

outside-the-facepiece and inside-the-facepiece concentrations for Pb and Zn were provided. For the purpose of WPF calculation, inside-the-facepiece samples with non-detected concentrations were treated as containing analyte at the detection limit (This situation only arose with lead, not zinc). For the 62 sample sets taken for lead, the GM WPF was 415, the GSD was 4.4, and the fifth percentile WPF was 36. For zinc, the GM WPF was 681, the GSD was 5.6, and the fifth percentile WPF was 40. The authors believe they handled their results conservatively since outside concentrations were collected as respirable particulate, rather than total mass, and inside-the-facepiece samples with non-detected concentrations were given values of the analytical detection limit when calculating WPF. In the study summary, the authors concluded that when the respirator is properly selected, fit tested, and used, their results supported its use for concentrations up to 10 times the PEL.

**Study 16.** A.R. Johnston and H.E. Mullins reported at the 1987 AIHCE on a WPF study in which they measured exposure to particulate aluminum (Al), titanium (Ti) and silicon (Si) for three participants working in the polishing and grinding area of an aircraft components manufacturing facility (Exs. 1-64-34, 1-146, 1-133). Although WPFs were also measured for two other participants, one in the blasting area and one in the coating area, no data were presented for these employees. All participants wore the disposable 3M 8715 dust/mist respirator. Prior to testing, the investigators trained the participants in the proper fitting of the respirator, fit tested the employees using the OSHA Lead Standard's saccharin qualitative fit test method, and explained the study to them. Participants had previously worn respirators, but on an "as needed" or elective basis only. Employees were observed one-on-one throughout the sampling period. The number of WPFs measured per subject was not specified, although it appears that about six WPFs were measured per subject.

The inside-the-facepiece sampling train was a closed 25 mm three-piece cassette containing a polycarbonate filter. The cassette was connected to a tapered nylon Liu probe that was inserted into the facepiece at an unspecified location. Inside-the-facepiece samples were collected at a flow rate between 1.5 and 2 Lpm. The outside-the-facepiece sampling train was a closed 25 mm three-piece cassette containing a polycarbonate filter. The cassette was connected downstream

from a tapered Liu probe. Outside samples were collected at a flow rate between 1.5 and 2 Lpm. Sampling times ranged from 35 to 235 minutes.

Sampling pumps were calibrated three times a day—at the beginning of the shift, lunch, and the end of the shift. Sampling equipment was removed for breaks, which occurred multiple times in some instances. While no mention is made of using a clean area to don and doff respirators, and start and stop sampling trains, the authors noted that cassettes had to be removed in the work area. Field blanks were used to identify possible filter contamination due to handling. The ambient particle size distribution was not characterized.

Samples were analyzed by proton induced x-ray emission analysis (PIXEA). Sample results were adjusted for field blank values, but no mention was made of adjustments for particle retention in the respiratory tract. The authors rejected sample sets in which: the outside filter weight was less than 11 times the mean blank value; the inside filter weight was non-detectable, or less than the mean field blank value; or the measured WPF was determined to be an outlier (*i.e.*, too far above or below the geometric mean WPF using 5% confidence intervals). A total of 38 sample sets were accepted for Al (10), Ti (14), and Si (14). Pairs of inside-the-facepiece and outside-the-facepiece concentrations, and the corresponding WPFs, are provided in supplemental data (Exs. 1-146, 1-133), but were not linked to specific participants. Also, a table of GM WPF, GSD, and fifth percentile WPF, by analyte, was presented. The authors calculated WPF values for the 10 sample sets of Al, reporting a GM of 145, a GSD of 2.3, and a fifth percentile of 32. For the 14 sample sets measured for Ti, the GM was 59, the GSD was 1.7, and the fifth percentile was 24. For Si, using 14 sample sets, the GM was 172, the GSD was 3.1, and the fifth percentile was 24. The authors concluded that their study supports using this respirator for concentrations up to 10 times the PEL. In addition, the authors noted a positive correlation between filter weight and WPF. Two explanations put forth for this effect were that respirators work better with higher dust loadings, and that WPF measurements are more accurate at higher dust loadings. The authors favored the latter explanation, and believed that to assess true respirator performance capabilities, testing should be conducted at or near the respirator's APF, or a filter weight versus protection factor curve should be defined for predicting performance at

higher concentrations. In a summary of this study submitted to OSHA (Ex. 1-146) the authors stated that:

\* \* \* the mass outside the respirator was very low. For this reason, the ability of the respirator to provide protection was not challenged. Therefore, this study should not be used for direct comparison to others in assigning protection factors as they are artificially low.

The authors also discussed sampling and analytical considerations for WPF studies, such as calibration reliability, sample cassette integrity, analytical sensitivity, and sample handling procedures.

## 2. WPF Study—Full Facepiece APR

**Study 2A.** C.E. Colton, A.R. Johnston, H.E. Mullins and C.R. Rhoe of the 3M Occupational Health and Environmental Safety Division in May, 1989 gave a presentation at the AIHCE on their WPF study (Ex. 1-64-14) performed with full facepiece air-purifying respirators worn in a secondary lead smelter. Air sampling for lead was conducted over 5 days in four areas of the plant; the blast furnace, reverberatory furnace, casting, and warehouse areas.

The respirator evaluated was the 3M 7800 Easi-Air full facepiece respirator used with 3M 7255 high efficiency filters. The respirator was equipped with a nosecup inside the facepiece. The sampling probe was inserted into the respirator in place of the speaking diaphragm to assure a gas tight seal and consistent probe location close to the breathing zone of the wearer. The respirators were equipped with sampling probes using a design by Dr. Ben Liu to minimize particle entry losses. Both the inside and outside sampling trains used the Liu designed probe for consistency.

Thirteen workers who normally wore full facepiece respirators in the plant qualified to participate in the study. They were trained in proper respirator use, the procedures to be followed for the study, and how to don and fit the 3M respirator. Quantitative fit testing was performed using the Portacount QNFT instrument and fit test operators followed the OSHA Lead standard exercise protocol for fit testing. The workers were fit tested wearing their normally required personal protective equipment (PPE), and care was taken to assure that this additional PPE did not interfere with facepiece fit. The criterion the authors used for passing the QNFT was a minimum fit factor of 500; 10 times the assigned protection factor of 50 given in the lead standard for a full facepiece negative pressure respirator. The 13 qualified workers were measured for face length and width, and