

RESPIRATOR ARTICLE ABSTRACTS

We review the articles published in the American Industrial Hygiene Association Journal (AIHJ) and the Applied Occupational and Environmental Hygiene Journal for information that is applicable to the field of respiratory protection; we then publish abstracts of these articles. We appreciate the cooperation of the American Industrial Hygiene Association and the American Conference of Governmental Hygienists in allowing us to do this.—Ed.

"A Probability Model for Assessing Exposure Among Respirator Wearers: Part I—Description of the Model," by M. Nicas and R.C. Spear, *American Industrial Hygiene Association Journal*, July 53(7):411–418, 1992

The basic respirator equation states that the contaminant level inside a respirator (C_I) is the product of the contaminant level outside the respirator (C_O) and the decimal fraction penetration (P). On the basis of this relation, the authors present a probability model for the log-normal total distribution of C_I levels among a respirator-wearing population; the model accounts for between-wearer and within-wearer variability in both C_O levels and P values. The assumptions underlying the model are shown to be consistent with current knowledge about the variability in C_O levels and P values. The model provides the basis for assessing the probability of overexposure to acute toxicants and to chronic toxicants among a respirator-wearing population.

"A Probability Model for Assessing Exposure Among Respirator Wearers: Part II—Overexposure to Chronic Versus Acute Toxicants," by M. Nicas and R.C. Spear, *American Industrial Hygiene Association Journal*, July 53(7):419–426, 1992

A model describing the log-normal total distribution of contaminant levels inside a respirator (C_I) is applied to assessing the probability of toxicant overexposure among a population of respirator wearers; the model accounts for between-wearer and within-wearer variability in ambient exposure levels (C_O) and decimal fraction respirator penetration (P) levels. The three exceedance probabilities are defined as PrI , the proportion of all C_I levels over the Permissible Exposure Limit (PEL); $PrII$, the proportion of wearers with an arithmetic mean C_I level over the PEL; and $PrIII$, the proportion of wearers with a 95th percentile C_I value over the PEL. $PrII$ is considered that fraction of the population overexposed to a chronic toxicant; $PrIII$ is considered that fraction overexposed to an acute toxicant. The behavior of $PrII$ and $PrIII$ over a range of exposure parameters is explored. An important observation is that a respirator-wearing population can have a substantial fraction of toxicant overexposure even though two conditions are met:

- (1) The P values for the population satisfy the criterion for the assigned protection factor (APF), and
- (2) The population arithmetic mean C_O level is at or below the Maximum Use Concentration (MUC), defined as $APF \times PEL$.

The authors recommend that the current MUCs for air-purifying respirators be reduced by one-half to reduce the potential respirator-wearing population fraction of overexposure and that appropriate exposure surveillance programs for the wearers be mandated.

"A Theoretical Model for Respirator Cartridge Service Life for Binary Systems: Application to Acetone/Styrene Mixtures," by Y.H. Yoon, J.H. Nelson, J. Lara, C. Kamel, and D. Fregeau, *American Industrial Hygiene Association Journal*, August **53**(8):493–502, 1992

A theoretical model, developed previously to assess respirator cartridge service life, was applied to various acetone/styrene binary assault systems. Experimental data, collected for several binary mixtures differing only with respect to the concentration of each of the two compounds, were interpreted in terms of the model. Styrene concentration varied from 228 to 1578 ppm; the range of acetone concentrations from 92 to 985 ppm. The specific influence of the compound assault concentrations on respirator service life was carefully characterized, as breakthrough curves were generated for both acetone and styrene for each of several different binary systems. Specifically, experimental data for each system were used to determine values of the following theoretical parameters: k'_1 , t_1 , k'_2 , t_2 , and A_m . These parameters were employed with the theory to generate complete theoretical breakthrough curves and to determine the time-dependence of the weight of each compound adsorbed by the respirator cartridge carbon bed. An interesting phenomenon observed for the acetone/styrene systems was the displacement (from the carbon) of previously absorbed acetone molecules by styrene molecules. Acetone breakthrough was observed first in each of the systems studied. Following the onset of this breakthrough, the acetone breakthrough concentration was enhanced by the displacement of acetone from the carbon bed by the adsorption of styrene. The theoretical model accurately predicts both this enhancement and the associated breakthrough characteristics of styrene. In addition, the theory is capable of predicting the ratio of the number of displaced acetone molecules to the corresponding number of displacing styrene molecules. For these studies, this ratio ranged from 0.3 to 0.7. The service life of respirator cartridges exposed to acetone/styrene mixtures depends on the assault concentration of each compound and is significantly influenced (shortened) by the displacement phenomenon.

"Characteristics of Face Seal Leakage in Filtering Facepieces," by C.C. Chen and K. Willeke, *American Industrial Hygiene Association Journal*, September **53**(9):533–539, 1992

Several studies have found that aerosol size, testing methods, leak size, leak position, sampling probe location, and the mixing condition inside the respirator affect the results of fit factor measurements. This study focuses on the effect of leak shape and filter resistance because leaks have been reported to vary in shape from circular to slit-like. Four leaks of different shape but the same cross-sectional area were used to study their effect on aerosol penetration. Dust-mist and high-efficiency particulate air filtering facepieces provided different filter resistances. An aerodynamic particle sizer and a laser aerosol spectrometer were used to measure the particle size-dependent aerosol concentrations inside and outside the respirators. The filtering facepieces were sealed to a mannequin and artificial leaks were inserted near the right cheek. Aerosol penetration was measured for five flow rates ranging from 5 to 100 L/min. The pressure drop across the mask was monitored with an inclined manometer. At a given pressure differential, a slit-like leak and multiple circular leaks have been found to pass less aerosols than a single circular leak of equal cross-sectional area because the leak flow decreases with an increase in leak shape complexity. If there is substantial lack of face seal fit and the breathing rate is low, a HEPA respirator may provide less protection than a dust-mist respirator because the pressure drop is considerably higher for a HEPA respirator, resulting in more aerosol flow through the leak.

"Respirator Performance Rating Tables for Nontemperate Environments," by A.T. Johnson, C.M. Grove, and R.A. Weiss, *American Industrial Hygiene Association Journal*, September **53**(9):548–555, 1992

Respirator performance rating tables have been constructed for hot, humid (29°C, 95% RH); hot, dry (49°C, 30% RH); and cold, dry (–32°C, 70% RH) conditions. These tables convey expected wearer performance percentages compared to unmasked workers for various mask elements and work rates. The hot, humid condition was found to be the most severe overall. Many table entries approach 100%, thus leading to difficulties in correcting mask deficiencies.

"Aerosol Penetration Through Filtering Facepieces and Respirator Cartridges," C.C. Chen, M. Lehtimäki, and K. Willeke, *American Industrial Hygiene Association Journal*, September **53**(9):566–574, 1992

Air-purifying respirators must be certified following the National Institute for Occupational Safety and Health (NIOSH) filter test criteria (30CFR11). The criteria specify a range for the mean particle size and the measure of spread permissible for the test aerosol. The authors' experiments have shown that aerosol penetration as a function of particle size differs considerably among certified respirators of the same type. Filtering facepieces (disposable respirators) and cartridges of the dust-mist, dust-mist-fume, and high-efficiency particulate air type were tested. The respirators were sealed to mannequins in a test chamber. The aerosol concentrations inside and outside the respirator were measured by an aerodynamic particle sizer and a laser aerosol spectrometer over a particle size range of 0.1 to 15 µm. Five flow rates ranging from 5 to 100 L/min were used to study flow dependency. The aerosol penetration through the filters is presented as a function of particle size. Aerosol penetration and pressure drop are combined to express the performance of each filter in terms of "quality factor." Under the same test conditions, the quality factor of one respirator may be as much as 6.6 times more than that of another respirator of the same type. The filter quality factor has a greater aerosol size dependency as airflow and aerosol size increase. In general, cartridges have a larger surface area than filtering facepieces but not necessarily lower filter penetration or higher filter quality. An analysis of the data shows that the best dust-mist respirator tested may provide five times more protection than the worst dust-mist respirator tested when exposed to the aerosol-size distribution specified by the NIOSH filter test criteria.

"An Assessment of Critical Anthropometric Dimensions for Predicting the Fit of a Half-Mask Respirator," by R.K. Oestensstad and L.L. Perkins, *American Industrial Hygiene Association Journal*, October **53**(10):639–644, 1992

The purpose of this study was to determine if facial dimensions for a group of subjects were predictive of the fit factors measured while one brand of half-mask respirator was worn. Fit factors and 12 facial dimensions measured on 30 female and 38 male subjects were analyzed by correlation coefficients; weighted, multiple linear regression; and discriminant analysis. Data were analyzed for all subjects, gender subgroups, a race subgroup (whites only), and race/gender subgroups. Significant correlation coefficients with the log-transformed fit factors were found for four dimensions; four dimensions had significant coefficients in four or more multiple linear regression models. Only two dimensions had significant coefficients in four or more discriminant analysis models. Menton-subnasal (lower face)

length was the only dimension included in all three of these groups. Gender-specific regression models had very high coefficient of determination values ($R^2 > 0.85$). Discriminant analysis of the data for all subjects and race/gender subgroups found very good predictive scores for statistical software-generated models and menton-subnasal length alone; these scores were significantly better than those for the model with the respirator test panel dimensions (face length and lip width). These analyses found that facial dimensions were good predictors of respirator fit for those subjects wearing one brand of half-mask respirator. Lower face length was consistently indicated as being correlated or associated with fit. These results would indicate that dimensions other than those currently used may be more appropriate to define a half-mask respirator test panel.