Flow based oxygen leak detection system in closed circuit self-contained breathing apparatus

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Even though closed circuit self-contained breathing apparatus (CC-SCBA) used in firefighting and other combustible atmospheres 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 face-piece area of the 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 face-piece area. Five different leak sizes were induced during normal breathing by installing different diameter tubes on the periphery of the face piece of the 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, these obtained results positively indicate that a flow based sensor system for oxygen leak detection can be employed for developing safer SCBA units to be used in combustible environments.