Arena *et al.* study, OSHA estimated Cr(VI) exposures for the cohort members based in part on exposures in the stainless steel industry. High-nickel alloys that contain chromium are roughly comparable to stainless steel in terms of chromium content and the temperatures at which they are melted. This in turn determines the amount of trivalent chromium that converts to hexavalent chromium in the heating process. For example, cast stainless steels with high nickel composition (*e.g.* Cast 18–38, Cast 12–60, Cast 15–65, and Cast 15–35) have chromium content ranging from 10–21% and have melting points between 2350 and 2450 degrees Fahrenheit. Other high-nickel alloys with chromium content, such as Hastelloy alloys C and G, Incoloy, Nimonic, and Inconel, range from 13 to 22% chromium (except Incoloy 804=29.7% Cr) with melting points of 2300–2600 degrees Fahrenheit. Stainless steels, in general, have 12–30% chromium content and melting points between 2350 and 2725 degrees Fahrenheit.

For this analysis OSHA projected that the proportion of workers in each production job category is approximately similar in stainless steel and high-nickel alloy production. For example, OSHA assumed that the percent of alloy production workers who are furnace operators is, as in steel production, about 5%. Assuming that both the Cr(VI) exposures typical of various production jobs and the proportion of workers employed in each job are roughly similar, workers in the Arena cohort producing high-nickel stainless steels and alloys containing chromium are likely to have Cr(VI) exposures comparable to those generally found in stainless steel production. Workers' exposures were estimated using the exposure profile shown in Table III–62 of the Final Economic Analysis section on steel mills (Ex. 49–1).

Not all workers in the Arena *et al.* cohort had Cr(VI) exposures comparable to those in stainless steel facilities. As discussed by Ms. Fessler at the hearing, exposure to ''* * * [c]hrome was not uniform in all [industries included in the study] because some of those industries * * * did only high nickel work or nickel mining or whatever specific nickel work there was'' (Tr. 683). OSHA assumed that Cr(VI) exposures of workers producing high-nickel alloys without chromium content, such as Duranickel, Permanickel, Hastelloy alloys B, D, and G, and Monel alloys, are similar to those found in carbon steel mills and other non-stainless facilities, which according to comments submitted by Collier Shannon Scott:

> * * * may generate Cr(VI) due to trace levels of chromium in feedstock materials or the inadvertent melting of stainless steel scrap, as well as during various maintenance and welding operations (Ex. 38–233, p. 10).

Exposure levels for Arena cohort workers producing these alloys were estimated using the carbon steel exposure profile shown in Table III–64 of the Final Economic Analysis section on steel mills (Ex. 49–1).

Table VI–10 below shows the risk ratios (ratio of excess plus background cancers to background only cancers) predicted by OSHA's model for workers producing high-nickel alloys with and without chromium content. The percentage of workers with 8-hour TWA exposures in each range shown below are calculated for Ni-Cr alloys and non-Cr alloys using profiles developed for the Final Economic Analysis sections on stainless steel and carbon steel industries, respectively (Ex. 49–1). An average exposure duration of 20 years was assumed. While it was not clear how long workers were exposed on average, the reported length of follow-up in the study indicates that the duration of exposure was probably less than 20 years for most workers. Risk ratios were calculated assuming that workers were followed through age 70. The average age at end of follow-up was not clear from the Arena *et al.* publication. Over half of the original cohort was under 30 as of 1978, and follow-up ended in 1988 (Ex. 38–233–2, p. 908). Follow-up through age 70 may therefore lead OSHA's model to overestimate risk in this population, but would probably not lead to underestimation of risk.

Table VI-10: Relative Risks Predicted for Workers in High Nickel Alloy Production

Range of Personal TWA exposures ($\mu g/m^3$)	Midpoint Exposure for Risk Model	Percentage of Workers		Risk Ratio Predicted by OSHA's Model
		Ni-Cr Alloys	Non-Cr Alloys	
Unexposed	0.0	66.1%	66.1%	1.000
below LOD	0.015	4.4%	9.8%	1.0002 - 1.001
LOD - < 0.25	0.133	5.4%	9.1%	1.002 - 1.009
0.25 - < 0.5	0.375	8.8%	4.1%	1.006 - 1.026
0.5 - < 1.0	0.750	4.1%	8.1%	1.012 - 1.051
1.0 - < 5.0	3.0	8.5%	0.3%	1.047 - 1.206
5.0 - < 10.0	7.5	0.3%	1.7%	1.117 - 1.514
10.0 - 20.0	15.0	1.7%	0.7%	1.233 - 2.026
> 20.0	30.0	0.7%	0.0%	1.466 - 3.046
Total - Ni-Cr Alloys	***	***	***	1.013 - 1.056
Total - Non-Cr Alloys	***	***	***	1.005 - 1.023