with some test procedures.

The presentation describes such a round robin test, primarily concerned with the measurement of rebreathed CO₂ (dead space) in RPE. It describes the development of a "transfer standard" as a substitute for the RPE so that the results from test apparatus can be compared without the variability inherent in fitting RPE; it discusses the results received and how problems with particular test house apparatus can be identified and remedied. It also describes how the device can be used to check breathing resistance measurements.

Respiratory Protection-Airflow Requirements

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Respirators have for many years been designed to meet various standards. These standards are said to be minimum performance standards, and there is an expectation that they meet the real demands of the user. Our long experience with breathing protection had made us think that this may not be the case.

When designing our new respirator, we decided to look at the actual user demands, not just the requirements of the standards. We started with a literature search. This search revealed many works that approached the problem from different angles, and included one very comprehensive work from the 1940's by Leslie Silverman.

We had mixed feelings about our discoveries. They confirmed, on the one hand, what we had suspected: that there was in fact a large difference between what the standards specified and what the user required. But on the other hand, how could there be so many standards, and products, in existence that fell so far short of what the user actually needed?

We decided to do some testing ourselves. We wanted to confirm the results we had found in the literature, and also to check a couple of things we could find no information about, like the effects of speech and body movements on breathing patterns.

This is a comparison of our test results with data from the literature.

Harmonizing Standards in a Shrinking World

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One of the most repeated buzz-words of the nineties must surely be globalization. Trade, commerce, knowledge, opinion and information all flow between the four corners of the world in ever growing amounts and with ever increasing speed. The explosive growth of the Internet and e-commerce is only one aspect of globalization. The lifting of trade barriers, the formation of trade blocs, the synergism of the European Union, the opening up of many economies in Eastern Europe and South-East Asia-all of these factors have lead to a burgeoning flood of people and products never seen in history.

The globalization process places much pressure on Standards. National Standards can no longer stay parochial and national. In a changing world, Standards must be able to keep up with the rapid influx of products and new technology. If it cannot keep up, the Standard will be a destructive stumbling block-not a constructive quality mechanism. A global quality mechanism can only be achieved by harmonizing Standards throughout the world, chiefly the American, European and Australian/New Zealand Standards.

Failure to reach a harmony between Standards will inevitably lead to stifling of the flow of excellence and suffocation of new technology which could otherwise have benefited entire nations and, in the case of occupational protection, raised the level of health and safety of their work forces. This discussion centers on the nature of such a harmonization process, how far it should reach, and how to strike a balance between national and international Standards.

Defending Buildings Against NBC Attack-The PREEMPT NBC Security System: A Comprehensive Integrated Approach

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This paper will present the basic concepts recently presented to the U.S. Department of State elucidating a twelve-point process comprising five component systems for NBC protection of embassies, consulates, and other buildings.

Update on NIOSH Standards Development Activities

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The National Institute for Occupational Safety and Health (NIOSH) has published revised rulemaking priorities in the Federal register on August 28, 1999 (64 FR 46178) based on public comments provided in response to earlier requests for input. The revised priorities represent a re-evaluation due to recent serious field problems with deployed SCSRs. NIOSH is currently in the process of developing three rulemaking modules; 1) an Administrative/Quality Assurance Module, 2) a Self-Contained Self-Rescuer (SCSR) Module, and 3) a Powered Air Purifying Respirator (PAPR) Module.

In addition to the regulation-development activities, NIOSH is formulating a policy-development process intended to allow the Institute to use flexibilities available in the existing regulation. The Institute has used Sections 84.60 and 84.63 flexibilities to evaluate individual respirators with unique features or characteristics. Chemical cartridge respirators and gas masks for gases and vapors not listed in the regulations have been approved under Sections 84.110 and 84.190. NIOSH is developing new procedures to develop and document any additional requirements under these flexibilities in a more public manner. One result of NIOSH's new process, if funding is received, is expected to be the ability to evaluate and approve respirators for use by responders to terroristic events.

ILEE-The European Experience

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The European approval system for respiratory protective devices is such that a number of Notified Bodies, situated in various European countries, are authorized to issue certificates of conformance. Part of the certification process is dependent on test reports generated by independent Accredited laboratories. In order to minimize differences that may exist between laboratories, a group was set up known as the ILEE-RPE, Inter-Laboratory Exchange of Experience for Respiratory Protective Equipment. Since the first meeting in 1993, the group has met on an annual to discuss procedures, organize interlaboratory testing and to analyze the results. To date, tests have been organized to compare filter penetration measurements by sodium chloride and paraffin oil aerosols, organic vapor and hydrogen cyanide filter cartridge service life, re-breathed carbon dioxide measurements and six burner flame testing. In this presentation the outcome of these meetings and the interlaboratory testing is reviewed.

Effects of Respirators on Worker Efficiency

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The purpose of this study was to quantify the effect of full face piece air purifying respirator use on worker efficiency. With and without a respirator, twenty nuclear power plant workers performed a typical mechanical work task and two dexterity tests in an environmental chamber maintained at a temperature of 35°C (95°F) and a relative humidity of 65%. The subjects were trained for one day and tested on the following day. On test day, each subject performed each standardized task twice in full cotton protective clothing once with a respirator and once without. The order in which subjects performed the task with and without a respirator staggered. The standardized tasks consisted of a stud torquing procedure and two separate trials of a pegboard dexterity test (before and after the torquing procedure). All subject testing was videotaped and the videotapes were time coded for evaluation by an independent reviewer who determined the times for task completion. The 95% confidence intervals for the mean percentage increase in time to complete the various tasks for trials using the respirator were: 1st Dexterity Test (Lower Limit-1.16%, Mean 3.055, Upper limit 7.27%); Stud Torquing (Lower Limit-0.99%, Mean 2.11%, Upper Limit 5.21%); 2nd Dexterity Test (Lower Limit-2.06%, Mean 1.625, Upper Limit 5.20%). These small increases in completion times attributable to respirator use were not statistically significant. It was concluded that respirator use had no significant effect on the efficiency with which workers conducted the tasks in this study. This study was designed to be representative of a specific nuclear power plant work task heavy bolt to be conducted in a typical plant environment. The dexterity test and torquing subtask results of this study may be applied to various other light and heavy plant work tasks, respectively. This study was not designed to be representative of work performed by teams where worker communication is essential for task completion.

Intelligibility of Speech Through Personal Respirators Used During Bronchoscopy

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Pulmonologists often perform flexible bronchoscopy to aide in the diagnosis of infections of the lower respiratory tract. The procedure may cause the subject to cough and thereby generate potentially infectious aerosols. This is of particular concern as the incidence of tuberculosis (TB) has been on the rise, and is transmissible with such exposure. To retard the nosocomial spread of TB, the Centers for Disease Control and Prevention has stated that the use of effective respiratory protection is required for those working in high risk procedures. The use of respirators with HEPA filters have been recommended.

At the University of Massachusetts Medical Center pulmonary physicians, and others exposed to potentially infectious aerosols use the 3M Series 6000 half faced personal respirators for respiratory protection. Problems with the current units, though anecdotal, have include: 1) muffled speech, 2) discomfort, 3) need for additional eye protection (exposure to HIV). As effective communication is critical at many levels we decided to embark on a study to compare the intelligibility of speech through different respirators of comparable protection. We compared the 3M model to three models made by Mine Safety Appliance, Inc. (MSA)- the Advantage 1000 with and without sound projection equipment and the Ultra Elite. Comparisons were made with two different tests of intelligibility the Phonetically Balanced Word List test (PBWL), and the Modified Rhyme Test (MRT). Respirator use was compared to the control condition of No Respirator.

Respirator Design Tools For the Next Millennium

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The bulk of major system design decisions occur while the system is still in the conceptual stage of development. This is also the case when designing new military respirators. By utilizing established computer-based modeling and simulation tools, designers of major systems are able to gauge the impacts of these early decisions in a cost-effective manner. Unfortunately, when it comes to respirator design, computer-based modeling and simulation tools that could support early design decisions are essentially non-existent. This limitation requires respirators to be designed and fabricated from scratch to support product development, prototyping, field testing, re-design, manufacturing, and distribution. Obviously, the precision of these methods is less than adequate and the entire process is extremely expensive and time consuming. Therefore, efforts have been initiated to develop a computer-based expert design system that will guide respirator design into the next millennium. This system will integrate several design analysis tools to assess and optimize the effects of various component designs on the overall function of the system before concept models are produced. To that end, three individual respirator design tools are currently being developed for the expert design system. For future computer aided design (Cad) needs Pro-Engineer software is being set up to permit parametric modeling of respirator components and face pieces. A Respirator Encumbrance Model (REM) has been developed to assess and optimize the effects of respirator component designs on human performance of different physical tasks. Finally, modeling of the interface between the respirator seal and the human face is under way to assess and optimize facepiece and suspension designs without compromising respirator comfort or fit. Other design tools envisioned for the expert design system include modules that will assess interfaces with operational equipment such as sighting devices and determine airflow characteristics within a respirator's facepiece. In the end, the development and validation of the expert design system or any of its individual components will significantly improve the military respirator design process by supporting early design decisions through modeling and simulation based on the primary factors of respirator design.

Respirator Design and Communications Effectiveness: How Important is a Speech Transmission Device:

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Verbal communication between individuals wearing respiratory protective devices (RPSs) can be an arduous task due to the fact that RPSs can muffle or distort speech. Without effective speech communication between co-workers, the quality of work may be reduced and worker safety may be comprised. Thus, it is common for respirator designs to include some type of device to enhance transmission of speech. However, not all full-facepiece respirators incorporate speech transmission devices into their designs and half-mask respirators with such devices are essentially non-existent. Therefore, two studies were conducted to assess speech communications effectiveness of various RPDs both with and without speech transmission devices. One study evaluated face-to-face communication between speaker and listener pairs and one study assessed communication between subject pairs using a telephone as the communication means. The Modified Rhyme Test (MRT), an objective test designed to determine how well monosyllabic words are transmitted and understood, was used to measure speech intelligibility for both studies. During all test sessions, test administrators positioned near both the talker and listener monitored data collection. During all test sessions, test administrators positioned near both the talker and listener monitored data collection. Spoken MRT words were checked for accuracy and both voice and background noise levels were measured using a sound-level meter. Respirator conditions for face-to-face communications testing included wear of the U.S. Army M40, a concept prototype of the U.S. Military Joint Service General Purpose Mask (JSGPM), and a commercially available respirator. The M40 respirator uses a speech transmission diaphragm whereas the JSGPM and commercial respirators do not. For telephone communications testing, subjects wore the U.S. Army M17 with a speech device, five commercial respirators (two with and three without speech diaphragms), and one commercial half-mask respirator without a speech device. Mean intelligibility scores for each of the face-to-face respirator conditions were 93.9%, 82.9%, and 91.3% for the M40, JSGPM, and commercial respirator, respectively. Intelligibility scores for the telephone communication test conditions will be summarized and the implications of the results of all tests for RPD design and communications effectiveness will be discussed.

The Efficacy of the Bitrex™ Qualitative Fit Test Method with N95 Filtering-Facepiece Respirators

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The Bitrex™ qualitative fit test is one of the qualitative fit tests referenced in the Occupational Safety and Health Administration regulations on respirators (Title 29, Code of Federal Regulations, 1910.134) and recommended by the National Institute for Occupational and Health for screening out respirators having poor facepiece fits. In this study, the results of Bitrex™ qualitative fit tests were compared to a total penetration test, an indicator of whether a respirator provided an adequate facepiece fit to its wearer using the PortaCount Plus™. Total penetration as defined in this study is comprised of face seal leakage and filter penetration. A respirator was determined to provide adequate protection if the total penetration is less than 10 percent (a protection factor greater than 10). This is the level of protection often expected for a half-mask respirator. Five different models of N95 half-mask filtering-facepiece respirators were tested on a panel of 25 subjects with varying facial sizes resulting in 125 tests. The order in which the Bitrex™ test and total penetration tests were performed was randomized. There was no re-donning of the respirator between the Bitrex™ fit test and the total penetration test. In 59% of the tests, passing a Bitrex™ test correctly identified respirators having an adequate fit. In 9% of the cases, wearers passed the Bitrex™ test but received inadequate protection. In 41% of the tests, Bitrex™ results caused respirators providing adequate protection to be rejected. In 91% of the tests, failing a Bitrex™ test correctly identified respirators which did not provide adequate protection. These results suggest passing a Bitrex™ may not ensure an adequately fitting respirator.

Seal Pressure: A New Measure of Protective Mask Performance

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Currently, protective mask seal designs are evaluated indirectly by measuring fit factor (FF), a ratio of the concentration of particles outside versus inside the mask. This paper describes an alternate process for evaluating mask seals by measuring the pressure distribution between the seal and face. The goal was to develop a relationship between FF and seal pressure. The FF and seal pressure relationship could be used to predict the seal pressure necessary to provide a specific FF or determine whether the seal pressure provided by a mask prototype is sufficient to meet a protection or FF requirement.

Pressure was measured using a thin film flexible sensor placed at 11 locations around the seal of an M40 protective mask on a head form. Corresponding FF was measured using a PORTACOUNT® Plus protective mask fit tester. Measurements were made for three degrees of strap tightness over a total of 22 trials. Regression analysis was used to determine the relationship between seal pressure and FF.

Data and model analysis indicated a strong relationship between FF and seal pressure ($R^2=0.87$). Eleven validation trials were conducted to verify predictive capability of the seal pressure and FF relationships. Passing or failing FF was correctly predicted by a single seal pressure measurement in 9 of 11 trials. Seal pressure profiles required for achieving a passing FF with the M40 mask were also determined. These findings suggest that pressure measurement may be a promising new tool for design and evaluation of protective mask seals and may also prove to be beneficial in the evaluation of other head-borne systems.

Effect of Eyewear Inserts on the Measured Fit of Military Gas Masks

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A study was conducted to examine the effect of eyewear inserts on measured gas mask fit. Additional study objectives included determining the capabilities of two different fit test technologies for measuring the impact of inserts, and assessing the effect of gas mask donning on measured mask fit. A DNI Fit Tester 3000 (controlled negative pressure (CNP) technology) and a TSI PortaCount Plus (ambient aerosol (AA) technology) were used to make mask fit measurements. Twelve subjects (3 females) donned their assigned gas mask fit (normal breathing exercise only) were made with both fit test systems during each mask donning. Care was taken to not disturb the fit of the mask during filter canister/CNP adapter change-out between each pair of fit tests. The order of fit test systems and eyewear status alternated between mask donning to control for any systematic bias.

Study results and conclusions: 1) significant reductions ($p < 0.0001$) in gas mask fit related to eyewear inserts were measured by both fit test systems; 2) negative pressure "fit checks" performed immediately after each mask donning were not effective in identifying gross levels of mask leakage; 3) without inserts, CNP fit factors were lower than AA fit factors by at least an order of magnitude with low correlation observed between the systems ($R^2 = 0.035$); 4) with eyewear inserts, the AA in mask sampling probe was located in close proximity to insert leak locations and measurements tracked CNP measurements of leakage very well ($R^2 = 0.829$); and 5) substantial effect of donning on mask fit evident in this study is consistent with findings of previously reported study.

Industrial Protection: Making Respiratory Protection User Friendly

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Respiratory Protective Equipment has been born out of the need for immediate protection. Because of this, most respiratory equipment has been developed from the nuclear biological and chemical requirements of the Military, or the need for the provision of cheap immediate protection where the hazard is visible. In the industrial environment the hazards encountered are not necessarily as immediate. Many respiratory complaints including bronchitis are now known to have been initiated by, or occurred because of, exposure to sub-micron particles. Typical examples are coal dust and diesel emission particles. Furthermore, in the industrial arena there are generally other hazards associated with the workplace. Current respiratory standards are written about providing respiratory protection in isolation, and without due regard to the necessity to protect from other more immediate physical risks.

The background to, development of, and functional characteristics, ergonomics and other aspects of a new respirator will be detailed. The equipment presented protects from most risks in an industrial workplace and protects from all of the factors that are within the influence of the workers involved. The equipment enables the employers to overcome the normal resistance to wearing protective equipment in the workplace. The author will question whether agencies responsible for approval and enforcement are given the latitude to respond quickly and realistically to take into account the changing needs of today's industrial workers and the pace at which technology advances.

Performance of Air-Purifying Respirators Against Chemical Warfare and Tear Gas Agents

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MSA recognizes the need of Emergency Response Personnel to have adequate, reliable respiratory protection when responding to acts of terrorism. Testing was conducted to quantify:

- the permeation resistance of the MSA elastomeric full facepiece materials against chemical warfare agents (mustard and Sarin according to Mil-Std-282, Methods 208.1 and 208.2).
- the service life performance of MSA's Negative Pressure Riot Control canister against Sarin, hydrogen cyanide, cyanogen chloride, CS and CN tear gases, oleoresin capsicum (the active in OC Pepper Spray), and dimethylmethyl phosphonate (a nerve agent stimulant) under controlled laboratory conditions (NISOH, CASHPAC, and Mil-C-51560).
- the performance of MSA's PAPR Riot Control canister against hydrogen cyanide, CS and CN tear gases, oleoresin capsicum, and dimethylmethyl phosphonate.

Testing revealed that the MSA's elastomeric facepiece materials are resistant to permeation by chemical warfare agents for more than 6 hours. Also, service life testing revealed that MSA's negative pressure and PAPR Riot Control canisters are very effective in removing toxic chemical warfare agents from an inspired airstream. The details of these laboratory investigations shall be presented at this secession.

U.S. Army SBCCOM Testing and Evaluation of Personal Protective Equipment for Civilian CB Defense

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An overview is presented of the U.S. Army's Soldier and Biological Chemical Command (SBCCOM) role in the testing and evaluation of personal protective equipment (PPE) for civilian chemical and biological (CB) defense. SBCCOM has extensive expertise in the research, development, and test and evaluation of CB detection, decontamination, collective protection, and personal protection equipment. Numerous joint agency programs involving civilian CB-PPE applications have been supported by SBCCOM over the last several years. Among the major programs supported are the Chemical Stockpile Emergency Preparedness Program (CSEPP), Domestic Preparedness Program (DP), and the Technical Support Working Group (TSWG) on counter terrorism.

At the Edgewood Chemical Biological Center (ECBC), SBCCOM, assessments have been performed on a variety of commercial respirators and protective clothing ensembles to characterize their performance against CB agents. These evaluations include both system and component level assessments and address specific performance needs for CB protection. Examples of system level tests include aerosol and vapor protection factor, system agent penetration/permeation, and human performance testing. Examples of component level tests include liquid/vapor permeation (swatch testing), filter gas-life, and filter aerosol efficiency testing. System testing is preferred since it involves the testing of the entire PPE assembly and can be used to augment or replace certain component level tests.

Test methods used by SBCCOM to evaluate PPE items for civilian applications have primarily been adopted from standard test procedures used to assess military PPE. Test protocols and criteria have been tailored to address key performance parameters based on the threat, intended use, and specific needs of the user. The lack of national standardized test procedures and criteria, however, currently preclude the certification of PPE for civilian CB applications. To help address this issue, SBCCOM, NIOSH and the Department of Justice have initiated an interagency agreement to develop and implement a national NIOSH certification standard for CB respiratory protection equipment used by local, state, and federal emergency first responders. The successful development of a national CB protection standard for respirators and other PPE will require a sound understanding of the potential use scenarios, limitations of equipment, and hazards associated with emergency response operations in a CB environment.

Assessment of Respirator Fit during Exercise in A Hot Environment

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A study was conducted to assess the effect of exercise under controlled environmental conditions of high temperature and humidity on the face seal fit of negative pressure respirators. Three different full-facepiece respirators having key design features of interest were evaluated. Respirator fit factor (FF) data were obtained using a portable condensation nuclei counter quantitative fit testing device to measure ambient aerosol leakage inside the facepiece. Overall FFs were determined before, during, and after a 60-minute treadmill walk performed by 17 subjects at an intensity of 75% of age-predicted maximal heart rate in an environmental chamber maintained at 30°C and 85% RH. Pre-exercise and post-exercise FFs were measured using a fit test protocol consisting of 10 one-minute exercises. Subject facial and whole body sweat production was also measured. The amount of sweat within one of the respirator face pieces was found to be significantly ($p > 0.05$) less when compared to the others. Statistical analysis of the pre-exercise and post-exercise FF results showed that the fit of each respirator was significantly ($p > 0.05$) degraded over the course of the exercise period. No significant differences in FFs were observed between the three respirators at any time. Although not statistically significant, other findings suggest that specific design features of the different respirators may play a role in lessening the potential for leakage due to facepiece slippage as a result of sweating. Additional analyses of the FF results will be summarized and the implications of these findings for respirator design will be discussed.

Response to Chemical/Biological (CB) Incidents: Sizing up the Hazards

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Effective response to chemical/biological incidents will require proactive integration of both response sectors of our government - military and civilian. This integrated framework should optimize response mission effectiveness and minimize the casualties to all emergency responders at any level of government.

A variety of toxic materials could be utilized by the non-conventional terrorist including both chemical and biological agents. Toxic industrial chemicals, as well as military-unique CB hazards may pose unique challenges to our current systems of individual protection. Because our incident responders could be confronted with such a broad spectrum of hazards: chemical or biological; very toxic to mildly toxic; interior vs. exterior events, etc., it is paramount that we approach these response issues from a systems perspective.

With regard to protective posture, operations and technology need to be thoroughly ingrained in this process. Three interrelated factors should become the focus for future developments. These are: 1) External environment (The WORLD), which includes the range of hazards the responders may experience 2) Protective ensemble (The BARRIER) which involves the continuing assessment of protective system capabilities including protection factors, logistics, and others 3) Internal environment (YOU) that assesses the physiological effects of the responder in specific ensembles in specific operational scenarios.

Surveillance of Respirator Use and Programs

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This report describes currently existing United States data regarding nationwide patterns of respirator programs and practices. This review was one step toward surveillance of respirator use and practices within the U.S.

The United States Occupational Safety and Health Administration (OSHA) compliance data for general industry during October 1997-September 1998 indicate that respirator regulations were the third most frequently-cited OSHA health-related regulation (1,784 citations), preceded by hazard communications (7,701) and general personal protective equipment regulations (2,168). The OSHA citation information for the period of 1993-1997 indicated the lack of proper instruction was the most frequent deficiency of respirator programs, followed by lack of written program, and lack of respirators being provided. A survey of U.S. general industry (National Occupational Exposure Survey-NOES) in the early 1980's indicated the manufacturing industry had the highest number (400,000) of respirators observed at work sites. The NOES also found that the construction industry had the highest ratio of respirators observed per hundred workers (4.0). A similar survey of the U.S. mining industry (National Occupational Health Survey of Mining-NOHSM), in the late 1980's, suggested that coal is the mineral industry with the highest percentage (26.3%) of workers using respirators. The most frequently-used types of respirators, based on observations of the NOES and NOHSM, were found to be particulate filter half-mask respirators (including the so-called quarter-mask type). Across all of the U.S. general industry, respirators were most often associated with potential exposures to crystalline silica (as many as 125,000 workers), followed by xylene, titanium oxide, and toluene. No information was found regarding fit testing methods.

While some data are now available to provide a historical perspective, no combination of current nationwide data provides what the authors believe to be a complete set of essential information. Additional surveillance of respirator programs and practices will be necessary to obtain that essential information. Consideration is also recommended for a survey of workers' perceptions, perhaps in a parallel effort, to identify modifiable characteristics of respirators that would encourage wider acceptance and appropriate use of respirators.

Military Respiratory Protection

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The basic design of respiratory protection equipment for military use has changed little since the advent of modern chemical warfare in 1917. Improvements in engineering have centred on the optimisation of the respirator canister for broad band protection against war gases, and increasing the performance of face seal design. However, as the role of the soldier has evolved to meet the demands of the modern battlefield, so the design of the respirator must also evolve.

Aside from the traditional design driver of Protection; new design criteria were established. The UK respirator programme has defined Increased Operational Effectiveness as the prime driver for respirator research. Improving Situational Awareness, Compatibility with Optical Sights & Imaging Systems, Systems Integration, and Reducing Physiological Burden were all defined as performance targets for new respirator research. In order to make this technical leap in respirator design and performance, a new User Based design methodology has been established. This process has enabled early definition of the detail specification, system concepts, research strategy, and the evaluation criteria for the respirator programme. This user based design approach is described.

Non-Destructive Testing of Collective Protection Carbon Filters

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Quality assurance tests for respiratory protective filters containing activated carbon are typically destructive tests, in that an irreversibly absorbed and usually toxic gas or vapor is used as the test agent. Collective protection respiratory filters, such as those used for buildings, military vehicles and ships can be large and expensive, so a destructive test is not ideal. An alternative test is described in which the carbon bed is not saturated or otherwise rendered unusable by the test agent. The method is non-destructive, does not use toxic test agents, is a fast test and adaptable to 100% testing. It has been applied successfully to personal respiratory protective filters. The scale-up to larger collective protection filters and high airflow rate is described. The test is capable of discriminating between defective, and properly packed activated carbon beds, as well as providing some information on the condition of the activated carbon.

Detection of Breakthrough of Organic Vapors in a respirator Cartridge Using a Semiconductor Sensor

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To predict the breakthrough of organic vapors in a respirator cartridge when a worker is wearing it is usually difficult because the service life of the cartridge for organic vapor depends on many factors, such as, the kinds of vapors, concentration, temperature, relative humidity and the respiratory rate. In this study, a method for determining the breakthrough of the vapors in the respirator cartridge was developed. Air containing organic vapors was introduced into the cartridge, and the breakthrough curve was obtained by measuring the vapor concentration at downstream of the respirator with a gas chromatograph (GC) equipped with a flame ionization detector. Simultaneously, an output signal from a semiconductor sensor that was inserted in the downstream of the cartridge was recorded in an IC card temporally. After the measurement, the data recorded in the card were transferred to a personal computer and the change in the output signal from the sensor was compared with the breakthrough curve obtained by the GC. More than eight kinds of solvents including aromatic hydrocarbons, chlorinated hydrocarbons, acetates, alcohols, ketones and aliphatic hydrocarbons were tested. The sensitivity of the sensor for chlorinated hydrocarbons was generally low, especially when the relative humidity was high, but the rising time of the signal from the sensor was almost the same as or earlier than the breakthrough time obtained by the GC. These results suggest that because the sensor has similar or greater sensitivity for many organic vapors, it is applicable as a detector of the breakthrough in respirator cartridges for organic vapors.

A New Principle For an End of Service Life Indicator

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Single pass activated carbon filters form a reliable means of protection against toxic gases when used under proper conditions. However, given their limited sorption capacity the time of use is restricted, while the measure of restriction is dependent in a complicated manner of many external circumstances for the same reason it is difficult to estimate the time of use beforehand. For this reason it is extremely useful for the wearer of a mask equipped with an activated carbon filter, to have a method at his disposal to signal the imminent exhaustion of his filter during actual use. At TNO-PML a new approach is being followed towards the realization of such a method.

The principle of the method has been proven. It works as follows. Near the end of the activated carbon layer a small volume of a different sorbent is built into the activated carbon bed, while downstream of this sorbent there is a direct connection the end of the bed. The sorbent is loaded to a predetermined extent with an odorous substance. When the adsorption front of the contaminant reaches the sorbent, it starts expelling this substance. While no re-adsorption takes place the smelling substance reaches unhindered the respiratory tract of the mask wearer who detects the substance with his nose. A number of variables come into play in realizing the principle, a.o. : selection of the sorbent and its dimensions and position in the bed, selection and load of the smelling substance. These variables must be tuned in a concerted way in order to assure proper working under a prior defined conditions of canister use. Investigations at TNO-PML on these matters are being continued.

In the presentation the principle will be demonstrated on the basis of experimental results which we obtained using isomylacetate as a smelling substance. These results will illustrate the potential of the underlying principle as a method to achieve an End of Service Life Indicator that will work for a large class of compounds under a variety of conditions.

Comparison of Treadmill Exercise Performance Times for Several Types of Respirators

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Respirators have been shown to impair work performance due to factors such as vision, communication, respiration, heat transfer, personal procedures, physical factors, and anxiety. Respiratory factors are especially important at intense work rates of about 80-85% of maximum oxygen uptake, and treadmill performance times have been found to be linearly related to inspiratory resistance levels at that rate of work.

There are several respirators on the market that have almost no inspiratory resistance. These are loose-fitting powered air purifying respirators configured as hoods, helmets, or face shields. This experiment was conducted using two commercially-available respirators and the US Army M17 respirator used in our lab. Treadmill performance times were measured for twelve volunteers wearing each respirator on a different day.

Performance times were longer for the respirators with lower inspiratory resistance, and ranged from 19 min for the control to 13 minutes for the M17. Breathing Apparatus Comfort ratings were higher (more comfortable) for the conditions that resulted in longer performance times.

Simulated Workplace Protection Factor Results for a Variety of Powered-Air Purifying and Supplied-Air Respirator Configurations—A Model for Setting "Respirator Type" APFs

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Simulated workplace protection factor studies (SWPF) have been carried out at the Lawrence Livermore National Laboratory (LLNL) since the mid 1980s. We have evaluated a variety of powered-air purifying respirators (PAPRs) and supplied-air respirators (SARs) in our laboratory man-test chamber utilizing a large number of test subjects and similar exercises. These SWPF results of individual models of commercially available PAPRs and SARs can be used to assess the utility of "respirator type" assigned protection factors (APFs). PAPRs and SARs are ideal respirators to evaluate the feasibility of "respirator type" APFs because their performance is minimally influenced by the respirator wearer. If appropriate design requirements are utilized by respirator manufacturers, a consistent minimum performance level should be observed in SWPF studies of the same types of respirators. If one assigns the enforcement of a minimum set of design or performance requirements to an approval organization such as the National Institute for Occupational Safety and Health (NIOSH), the evaluation and approval process needs to be robust enough to assure minimum performance requirements for all approved respirator models in each "respirator type" designation.

We have evaluated nine different NIOSH approved SAR models and ten different NIOSH approved PAPR models in six different SWPF studies. We have determined that NIOSH approval is not adequate to assure an acceptable minimum level of individual respirator model performance. Our evaluations found large variations in measured SWPFs of the same type of NIOSH approved SARs and PAPRs. Critical design parameters such as airflow rate, head enclosure envelope, neck seal, and tucked-in bib influenced the measured performance of individual respirators. Other design factors such as adjustable head harness, chinstrap, air hose length and battery life was also found to influence the respirator performance. The importance of the various design parameters was accentuated in the different exercises carried out by our test subjects. The need for a chinstrap was obvious during the running and touching-the-toes exercises. Airflow rate was critical, if a tucked-in bib or tight neck seal was not utilized in the design. A complete head enclosure design was found necessary to assure a consistent high level of protection. Poor performing models of NIOSH approved respirators make the assignment of meaningful "respirator type" APF for SARs and PAPRs very difficult.

An agreed upon statistical treatment of the test data is required for all of the seven options discussed and safety factors should also be used where appropriate. At the present time, Establishing a two-tier APF system which uses the "respirator type" APF determined in one option, and the model-specific APF of another is the best model to follow for establishing "respirator type" APFs because it establishes an APF for the poor and high performing respirators of each "respirator type" designation. This option also provides the respirator manufacturer the ability to test specific respirator models to obtain a higher APF. The end user also benefits from this two-tier option because improved performance higher cost respirator models are available to be used where appropriate.

Changes in the Performance of Dust Respirators in Actual Use

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The proper use of dust respirators is guaranteed by the provision of certified respirators and by securing their appropriate selection and usage by workers. The certification system of dust respirators in Japan requires an official approval of each type of dust respirators based on the standards established by the Ministry of Labor. The performance of dust respirators in actual use, however, depends on the changes in the efficiency of dust collection and in air flow resistance. The extent of these changes may vary in relation to the kinds of filters used, the characteristics and concentrations of dust and the individual conditions of workers. The performance of 22 dust respirators that had been used by workers engaged in stone processing and in quarries was examined. The majority of these respirators were found to have a performance level below the prescribed level. Then filter samples were collected from 40 workers, each worker presenting five samples each of which had been used for five consecutive days. Thus 200 samples were collected during the survey period of five weeks. The air flow resistance and dust collection efficiency were determined for them. The quantity of dust caught on the sample filters was further determined. A significant correlation was found between the increase in air flow resistance and the dust quantity. The individual levels of dust exposure were measured for some of the workers, and the relationship between the exposure levels and the performance changes of the dust respirators was discussed. These results indicated the need for proper maintenance of dust respirators and training of workers about their appropriate use.

The Oxygen Cost of a Mine Escape

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The objective of this study was to develop a practical method for planning a mine escape when miners must evacuate while wearing a Self-Contained Self-Rescuer (SCSR).

In-mine data was gathered on escape times, distances and heart rates using miners making simulated escapes on foot and under oxygen from the deepest point of penetration in the mine to the surface. Factors such as: body weight, escape distance and grade, condition and height of the escape way and the effect of wearing an SCSR were studied.

The results of this investigation are a scientific definition of a mine **escape**, providing both the content and context for designing new testing and approval standards for SCSR's used in mine emergencies.

The First Responders' Needs

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The explosions in New York's World Trade Center and in Oklahoma City's Federal Building brought an awareness of the significance of domestic terrorism to the general public. The Tokyo Sarin incident was a turning point in the world's grasp of terrorism, introducing new frightening concepts, and emphasizing the need for appropriate preparation and response to such events.

In Israel we have been living for years under the threat of terrorism- a situation to which one can never become accustomed and where every incident leaves a permanent scar. However, it is possible to prepare for dealing with a terrorist attack, organizationally, technologically and psychologically. In addition, Israel has been under the threat of B&C warfare for years; four decades ago it was decided to prepare the homefront to face this threat. Since the Gulf War, when we witnessed the possibility that missiles armed with Biological or Chemical agents might hit civilian centers, the level of preparedness and ability to deal with the aftermath rose dramatically. There is great similarity between the preparedness for Bio/Chem. attack on civilian centers and that for a terror attack. In both situations, emergency and rescue personnel would be called upon to enter an affected area, quickly give first aid, evacuate the wounded, locate and neutralize the contaminant source. The first responders are civilian personnel, either in an official capacity or as volunteers. This population is inhomogeneous-men and women of different ages, most of whom are not trained to carry out their mission in protective gear.

There have been attempts in different countries to adapt battlefield protective gear and civilian gear used for hazardous material (HAZMAT) incidents to the needs of first responders. On the basis of our experience these are incorrect solutions, and may harm the entire process of dealing with a Bio./Chem. event. It is imperative that the protective respiratory gear be suitable for the event itself and the hazard assessment, on the one hand, as well as for the tasks in the affected area, the ability of the team to function rapidly, and carry out its duties under differing environment conditions.

The respiratory protective system for the first response teams must provide a high and reliable degree of protection, and at the same time allow for typical and comfortable functioning. The system must be simple to operate, while providing answers to the physiological requirements-respiration, low heat stress, vision and hearing.

The R&D organization, testing and standards institutes and acquisition bodies that accompany the establishment and organization of the first response units, must understand that these units are different from military units and are not similar to HAZMAT crews. They operate in different environments, under different threats and are required to carry out different activities and thus require unique respiratory protective gear.

Self-Contained Self-Rescuer Field Evaluation: Sixth-Phase Results

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The U.S. National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory (PRL) (formerly part of the U.S. Bureau of Mines) has undertaken a study to determine how well self-contained self-rescuers (SCSRs), deployed in U.S. underground coal mines in accordance with Federal regulations (30 CFR 75.1714), held up in the underground environment with regard to both physical damage and aging. This report presents findings regarding laboratory-tested SCSRs in the sixth phase of testing from mid-1996 to early 1998. These SCSRs were tested on human subjects (10%) and on a breathing and metabolic simulator (90%). These results indicate that most of the apparatus, if they pass their inspection criteria, perform satisfactorily. However, several MSA Portal-Packs were found to have KO₂ dust in their mouthpieces. Since there was apparently no way to distinguish good from bad apparatus, NIOSH-Morgantown and MSHA, after finding more instances of this problem, decided to decertify the Portal-Pack. In addition, deployed CSE SR-100s exhibited significantly higher inhaled CO₂ levels than new units, as they did in the previous phase. This will cause higher ventilation rates in most users which will, in turn, result in higher breathing pressures possibly causing users to prematurely remove the apparatus. Steps are being taken to ensure that affected apparatus are removed from service.

Three Topics of Recent Respiratory Protection Research at TNO-PML

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Respiratory protection research at TNO-PML is primarily directed to filtering devices. It focuses both on improvement of design and use of activated carbon filters and on more realistic test methodology. Most of the work is performed under contract for the Dutch MoD. In the presentation three examples of current research will be described briefly.

First our ongoing work on sorption process simulation will be discussed. The objective is to extend the validity of our present simulation model to a greater number of practical situations. One important specific item is the inclusion of multiple adsorption into the model.

A second project aims at defining physical simulants for assessing the protection level of respiratory protection devices to be used against bioagents. The general approach will be presented as well as some preliminary results. Our expectation is that, at least for some situations, bioaerosols can be represented by physical aerosols.

The third project also addresses test methodology of respiratory protective devices. A method is being developed for assessing the field protection level of military gas masks, which is the equivalent of one of the various of Work Place Protection Factors. Characteristic for the method is that the test subject should be capable of performing normal duty activities. The method includes the use of the TSI PortaCount.

Respirator Programs From the Users Point of View

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Since we began our program at the Center in 1987 we have had the privilege of sharing information with thousands of workers. Primarily we conduct Emergency Response training in accordance with 29 CFR 1910.120 paragraph (q). Respiratory protection of course is a large part of this type of training and comprises one of our largest modules.

We have contact with at least 100 workers each month and over the years have noticed some definite trends. A few statements we can make with a great degree of confidence are:

- 1 A large number of workers who wear respirators are unaware that a respirator program exists.
- 2 A large number of workers who wear respirators receive little or no training.
- 3 A large number of individuals responsible for delivering training have little or no qualifications.
- 4 Very few workers who wear respirators know the difference between a fit check and a fit test.
- 5 Very few workers who wear respirators have any knowledge regarding selection criteria.
- 6 Just about every worker who wears a respirator is aware that they must be clean shaven in and around the sealing surface.

We have a high level of confidence that in the area of knowledge the respirator community has "got it covered." We believe that the largest gap in the field lies between the user and supervision. We can write great policies and procedures but until we figure out how to get it out to the shop floor a great deal of our efforts are futile.

Ventilatory Responses to Carbon Dioxide during Moderate Exercise

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Elevated carbon dioxide concentration is one of the most serious physiological stressors while using closed-circuit-breathing-apparatuses. For considering the appropriateness of the criteria for permissible level of inhaled CO₂, we need more accurate information about the ventilatory responses to CO₂ during working condition.

The responses were measured by 13 subjects with the steady-state method; breathing air and 3 % CO₂ while rest and moderate exercise conditions. It has been demonstrated that there was very wide range of the respiratory response among the subjects, and the responses during exercise were approximately 70 % higher than the values during rest. As the physiological stress on human body will be more serious with increasing ventilation, so the criteria must be decided on the basis of the effect of CO₂ during exercise.

Update on CSA Respirator Standards Development Activities

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The CSA Technical Committee for Compressed Breathing Air has recently updated Standard Z180.1. The committee recommended significant revisions to the Compressed Breathing Air standard in part to reflect industry standards, as well as to bring clarity and consistency. They proposed to move aspects relating to respirators into the Z94.4 standard, to use definitions that are common to both standards and to reference rather than paraphrase other standards as appropriate. The inclusion of ambient air blowers eliminates the confusion around the application of the standard to this type of respirator. Substantial additions to the Appendices were included to provide guidance materials for those who design, select, install, commission, operate and maintain compressed breathing air systems. Background materials were also collected and filed for future reference by the technical committee. The results of the ballot should be known in time for this conference.

A Re-write Committee is currently reviewing the Selection, Use and Care of Respirators standard Z94.4. The introduction of an Internet-based Collaborative Tool has provided a new dimension in communication for the Re-write Committee. Several issues previously addressed by sub-committees relating to Medical Surveillance, Fit-Testing Protocols and SCBA Cylinders have been revisited, as well as those items deferred by the Z180.1 committee. In addition, harmonization has received significant attention. A progress report on this standard will be premature at this conference, but an overview of the issues being raised will be possible.

Selecting Respirators for Exposures to Infectious Aerosols

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A method has been developed for selecting respirators for protection in infectious aerosol environments, which builds on a procedure used to choose respiratory protection for environments containing non-biological contaminants. Modifications in the traditional respirator selection method are proposed for situations where information is absent regarding level of hazard and airborne concentrations. Until the necessary quantitative information is available to allow use of the traditional respirator selection method, it is suggested that qualitative methods of ranking hazard and concentration be used. Methods for ranking hazard utilize risk rankings assigned by several organizations including the Centers for Disease Control and Prevention, the National Institutes for Health, the Canadian Laboratory Center for Disease Control, the European Community and the one proposed by the European Federation of Biotechnology. In general, the least hazardous organisms (those with low risk rankings) have a low potential to cause health effects in individuals and are unlikely to result in community outbreak while more hazardous organisms (with higher risk rankings) may threaten life and result in widespread outbreaks. The nature of the activity or procedure allows an assessment of the generation rate from a source, which is combined with room volume and air flow through the room to obtain a ranking of airborne concentration. Finally, concentration and hazard ranks determine a minimum assigned protection factor, which corresponds to a respirator class. Case studies are presented to illustrate the proposed decision logic. For each situation, the procedure yielded choices that were both protective and reasonable. These results suggest that the proposed decision process will be applicable to a variety of settings for a range of infectious organisms.

Respirator User Seal Checks: Use, Limitations, and Defining a Standard Method

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Negative and positive pressure user seal checks are commonly used by respirator wearers to assess whether or not a previously fitted respirator continues to fit and/or function properly. When used in combination with a complete respirator program including daily inspection, the user seal check procedure can help to identify proper strap tension and respirator placement needed to obtain a tight sealing surface. Despite the importance of the user seal check procedure, very few published studies have compared the effectiveness of user seal check results to fit factors derived from quantitative fit testing or workplace protection factor studies.

The ability to objectively compare user seal checks with fit factors derived from quantitative fit testing is limited in part by the lack of a standard definition. Evaluation of user seal check procedures is itself subjective at best and relies upon the response of the subject. Experienced respirator fit test operators frequently witness respirator wearers who appear to clearly "fail" the user seal check procedure, even when the wearer states otherwise. In other cases, the design of the respirator can prevent a user seal check from being conducted properly. Part of the ambiguity lies within the definition of an acceptable user seal check procedure itself. A review of user seal check procedures established by governmental agencies, manufacturers, and various organizations reveals inconsistencies in these procedures. Investigators at the University of Cincinnati (AG Freeman & RT McKay) have previously reported on the development of a Respirator Leak Checker that can be used to objectively evaluate the ability of a wearer to perform user seal checks. This device has been used to monitor user seal check procedures on a variety of respirator wearers using different types of respirators for the purpose of establishing information regarding depth of inspiration/expiration and breath-hold time.

NIOSH SCSR Certification Program

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The National Institute for Occupational Safety and Health (NIOSH) tests and certifies respirators in accordance with the regulatory requirements of Title 42 Code of Federal Regulation (CFR) Part 84. This regulation identifies a wide range of specific respirator types in Subparts H thru L. This regulation also allows other types of respirators not specifically listed in 42 CFR Part 84, to be tested and certified by NIOSH if specific test requirements can be identified and developed. Self-contained self-rescuer (SCSR) devices are not listed as a specific respirator type in 42 CFR Part 84. However, NIOSH has developed specific certification requirements for SCSRs by adapting self-contained breathing apparatus (SCBA) performance requirements listed in Subpart H with additional requirements unique to self-contained self-rescuer (SCSR) devices. NIOSH has approved both compressed-oxygen SCSRs and those that generate oxygen from a chemical bed.

The NIOSH respirator certification process includes hardware evaluation and testing, as well as a review of the manufacturer's quality assurance program, engineering drawings and quality assurance documentation, user instructions, approval labels, and packaging. NIOSH also requires a Service Life Plan (SLP) for each SCSR model which identifies a finite time period from date of manufacture until the SCSR must be removed from service and discarded.

The NIOSH performance requirements include both laboratory bench tests and functional testing which requires human test subjects to open, don, and wear the SCSR while performing specific exercises. These exercise tests are commonly referred to as "man-tests".

Present and Future Challenge Aerosols for Dust Respirator Certification in Japan

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A comparative study of challenge aerosols was conducted to review a performance test of dust respirators. The national approval test for dust respirator certification in Japan requires that air containing quartz particles of smaller than 2 μm in diameter be used as the test aerosol. Therefore, aerosols, with broad size distributions may be used as the test aerosols. In view of the international harmonization of respirator certification standards, it will be necessary to use alternative test aerosols, like sodium chloride aerosol and/or any oil mist, for the approval test for dust respirators in near future.

The present study was undertaken to measure that collection efficiency of dust respirators using three kind of test aerosols, i.e., quartz dust, sodium chloride aerosol and dioctyl sebacate (DOS) mist. We used the cartridges of dust respirators and filtering face pieces from eight Japanese and foreign manufacturers, all of which have been certified by present approval test. Good correlation among the measured collection efficiencies was found for the three test aerosols, but penetration with sodium chloride aerosol and DOS mist was more than 10 times that of present test aerosol.

Overview of the Canadian Standards Association (CSA) Standards Development Activities

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CSA International is an independent, not-for-profit organization supported by more than 8,000 members. We have a network of offices, partners, and strategic alliances in Canada, the U.S., and around the world. Established in 1919, CSA International is a leader in the field of standards development and the application of these standards through product certification, management system registration, and information products. CSA's purpose is "to make standards work for people and business."

Our Standards provide safety or performance requirements for products and services. Today, we have published over 1,500 standards in nine major program fields. CSA has more than 1,000 standard development committees. CSA standards are written and updated by volunteer committee members representing the groups (e.g. manufacturers, industry associations, government, employer, labor, etc.) most affected by a particular standard. Each committee has balanced representation to ensure that no one group can dominate. Committee members work to obtain substantial agreement—a consensus of expert opinions—on the standards content. CSA also offers seminars and publishes handbooks/guidelines that help users understand and apply standards.

This presentation will provide a brief update on the status of our respiratory protection standards, *CAN/CSA-Z94.4 Selection, Use and Care of Respirators* and *CSA Z180.1 Compressed Breathing Air and Systems*.

Workplace Performance of a Supplied Air Hood During Aircraft Priming

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Supplied air hoods and helmets have various assigned protection factors (APFs). NIOSH assigns a value of 25, ANSI Z88.2 assigns 1000. OSHA assigns values from >10 to 1000 depending on the substance.

In February 1994, Air Force Occupational Safety and Health (AFOSH) Standard 48-137, Respiratory Protection Program, lowered the assigned protection factor for supplied air respirators equipped with a hood/helmet from 1000 to 25, to adhere to the more restrictive value assigned by NIOSH. As a result, personnel involved in aircraft painting and sanding operations at Tinker AFB were required to stop wearing the air-supplied loose-fitting hoods and start wearing full-face supplied air respirators operated in the pressure demand mode. This change caused an increase in production time. Employee complaints related to a limited field of vision, decreased communication capability, and heat stress, fatigue, and ergonomic issues also increased. Additional costs have been incurred for the purchase of the new respirators and for respirator fit tests.

To determine the actual performance of a supplied air hood during aircraft priming operations, samples were collected inside and outside the hood while it was being worn. The samples were analyzed for strontium, as a surrogate for strontium chromate contained in the primer.

No detectable concentrations of strontium were found inside the hoods during these operations. Therefore, a direct calculation of respirator performance cannot be made. A Monte Carlo analysis was designed to estimate the level of respiratory protection that would produce the results found. This analysis estimates the mean workplace protection factor to be greater than 10,000, with a 5th percentile value of at least 1600. These values are consistent with the ANSI APF of 1000.

Symptoms of Victims Suffered From Sarin Nerve Gas Attack on the Tokyo Subway System

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On the morning of March 20, 1995, the Tokyo subway system was attacked with nerve gas. Liquid, in plastic bags, left on the subway cars was analyzed and Sarin, hexane, and N, - diethylaniline were detected as the main components. The health effects of victims were studied through questionnaire and hospital records. Plasma cholinesterase levels were used as exposure indicators. Muscarine-like symptoms appeared generally and could be use as early warning signs. Nicotine-like symptoms and effects on central nervous system appeared in more severely exposed cases suggesting that they can be used as severity indicators. Muscarine-like effects to the eye and respiratory system must be induced by the direct contact of Sarin gas to mucous membranes. On the other hand, nicotine-like effects are caused by a systemic exposure to Sarin.

Pressure Drop and Service Life Predictions for Respirator Filter Canister Performance

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Filter designers and manufacturers have a responsibility to provide filter canisters with increasingly higher levels of protection due to rising safety standards in the workplace. Optimizing the protective capacity of conventional canisters is not simply about increasing the depth of adsorbent present in the canister since this will lead to an increased resistance to airflow, and a greater physiological burden on the user.

In order to optimize canister design it is necessary to establish how the physical dimensions of the adsorbent bed affect breathing resistance and adsorption performance. A study was carried out as part of the UK MoD Respirator Program to investigate both the pressure drop and cyanogen chloride chemisorption performance of a granular activated carbon adsorbent.

Results obtained show relationships which correlate adsorption performance and pressure drop to the quantity of adsorbent, the linear flow velocity, and, where applicable, the challenge vapor concentration. The results show that altering linear velocity by increasing cross-sectional surface area has a more beneficial impact on filter performance than altering the adsorbent bed depth. The use of these relationships to predict the performance of various canister designs with a view to enhancing protection whilst reducing breathing resistance will be demonstrated.

A Model for the Utilization of Independent Testing Laboratories for NIOSH Certification of Respiratory Protective Devices

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The paper presents a model for NIOSH respiratory protective device approval (certification) utilizing accredited independent testing laboratories for the evaluation of the various functional and performance attributes of such devices. The Independent Laboratory test results (and test report thereof as submitted to NIOSH form the basis of the respiratory protective devices performance conformity to the standards and regulations as set forth by NIOSH.

Applicants seeking NIOSH approval of respiratory protective devices (RPD) submit samples of the RPD to the accredited laboratory of their choice. Upon receipt of the test report from the laboratory, the applicant forwards their application, inclusive of applicable drawings and documentation to NIOSH, as per their designated role within the United States as approval body (certified) of respiratory protective devices. The approval process as pertain to NIOSH is now administrative in the formal review of the technical file consisting of drawings, documents, QA protocols and the test report itself.

Laboratories desiring recognition of their test reports by NIOSH, apply to the agency for accreditation. The agency, pending the positive review and audit of the applying laboratories capabilities, competence and quality assurance practices, then accredits the laboratory pursuant to the limitations of scope. Laboratories are subject to annual audit and review by NIOSH in order to maintain accreditation status.

Asbestos and Performance of Respirators

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Breathing in asbestos fibers can lead to asbestos related diseases and they kill more people than any other single work-related cause. The law states that employers must not use respirators as the only control measure and it should not be used as a first-line of protection. However, there are occasions where respirators are chosen as a first line of protection. Some employers do not pay sufficient attention to the selection of right respirators; fit testing and methodologies for making sure that the chosen respirators continue to provide adequate protection.

Protection Factor Studies on Fullface Mask Respirators

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Respirators may be used as a last resort for controlling exposure to toxic substances. One aspect that contributes to the selection of suitable respirators is the extent of the likely performance of respirators. This may be indicated by the term protection factor. A number of studies have been conducted to assess respirator performance in real-world applications.

However, different enforcement and standard setting organizations may determine different assigned protection factors for the same class type of respirator. The reasons for this include the application of different philosophical arguments for carrying out protection factor studies and approaches taken to interpret the results obtained.

This paper will present the findings of a series of protection factor studies on fullface mask respirators. The studies were carried out using different contaminants and conditions. The data obtained will be analyzed critically and an appropriate assigned protection factor will be proposed for fullface mask respirators.

NBC-Threats: Is there a Role for Protective Masks for civilians? Survey of an Opinion Poll

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In 1981, the Swedish Government decided that all civilians should have access to a protective mask to be distributed in wartime or in special critical situations. Enough masks to provide practically every Swede with a personal mask are now stockpiled in centrally located warehouses. Since the decision in 1981, the main threat has changed dramatically from large scale NBC warfare to peacetime terrorist attacks with BC-agents. These masks might also be useful to protect the general public from accidentally released toxic industrial chemicals (TICS).

Should the stockpiled protective masks be distributed to the general public to increase the preparedness against BC-agents or TICS contaminating the neighborhood? In this paper we describe an opinion poll aimed at measuring risk perception, knowledge of the function of protective masks and attitudes with respect to possess and take care of a personal mask.

The questionnaires were distributed to 1500 persons, 71% responded. The main findings can be summarized as follows: 44% of the Swedish population know that there is a protective mask reserved for them in case of war or a peacetime crisis, 61% of the male population know how to handle a mask, while only 13% of the females thought so. Part of this difference is likely to be due to experience from compulsory military service. Only 5% of the population had a full knowledge of the protection ability of the mask. However, a majority felt that their personal security would increase if they had access to a personal mask. Only 16% thought it should be a problem to store the mask at home. 24% told that they were willing to pay to get access to a mask of their own. 41 % were willing to participate in a field trial with protective masks, whereas 34% expressed uncertainty. We are now planning for field trials at different places in Sweden late this year.

A System for the Remote Acquisition of Respirator Protection Factors

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It has been highlighted in previous studies the discrepancy between respirator protection factors obtained in the laboratory and those observed in the workplace. This has led to the introduction of a respirator Assigned Protection Factor which has a significantly lower value than the Nominal Protection Factor. To further investigate the protection offered by RPE in 'real' environments, i.e. the workplace or the battlefield, a remote sensing system has been developed. The system consists of a PortaCount condensation nuclei counter interfaced with a RF telemetry system. Real-time data from the PortaCount is received by a RF unit connected to a PC, where dedicated software is used to process and display, in real-time, the respective particle concentrations together with the calculated protection factors. In addition, the software controls the internal PortaCount valves, enabling the PortaCount sample to be switched between the ambient challenge and mask concentrations. The entire unit fits into a small rucksack, allowing the volunteer to perform their normal activities. This system will be described in full together with a recent development incorporating a miniature helmet mounted video system that permits the level of protection to be correlated to an activity or movement.

An Improved High Sensitivity Sodium Flame Photometer for Determining the Protection Factors Provided by Military Respirators

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With the advancement of respirator technology providing higher levels of protection, the current generation of flame photometers employed to detect the salt analyte are found to lack the resolution to detect the low levels that penetrate into the respirator. Compounds such as CO₂ and H₂O present within the respirator sample as well as pressure and temperature fluctuations are observed to affect the flame background. In the current instrumentation this change in flame background is misinterpreted as salt. By employing a patented technique, it is now possible to monitor these changes in flame background. The system incorporates a rotating filter wheel located in front of the photo multiplier detector, which contains a number of optical bandpass filters that are insensitive to the sodium emission. As the wavelengths have been selected to respond in an identical manner to the sodium band to impurities and other flame changes, it is possible to precisely predict the flame background using a dedicated software package. Other features are also incorporated to further improve the system resolution. The entire unit has been mounted in a mobile laboratory facility to allow protection factors to be acquired both at military installations and out in the field.

Statistical Investigation of Accelerating Quantitative Fit Testing of Respirators

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Quantitative fit testing is a method to characterize and evaluate the respirator fit for individual users. It is also helpful in selecting appropriate respirator for individual workers and help gain insights into potential contaminant leakage. The most common method of testing involves fitting a respirator on to a worker and measuring the ambient and in-mask aerosol concentration, a ratio, which is called the fit factor. During this test, the worker is required to perform a set of exercises designed to produce head and facial movements thereby testing the respirator face-piece to face seal. OSHA specifies the various activities the worker should be performing in 29CFR1910.134.

The purpose of this study is to shorten the length of time for the testing. The number of tasks and the order of exercises the worker has to perform cannot be changed since it is an OSHA requirement. Hence, the goal of the statistical analysis is to find ways to reduce the sample time during each test.

There are a number of ways to analyze the data. Our approach is to introduce simple statistics to look at correlation between different exercises and between different test time periods. This will help us determine which exercises are critical and how fit factors tend to change with test time. By simple statistical analysis of comparing overall fit factors obtained at different time intervals with the "true" full 60 seconds fit test results, one can choose the lowest time interval that yields results similar to the overall fit factor. However, the analysis does not stop here. Our approach will also determine the probability of occurrence of a "pass" when the true 60 seconds fit test would yield a "fail". By limiting the probability that such an event to occur, we can establish a new fit test protocol which would be more efficient than the existing method without compromising the quality of the test. The statistical analysis will also consider the probability of occurrence of failure during the shortened test cycle that would have otherwise passed during a full 60 seconds test, information very critical for the employers who would not like too many good fits to be rejected. The analysis requires determination of specificity and sensitivity for various conditions that are then used to determine optimum sample time. The statistical analysis is in progress and it is hoped that the results will be discussed in detail at the conference.

Metabolic and Respiratory Responses During the Performance of a 60-Minute Man Test 4

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Human physiological variables, such as body weight, height, strength, and aerobic capacity, can affect the results of such exercise tests as that used for Man Test 4 (MT4), a U. S. respirator certification test described in Title 42, Code of Federal Regulations, Part 84. The Automated Breathing and Metabolic Simulator (ABMS) is a computer-controlled system designed to simulate human oxygen consumption, carbon dioxide production, and minute ventilation. The purpose of this research was to characterize the metabolic responses of various body weight human subjects performing a 60-minute MT4, with the intent to use these results in the development of an ABMS test protocol for respirator certification.

Fourteen male volunteers performed MT4 for one hour while they wore a portable, telemetric metabolic measurement device weighing 0.5 kg. The subjects were stratified into four body weight categories: 80-86.5 kg (BW1, n=4); 86.6-92.5 kg (BW2, n=4); 92.6-100 kg (BW3, n=4); and >100.5 kg (BW4, n=2). Heart rate (HR), minute ventilation (VE), tidal volume (VT), oxygen consumption (VO_2), carbon dioxide production (VCO_2), and respiratory quotient (RQ) were measured for every breath and averaged for each minute of each task.

There were no significant differences among the four body weight categories for mean MT4 HR, VE, VT, or RQ. Mean MT4 VO_2 was significantly greater for BW3 ($1.53 \text{ L} \cdot \text{min}^{-1}$) and BW4 ($1.69 \text{ L} \cdot \text{min}^{-1}$) than for BW1 ($1.06 \text{ L} \cdot \text{min}^{-1}$, $p < 0.05$). Mean MT4 VCO_2 was significantly greater for BW3 ($1.40 \text{ L} \cdot \text{min}^{-1}$) and BW4 ($1.41 \text{ L} \cdot \text{min}^{-1}$) than for BW1 ($1.07 \text{ L} \cdot \text{min}^{-1}$, $p < 0.05$).

For all MT4 tasks except the overcast, these data represent lower values than those observed or predicted in previous research (Kamon, 1975). These differences are the result of the absence of steady-state conditions in the current study.

Comparison of Protective Mask Leakage Tester Equipment to Enhance Soldier Survivability

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The size and weight of current military respirator quality assurance test devices make them difficult to deploy to forward elements who must be able to test and maintain respirators in a state of operational readiness. The Air Techniques International Model TDA-99M Mask Leakage Tester performs all the capabilities of the current M14, Q179, Q204, and M4A1 mask components testers in one portable, suitcase-sized container. The main objective of this evaluation was to determine if the TDA-99M Protective Mask Leakage Detector performed as well as, or better than, the currently used standard set of mask testing instruments. The Army Research Laboratory was asked to develop the test protocol and conduct an analysis of the data collected by the Marine Corps NBC Test and Evaluation Unit. Two each of the currently used instruments were tested against two TDA-99M instruments. Four operators utilized each of these machines in random order twice each day for five consecutive days. Each operator tested their assigned 20 masks in random order on each machine every day. 80 M40 and 80 MCU2/P masks were tested with respect to overall leakage, outlet valve leakage, drink tube flow, and drink seat valve integrity. The experimental design matrix was set up for a statistical analysis of variance comparing differences between equipment types, differences within equipment types, differences between operators, and differences within operators using the same machine. The test data collected and the in-depth statistical analyses performed clearly show the TDA-99M equaled and exceeded the ability to detect and identify leakage sources and defective components in both the M40 and MCU2/P series of masks. The TDA-99M consistently failed a mask in the location whereas the current test instruments did not necessarily do this.

Ozone Removing Ability of Washable Filers after Repeatedly Use and Washing

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We have studied the cleaning method of our water-repellent mechanical filters, and we proved that such type of filters can be cleaned repeatedly. The filters are expected to be used for welding operation, therefore, activated carbon fibers are blended to remove toxic ozone together with welding particulate fumes. In order to examine the ozone removing ability of the filters under the repetition of cleaning, we conducted the two types of test. One is the measurement of service life against ozone after any times of welding fumes loading and cleaning. The other is the measurement of ozone penetration concentration against various levels of ozone exposure and cleaning repeatedly. As a result of the first test, we observed that the service life decreases with the cleaning repetition, however, the service life after the initial cleaning is almost the same as new. It means that the degradation is not caused by the cleaning, but by the ozone exposure. The second test revealed that the ozone penetration was observed in case of 150 ppm-min ozone exposure, and the penetration concentration was lower than 0.05 ppm for 11 times ozone exposure. In case of ozone exposure ranging from 6 ppm-min to 30 ppm-min, the ozone penetration was not observed. We conclude that the filters can be used 11 times by cleaning for MIG and TIG welding which are thought to generate high concentration of ozone.

Comparison of the Companion and Modified PortaCount™ Methods for Fit Testing N95 Respirators

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In 1995, the National Institute for Occupational Safety and Health (NIOSH) revised the particulate respirator performance regulations contained in Title 42 Code of Federal Regulations, Part 84. Soon after questions arose regarding whether N95 respirators (one of the new classes of particulate respirators) could be quantitatively fit tested. In response, NIOSH and TSI Incorporated researchers developed a method for fit testing N95 filtering-facepiece respirators using the PortaCount Plus™. The PortaCount Plus™ fit test was designed to measure fit factors (i.e., face seal leakage only). Due to some N95 filter media having significant penetration of ambient particles, the PortaCount Plus™ when used with a N95 respirator may not measure just face seal leakage but total penetration (i.e., filter penetration and face seal leakage). Total penetration was converted to face seal leakage by subtracting out filter penetration. A filter ratio test clamp was developed to measure filter penetration with the PortaCount Plus™. TSI also developed a new accessory (the N95-COMPANION™ for the PortaCount Plus™) to fit test N95 respirators.

The purpose of this study was to determine how well the fit factors from these two methods correlate. The facepiece fit of each respirator model was measured on a panel of subjects with varying face sizes. A "standard" PortaCount Plus™ test was conducted for each subject/respirator combination. Immediately after the "standard" PortaCount Plus™ test, a fit test for each subject/respirator combination was conducted using the N95-COMPANION™ in conjunction with the PortaCount Plus™ without the respirator being redone. After the N95-COMPANION™ test, filter penetration was measured on each respirator using the PortaCount Plus™ with the clamp, and an adjusted fit factor computed. The results of analysis of variance indicated that the geometric mean of the N95-Companion™ fit factor (49) was not significantly different from the geometric mean of the adjusted fit factor (35).

The Effect of Ambient Concentration and Exercise on PortaCount™ Quantitative Fit Factors

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The PortaCount™ is a quantitative fit test method which uses ambient aerosols to determine the fit of a respirator. The current Occupational Safety and Health Administration (OSHA) regulations in the United States stipulate that eight exercises lasting one minute each are to be performed for this fit test. Ambient aerosol concentration levels vary greatly among workplaces, but OSHA does not stipulate a specific concentration. Due to the length of a fit test, considerable time and financial commitments must be made by employers to select a "best fitting" respirator for a given worker. Thus, the purposes of this study were to determine: (1) if PortaCount fit factors are affected by ambient concentration; (2) if any of the exercises are the most critical in determining the overall fit factor; and (3) if any exercise can be possibly eliminated. A data set of 20,974 PortaCount fit tests conducted at various workplaces was obtained. The data set was divided into two data sets: one consisting of half-mask (filtering-facepiece and elastomeric) and the other, full-facepiece respirators. The ambient concentrations were divided into five levels and Duncan's multiple range test was performed to determine if the fit factors vary among the five levels. The analyses of both data sets also involved determining the frequency of each exercise in having the lowest and highest fit factor. The fit factors for each exercise were also normalized to the highest fit factor among all exercises in each test and the mean ratio was determined for each exercise. Correlations between exercise fit factors were determined as well. Overall fit factors were found to be significantly dependent on the ambient concentration in both the half-mask and the full-facepiece data sets (p -value < 0.01). For overall fit factors greater than or equal to 100, the fit factor for "reading" or "the first normal breathing" was found to be the lowest fit factor among fit factors for each exercise for about 60% of the fit tests for half-mask respirators using six exercises; the normalized fit factors for these two exercises were also the smallest and second smallest. Fit factors for any exercise were found to be highly correlated with fit factors for other exercises. Fit factors for the first normal breathing were significantly smaller than those for the second normal breathing. Similar results were observed with the fit test data for full-facepiece respirators. The authors conclude that further study is needed to determine if the fit test pass/fail criterion should be adjusted for ambient concentration level. It is also postulated that controlled laboratory experiments may find that some exercises can be eliminated from the current fit test protocol without affecting the selection of a "best fitting" respirator for a given worker.