Journal of the International Society for Respiratory Protection

Vol. 36, No. 2, 2019

History of U.S. Respirator Approval (Continued) Particulate Respirators

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ABSTRACT

This is the final article in a series of four articles on respirator history. This article continues to follow the history of respirator approval, use, and improvements in the U.S. as discussed in our article entitled, *History of U.S. Respirator Approval*, published in the ISRP Journal, Vol. 35, No. 1, 2018 (Spelce et al., 2018). This article is entirely about the history of respirators for protection against particulate hazards since the most extensive records available for the United States Bureau of Mines (USBM) approval schedules are for dust/fume/mist respirators.

Keywords: respirator approval, certification history, particulate respirator, air-purifying respirator, and dust/fume/mist respirator

Respiratory Resistance Increases with the Addition of External Resistance Elements

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ABSTRACT

Respiratory protective masks are used by millions to guard against the inhalation of toxic contaminants. These add resistances to the respiratory circuit. Whether or not someone can successfully wear respiratory protective masks has been shown to be affected by the respirator mask inhalation and exhalation resistances. What is not completely known is the effect that adding external resistance to the breathing circuit might have on the person wearing the respirator. This exploratory study was conducted to determine what effect, if any, added external resistances have on human respiratory system responses.

The Airflow Perturbation Device (APD) was used to measure respiratory resistance of the human respiratory system in the presence of external resistance elements in increments of 1 cm $H_2O \cdot sec/L$ from zero up to 5 cm $H_2O \cdot sec/L$ resistance. It was determined that the addition of external resistance elements increased internal resistance in the exhalation direction at a proportional rate of 1.25 cm $H_2O \cdot sec/L$ per 1 cm $H_2O \cdot sec/L$ added external resistance, whereas internal resistance during inhalation increased proportionately at 1.18 cm $H_2O \cdot sec/L$ per 1 cm $H_2O \cdot sec/L$ added external resistance. The means of the inhalation resistance and exhalation resistance increments were found to be statistically significant utilizing a t-test with a p value of 0.05. The conclusion reached was that the wearer of a respiratory protective device is not passive, but reacts to the resistances of the respirator by increasing resistance of the respiratory system. Among other things, this finding may have implications for medical determination for who can successfully wear respiratory protective devices.

Keywords: respiratory resistance, respirator resistance, physiological effects of respirator wear, airflow perturbation device

Numerical Simulations of Exhaled Particles from Wearers of Powered Air Purifying Respirators

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ABSTRACT

In surgical settings, infectious particulate wound contamination is a recognized cause of post-operative infections. Powered air purifying respirators (PAPRs) are worn by healthcare workers for personal protection against contaminated aerosols. Healthcare infection preventionists have expressed concern about the possibility that infectious particles expelled from PAPR exhalation channels could lead to healthcare-associated disease, especially in operative settings where sterile procedural technique is essential.

This study used computational fluid dynamics (CFD) modeling to simulate and visualize the distribution of particles exhaled by PAPR wearers. Using CFD simulations, the PAPR inside to outside ratio of particle concentrations was estimated. Also, the effects of particle sizes, supplied-air flow rates, and breathing work rates on outward leakage were evaluated.

This simulation study reconstructed a geometrical model of a static median headform wearing a loose-fitting PAPR by capturing a 3D image. We defined a mathematical model for the headform and PAPR system and ran simulations with four particle sizes, three breathing workloads and two supplied-air flow rates (a total 24 configurations; 4x3x2=24) applied on the digital model of the headform and PAPR system. This model accounts for exhaled particles, but not ambient particles. Computed distributions of particles inside and outside the PAPR are displayed.

The outward concentration leakage was low at surgical setting, e.g., it was about 9% for a particle size of 0.1 and 1 µm at light breathing and a 205 L/min supplied-air flow rate. The supplied-air flow rates, particle sizes, and breathing workloads had effects on the outward concentration leakage, as the outward concentration leakage increased as particle size decreased, breathing workload increased, and the supplied-air flow rate decreased. The CFD simulations can help to optimize the supplied-air flow rates. When the loose-fitting PAPR is used, exhaled particles with small size (below 1µm), or heavy breathing workloads, may generate a great risk to the sterile field and should be avoided.

Keywords: Exhaled particles, outward leakage, powered air purifying respirators, Computational Fluid Dynamics, simulation, surgical setting, sterile surgical field