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Project BREATHE – Prototype Respirator Evaluation Utilizing Newly Proposed Respirator Test Criteria

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ABSTRACT

Machine and human subject testing of four prototype filtering facepiece respirators (FFR) and two commercial FFR was carried out utilizing recently proposed respirator test criteria that address healthcare worker-identified comfort and tolerance issues. Overall, two FFR (one prototype, one commercial model) were able to pass all eight criteria and three FFR (two prototypes, one commercial model) were able to pass seven of eight criteria. One prototype FFR was not tested against the criteria due to an inability to obtain satisfactory results on human subject quantitative respirator fit testing. Future studies, testing different models and styles of FFR against the proposed criteria, will be required to gauge the overall utility and effectiveness of the criteria in determining FFR comfort and tolerance issues that may impact user compliance and, by extension, protection.

Keywords: filtering facepiece respirators, prototypes, proposed respirator test criteria.

Integrating a Toxicological Approach for Breakthrough Curves of Vapor Mixtures in the Estimation of Respirator Cartridge Service Life

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ABSTRACT

The estimation of cartridge service life (CSL) for mixtures of contaminants is a complex task. OSHA-CPL-02-00-158 recommends the use of the additivity principle, which assumes that the entire mixture behaves like a pure system of the most volatile contaminant (i.e., sum up the concentration of the components). Here we present a quantitative risk assessment framework to predict potential human health risk when estimating CSL to avoid vapor gas breakthrough inside the mask, premature change schedules, and unnecessary costs. Simulations using the Ideal Adsorbed Solution Theory (IAST) - Langmuir model combined with the modified Wheeler-Jonas equation allowed the calculation of breakthrough curves for vapor mixtures. Acetone was used as an example of a volatile organic contaminant combined in binary mixture with one of the following: m-xylene, o-xylene, styrene, or toluene. Simulations of exposures to acetone (10-700 ppm) and the other contaminant of lower volatility (500 ppm) through a respiratory cartridge with 50 g of carbon at 25°C and a flow rate of 24 L/min were performed. Outlet concentrations were used to determine the Hazard Index (HI) throughout the exposure. The HI is defined as the sum of concentrations for each mixture component normalized by its Occupational Exposure Limit (OEL) Value (HI > 1 indicates a health risk). Cartridge service life estimations based on the 10% breakthrough times of acetone and the 10% of HI for the mixture were compared. Simulations of breakthrough curves were in agreement with experimental data previously published. At lower acetone concentrations (< 50 ppm), the simulated CSL using 10% HI of the vapor mixture were up to two times greater than the 10% than the ones calculated following the 10% breakthrough time additive concentration's approach). At higher concentrations of acetone, both approaches gave similar results. The breakthrough time of HI is inversely proportional to the concentration ratio of contaminant 1 (C1), the more volatile, to contaminant 2 (C2), the less volatile contaminant, suggesting that using the HI approach can be useful when C1/C2 < 2.

Keywords: breakthrough curve, vapor mixtures, cartridge service life, hazard index.

Testing Air-Purifying Chemical Respirator Cartridges: A Review of Options

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ABSTRACT

Due to a wide variety of applications many tests have been developed, published, and used to determine if air-purifying respirators and their cartridges (or canisters) for removing airborne chemicals meet government and manufacturing standards. Effectiveness is defined by efficiency of contaminant removal (protection factor) and duration (breakthrough time or service life). Although “There is no widely accepted, standard protocol for performing service life testing” (OSHA website 2017), the U.S. EPA has developed “Interim Recommendations for Determining Organic Vapor Service Life for NIOSH Approved Respirators” (1991, 1995, 2002) based on an earlier published testing protocol (Wood and Ackley 1989). This current article expands on these by describing laboratory and field testing options, advantages, limitations, and needs depending on testing objectives.

Keywords: Air-purifying respirator, cartridge, testing

Development of a Manikin-Based Performance Evaluation Method for Loose-Fitting Powered Air-Purifying Respirators

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ABSTRACT

Objective: Loose-fitting powered air-purifying respirators (PAPRs) are increasingly being used in healthcare. NIOSH has previously used advanced manikin headforms to develop methods to evaluate filtering facepiece respirator fit; research has now begun to develop methods to evaluate PAPR performance using headforms. This preliminary study investigated the performance of PAPRs at different work rates to support development of a manikin-based test method.

Methods: Manikin penetration factors (mPF) of three models of loose-fitting PAPRs were measured at four different work rates (REST: 11 Lpm, LOW: 25 Lpm, MODERATE: 48 Lpm, and HIGH: 88 Lpm) using a medium-sized NIOSH static advanced headform mounted onto a torso. In-mask differential pressure was monitored throughout each test. Two condensation particle counters were used to measure the sodium chloride aerosol concentrations in the test chamber and also inside the PAPR facepiece over a 2-minute sample period. Two test system configurations were evaluated for returning air to the headform in the exhalation cycle (filtered and unfiltered). Geometric mean (GM) and 5th percentile mPFs for each model/work rate combination were computed. Analysis of variance tests were used to assess the variables affecting mPF.

Results: PAPR model, work rate, and test configuration significantly affected PAPR performance. PAPR airflow rates for the three models were approximately 185, 210, and 235 Lpm. All models achieved GM mPFs and 5th percentile mPFs greater than their designated Occupational Safety and Health Administration assigned protection factors despite negative minimum pressures observed for some work rate/model combinations.

Conclusions: PAPR model, work rate, and test configuration affect PAPR performance. Advanced headforms have potential for assessing PAPR performance once test methods can be matured. A manikin-based inward leakage test method for PAPRs can be further developed using the knowledge gained from this study. Future studies should vary PAPR airflow rate to better understand the effects on performance. Additional future research is needed to evaluate the correlation of PAPR performance using advanced headforms to the performance measured with human subjects.

Keywords: powered air-purifying respirator, PAPR, NIOSH-approved respirator, respirator performance.

Studying the Influence of a Filter Box Design on Respirator Resistance to Breathing

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ABSTRACT

Work safety, including respiratory protection, is one of the priorities in modern industries. Thus, the objective of the paper is to study the influence of a filter box design on the air purifying respirator efficiency. Dust holding capacity of filters was determined with dust concentration of about 500 mg/m3 until the ultimate drop of pressure of 500 Pa was reached (according to DSTU requirements EN 143 for filters of Protection rating 2). The following devices were used: AFA VP-10 filters with a diameter of about 36 mm, VLO 200 laboratory balance, an electronic stop-watch timer of HS43 type; the drop of pressure at filter boxes was controlled by using an MKV-250 compensated micromanometer.

It has been established that the design of filter boxes influences the pressure drop of a respirator because of non-use of filter surface (formation of dead zones where the air does not flow) thereby increasing resistance to breathing and decreasing dust holding capacity and protective effect.

The results of laboratory tests showed that the initial breathing resistance of a filter box with a truncated cone is almost 25% lower than that of other boxes, at the same time dust holding capacity and protective effect duration doubled with dust concentration in the air being 500 mg/m^3

Based on the conducted research, it is possible to define rational parameters of filter boxes which will provide air filtration over the whole filtering surface, decreasing initial pressure drop while breathing and increasing protective effect duration.

Keywords: respirator, filter, filter box, drop of pressure.