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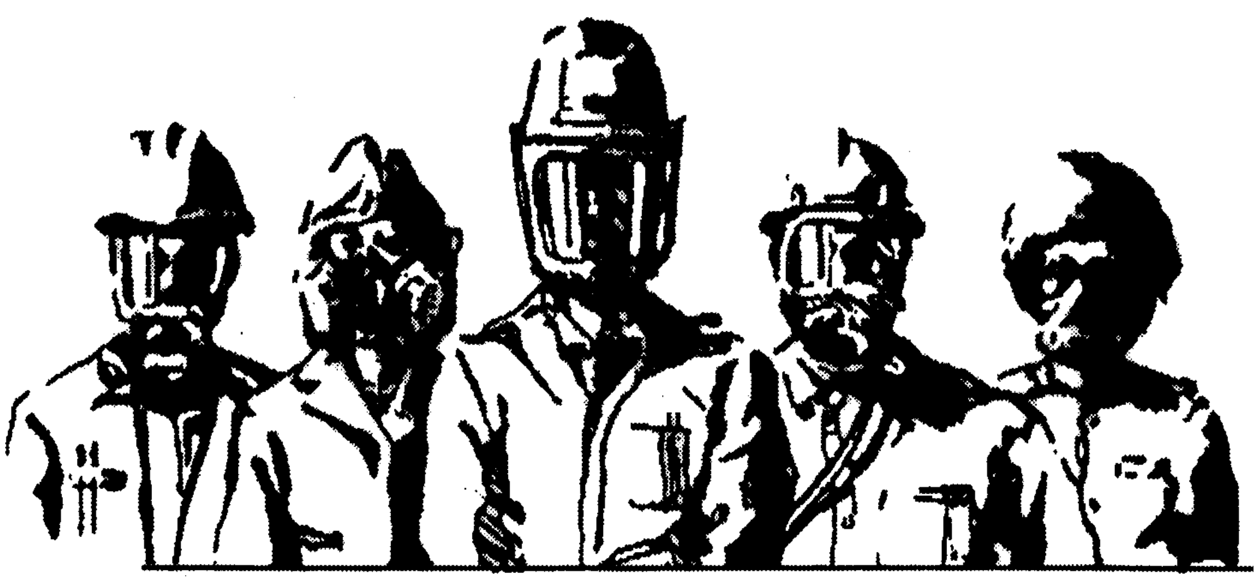

# Flow Based Oxygen Leak Detection System in Self-Contained Breathing Apparatus

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## ABSTRACT

Even though closed-circuit self-contained breathing apparatus (CC-SCBA) used in firefighting and other combustible atmospheres can possibly improve physical performance of the wearer and have increased service times by recycling the exhaled air, there exists a serious burn hazard to the wearer due to oxygen-enriched air leaking from the positive-pressure facepiece area of the CC-SCBA. NIOSH has imposed a long-standing advisement against the use of oxygen-based closed-circuit respirators in high radiant or open flame environments. The purpose of this study was to develop and employ a flow sensing system to be installed on a SCBA unit with a goal of minimum oxygen leak detection and quantification. Three flow sensors were placed and adapted at various locations of the oxygen flow loop, and the flow data, taken on a breathing machine and headform, were acquired to determine the magnitude of the various leaks induced on the facepiece area. Five different leak sizes were induced during normal breathing by installing different diameter tubes on the periphery of the face piece of the CC-SCBA allowing for air to escape at different rates that increased with increasing diameter of the tubes. Flow measurements were performed for seven different conditions: no leak, no leak repeated, and 5 different leak sizes. For each sensing unit, total flow and mean flow rates were calculated and the information was used to determine the magnitude of total leaks. Results indicated two major conclusions: i) Mean flow rates of inhalation and exhalation decreased with increasing leak sizes, ii) Calculated leaks increased with increasing induced leaks. Both of these analytical observations validated the theoretical assumption under which the experiments were performed. A less than 5 % difference was observed between two no leak conditions; and between no leak and the smallest leak conditions, a more than 20 % difference was observed indicating a sufficient sensitivity of the system necessary to differentiate a leak from a no leak scenario. There was a greater than 350 % difference calculated between the biggest induced leak and no leak condition. Results were limited by the reproducibility of the breathing waveform. However, given that restriction, the obtained positively indicate that a flow based sensor system for oxygen leak detection can be employed for developing safer CC-SCBA units to be used in combustible environments.

**Keywords: closed circuit self-contained breathing apparatus, respirator fit, respiratory protection, oxygen leak**

# Simulated Workplace Protection Evaluation of a Dual Cavity Respirator Concept

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## ABSTRACT

This investigation sought to quantify levels of protection afforded by a single filter dual cavity (DC) respirator concept under simulated workplace conditions. The DC concept included a customized internal fan and a customized nose cup that isolated the nose cup and eye cavity regions within the facepiece. Twelve volunteers completed wear trials of the DC concept and an air-purifying respirator (APR) to quantify levels of protection and subjective feelings of thermal sensation and comfort of each respirator type while performing simulated tactical law enforcement and military personnel tasks. The duration of task performance averaged 31 ± 3 min across all conditions. Methods for continuous reading of in-mask particles with a body-mounted TSI PortaCount® Plus (Model 8020) from freely moving subjects were used to derive simulated workplace protection factors from both the eye ($SWPF_{Eye}$) and nose ($SWPF_{Nose}$) regions of the respirator facepiece by dividing ambient by in-mask particle concentrations. All SWPF data were log transformed for analysis. In-mask eye cavity pressures were also recorded continuously during wear of the DC concept. In-mask pressures of the DC concept were not always positive; negative pressures occurred most frequently during performance of the moderate to hard physical tasks. However, average $Log_{10}SWPF_{Eye}$ values did not differ between the APR and DC conditions at any time. Average $Log_{10}SWPF_{Nose}$ were significantly ($p<0.05$) higher for the DC condition compared to the APR condition during the Fit test (5.44 ± 0.15 vs. 5.21 ± 0.31) and Rifle (5.12 ± 0.22 vs. 4.73 ± 0.89) activities, but lower during the Lift task (4.94 ± 0.49 vs. 5.12 ± 0.21). The DC concept produced cooler thermal sensation ratings than the APR condition across all SWPF tasks; however, statistical differences between conditions were only found during the Crawl and Shovel activities. Subjective ratings of comfort did not differ between DC and APR conditions at any time. The results of this investigation suggest that advantages of a single filter, dual cavity pressurization concept over a properly sized and fitted standard full-facepiece APR were marginal at best when performing simulated tactical operational activities. Additional refinements to the dual cavity pressurization concept are currently being investigated.

**Keywords: simulated workplace protection factor, respirator fit, respirator design, comfort**

# Performance Characteristics of an Elastomeric Half-mask Respirator Modified with a Polymer Micro-Patterned Adhesive

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## ABSTRACT

The objectives of this study were: to evaluate the fitting characteristics of an elastomeric half-mask respirator modified with a polymer micro-patterned adhesive applied to the sealing surface; to compare the performance of the modified respirator to that of a conventional (non-modified) one. Twenty-five adult subjects representing a NIOSH bivariate panel were tested with a modified and non-modified elastomeric half-mask respirators while participating in a standard OSHA fit testing protocol. NaCl particles were generated as the challenge aerosol and the concentrations inside and outside of the respirator were measured to determine the fit factor for each subject. Additional tests were performed with one subject under challenge facial conditions, including wet and/or unshaved face. The modified respirator produced a geometric mean (GM) fit factor of 7,907 with a geometric standard deviation (GSD) of 4.9 compared to GM=4,779 and GSD = 9.1 for the non-modified respirator ($p = 0.07$, paired t-test). For all challenge facial conditions, the modified half-mask prototype was consistently achieving significantly ($p < 0.05$) higher fit factors than the conventional half-mask. Applying a polymer micro-patterned adhesive to the sealing surface of an elastomeric half-mask respirator was found to improve respirator fit and showed promise towards improving performance with challenge facial conditions.

**Keywords: elastomeric half-mask, polymer micro-patterned adhesive, fit testing**

# Computational Fluid Dynamics-Based Respirator Fit Evaluation - A Pilot Study

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## ABSTRACT

This paper presents a computational fluid dynamics (CFD)-based approach to evaluate fit of a filtering facepiece respirator (FFR). A medium size digital headform and a medium digital FFR were obtained from the National Institute for Occupational Safety and Health (NIOSH) database. After the headform and the FFR contact was simulated, a chamber was generated to represent the zones of the FFR cavity, the filtering medium and the region outside the FFR. Inside the chamber, air flow and particle movement were calculated. The air flow was driven by the human inhalation and the freestream towards the human face, and the particle movements were driven by the air drag force and gravity force. Respirator fit was evaluated by a computer simulated fit factor (CSFF) defined as the particle concentration of the air flow inhaled by the nostril to the particle concentration of the air flow passing through the flow inlet boundary. The CSFF of the headform/FFR combination in the simulation results was 90.20, which was higher than 10, the Assigned Protection Factor for FFRs and was lower than 150-200, which encompasses most of the fit factors measured in experiments. The simulation results also showed that the geometries of the human face and FFR affected the air flow pattern in the region outside FFR. The air flow velocity inside the FFR cavity was distinctly different from the velocity outside. The particles inside the FFR cavity were not uniformly distributed.

**Keywords: Computational fluid dynamics, filtering facepiece respirator, particle movement, respirator protection factor.**

# Evaluation of a Faster Fit Testing Method for Full-Facepiece Respirators Based on the TSI PortaCount®

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## ABSTRACT

In the United States, employees that wear tight-fitting respirators in the workplace are required to be fit tested annually using an Occupational Safety and Health Administration (OSHA)-accepted protocol. Given the large number of fit tests performed annually, industry would benefit if the time required to complete a fit test was reduced. TSI, Inc. (Shoreview, MN) has developed a method for full-facepiece respirators that is a modification of the OSHA-accepted 'Ambient aerosol condensation nuclei counter (CNC) quantitative fit testing protocol' that reduces the test duration from about 7.2 min to 2.5 min. The objective of this study was to compare the fit factors measured with the TSI modified method to that of a reference method. The method comparison approach was based on American National Standards Institute (ANSI) Z88.10-2010 Annex A2, "Criteria for Evaluating New Fit Test Methods". Sequential, paired fit tests were performed on test participants with the modified (i.e., faster) method and a reference method during the same respirator donning. The fit factors for both methods were measured using the PortaCount® Model 8030, a CNC-based instrument. The exercises for the reference method were the standard OSHA exercise set without the grimace. The exercise set for the modified method included bending, jogging, head side-to-side, and head up and down. The results demonstrated that the new faster method can identify poorly fitting respirators as well as the reference method, as the test sensitivity of 0.98 was greater than the requirement (≥0.95) defined in ANSI Z88.10-2010. This new method also met the requirements for the predictive value of a pass, test specificity, predictive value of a fail, and the kappa statistic contained in the ANSI standard.

**Keywords: respirator fit, quantitative fit test, full-facepiece respirators**