Hexavalent Chromium Exposures During Hot Work

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Regulatory Analysis and Scientific Affairs Department

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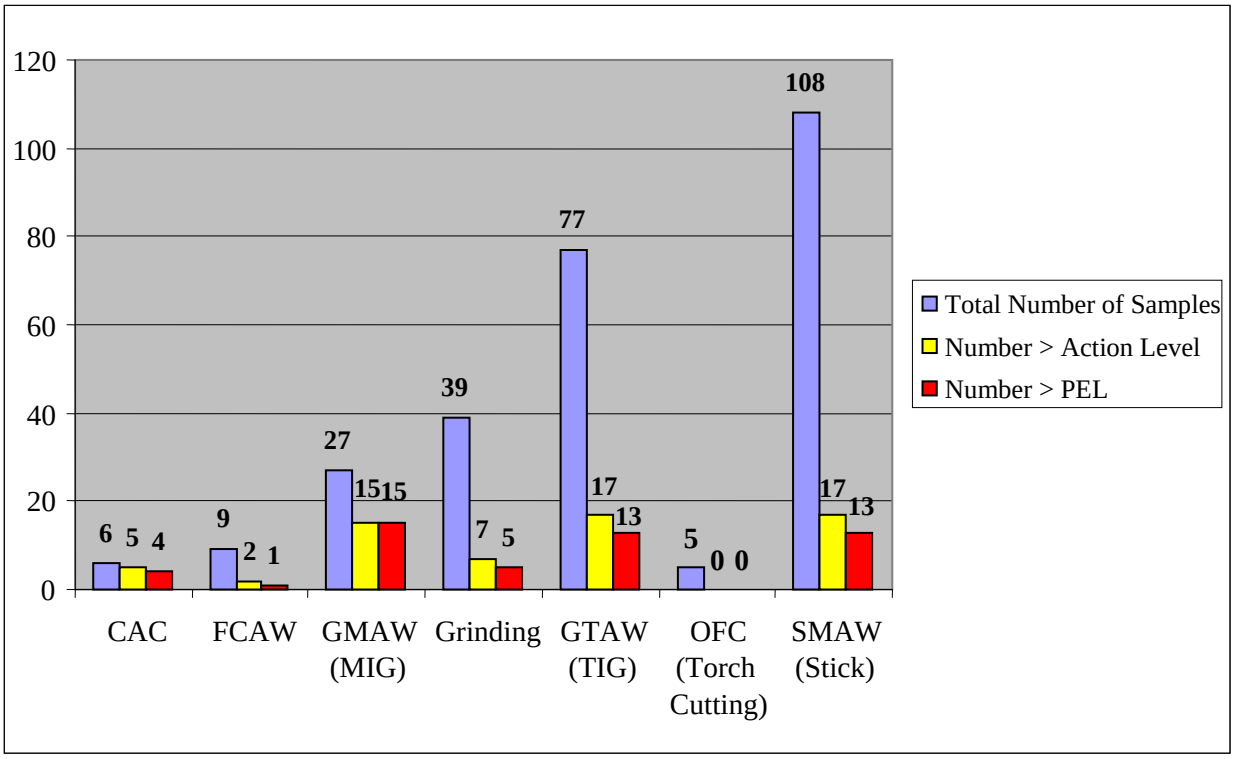
Executive Summary

This report details the findings from an air sampling survey contracted by the American Petroleum Institute (API) to evaluate inhalation exposures to hexavalent chromium (chromium (VI)) during seven types of hot work: carbon arc cutting (CAC), flux cored arc welding (FCAW), gas metal arc welding (GMAW or MIG), grinding, gas tungsten arc welding (GTAW or TIG), oxyfuel gas cutting (OFC or torch cutting), and shielded metal arc welding (SMAW or stick). Eighty-three samples were collected in October and November 2005 at two petroleum sites during maintenance turnarounds by API member companies. An additional 188 samples were collected April – June 2006 at three different petroleum company sites by ICU Environmental Health and Safety. Of the 271 total samples, 63 samples were at or above the Occupational Safety and Health Administration (OSHA) action level of 2.5 ug/m^3 and 51 were at or above the OSHA permissible exposure limit of 5 ug/m^3.

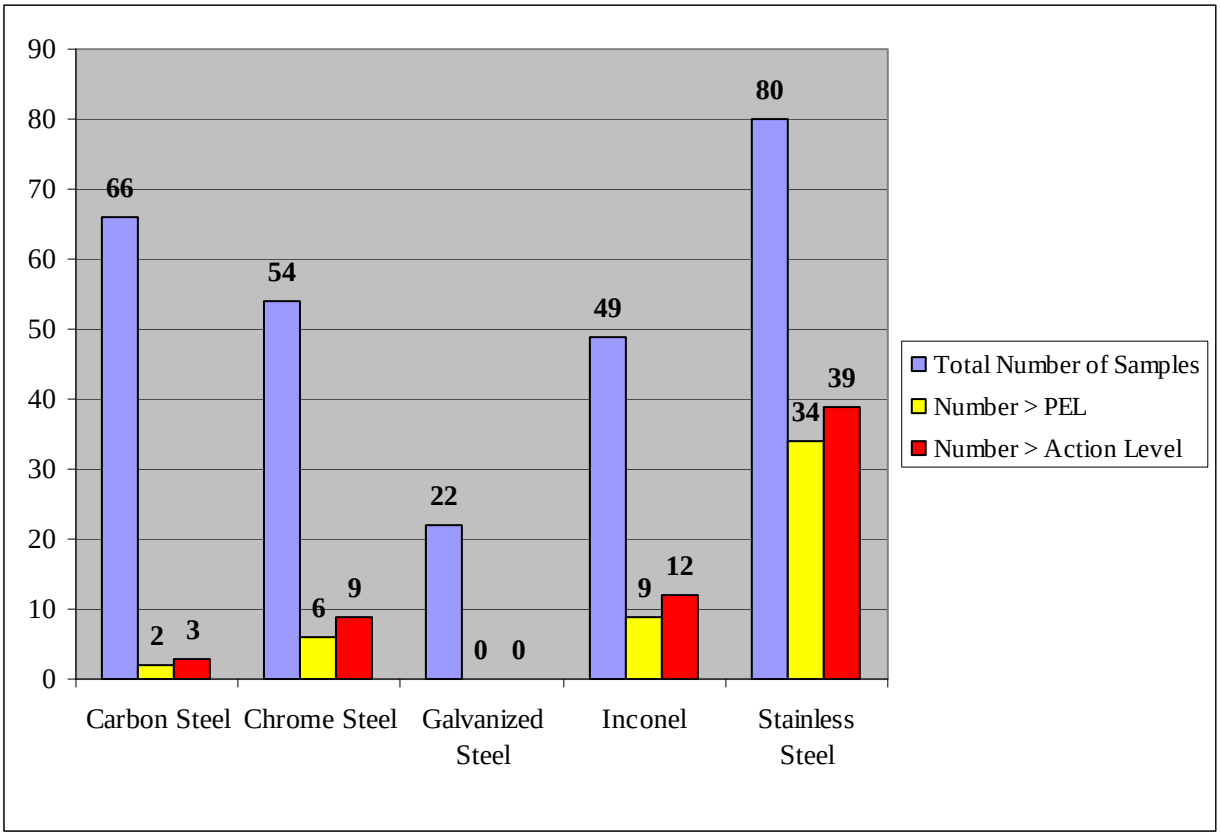
The following two figures show an overview of the results. The first figure shows the number of samples collected for each type of hot work and the number of those samples that exceeded the OSHA permissible exposure limit and/or action level.

Figure 1: Overview by Type of Hot Work



The second figure shows the distribution of samples exceeding the exposure limit and/or action level grouped according to the base metal involved during the sample collection.

Figure 2: Overview by Base Metal



From the two figures, it is apparent that both the type of hot work and the type of base metal must be considered together in order to draw conclusions on expected airborne concentrations. As discussed in the report, sample results were grouped based on type of hot work and base metal. In some cases, it was also important to look at the environmental conditions and the welding electrode as well. The intent of this survey is to provide sampling data that can be used as objective data to characterize employee exposure to chromium (VI) in accordance with the requirements of 29 *CFR* 1910.1026.

Methodology

Samples were collected and analyzed in accordance with the National Institute of Occupational Safety and Health (NIOSH) Method 7605. All activities were sampled by drawing known volumes of air through 37-mm polystyrene cassettes containing PVC filters. Prior to sampling, personal air sampling pumps were calibrated to +/- 5% of the recommended flow rate of 1.0 liter/minute with the representative sampler in line. Flow rates were verified after sampling. The air sampling pump was placed on the worker's belt and the sampling cassette was placed in the breathing zone outside the welding helmet. The majority of the samples were TWA samples, collected for the majority of the shift (8- 10- and 12-hour shifts were monitored). Twelve of the samples are considered task samples (sample time was less than five hours). After sampling, the samples and field blanks were kept refrigerated until shipped overnight to the Conoco Phillips Laboratory in Bartlesville, Oklahoma for analysis. The Conoco Phillips laboratory is accredited by the American Industrial Hygiene Association. The samples were analyzed by ion chromatography with UV detection. Results were calculated as a time-weighted average over the total sample time. Adjustment to a specific shift length was not made.

Samples were collected at five different sites over a period of five months. Samples were collected at three of the sites during maintenance turnaround activities, and during new construction at the remaining two.

Discussion

The main health effects of workplace exposure to chromium (VI) are lung cancer, asthma, bronchitis, and damage to nasal epithelia, skin, and eyes. Chromium (VI) can be produced during welding operations even if the chromium was originally present in another valence state. Welders/cutters were the primary job tasks sampled, along with some fitters and helpers.

During the sampling, notes and observations were recorded concerning the task monitored (welder/cutter, fitter, helper, etc.), the work process (hot work process, base metal, and filler/electrode), the work environment (inside vessel, temporary fab tent, wide open area, spark enclosure, etc.), the vessel type (if applicable), the ventilation type, respiratory protection, and sample identification information (sample number, date sample collected, worker name, ID, employer). This information, along with the monitoring results, monitoring time, analytical method, and type of sample, was loaded into a Microsoft Access database. The data allows for a variety of combinations for analyzing and interpreting the data. In order to provide information that is both statistically significant as well as being practically relevant, the two main parameters used to compare the data in this report are the type of hot work and base metal. Select data fields have been attached to this report as an Excel spreadsheet.

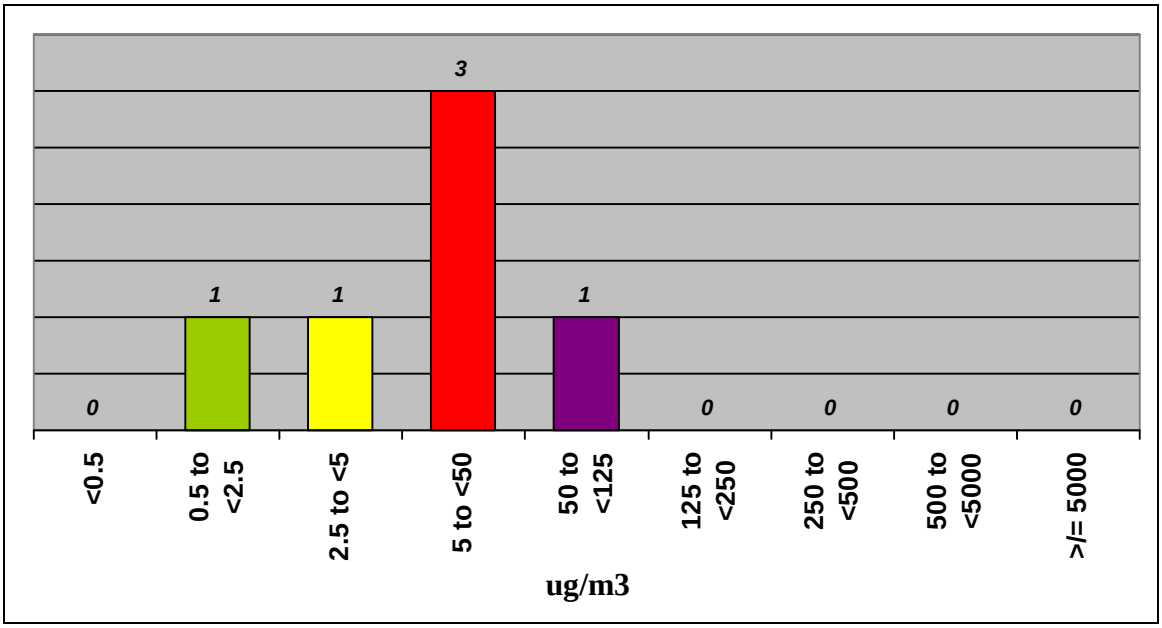
Carbon Arc Cutting (CAC)

Only six samples were collected during CAC, and all samples were collected on welders/cutters working inside a vessel. Results generally indicate the potential for concentrations to exceed the exposure limit regardless of the base metal. Due to the small sample set, specific conclusions cannot be made about this particular type of hot work. Results are summarized in Table 1:

Table 1: CAC Results Summary

Base Metals	Total # Samples	# > PEL	Minimum (ug/m3)	Maximum (ug/m3)	Geometric mean	Arithmetic mean
All	6	4	1.97	56.599	7.979	14.867
Chrome steel	0	0	0	0	0	0
All Chrome steels	3	2	1.97	9.652	5.581	6.921
• Chrome 9%	3	2	1.97	9.652	5.581	6.921
Galvanized steel	0	0	0	0	0	0
Inconel	0	0	0	0	0	0
All Stainless Steels	3	2	2.95	56.599	11.407	22.813
• SS 17–19% Cr	1	1	56.599	56.599	56.599	56.599
• SS >19% Cr	2	1	2.95	8.89	5.121	5.920

Figure 3: CAC Results Distribution



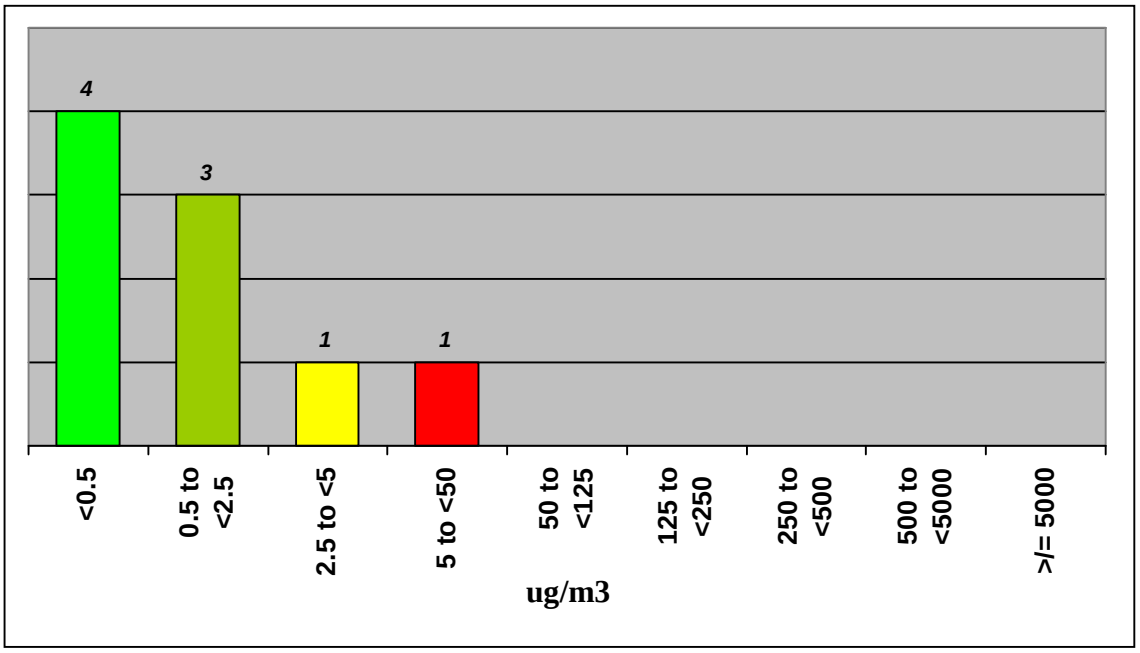
Flux Cored Arc Welding (FCAW)

Nine samples were collected during FCAW, all when welding on S200-304; 316-321; 330-347; 43 stainless steel (containing 17-19% chromium). The one sample that exceeded the exposure limit was the only sample that was collected during welding inside a vessel. The remaining eight samples were collected outside the vessel or in open air. The result for this one sample was over 15 times greater than the next highest sample result. Although results indicate that exposures to chromium (VI) will be below the PEL during FCAW operations on stainless steel outside a confined space, based on the statistical calculations, concentrations in excess of the PEL are still likely to occur.

Table 2: FCAW Results Summary

Base Metals	Total # Samples	# > PEL	Minimum (ug/m3)	Maximum (ug/m3)	Geometric mean	Arithmetic mean
All	9	1	0.016	40.869	0.575	5.486
Carbon steel	0	0	0	0	0	0
All Chrome steels	0	0	0	0	0	0
Galvanized steel	0	0	0	0	0	0
Inconel	0	0	0	0	0	0
All Stainless steels	9	1	0.016	40.869	0.575	5.486
• SS 17–19% Cr	9	1	0.016	40.869	0.575	5.486

Figure 4: FCAW Results Distribution



Gas Metal Arc Welding (GMAW or MIG)

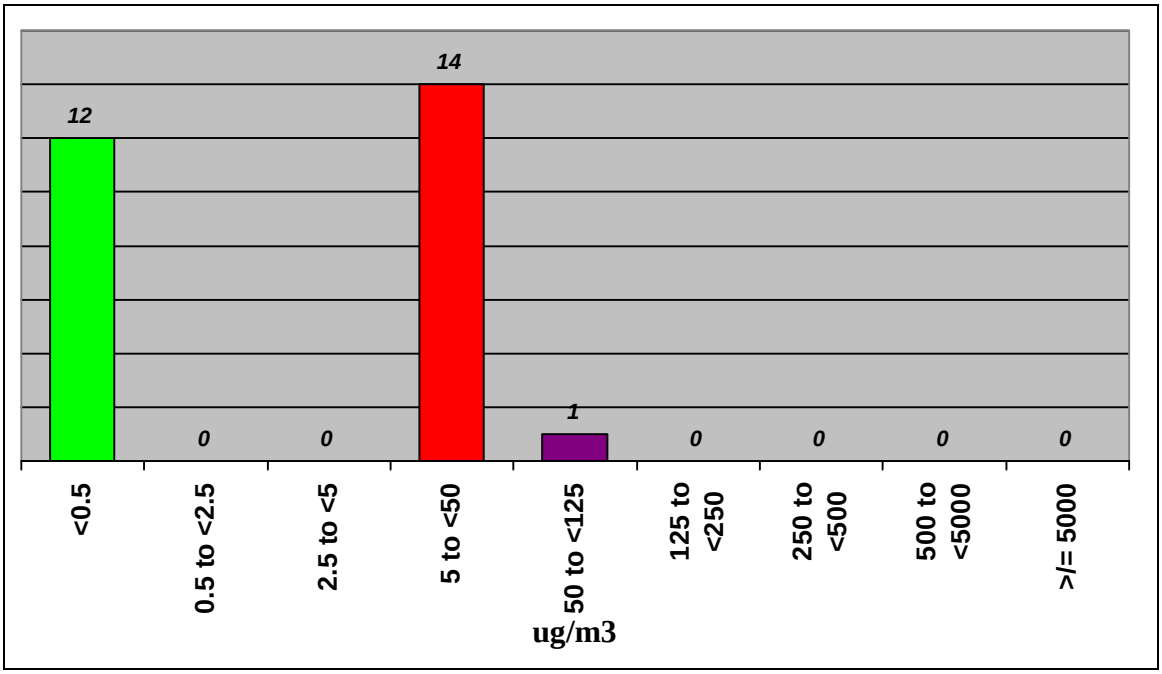
Twenty-seven samples were collected during GMAW (MIG welding) tasks and fifteen of the samples exceeded the exposure limit. All fifteen of these samples were collected when installing a 309 stainless steel welded overlay on a carbon steel vessel using ER309L electrode. This electrode contains 23% chromium. All were collected at the same job site and mechanical ventilation was in use during each task. Fourteen of the fifteen samples were collected during welding tasks inside a vessel; the exception was collected inside a spark enclosure. Sample results indicate that the PEL is likely to be exceeded during operations on stainless steel inside a vessel.

Nine samples were collected during MIG welding on Inconel using Inconel 617 wire. All nine samples were collected during welding inside a vessel, and seven of these welders were using local exhaust ventilation during the sampling. The other two welders used only natural ventilation. Despite the 16% chromium content in Inconel alloy, these results indicate that exposures are not likely to exceed the PEL.

Table 3: GMAW Results Summary

Base Metals	Total # Samples	# > PEL	Minimum (ug/m3)	Maximum (ug/m3)	Geometric mean	Arithmetic mean
All	27	15	0.009	51.91	0.907	13.004
Carbon steel	0	0	0	0	0	0
All Chrome steels	0	0	0	0	0	0
Galvanized steel	0	0	0	0	0	0
Inconel	9	0	0.009	0.066	0.013	0.017
All Stainless steels	18	15	0.012	51.91	7.689	19.498
• SS >19 Cr	15	15	8.44	51.91	20.599	23.381
• Stainless (unspecified)	3	0	0.012	0.15	0.056	0.086

Figure 5: GMAW Results Distribution



Grinding

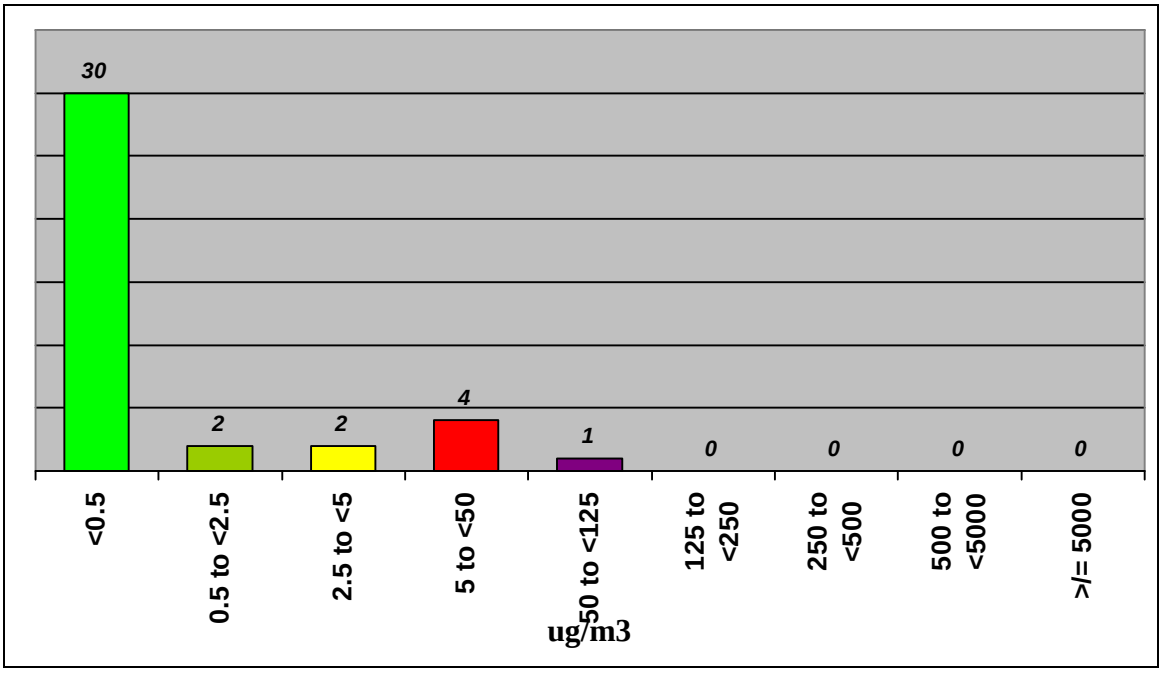
A total of 39 samples were collected during grinding operations and five of the samples exceeded the PEL. All five of these samples were collected during grinding inside a vessel while one or more welders were welding in the same vessel and mechanical ventilation was in use. The highest sample result (56.626 ug/m^3) occurred when there were four welders inside the drum while the sampling took place. Four of the samples were collected during grinding inside a coke drum on SS410 (contains 11-13% chromium) and Inconel rod. The fifth sample was collected while grinding inside a vessel above a welder who was gouging. The air was flowing from the bottom to the top of the vessel, across the breathing zone of the individual being sampled. Based on these observations, these sample results were most likely elevated due to the interference from the other operations taking place in the immediate area. Ten other samples collected when grinding on stainless steel were below the PEL.

Fourteen samples were collected when grinding on carbon steel and all samples were below the PEL. All seven samples collected when grinding on chrome steel were also below the PEL. Based on the results of this sampling, tasks involving grinding on carbon steel and chrome steel are unlikely to produce concentrations above the PEL.

Table 4: Grinding Results Summary

Base Metals	Total # Samples	# > PEL	Minimum (ug/m3)	Maximum (ug/m3)	Geometric mean	Arithmetic mean
All	39	5	0.005	56.626	0.116	3.786
Carbon steel	14	0	0.005	0.297	0.031	0.058
All Chrome steels	7	0	0.015	0.16	0.053	0.080
• Chrome <2.5%	2	0	0.019	0.132	0.050	0.076
• Chrome 5%	2	0	0.015	0.16	0.049	0.088
• Chrome 9%	3	0	0.018	0.139	0.057	0.077
Galvanized steel	1	0	0.034	0.034	0.034	0.034
Inconel	2	0	0.0097	0.012	0.011	0.011
All Stainless steels	15	5	0.0088	56.626	0.842	9.748
• SS 11-13% Cr	6	4	2.233	56.626	12.421	20.788
• SS 17–19% Cr	8	1	0.0104	14.906	0.198	2.686
• Stainless (unspecified)	1	0	0.0088	0.0088	0.0088	0.0088

Figure 6: Grinding Results Distribution



Gas Tungsten Arc Welding (GTAW or TIG)

Of the 77 samples collected during GTAW (TIG welding), only 13 exceeded the exposure limit. Nine of the 38 samples collected when welding on Inconel exceeded the exposure limit. All nine samples were collected during welding operations inside a vessel using Inconel rod 117 and used mechanical ventilation. Twelve additional samples collected inside a vessel were below the exposure limit. These twelve welders were using either Inconel rod 117 or 617, and those who used rod 117 had higher results. These results indicate there is a potential for concentrations to exceed the exposure limit when welding on Inconel inside a vessel.

Only five samples were collected during TIG welding on carbon steel and one exceeded the exposure limit. This welder was TIG welding using electrode ER7018, and he was also gouging and grinding. All five samples were collected during welding operations outside. Due to the small sample set, specific conclusions cannot be made about TIG welding on carbon steel.

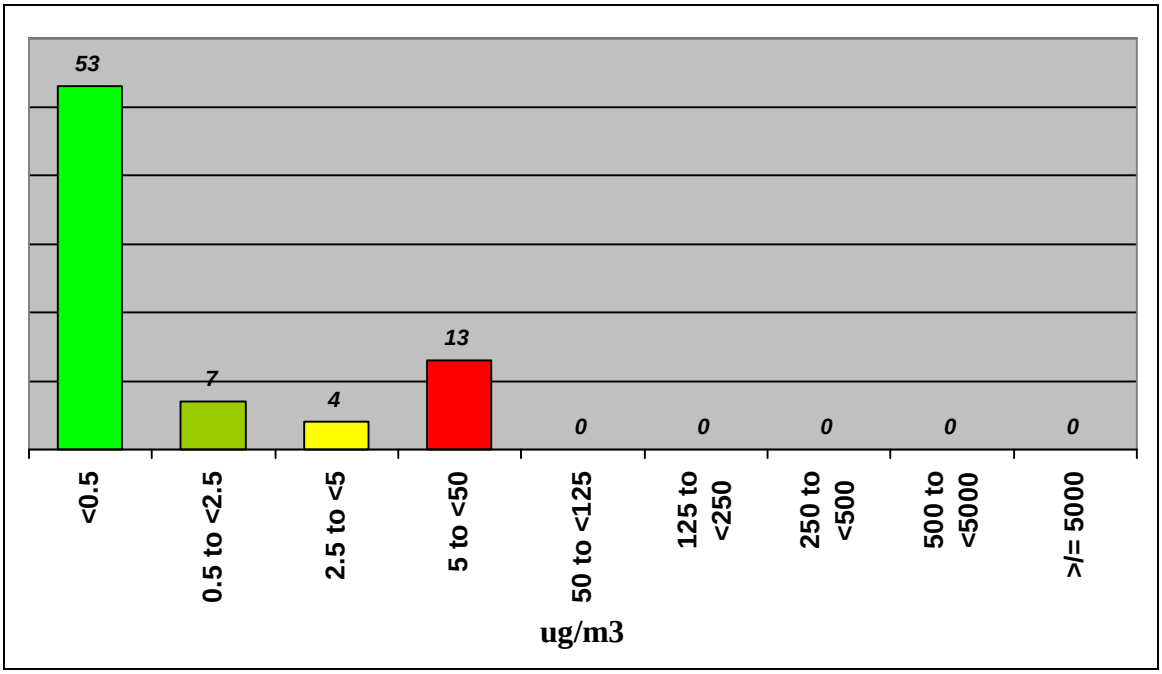
Sixteen samples were collected during TIG welding on chrome steels, and two exceeded the exposure limit. Both were collected during welding on 5% chrome steel inside a fab tent. Both of these samples were collected during grinding and welding on a 5% chrome pipe run to a 9% chrome 90^{o} joint. Both welders were using electrode 8018 during the sampling. Three additional samples were also collected during operations inside a fab tent, but were below the exposure limit. The remaining eleven samples were collected inside a vessel (4 samples) and outside (7 samples), and results were below the PEL.

Of the eighteen samples collected when the base metal was some type of stainless steel, only one exceeded the exposure limit. This was the only sample collected on stainless steel 400-420 (containing 11–13% chromium). During this sampling, the welder was using an Inconel rod and grinding the welds in between welding. This sample was collected during welding tasks inside a vessel. Sample results indicate that concentrations above the exposure limit are unlikely to occur during welding other stainless steels. Ten other samples were collected inside a vessel, and were below the PEL. The remaining seven samples were collected inside a temporary fab tent (3 samples), and in a shop (4 samples).

Table 5: GTAW Results Summary

Base Metals	Total # Samples	# > PEL	Minimum (ug/m3)	Maximum (ug/m3)	Geometric mean	Arithmetic mean
All	77	13	0.008	33.146	0.182	2.726
Carbon steel	5	1	0.017	5.982	0.069	1.216
All Chrome steels	16	2	0.017	11.7	0.288	1.692
• Chrome <2.5%	4	0	0.055	0.122	0.092	0.0963
• Chrome 5%	5	2	0.031	11.7	1.448	4.520
• Chrome 9%	4	0	0.017	0.643	0.053	0.179
• Chrome 12%	3	0	0.38	2.28	0.850	1.123
Galvanized steel	0	0	0	0	0	0
Inconel	38	9	0.008	33.146	0.241	4.423
All Stainless steels	18	1	0.01	5.638	0.088	0.481
• SS 11–13% Cr	1	1	5.638	5.638	5.638	5.638
• SS 17–19% Cr	13	0	0.017	0.83	0.081	0.213
• Stainless (unspecified)	4	0	0.01	0.14	0.040	0.059

Figure 7: GTAW Results Distribution



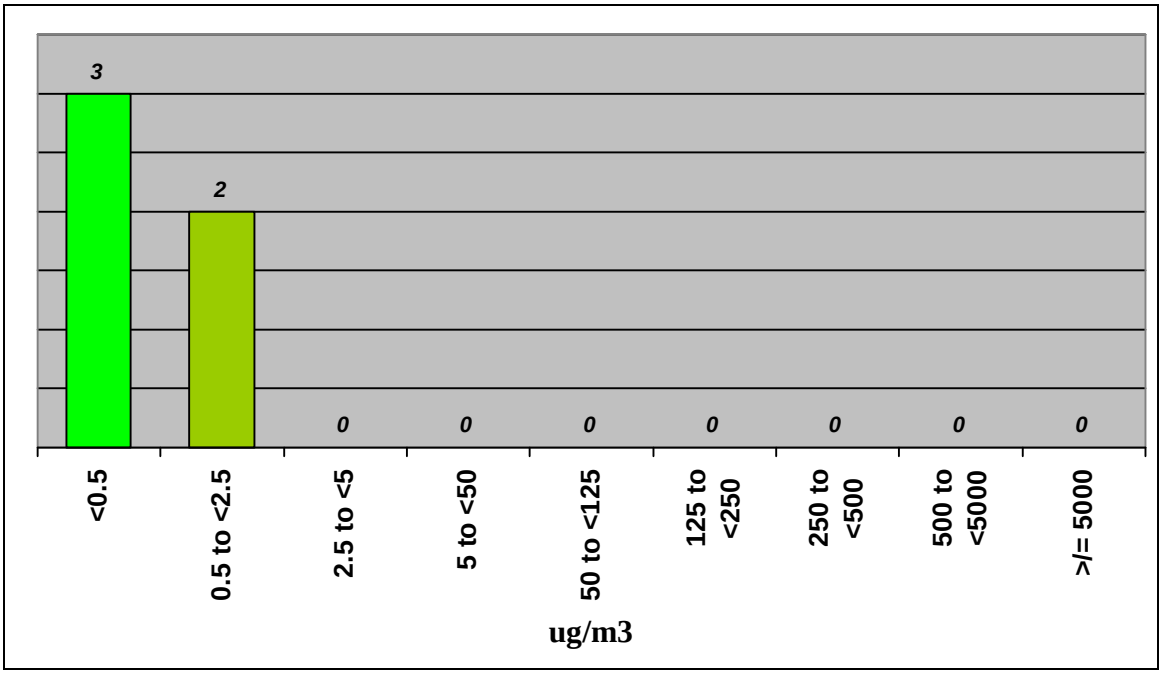
Oxyfuel Cutting (OFC)

Only five samples were collected during OFC (torch cutting). Results generally indicate that exposures are below the exposure limit. Due to the small sample set, specific conclusions cannot be made about this particular type of hot work. Results for these samples are summarized in Table 6:

Table 6: OFC Results Summary

Base Metals	Total # Samples	# > PEL	Minimum (ug/m3)	Maximum (ug/m3)	Geometric mean	Arithmetic mean
All	5	0	0.015	1.125	0.121	0.390
Carbon steel	3	0	0.015	0.099	0.032	0.046
All Chrome steels	0	0	0	0	0	0
Galvanized steel	1	0	1.125	1.125	1.125	1.125
Inconel	0	0	0	0	0	0
All Stainless steels	1	0	0.689	0.689	0.689	0.689
• SS 11-13% Cr	1	0	0.689	0.689	0.689	0.689

Figure 8: OFC Results Distribution



Shielded Metal Arc Welding (SMAW or stick welding)

Only 13 of the 108 samples collected during SMAW (stick welding) exceeded the permissible exposure limit. During welding on carbon steel, only one of 44 samples exceeded the exposure limit and results indicate that exposures above the exposure limit are unlikely to occur. The one sample that exceeded the exposure limit was collected on a welder working inside a vessel, using electrode ENICROM-4. This was the only sample collected using this particular electrode. Fourteen additional samples were collected during stick welding on carbon steel while inside a vessel that were below the exposure limit.

During stick welding on chrome steels, results generally indicate that concentrations will not exceed the exposure limit. Two of the 28 samples exceeded the PEL. The one sample collected during welding on 5% chrome steel that exceeded the exposure limit was collected inside a vessel, using electrode E8018. Two others that were also collected inside a vessel using this electrode were below the exposure limit. The one sample collected on 9% chrome steel that exceeded the exposure limit was collected on an individual working inside a spark enclosure. The individual was also TIG welding and grinding during the monitoring period, which may have contributed to the concentration measured. Five other samples collected inside a spark enclosure were below the exposure limit.

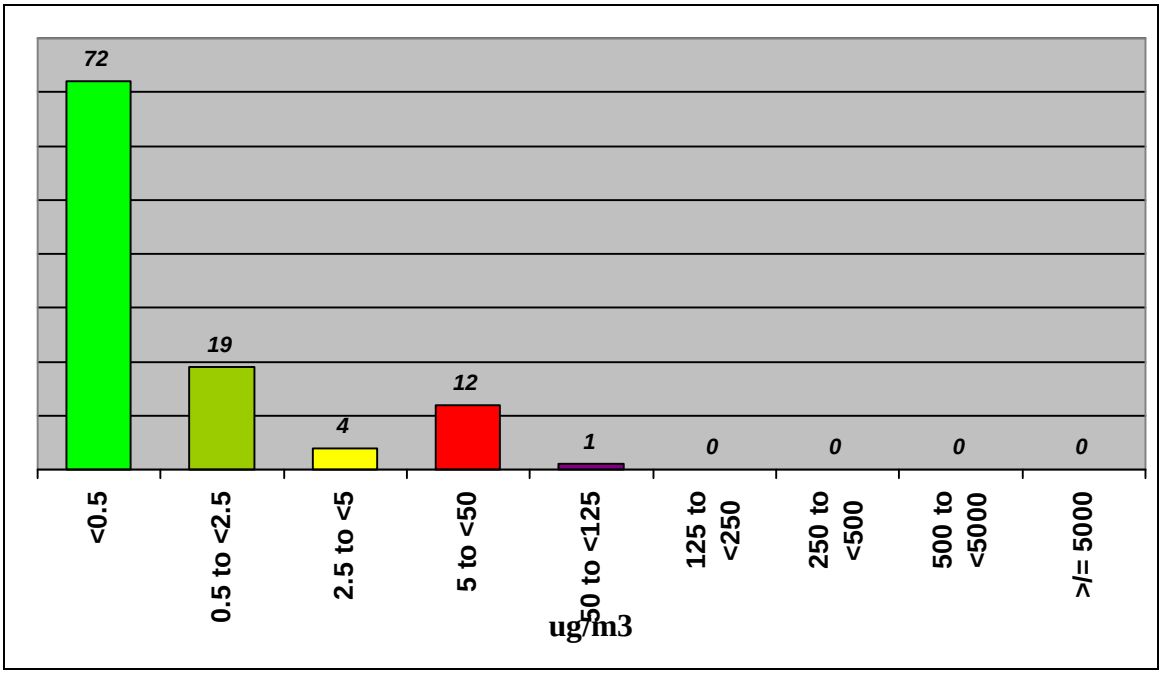
Results for stick welding on galvanized steel indicate that concentrations are not likely to exceed the exposure limit. Only one of the samples was collected inside a vessel. All twenty of the samples results were below the PEL.

Ten of the sixteen samples collected during welding on stainless steels exceeded the PEL. All of the samples were collected during welding inside a vessel. These results indicate that concentrations in excess of the exposure limit are likely to occur.

Table 7: SMAW Results Summary

Base Metals	Total # Samples	# > PEL	Minimum (ug/m3)	Maximum (ug/m3)	Geometric mean	Arithmetic mean
All	108	13	0.008	79.878	0.301	3.371
Carbon steel	44	1	0.008	16.1	0.168	0.709
All Chrome steels	28	2	0.018	23.2	0.295	1.741
• Chrome <2.5%	5	0	0.018	0.15	0.035	0.051
• Chrome 5%	11	1	0.133	8.0	0.729	1.668
• Chrome 9%	12	1	0.018	23.2	0.314	2.511
Galvanized steel	20	0	0.017	0.84	0.141	0.266
Inconel	0	0	0	0	0	0
All Stainless steels	16	10	0.023	79.878	4.002	17.423
• SS 11–13% Cr	11	10	4.114	79.878	17.549	25.199
• SS 17–19% Cr	1	0	0.023	0.023	0.023	0.023
• SS >19% Cr	1	0	0.077	0.077	0.077	0.077
• Stainless (unspecified)	3	0	0.17	1.0	0.371	0.490

Figure 9: SMAW Results Distribution



Conclusions

Based on the results of this survey, some general observations can be made concerning personal exposures to hexavalent chromium based on the type of hot work in conjunction with the base metal. A statistical analysis of the sample results collected during this survey was completed to determine the exceedance fraction or probability of non-compliance. The one-sided 95% upper confidence limit ($UCL_{1,95\%}$) of the exceedance fraction was calculated. If the value of the $UCL_{1,95\%}$ was 20%, we are 95% confident that 20% or less of the exposure profile is above the PEL or Action Level. These conclusions are affected by the number of samples in the sample set, and the statistical calculations are more accurate as the number of samples increases. Calculations were not performed for sample sets of less than six samples.

The following operations had a calculated $UCL_{1,95\%}$ of 20% or more and are considered likely to produce concentrations in excess of the OSHA PEL for chromium (VI):

- FCAW on stainless steel outside
- GMAW on stainless steel inside a vessel
- GTAW on Inconel inside a vessel
- SMAW on stainless steel inside a vessel

The following operations had a calculated $UCL_{1,95\%}$ or 20% or more and are considered likely to produce concentrations in excess of the OSHA Action Level but below the PEL for chromium (VI):

- SMAW on chrome steel outside

The following operations had a calculated $UCL_{1,95\%}$ of less than 20% and are not likely to produce concentrations above the OSHA PEL or Action Level for chromium (VI):

- GMAW on Inconel inside a vessel
- Grinding on carbon steel outside
- GTAW on chrome steels outside
- GTAW on stainless steel inside a vessel
- SMAW on carbon steel regardless of environmental conditions
- SMAW on galvanized steel outside

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