

type of facepiece, and sample time. The study reported that the half-mask PAPR did not provide the protection factor of 1,000 previously expected; instead, the protection factors ranging from 16 to 193. The authors also provided results for DOP filter penetration, aerodynamic mass median particle size and GSD, x-ray powder diffraction tests, and free-standing PAPR leakage measurements. The researchers discussed several parameters that could have affected results, including poor respirator use practices of the participants (which the authors believed they controlled and maintained at a minimal level); inside-the-facepiece sampling flow rate (which the authors believed was not a major source of error); and inherent PAPR leakage (however, the free standing PAPR results indicated minimal leakage). Also discussed as reasons for the low protection factors were possible leakage of Si past the blower housing grommet when employees bumped the PAPR during work (the effect of this was unknown) and leakage from inadequate facepiece fit (which the authors considered could be significant at moderate to heavy work rates).

*Study 6.* S.W. Lenhart and D.L. Campbell of NIOSH reported in 1984 on a WPF study in which they measured protection against exposure to particulate lead (Pb) for 25 primary lead smelter workers; 7 of the employees worked in the sinter plant, and 18 worked in the blast furnace area (Ex. 1–64–42). The predominant aerosol forms of Pb were dust in the sinter plant and fume in the blast furnace. In both areas, Pb comprised about 50% of the total aerosol particulate, with composition of the remaining 50% of particulates being unknown. All participants wore an MSA half-mask PAPR with high-efficiency filters (the authors provided no respirator model number in the report). The study also examined the performance of an MSA negative-pressure air-purifying respirator, which is discussed above in the half-mask air-purifying respirator study summaries. The participants routinely used respirators, but the investigators do not mention respirator training for the employees. The participants were not normally fit tested with the half-mask PAPR facepiece; however, for this study, they had to achieve a fit factor of at least 250 while wearing a negative pressure air-purifying respirator with the same half facepiece as the PAPR. Employees were instructed not to remove or manipulate the respirator during sampling, and were observed throughout the sampling period.

The inside-the-facepiece sampler consisted of a closed-face 37 mm

cassette containing an AA filter and AP10 support pad. This cassette was connected to a tapered Liiu probe that was inserted into the respirator between the nose and upper lip. In-mask samples were collected at 2 Lpm. The outside-the-facepiece sampling train was a closed-face 37 mm cassette containing an AA filter and AP 10 support pad (with no tapered Liiu probe used). The outside sample cassette was attached to the worker's lapel. Outside samples were gathered at 2 Lpm. Samples were collected for "as much of the 8-hr work shift as possible." Respirators and sampling trains were donned and doffed, and started and stopped, in a lead-free area. The inside of the respirator facepieces were wiped clean prior to donning after each break, and were cleaned and sanitized after each shift. The PAPR batteries were replaced after four hours of use (*i.e.*, according to manufacturer's instructions). Battery voltage was checked, and airflow rates were verified to exceed 15 Lpm before use. One WPF was measured for each participant. The ambient particle size distribution was determined by 19 Marple cascade impactor samples (11 in the sinter plant; 8 in the blast furnace area).

Analysis of Pb was by flame atomic absorption spectroscopy according to NIOSH Method S–341. Inside-the-facepiece samples that contained less than 10 µg of lead were reanalyzed by graphite furnace atomic absorption (limit of detection = 0.2 µg). The report provided ranges of the mass median aerodynamic diameters (in micrometers), as well as the GSD values. The authors provided a total of 25 pairs of inside- and outside-the-facepiece concentrations, and the corresponding WPFs, by employee, job title, and job location, as well as the overall GM and GSD of the PAPR WPFs and several percentile values. For samples containing Pb below the level of detection, the authors determined concentration values " \* \* \* from the least amount of lead detectable by the analytical method and the sampled volume of air." In-mask measured values were not adjusted for particle retention in the respiratory tract (the authors imply that retention had a non-significant effect on the results, but could cause WPF to be overestimated). No mention is made of using field blanks. Two approaches to defining an assigned protection factor (APF) were also discussed. These approaches are: Defining the APF in terms of a specific proportion of WPFs expected to exceed the APF, and defining the APF "in terms of a one-sided lower tolerance

limit above which we may predict with a specific confidence level that 95% of the workplace protection factors lie."

The WPF for the PAPR had a GM of 380 and a GSD of 2.6, and the individual WPFs ranged from 23 to 1,600. Approximately 98% of the WPFs for the half-mask PAPR were above 50, 90% above 110, 75% above 200, 40% above 500, and only 25% above 1,000. The authors concluded that an APF of 50 was appropriate for the PAPR they tested, and that an APF of 500 was inappropriately high for the half-mask PAPR. A protection factor not in excess of 50 was recommended for half-mask PAPRs. The authors noted that the WPFs may be too high because the workers did not routinely undergo a quantitative fit test screen with negative pressure respirators before receiving their PAPR.

#### 4. WPF Studies—Full Facepiece PAPRs

*Study 21.* W.R. Myers and M.J. Peach of NIOSH reported in 1983 on the performance of an unspecified brand of PAPR equipped with a tight-fitting elastomeric full facepiece and HEPA filters; four employees used the respirator in a silica bagging operation (A detailed description of the work setting, sampling methodology, and study protocol for this study is presented in the discussion of Study 21 in the section on half-mask PAPRs above) (Ex. 1–64–46). The full facepiece PAPR had a sealing edge consisting of a flat edge with an inner flap. The participants routinely used this PAPR and, therefore, the investigators did not train them in its use. Fit testing was not performed.

The investigators calculated WPFs for only three of the four employees because the sample for the fourth employee had an inside-the-facepiece concentration less than the limit of detection, making it unsuitable for WPF determination. The samples were evaluated for crystalline Si by x-ray diffraction. The full facepiece WPFs ranged from 25 to 215, which are low for a PAPR. In this regard, the authors reported that the employees routinely bumped and rubbed the belt-mounted motor blower housing and filter assembly during the bagging operation. They believed such action may have caused movement between the neck of the filter and the blower housing grommet; thereby resulting in the seal failing and allowing unfiltered air to bypass the filter. They reported some evidence to support this conclusion, but could not determine the contribution of this problem to the overall leakage into the facepiece. Although the blowers were checked to ensure each PAPR