Penetration of N95 Filtering-Facepiece Respirators by Charged and Charge-Neutralized Nanoparticles

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Aerosol-based quantitative respirator fit testing relies on the assumption that all particles detected inside the mask arrived there through a face seal leak. When less efficient media is used, this assumption may no longer be valid since a significant number of particles may penetrate the filter media. To address this issue, TSI developed an accessory for the PortaCount called the N95-Companion™, which uses electrostatic principles to select a specific size range of particles that are far from the most penetrating particle size (MPPS). The narrow size range selected by the N95-Companion is centered nominally at 55 nm. Recent studies indicate that the MPPS for commercially available N95 filters is now between 40-60 nm and can exceed 5%. This caused concerns to be raised that the N95-Companion method is not valid for N95 filtering facepiece respirators that use charged fibers.

To further quantify the amount of aerosol penetrating the N95 filter media and its effect on the fit factor, TSI conducted a study to measure the fractional penetration efficiencies of several commercially available N95 filtering-facepiece respirators using charge-neutralized, positively charged, and negatively charged monodisperse aerosols.

Six different models of NIOSH-certified N95 filtering-facepiece respirators from five different manufacturers were used in this study. Each respirator was mounted on a manikin head and sealed using a silicone sealant applied to the edges to prevent face seal leakage. The manikin was then placed in the center of a 47x24x28 inch test chamber. Charge-neutralized, negatively charged, and positively charged monodisperse aerosols (40, 50, 65, 80, and 100 nm) were introduced into the chamber one at a time. The aerosol concentrations inside and outside the respirators were measured with a TSI 3772 Condensation Particle Counter (CPC). The fractional penetration efficiency of the respirator was calculated as the ratio of C_{mask} and $C_{challenge}$: $[1 - (C_{mask}/C_{challenge})]*100$. Percent penetration = $100*C_{mask}/C_{challenge}$. The penetrations of positively charged and negatively charged aerosols were very similar to each other for all respirators, and were much lower than the penetration of charge neutralized particles. Using charged aerosol (N95-Companion method) all respirators showed penetrations below approximately 0.25% indicating a maximum (zero face seal leakage) fit factor of 400.

This study showed that the N95-Companion method is a valid method for performing quantitative fit testing on any respirator using NIOSH series-95 or similar filter media. For mechanical filters, the N95-Companion relies on the conventional particle entrapment schemes of impaction, interception and diffusion to reduce 55 nm particle penetration to insignificant levels. For electrostatic filters, the N95-Companion relies mainly on electrostatic forces to trap the negatively charged particles and reduce penetration to insignificant levels.