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Performance Characteristics of Loose-fitting Powered Air Purifying Respirators Analyzed by a Robotic Mannequin

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ABSTRACT

A robotic mannequin was developed to measure the inward leakage (IL) of powered air purifying respirators (PAPRs) and was designed to breathe at certain levels of work rate and to drive its head and arms to move periodically. This study presents the results of the application of this robotic mannequin to practical measurements of ILs of loose fitting PAPRs (two hood types and two face-shield types).

The robotic mannequin was designed as follows: the head bent up to 30 degrees up and down in both directions from its upright position at a frequency of (17+/-1) times/min and rotated 50 degrees to the right and to the left at a frequency of (11+/-1) times/min. The upper arms moved up and down in the range between 10 and 130 degrees from the hanging position at a frequency of (7+/-1) times/min. One mode of movement of each part continued for 5 minutes and was then automatically followed by the next mode under control of a processor until the program reached the final mode. The mouth of the mannequin head was composed of an opening of concentric double tubes for inhalation and exhalation generated by a breathing machine.

Before an IL measurement started, each sample PAPR was separated into the respiratory inlet covering (RIC) and the units containing electric blower and filter, and only the RIC was examined for the IL, meaning the observed IL is different from TIL by excluding the particle penetration through filter. For the start of the examination, the robotic mannequin was placed in a NaCl aerosol chamber with a sample PAPR on its head and connected with the compressed air-line to supply air flow into the RIC of the PAPR and with an aerosol counter for monitoring the NaCl aerosol concentration in the RIC using separate tubes. The NaCl aerosol concentration in the chamber was continuously monitored with another aerosol counter throughout the measurement. As test conditions of the IL measurement using this mannequin, the breath of the mannequin was set at two work rate levels of 30 L/min and 40 L/min in sine wave form, and the air supply into the RIC was maintained at a certain flow rate varying within the range from 60 L/min to 160 L/min.

The ILs of the sample PAPRs apparently showed higher values at a work rate of 40 L/min than those at 30 L/min and showed decreasing ILs along with an increasing air supply rate, but the extents of the changes in the ILs by these test conditions varied depending on the configurations of the sample PAPRs. Among the movements of the mannequin, the head bending up and down caused an increase in the IL of the hood-type PAPR with a short shoulder covering, and the head rotation caused an increase in the IL of a face-shield type

PAPR. The movement of the mannequin's arms did not affect the ILs of the hood-type PAPR samples adopted in this study.

From the results, the robotic mannequin was considered useful to evaluate the ILs of loose-fitting PAPRs as a test method, which apparently reflected the effects of the supplied air flow rate, the breathing rate of the mannequin and the movements of the mannequin's parts on the observed ILs at certain tendencies. It could also provide information on the effective selection of loose fitting PAPRs with respect to their configuration and to the workers' movements at their worksites.

Keywords: powered air-purifying respirator, PAPR, robotic mannequin, inward leakage, IL, body movement, work rate, air flow rate

Evaluation of Rigidity of Surgical N95 Respirators Using a Manikin-System: A Pilot Study

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ABSTRACT

Background: Surgical N95 respirators are devices certified by the National Institute for Occupational Safety and Health (NIOSH) and also cleared by the Food and Drug Administration (FDA) as a medical device. They are commonly used in healthcare settings to provide protection from infectious aerosols, as well as, bodily fluid sprays and splashes. It is hypothesized based on design, some models may change their shape significantly (i.e., collapse) during heavy breathing, which may allow the device to touch the wearer's face. Concerns have been raised that droplets of infectious biological fluids may reach the inner layer of surgical N95 respirators leading to the transfer of microorganisms to the oronasal facial region upon collapse. Unfortunately, little data currently exists on respirator rigidity testing or its relation to efficacy. The objective of this study was to develop and optimize a manikin-based test system to evaluate respirator rigidity.

Methods: Six surgical N95 models of three different designs (cup-shaped, flat fold and trifold) were tested at two different environmental conditions on the NIOSH medium headform. Rigidity evaluation was performed at 50% relative humidity (RH) and 22ºC, and at ~100% RH and 33ºC at 40, 50, and 60 L/min breathing flow rates. Facial contact secondary to shape change was assessed by coating the inner layer of the surgical N95 respirators with a fluorescent tracer and its transfer to the manikin face.

Results: The results showed that the cup-shaped models were rigid and resistant to shape change at both environmental conditions and all flow rates. In contrast, the flat fold models and trifold models showed significant changes with rigidity, at higher breathing flow rates and higher RH and temperature conditions. The flat fold models showed transfer of the fluorescent tracer to the manikin face at higher RH and breathing rates, confirming a change in rigidity.

Conclusions: The results from the study suggest that the manikin-based test system designed for the purposes of this study can be used to evaluate respirator rigidity.

Keywords: surgical N95 respirator, rigidity, fluorescence tracer, fluid penetration