Table VI-9
Relative Risk (RR) of Lung Cancer in Boice Cohort with Duration of Exposure to Selected Chemicals

Years Exposed	Chromate		Trichloro-ethylene		Perchoro-ethylene	
	RR	95% CI	RR	95% CI	RR	95% CI
0	1.00	p>0.2	1.00	P<0.01	1.00	P=0.02
<1	0.90	0.69-1.16	0.85	0.65-1.13	1.15	0.80-1.66
1-4	1.02	0.78-1.33	0.98	0.74-1.30	1.09	0.80-1.48
≥5	1.08	0.75-1.57	0.64	0.46-0.89	0.71	0.49-1.02

As shown in the table, there was a statistically significant decline in relative risk of lung cancer among factory workers with duration of TCE exposure (p<0.01) and PCE exposure (p=0.02). This mirrors the decline with increasing employment duration seen in comparison with the general California population and strongly suggests the internal cohort analysis failed to adequately adjust for HWE.

The table shows that, despite the downward influence of HWE on lung cancer risk, there was a slight nonsignificant upward trend in excess lung cancer mortality with duration of exposure to Cr(VI). The result is that aircraft workers potentially exposed to chromate for five or more years had 50 to 70 percent greater lung cancer mortality than coworkers with a similar duration of potential exposure to the chlorinated solvents. The relative excess is even more noteworthy given that the subgroups had considerable overlap (*e.g.*, many of the same workers in the PCE and TCE groups were also in the chromate group). This implies that a subset of Cr(VI) workers not exposed to chlorinated solvents, possibly spray painters routinely applying Cr(VI) primers over many years, may be at greater lung cancer risk than other Cr(VI)-exposed members of the cohort.

The AIA and its technical representative, Exponent, objected to OSHA reliance on the non-statistically significant upward trend in excess lung cancers with increasing Cr(VI) exposure duration described above (Exs. 38–215–2; 47–29–2). Exponent stated:

Statistical tests for trend indicated there is no evidence for a trend of increasing risk of lung cancer with increasing years exposed to chromate (P<0.20). OSHA seems to have 'eye-balled' the estimates and felt confident accepting the slight and non-significant increases among risk estimates with overlapping confidence intervals as evidence of a ''slightly positive'' trend. However, OSHA's interpretation is an overstatement of the finding and should be corrected in the final rule (Ex. 38–215–2, p. 13).

OSHA does not agree with these comments and believes it has objectively interpreted the trend data in a scientifically legitimate fashion. The fact that an upward trend in lung cancer risk with Cr(VI) exposure duration fails to meet a statistical confidence of 95 percent does not mean the relationship does not exist. For example, a trend with a p-value of 0.2 means random chance will not explain the relationship 80 percent of the time. The positive trend is all the more notable given that it occurs in spite of a significant downward trend in lung cancer mortality with years of employment. In other words, aerospace workers exposed to Cr(VI) experienced a slightly greater lung cancer mortality with increasing number of years exposed even while their co-workers exposed to other chemicals were experiencing a substantially lower lung cancer mortality with increasing years exposed.

In its post-hearing comments, NIOSH calculated the observed excess lung cancer risk to the Boice spray painters expected to have the highest Cr(VI) exposures (SMR=1.11) to be 21 percent higher than the minimally Cr(VI)-exposed assembly workers (SMR=0.92). NIOSH assumed the painters were exposed to 15 μg CrO_3/m^3 (*i.e.,* the arithmetic mean of Cr(VI) air sampling data in the plant between 1978 to 1991) for 10 years (*i.e.,* the approximate average duration of employment) to derive an excess risk per mg CrO_3/m^3 of 1.4 (Ex. 47–19–1). NIOSH noted that this was very close to the excess risk per mg CrO_3/m^3 of 1.44 determined from their risk modeling of the Gibb cohort (Ex. 33–13). In a related calculation, OSHA derived the expected excess risk ratio from its linear relative risk model using a dose coefficient consistent with the Gibb and Luippold data sets. Assuming the Boice spray painters were exposed to 10 μg $Cr(VI)/m^3$ (90th percentile of plant air sampling data converted from μg CrO^3 to μg Cr(VI)) for 12 years (average employment duration of Boice factory workers), the model predicts a risk ratio 1.20 which is also very close to the observed excess risk ratio of 1.21 calculated from the observed SMR data for spray painters above. These calculations suggest that the excess lung cancer mortality observed in the Boice subcohort of Cr(VI)-exposed aerospace workers is consistent with excess risks predicted from models based on the Gibb and Luippold cohort of chromate production workers.

The other cohort studies of aerospace workers cited by AIA were not informative with regard to the association between Cr(VI) and lung cancer. A cohort study by Garabrandt *et al.* of 14,067 persons employed by an aircraft manufacturing company found significantly reduced excess lung cancer mortality (SMR=80; 95% CI: 68–95) compared to adjusted rates in the U.S. and San Diego County populations (Ex. 35–210). The mean duration of follow-up was only 16 years and the study authors are careful to state that the study can not rule out excess risk for diseases, such as lung cancer, that have long latencies of 20 years or more. The consistently low all-cause and cancer mortalities reported in the study strongly suggest the presence of a healthy worker effect. Another cohort study by Blair *et al.* of 14,457 aircraft maintenance workers at Hill Air Force base in Utah did not find elevated lung cancer mortality (SMR=90; 95% CI: 60–130) when compared to the general population of Utah (Ex. 35–213). However, the study was exclusively designed to investigate cancer incidence of chlorinated solvents (*e.g.* TCE, PCE, methylene chloride) and makes no mention of Cr(VI). This was also the case for a cohort study by Morgan *et al.* of 20,508 aerospace workers employed at a Hughes Aircraft manufacturing