

all the workers except 1 were in Grids 1–4 of the Los Alamos Test Panel. The one remaining worker's face was wider than those accommodated by the Los Alamos Test Panel.

Samples were analyzed by proton induced x-ray emission analysis (PIXEA) for lead. The authors reported that for PIXEA the sensitivity is good, typically 10 nanograms per sample. Area samples for particle size analysis were also collected, using Marple cascade impactors, in the reverberatory furnace, casting, and warehouse areas. Three particle size ranges were found; less than 1  $\mu\text{m}$  (15% of the total aerosol), between 1 to 10  $\mu\text{m}$  (20% of the total aerosol), and greater than 10  $\mu\text{m}$  (65% of the total aerosol). The particle size distribution showed that both lead dust and lead fume were present.

The authors had pre-established that if the outside filter weights were less than 51 times the field blank value, the sample set would be rejected. The authors stated, "You need at least this much differential between inside and outside samples if you want to prove or disprove that a respirator provides a PF of 50." None of the workplace samples were rejected for being less than 51x the field blank value. However, several sample sets were rejected for other reasons such as the inside sample coming loose from the probe, sample pump failure, *etc.* Field blanks were used, and were handled the same as other samples. Detectable amounts of lead were found on the field blanks. The mean value of the field blanks was used to correct the sample values by subtracting the mean field blank value from the inside and outside sample weights. WPFs were calculated by dividing the outside concentration ( $C_o$ ) by its corresponding inside concentration ( $C_i$ ), and checked for outliers. The authors reported that for the 20 samples collected the geometric mean WPF was 3929 and the GSD was 9.6, and the 5th percentile WPF estimate was 95. The outside concentrations ranged from 150 to 8380  $\mu\text{g}/\text{m}^3$ , and the inside concentrations ranged from 0.03  $\mu\text{g}/\text{m}^3$  to 3.0  $\mu\text{g}/\text{m}^3$ . Sampling periods ranged from 30 minutes to 3 hours. The workers were under constant observation to ensure proper respirator use and wear and to ensure sample validity.

The authors looked at subsets of the data using multiples of the field blank mean values ranging from 1,000 times the field blank to 25,000 times the field blank value. The authors found a strong correlation between filter weight and workplace protection factor when they looked at the log of the mean filter weight and the log of the mean WPF.

The authors stated that the data appeared to be close to the plateau region. The authors also stated that the quantitative fit factors measured during worker fit testing did not correlate with the WPFs measured in this study.

The authors concluded that " \* \* \* the results of this study indicate that this full facepiece respirator with high efficiency filters reliably provides workplace protection factors in excess of 50 against lead dust and fume aerosol." The authors stated that they would expect 95% of the workplace protection factors to be above 95. They also stated that "The ANSI Z88.2 proposed Standard for Practices for Respiratory Protection has assigned a protection factor of 100 to this type respirator. These data support that recommendation."

### 3. WPF Studies—Powered Air-Purifying and Supplied-Air Respirators Half-Mask PAPRs

*Study 21.* In 1983, W.R. Meyers and M.J. Peach of NIOSH reported half and full facepiece PAPR performance measurements for four workers during bagging of micro-crystalline silica (Si) in a silica processing plant (Ex. 1–64–46). The study examined several aspects of the respirator's performance. Prior to the workplace evaluation, dioctyl phthalate (DOP) was used to determine filter efficiency. A 4-hour Si dust chamber study was performed by mounting the PAPR on an anthropomorphic head, simulating worker breathing, and gathering inside- and outside-the-facepiece silica samples. Workers were provided with an unspecified brand of PAPR, with either a tight-fitting half-mask or full facepiece, and equipped with high-efficiency filters. Both styles of facepiece were made of natural rubber and had two exhalation valves. The sealing edge of the facepiece was either an internal roll (half-mask) or a flat edge with an inner flap (full facepiece). The filters were located downstream of the respirator's blower unit.

The PAPRs used in the study were identical to those already being used by the employees; the authors did not mention training the participants in proper use of the respirator. Respirators were placed on and removed from the participants by the investigators, as needed (*e.g.*, start of shift, lunch break, personal breaks, end of shift). Donning and doffing the respirator, and sampling train starting and stopping, occurred in a clean area. Samplers were started after the PAPR was donned and turned on, and were stopped before the PAPR was turned off for doffing. Facepiece interiors were examined for dust

contamination after each removal (gross contamination was not observed), and the facepieces were cleaned by the investigators after each shift. In addition, each PAPR's volumetric air output (with the facepiece removed) was measured with a dry gas meter. Filters and batteries were changed according to the manufacturer's instructions. While no mention is made of fit testing the participants, the investigators instructed them not to manipulate, lift, or remove the facepiece during sampling. Participants were observed 100% of the time during donning and doffing, and about 80% of the time at their workstations. The authors used field blanks to assess contamination caused by handling.

The sampling train for the inside-the-facepiece samples consisted of a 37 mm two-piece cassette containing a 5 micron pore size FWS-B polyvinyl chloride filter. The cassette was attached directly to a modified Luer adaptor sampling probe, inserted into the facepiece between the nose and upper lip of the employee. The flow rate of the pump was 1.5 Lpm. The outside-the-facepiece samples were collected with a 37 mm two-piece cassette and a 5 micron pore size FWS-B polyvinyl chloride filter. The sampling airflow rate was 1.5 Lpm, and the cassette was attached to the subject's lapel. Outside samples were collected as total dust since previous sampling revealed 70% or more of the dust particles to be 10 microns or less in size (*i.e.*, respirable). Sample times ranged from 84 to 320 minutes, with cassettes being changed during the employees' lunch break. Overall PAPR performance (leakage) was determined by replacing the facepiece of two respirators with an air-filtering head containing a pre-weighed 76 mm glass fiber filter. The respirators were mounted in a free-standing stationary position, and run for 6–7 hours (with a battery change at 4 hours). The air output was measured, the filter weighed, and the ambient Si concentration estimated. Area samples were collected to determine particle size. An Anderson impactor was placed 4–8 feet from the participants and collected samples for about 3 hours at a flow rate of 1 cfm.

Samples were analyzed for free Si according to NIOSH P&CAM 259 (*i.e.*, gravimetric weight and x-ray powder diffraction for Si). Results were corrected for the average blank filter weight gain, but not for pulmonary retention (which the authors believed was negligible). Ten individual inside- and outside-the-facepiece concentrations, with associated WPFs, are tabulated by sample period, worker,