Performance Evaluation of an Elastomeric Half-mask Respirator on a Manikin with Combustion Aerosol

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Objectives: To investigate the effects of faceseal leakage, particle size, breathing flow rate and combustion material on the particle penetration into a half-mask elastomeric respirator equipped with P-100 filters used by firefighters.

Methods: The experiments were conducted in the University of Cincinnati exposure test chamber (142 x 95 x 102 inches, L x W x H). The respirators were tested on a breathing manikin exposed to aerosols, which were produced by combustion of three materials (wood, paper, and plastic). The tests were conducted at three sinusoidal cyclic flow rates, with mean inspiration flows (MIFs) of 30, 85, and 135 L/min, and breathing rate of 25 breaths/min (0.42 Hz) for all three MIFs. Three sealing conditions, namely "unsealed", "partially (nose) sealed", and "fully sealed", were examined to evaluate the respirator faceseal leakage. The particle concentration was measured size-selectively inside (Cin) and outside (Cout) of the respirator using a newly developed Nanoparticle Spectrometer (Nano-ID NPS500, Naneum Ltd., UK). The penetration through the respirator was determined for different particle size ranging from 20 to 200 nm as a ratio of the two (P = Cin / Cout). Analyses of Variance (ANOVA) with Tukey's range test were performed to study the effects. P-values of < 0.05 were considered significant.

Results: The faceseal leakage was a very significant factor ($p < 0.001$) influencing the respirator performance. For the partially sealed half-mask (nose area only), particle penetration was an order of magnitude greater than that measured for the fully sealed respirator. In turn, the unsealed half-mask provided the worst protection level with the penetration being an order of magnitude higher than that for the partially sealed respirator. Particle size effect was significant ($p < 0.01$). When testing the partially sealed half-mask, the highest penetration was detected at 180 nm for the aerosols generated due to combustion of wood and paper, and around 120 to 160 nm for plastic combustion aerosol. In the fully sealed condition, the first peak occurred at sizes of 80, 100, and 120 nm for wood, paper, and plastic, respectively. The effects of flow rate and combustion materials were also found to be significant ($p < 0.01$).

Conclusions: The results suggest that eliminating or minimizing the faceseal leakage is the key aspect for improving the efficiency of elastomeric respirators against combustion particles regardless of their composition and particle size distribution.