The Workplace Performance of a Tight-fitting Full Facepiece Respirator with High Efficiency Filters

This article presents and discusses the results of a recent WPF study on the 3M™ Full Facepiece Respirator 6000 Series. This is a summary of the forthcoming Journal of Occupational and Environmental Hygiene (JOEH) article.

In the United States, workers exposed to lead aerosols at concentrations up to 50 times the permissible exposure limit (PEL) of 50µg/m³ are required to wear, at a minimum, a full facepiece, negative pressure air purifying respirator with class 100 filters. This requirement is based on the presumption that this respirator will provide a 50-fold reduction in the ambient contaminant exposure. That is, the respirator has an assigned protection factor (APF) of 50.

Definitions

Assigned Protection Factor the (APF) represents the level of respiratory protection that a properly functioning respirator or class of respirators would be expected to provide to properly fitted and trained users in the workplace.¹

Workplace protection factor (WPF) measurements provide a range of the protection provided in a workplace, under the conditions of that workplace, by a properly selected, fit tested and functioning respirator while it is correctly worn and used.²

Since WPFs are direct measurements of respirator performance capabilities in a specific work environment, they provide data to help support, refute or establish the APF. When WPF data are used to set the APF, typically the fifth percentile WPF value is used. More clearly, 95% of WPFs would exceed the recommended value that would be used to set an APF.

This WPF study was conducted to determine the workplace performance of the 3M™ Full Facepiece Respirator 6000 Series.

This WPF study was conducted to determine the workplace performance of a tight-fitting full facepiece with high efficiency filters. The current APF for this class of respirators is 50 recommended by the National Institute for Occupational Safety and Health (NIOSH)¹ and proposed for the respiratory protection regulation 29 CFR 1910.134 by the Occupational Safety and Health Administration (OSHA).⁴

Jeanne Bidwell

Jeanne Bidwell is an Industrial Hygienist with the 3M OH&ESD Laboratory

continued on page 2 >
WPF may be expressed mathematically as follows,

$$\text{WPF} = \frac{C_o}{C_i}$$

where:

- $C_o$ represents inhalation exposure outside the respirator (ambient sample);
- $C_i$ represents inhalation exposure inside the respirator (in-facepiece sample); and
- $C_o$ and $C_i$ are determined simultaneously only while the respirator is worn and used during normal work activities.

Workplace Testing

The 3M™ Negative Pressure Air Purifying Respirator 6000 Series with 3M™ Filter 2097, P100 was tested against lead particulate contaminants in a lead refining plant. This workplace was chosen because:

- the respirator was already being used in the workplace;
- the exposure levels were high enough to challenge the respirator; and
- the company was willing to participate in the study.

A preliminary visit to the site helped confirm these key criteria for conducting a WPF study were met.

WPF measurements were made while workers performed their normal work duties that included lifting and stacking lead ingots, skimming dross from molten lead, operating a blast furnace, sweeping and shoveling, and driving forklift trucks. Eighteen clean-shaven, male workers participated in the study over a four-day period. They had been medically evaluated, trained in proper use of the respirator and quantitatively fit tested with the PortaCount® Plus by their employer.

In-facepiece samples ($C_i$) were collected via a sampling probe patterned after a design by Liu et al. to minimize entry losses of particles $\geq 5\mu m$. Because of the characteristics of the full facepiece tested, the probe in this study was approximately 8cm long so it could be threaded far enough into the facepiece, inside the nosecup, so that its inlet was approximately 1cm from the test subject’s mouth. A sample cassette was fitted directly to the probe for collection of the in-facepiece sample. As in previous studies, a heating bonnet was attached to the cassette during sampling to prevent condensation of water vapor from exhaled breath inside the $C_i$.

The ambient sample cassette was placed in the worker’s breathing zone (outside the respirator), typically on the collar of the worker’s coveralls. A probe was fitted to the outside sample cassette, so if any particle loss was caused by the probe on the inside sample, it would also be experienced by the outside sample. The cassettes and sample tubing were attached to personal sampling pumps. Each worker wore two pumps as samples were taken simultaneously.

The workers were sampled for the entire shift. Samples were changed when breaks and lunch times permitted. Sampling times ranged from 40 to 178 minutes. Three to four samples per day per worker were collected. Pumps were calibrated in-line at the start and end of each day of sampling. The samples were collected at two liters per minute. Field blanks were collected and handled in the same manner as the $C_o$ and $C_i$ samples, except no air was drawn through them. Manufacturers’ blanks (unused sample cassettes) were also sent to the analytical laboratory with the field blanks and samples to check for background levels of contaminants. Particle size sampling was conducted twice using six-stage single-jet cascade impactors.

All samples and blanks were analyzed for lead. The $C_i$ samples and blanks were analyzed with proton induced x-ray emission spectroscopy (PIXE). The detection limit for lead was 0.019µg per filter. $C_o$ samples and cascade impactor samples were subjected to inductively coupled plasma (ICP) analysis using NIOSH method 7300. The detection limit for lead was 0.38µg per filter.

Results

Of the sample sets collected, fifteen were eliminated due to equipment failure or worker error. The remaining 52 sample sets were treated statistically and used to calculate workplace protection factors. The outside lead concentrations ranged from 9 to 2500µg/m³. The permissible exposure limit (PEL) of lead, 50µg/m³, was exceeded in all but one $C_o$ sample. The inside concentrations were all non-detectable except for one which was well below the PEL.

Because no lead was detected on the majority of the $C_i$ samples, an estimate of the WPF could not be directly calculated. Instead, a conservative estimate of respirator performance was made by assuming lead at the detection limit.
limit was present in the non-detectable Ci samples. By using the detection limit as the mass value for the Ci samples, subsequent calculations of the Ci and Co concentrations lead to a minimum WPF result for each sample pair. Finally, a rank and percentile function was performed, resulting in a 5th percentile WPF estimate of approximately 900. This is considered very good performance and may be due to the conscientious use and sound respiratory protection program of the facility.

Particle size distributions for the cascade impactor samples were 10.2µm mass median aerodynamic diameter (MMAD) in the general work area and 7.5µm mmad in the casting area. These results indicate that large particles were predominant; however, 6.5% and 13.6% of the mass, respectively, were found in particles less than 2µm in aerodynamic size. Based on this information, it is likely that dust and fume particles were present in the workers’ exposures.

Conclusion
As indicated by the inside sampling results, no worker was overexposed to lead during the study. Therefore, the respirator provided adequate protection. This study is consistent with other WPF studies that support the APF of 50 for this class of respirators.

References