

delivered a minimum 115 Lpm (4 cfm) airflow to the facepiece, the authors concluded that “* * * migration of contaminant into the facepiece of the PAPR system could be a significant source of leakage when the respirator is exposed to the wide ranging conditions that exist in the work environment.” While the WPFs measured in this study were well below the level expected of a PAPR, the authors stated that these results “* * * represent a more accurate measure of the level of worker protection that can be expected from this type of PAPR system.”

Study 18. At the 1990 AIHCE, C.E. Colton and H.E. Mullins presented a WPF study in which they assessed protection against exposure to lead fume and dust for 20 employees working in the blast furnace, reverberatory furnace, casting, and baghouse areas of a secondary lead smelter (Ex. 1-64-12). The employees were provided with a 3M Whitecap PAPR with a high-efficiency filter (TC-21C-456). The investigators trained the employees in the proper donning, fitting, and operation of the respirators. Using a TSI Portacount, the investigators conducted fit testing while the participants performed the exercise sequence contained in Appendix D of OSHA's Lead Standard; the required fit factor was 500. Participants were observed continuously throughout the sampling.

The inside-the-facepiece sampling train consisted of a 25 mm three-piece cassette containing a 0.8 micron pore size polycarbonate filter. The authors mounted the sampling cassette directly to an ABS Liu probe and inserted the probe into the facepiece in place of the speaking diaphragm. The outside-the-facepiece sampling train was a 25 mm three-piece cassette containing a 0.8 micron pore size polycarbonate filter. The authors did not mention attaching the outside cassette to a probe or the location of the sampling cassette on the employee. Airflow rates of the sampling pumps were calibrated in-line before and after each sampling interval, but no sampling airflow rate was provided. Sampling was conducted for as much of the 8-hour shift as possible, with sampling intervals ranging from 1 to 4 hours. Field blanks were used, and area samples for particle size analysis were gathered with a Marple personal cascade impactor (Model 2401).

Sample and field blank analyses were performed using proton induced x-ray emission (PIXE) analysis. Particle size analysis by inductively-coupled plasma-mass spectrometry indicated particles in the dust and fume range. While the range of inside- and outside-the-facepiece concentrations were

presented, individual inside and outside concentrations or results by employee or job classification were not provided.

Similarly, the report presented an overall GM WPF, GSD, and fifth percentile WPF, but not individual WPFs. Of the 55 sample measurements, 34 of the inside-the-facepiece results were below the analytical limit of detection. In these instances, the authors used a conservative WPF calculation by setting the values at the limit of detection. No lead was detectable on the field blanks so no adjustments were made to sample weights. The authors do not mention adjusting inside-the-facepiece values for pulmonary particle retention. Final calculations used only those sample pairs with outside sample weights greater than 1,000 times the detection limit. The authors believed this procedure was necessary to determine that the respirator was capable of providing a protection factor of 1,000. The authors also analyzed the data for outliers (at the 99% confidence level). The overall data analysis resulted in a GM WPF of 8,843, a GSD 3.2, and a fifth percentile WPF of 1,335. The authors concluded that the data supported ANSI's proposed APF of 1,000 for full facepiece PAPRs. They also recommended that fit testing be performed on all tight-fitting respirators.

5. WPF Study—Helmet/Hood PAPRs

Study 27. At the 1990 AIHCE, D.R. Keys, H.P. Guy, and M. Axon reported on a 3-month WPF study in which they evaluated exposure to estradiol benzoate (a steroid) for an unspecified number of workers in a pharmaceutical facility (Ex. 64-40). They included three loose-fitting hood/helmet type PAPRs in the study: Racal Breathe Easy 10, Bullard Quantum, and 3M Whitecap II. All three PAPRs had double-bibbed capes, were equipped with HEPA filters, and did not have lift-up visors. A Tyvek hood was part of the Racal and Bullard PAPRs while the 3M had a hard helmet. PAPRs were previously used at the facility, so workers were already properly trained in their use and were familiar with wearing them. The investigators observed the participants continuously, one-on-one, during sampling. While the authors used field blanks, they did not mention determining particle size or using a clean area for donning and doffing or for starting and stopping the sampling train.

The inside- and outside-the-facepiece sampling trains consisted of a 37 mm two-piece cassette with a glass fiber filter, attached to a nylon Liu probe. Location of the inside-the-facepiece probe was not specified. Samples were

gathered for 1/2–3 hours at a flow rate of 2.5–3.5 Lpm. Pumps were calibrated in-line before and after each sampling period.

The authors used radioimmunoassay (RIA), a very sensitive analytical technique, to analyze inside-the-facepiece samples, and HPLC to analyze outside samples; they rejected inside samples with weights below the limit of quantification. Also, the investigators rinsed the outside sample probes with methanol and analyzed the rinsate by HPLC to determine sample loss due to probe use. The authors did not provide any further analytical information.

Sixty valid sample sets were obtained from the study. Results were not adjusted for blank value (*i.e.*, all blank values were below 1 nanogram per filter) or probe loss (*i.e.*, the GM of 1% was not statistically significant). Individual inside and outside concentrations or WPFs were not reported. Instead, the authors presented the range of inside- and outside-the-facepiece concentrations. They determined an overall fifth percentile WPF for each respirator, along with the number of samples, the minimum and maximum WPF achieved, a GM WPF, and the GSD. In addition, the authors determined the percentage of WPFs that fell in selected ranges (*e.g.*, <1,000, 1,000–10,000) for each PAPR, and they briefly discussed the correlation between WPF and outside concentration (*i.e.*, they found WPF to be independent of outside filter loading in this study). The Racal Breathe Easy 10, with 29 sample pairs, had a GM WPF of 11,137, a GSD of 3.9, and a fifth percentile WPF of 1,197. The Bullard Quantum, with 9 sample pairs, had a GM WPF of 9,574, a GSD of 3.1, and a fifth percentile WPF of 1,470. The 3M Whitecap II helmet, with 22 sample pairs, had a GM WPF of 42,260, a GSD of 9.8, and a fifth percentile WPF of 997. The authors stated that they obtained WPFs above 10,000 for the three PAPRs at least 44% of the time, and that the three respirators provided WPFs above 1,000 throughout the study. The authors concluded that the results of their study agreed with the then-proposed ANSI Z88.2-1992 APF of 1,000 for PAPRs with hoods or helmets.

6. WPF Studies—Loose-Fitting Helmet/Hood PAPRs & Loose-Fitting Facepiece PAPRs

Study 23. W.R. Meyers, M.J. Peach, K. Cutright, and W. Iskander reported in 1984 on a study in which they examined lead (Pb) exposure of 12 workers in a secondary lead smelter (Ex. 1-64-47). The job classifications studied were furnace operator, helper,