

that are most important to workers, whether these factors change during respirator wear, and whether factors are task dependent. Therefore, this study investigated the psychophysiological effects of respirator wear and task performance on soldiers executing vehicle maintenance tasks. A 10-item questionnaire was administered to 28 volunteers after completing two iterations of vehicle maintenance, one during respirator wear and one with no respirator. Subjects rated item importance for completing the tasks on a 10-point scale. Independent of respirator wear, factor analysis of the questionnaire identified four stable psychophysiological factors associated with performance of the maintenance tasks. These factors were identified as vision (V), comfort (CF), communications (COM), and head positioning (HP). Average factors scores for V (8.1 +/- 1.9), COM (8.3 +/- 1.8), and HP (7.5 +/- 2.4), corresponding to a rating of "very important" were significantly greater than the score for CF (6.1 +/- 2.6) which coincided with a "fairly important" rating. Factor scores were similar between respirator conditions, but time to complete maintenance tasks was significantly greater during respirator wear. These results indicate that the psychophysiological factors of worker performance of the vehicle maintenance tasks are not influenced by respirator wear. Furthermore, these findings suggest that design or use of a respirator that enhances vision and communications, and minimizes its effect on a wearer's ability to position the head, would limit the degradation in worker performance time to complete these maintenance tasks. Additional studies are ongoing to determine whether the psychophysiological factors of respirator wear and work performance are task dependent.

## 53

TREADMILL PERFORMANCE WITH INCREASED RESPIRATOR INSPIRATORY RESISTANCE. A.T. Johnson, W.H. Scott, Biological Resources Engineering, University of Maryland, College Park, MD

People cannot work as long nor as hard wearing respirator masks as they can without them. Knowing why this is so can be important for those who design respirators and for those who supervise wearers. Respirator inspiratory resistance is naturally considered to be one of the determinants of performance decrements, but only when the rate of work is heavy. To experimentally verify the inspiratory resistance effect on performance decrement, a treadmill test was conducted with ten subjects in the age range of 18-34 years walking at a constant load of 80-85% of maximal oxygen consumption. Subjects walked during each test session until they reached voluntary end-point. Treatment conditions consisted of: no mask control, unmodified M-17 mask, and M-17 mask with modified resistances of 20, 30, 40, and 50 mm H<sub>2</sub>O at 85 L/min. Heart rate, oxygen consumption, rating of perceived exertion, and breathing apparatus comfort scale were measured throughout the test. Results showed that treadmill performance at 80-85% of maximum oxygen consumption is very sensitive to inspiratory resistance level,

decreasing from an average performance time of 14 minutes at the slightest resistance to 4 minutes at the highest. Oxygen consumption decreased as resistance increased, indicating severe hypoventilation. Inspiratory resistances greater than 30 mm H<sub>2</sub>O at 85 L/min gave significantly reduced performances. These results confirmed the sensitivity of the performance protocol to respiratory stress. Respirators used at lower work rates are expected to have smaller performance dependence on resistance level.

## 54

VIOLATIONS OF OSHA'S RESPIRATORY PROTECTION STANDARD CITED IN ACCIDENT INSPECTIONS DURING CY 1994 AND 1995. T.A. Towers, OSHA, Washington, DC

An analysis of OSHA's enforcement data for the 1994 and 1995 calendar years reveals that employers have been cited for violations of the respiratory protection standard (29 CFR 1910.134) 18,270 times, or nearly one third of the 56,041 citations for violations of federal health standards. In a subset of this data, the FATCAT (Fatality and catastrophic injury) inspections, the respirator standard was cited in more than three percent of the total number of accident investigations. The abstracts and data from 109 of these investigations were examined in order to determine the extent to which the respirator standard had been violated and which provisions were most frequently cited. The 109 cases were reviewed in an effort to first determine the number of fatalities, to determine which of those were attributable to causes other than improper application of the respiratory standard, and which of the fatalities could most likely have been prevented by proper application of the standard. It was found that there were 129 citations issued for injuries and 21 issued for fatalities. There were 46 fatalities in the 109 cases. Of the fatalities, 17 were found to have resulted from exposure to chemical hazards or from oxygen deficient atmospheres. Some of the victims were killed outright from the overexposure, while others died from secondary causes, such as falling from elevation after having been overcome by chemical exposure. It was concluded that most of the fatalities could have been prevented by a respirator program which included proper respirator selection and fit and training in the nature of chemical hazards and respirator limitations.

## 55

PROTECTION FACTOR STUDIES OF ABRASIVE BLASTING RESPIRATORS IN SIMULATED AND ACTUAL WORKPLACE ENVIRONMENTS. J.A. Parker, K.E. Crump, J.H. King, E.D. Bullard Co., Cynthia, KY; Y.Y. Hammad, University of South Florida, Tampa, FL

The assigned protection factor (APF) for continuous flow, hood and helmet type atmosphere-supplying respirators has been the subject of much debate over recent years. The APF assigned by ANSI Z88.2-1992 to this class of respirators is 1000. OSHA has adopted an APF of 25 for this class of respirators in the Cadmium and the Lead in Construction

Standards. The objective of this study is to determine the range of protection factors achieved during actual work conditions and simulated work conditions for two models of an abrasive blasting respirator. In the simulated workplace study, the aerosol used was polyethylene glycol 400 with a mass median aerodynamic diameter of 0.78 micrometers and a GSD of 1.5. An expanded exercise protocol was used. Aerosol measurements were made with a forward light scattering photometer. Overall calculated protection factors for both helmets were greater than 40,000. Pressure inside the helmets was also measured during the tests and no significant negative spikes occurred.

In the workplace study, the tests were conducted at an indoor sand blasting booth. Respirable dust was measured inside and outside the respirators. Dust concentrations were determined by proton induced X-ray emissions (PIXE). The average outside silica concentration was 28.3 +/- 8.5 mg/cubic meter. The average WPF obtained was 28,500. The 5th percentile was 2870.

As a result of the simulated workplace study, OSHA will treat the respirators tested as if they have an APF of 1000 for the Lead in Construction Standard. Both studies support the use of an APF of 1000 for the respirators tested and for this class of respirators.

## 56

COMPARISON OF RESPIRATOR FIT TEST METHODS WITH AN ACTUAL MEASUREMENT OF EXPOSURE. C. Coffey, D. Campbell, NIOSH, Morgantown, WV; W. Myers, S. Das, West Virginia University, Morgantown, WV

Quantitative fit-tests (QFT) have been assumed to be predictive of the protection respirators would provide a wearer in his workplace. Workplace studies have consistently found no correlation between quantitative fit factors and workplace protection factors. This study was undertaken to correlate six QFT methods under laboratory conditions against exposure to 1,1,2 trichloro-1,2,2 trifluoroethane (Freon®) assessed by exhaled breath analysis. The six QFT method protocols were based on using either corn oil or ambient aerosol or controlled negative pressure. Respirators used in the study were both disposable and elastomeric organic vapor/high efficiency half masks. The exhaled breath of subjects exposed to 0.5, 3, 5, 25, 50 and 100 ppm-minutes of Freon was evaluated at 30 minutes postexposure. This characterization was then used to predict the actual exposure to Freon during correlation testing. Fit factors resulting from the QFT protocols were then individually correlated with the protection determined from these predicted Freon exposures using the coefficient of determination, R<sup>2</sup>. The QFT methods were 1) low flow, flush probe (CLF); 2) high flow, deep probe (CHD); 3) exhalation valve discharge (EVD); 4) controlled negative pressure (CNP); 5) ambient aerosol 1-10 minutes, 6 exercises (AA1); and 6) ambient aerosol 2-30 minutes, 17 exercises (AA2). The lowest R<sup>2</sup> value, 0.187, was found with the EVD method. The highest R<sup>2</sup> values, 0.788 and 0.774, were associated with respec-

tively the CHD and AAI methods. The results of this study suggest that some QFT methods can be predicative of actual respirator performance.

## 57

### SELECTING RESPIRATORS FOR CONTROL OF INFECTIOUS AEROSOLS. N.V.

McCullough, L.M. Brosseau, University of Minnesota, Division of Environmental and Occupational Health, Minneapolis, MN

In some settings, where engineering and other controls cannot be easily implemented, respiratory protection may be the only method by which to lower exposures to infectious aerosols. The current respirator selection process for non-biological aerosol exposures cannot be used to choose respirators to minimize exposures to infectious aerosols. There are no data on airborne concentrations or the health effects associated with different levels of exposure. There are no occupational exposure limits for biological organisms. A strategy for selection of respiratory protection in a variety of settings is proposed; qualitative estimates of airborne concentration and toxicity are suggested. A process has been developed for selecting respirators to control exposures to infectious aerosols. The traditional industrial hygiene respirator selection method has served as the basis for this proposal with suggestions for modifications when data on occupational exposure limits, toxicity, concentrations, etc. are lacking. The modifications include methods for ranking toxicity using infectious dose and measures of disease severity, as well as methods for ranking concentrations using knowledge of room volume, uncontaminated air flow, and source. Source is ranked by activity or procedure. Concentration and toxicity are used to select a minimum assigned protection factor (APF) from a table, to which APFs have been assigned using the Center for Disease Control and Prevention's guidelines as a benchmark. The APF is then adjusted for special use considerations. Two case studies are presented to illustrate the proposed decision logic. For each situation, the procedure yielded choices which were both protective and reasonable. These results suggest that the procedure will be applicable to a variety of settings for a range of infectious organisms.

## 58

### AEROSOL FILTRATION CHARACTERISTICS OF AIR-PURIFYING ESCAPE MASK. C. Chen, C. Chang, S. Huang, F. Jeng, National Taiwan University, Taipei, Taiwan

Escape masks are used to allow a person working in a normally safe environment sufficient time to escape from suddenly occurring respiratory hazards. According to the CNS filter test requirements, the cigarette smoke is the test aerosol; the mass concentration should be ranging from 100–200 mg/m<sup>3</sup>, and the aerosol penetration must be less than 5%. To set up the testing system, the cigarette smoke was replaced with incense smoke, because most of the cigarettes last for about 5 to 10 minutes, too short to confirm the stability of the testing system. Four instruments were used to measure the aerosol penetration through the filter medi-

um: an automated filter tester, a scanning mobility particle sizer, and two portable real-time aerosol monitors; a handheld aerosol monitor and a miniature real-time aerosol monitor. The particle size analysis showed that incense smoke had a count median diameter (CMD) of 0.123 µm and a geometric standard deviation (GSD) of 1.67, which is slightly larger than that of the cigarette smoke (CMD=0.106 µm, GSD=1.48). The aerosol penetration increased with increasing sampling flow rate. The penetration of the most penetrating size particle was about 6.5% at sampling flow rate of 30 L/min. The size dependency of aerosol penetration became weaker as the sampling flow rate decreased. The penetration data of these four instruments are in a good agreement with mass measurement (membrane filter method), all in the range from 5.3% to 9.4%. Therefore, the manufacturer needs to improve the filter quality of this escape mask in order to be certified.

## 59

### PREDICTION OF GAS AND VAPOR CARTRIDGE SERVICE LIVES OF AIR-PURIFYING RESPIRATORS FOR CARBON TETRACHLORIDE, ACETONE, METHYLENE CHLORIDE AND VINYL CHLORIDE. D.Y. Park, The University of Michigan, School of Public Health, Ann Arbor, MI; L.A. Brey and A.R. Johnston, 3M, St. Paul, MN

Prediction of respirator cartridge service lives against gases and vapors is a subject of increasing interest to industrial hygienists. Various mathematical models have been proposed to describe the increase in breakthrough concentration with time (the breakthrough curve). Full breakthrough curves for three commercially available organic vapor cartridges were obtained at three or more challenge concentrations against carbon tetrachloride, acetone, methylene chloride and vinyl chloride at 50% RH and 20.8° C at an air flow rate of 32 L/min. Cartridge service lives were estimated by computing carbon adsorption capacities using data from multiple breakthrough curves at several challenge concentrations. Some deviations were observed between breakthrough curves experimentally obtained and those theoretically derived. These deviations result in underprediction of observed service lives. Improved accuracy in service life prediction was obtained by using only the 0–50% part of the experimental breakthrough curve to derive the parameters for the model. In addition to estimating breakthrough times, useful information on isotherm slope and adsorption wave dynamics was derived from the breakthrough curves. This approach provides industrial hygienists with a useful tool for estimating service lives of organic vapor cartridges.

## 60

### THE EFFECTIVENESS OF RESPIRATOR CARTRIDGE AND OTHER CARBONS IN REMOVING VAPORS OF NITRIC ACID FROM AIR. G. Wood, R. Kissane, Los Alamos National Laboratory, Los Alamos, NM

Industrial and laboratory workers can be exposed to vapors of nitric acid, especially in accidents, such as spills. Nitric acid can also

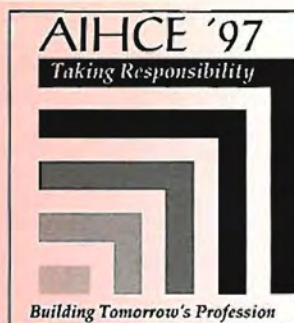
be a product of incineration for energy production or waste disposal. Studies have been done to determine the effectiveness of activated carbon sorbents from commercial respirator cartridges (and other sources) for nitric acid removal from air. Most of these carbons were impregnated by manufacturers with various chemicals for enhancing the collection of acid vapors and other air contaminants. The nitric acid vapor was generated from concentrated acid solutions and detected by trapping a water bubbler for pH measurements. Both low and moderate relative humidity conditions were used. Packed bed depths (contact times) and vapor concentrations were varied to study the mechanisms and rates of removal. All carbons were efficient at vapor contact times representative of air-purifying respirator use. Capacities were also high. One surprising observation was the desorption of low levels of ammonia from two of the carbons. This was apparently due to residual ammonia from the impregnation process.

## 61

### FILTER QUALITIES OF FILTERING FACEPIECES—WHAT DO THE NEW FILTER TEST REQUIREMENTS DRIVE? C. Chen, S. Huang, G. Chiu, National Taiwan University, Taipei, Taiwan; Y. Hunag, Y. Lai, Center for Industrial Safety and Health Technology, Hsinchu, Taiwan

The new certification requirements for respiratory devices (42 CFR Part 84) were promulgated in 1995. Upgrading testing requirement for particulate filters, the new rule intended to enable respirator users to select from a broader range of certified respirators, and to expedite the incorporation of technological advancements. In present study, 10 filter media of different properties were tested for the filtration efficiency and the air resistance. Filtering facepieces approved under 42 CFR 84 and 30 CFR 11 were tested and compared for the performance and the filter quality. The filtration mechanisms, including shift of the most penetrating size, were theoretically and experimentally examined. To conduct the filter performance testing, a constant-output aerosol nebulizer was used to generate submicrometer-sized particles; an ultrasonic atomizing nozzle was used to generate micrometer sized particles; a 10-mCi Krypton-85 radioactive source was used to neutralize the particles to Boltzmann charge equilibrium; a scanning mobility particle sizer was used to measure the aerosol penetration for particles smaller than 0.8 µm; and an aerosizer was used for measuring particles larger than 0.8 µm. The results showed that there is still a gap between the filtration theory and the experiment. The most penetrating size is determined by many factors, including fiber size, filter porosity, face velocity, and charges carried by the fibers and the particles. The new products that meet the new requirement do not always perform better than the products certified under the old law, from the standpoint of filter quality.

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*Paper Withdrawn by Author*

2

PRAGMATIC PRINCIPLES FOR AVOIDING MANAGEMENT PITFALLS. M.L. Sanders, Naval Engineering Field Activity, Poulosbo, WA

Making the transition from an industrial hygienist managing programs to a manager programming industrial hygienists can be traumatic and career damaging. Keen technical and verbal skills are common entrance requirements to the people-management arena, but industrial hygienists who desire to make that professional move must be aware of three particularly dangerous pitfalls which neither of those skills will protect against.

One pitfall results from failure to distinguish between leadership and management, another from failing to distinguish between organizational process and function, and the third for failing to recognize the customer. Industrial hygienists must have the insight to recognize and evaluate those pitfalls, avoiding or back-filling in order to walk safely over them.

Specific and succinct descriptions of principles for both the prevention and the resolution of these problem areas have been developed; use of these principles is the catalyst for efficacious management. Whether the profes-

sional industrial hygienist is in the private or the public sector, assuming the responsibility for a controlled management response using these principles in the face of business adversity can turn impending failure into resounding success and ensure career growth.

3

SCIENTIFIC CONTRIBUTIONS TO THE REVISION OF THE OSHA'S 1,3-BUTADIENE HEALTH STANDARDS. C.T. Chen, OSHA, Washington, DC

The current OSHA's 1,3-butadiene (BD) health standard is an 8-hour time-weighted average (TWA) exposure of 1,000 ppm for workers exposure to BD which is adopted from 1968 American Conference of Governmental Industrial Hygienist's (ACGIH's) threshold limit values (TLVs®) in 1971 to prevent irritation and narcosis effects. Due to the demonstration that BD causes multiple cancers in two animal studies in 1983, OSHA was petitioned by unions in 1984 and referred by EPA in 1985 for regulatory action. In 1990, OSHA published a proposed BD standard with an 8-hour TWA exposure of 2 ppm, a short-term exposure limit (STEL) of 10 ppm, and the ancillary provisions. There are many scientific studies contained in OSHA BD docket which enhanced the completion of a BD standard. Animal bioassays, human epidemiologic studies, experimental investigations on the metabolites and their mechanism in vitro and in vivo systems provides convincing evidence that BD is a probable human carcinogen. Three out of five quantitative risk assessments used NTP study with exposures of 6.25-625 ppm BD to calculate their best estimates of risk. Due to the availability of

three breakthrough studies on BD, OSHA was able to allow the use of cartridges and canisters for respiratory protection that would enhance workers' protection, address industry's concerns, and reduce compliance cost. A series of plant visits conducted by the National Institute of Occupational Safety and Health (NIOSH) produced worker exposure profiles and information on technological feasibility which greatly helped in economic analysis. An epidemiologic study sponsored by the International Institute of Synthetic Rubber Producers (IISRP) completed in late 1995 clearly demonstrated an excess risk of cancer among workers exposed to BD which is complementary to the animal studies. This promoted IISRP to engage with unions to reach agreement on a standard with an 8-hour TWA exposure of 1 ppm, a STEL of 5 ppm, and other aspects of standard. This demonstrates that studies from various disciplines of science will greatly enhance the development of a workplace health standard. The opinion expressed here is sole of author.

4

CIH PLUS IHIT UTILIZATION BY INDUSTRY OR INDUSTRY GROUP, AND PRELIMINARY PROJECTIONS OF FUTURE NEED FOR SUCH INDUSTRIAL HYGIENE PROFESSIONALS. L.W. Whitehead, CIH University of Texas-Houston Houston, TX, M. West Baylor College of Medicine, Houston, TX

Estimates of future need for public health professionals are very useful for planning educational programs and incentives for graduate education, and for staffing projections. No such estimates are known to exist for