Industry-Wide Survey for Hexavalent Chromium (CrVI) Exposures in Shipyard Operations

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INDUSTRY-WIDE SURVEY FOR HEXAVALENT CHROMIUM (CrVI) EXPOSURES IN SHIPYARD OPERATIONS

This report was prepared by Atrium Environmental Health and Safety Services, LLC (Atrium) under a partnership with the National Shipbuilding Research Program (NSRP) Safety and Health Advisory Committee (SHAC). Data contained in this report was collected and provided to Atrium by participating organizations, including:

- Northrop Grumman Newport News
- Northrop Grumman Ship Systems – Pascagoula
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Ms. Thresa Nelson of Northrop Grumman Newport News was the Project Co-Chair for the project.

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LIMITATIONS

This report was prepared using sound scientific and recognized data analysis techniques. The conclusions presented in this report are based on the data provided by the organizations participating in this project. Every effort has been made by Atrium to assure the accuracy and reliability of the data contained within; however, Atrium makes no representation, warranty, or guarantee in connection with this report and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this report may conflict.

This report is intended to facilitate the broad availability of proven, sound engineering and operating practices. This report is not intended to preclude or interfere with the need for applying sound engineering judgment regarding when and where the conclusions and recommendations should be utilized. The conclusions and recommendations presented in this report are not intended in any way to inhibit anyone from using any other practices that provide effective protection of employee health and safety.

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EXECUTIVE SUMMARY

In February 2006, the Occupational Safety and Health Administration (OSHA) promulgated an expanded health standard for workplace exposures to hexavalent chromium (CrVI). This new standard became effective November 27, 2006 for large employers. This new standard has significant impact on the shipbuilding industry. In order to promote a practical and well-directed compliance effort, the shipbuilding industry determined the need to collect and review existing historical objective CrVI exposure monitoring data. This survey was designed to be a resource that characterizes exposures by activity; and, if necessary, identifies those activities where additional monitoring may better characterize exposures.

Initially, 1,413 records were collected and analyzed from participating organizations and other available data sources. These records represented hot work processes, paint removal processes, and other processes where CrVI exposures were measured. Following the Quality Assurance and Data Verification process, the data set that was analyzed included:

- Eleven separate job descriptions were represented in 601 discrete 8-hour time-weighted average (TWA) exposure results.
- 32 separate activities were represented in 613 discrete TWA exposure results. These included:
    - 527 discrete 8-hour TWA results were represented in 560 exposure monitoring results collected during hot work activities.
    - 83 discrete 8-hour TWA results were represented in the 95 exposure monitoring results collected during paint removal activities
    - 3 discrete 8-hour TWA results were represented in monitoring results collected during other activities where CrVI exposures may exist.

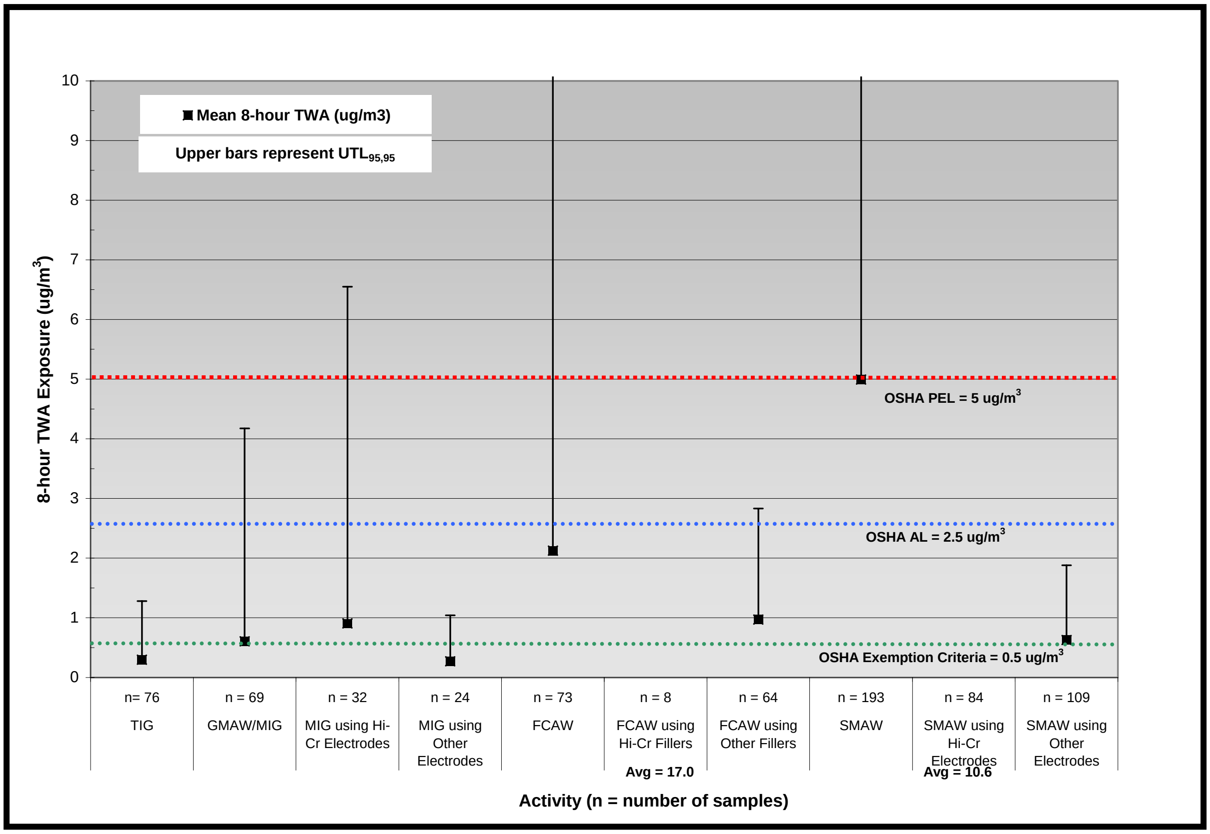
Only 10% of the 613 validated 8-hour TWA CrVI exposure results provided by participating organizations exceeded the OSHA PEL for CrVI of 5µg/m^3. The data can be summarized as follows:

- 337 results, or 55%, were less than the OSHA compliance exemption criterion of 0.5µg/m^3.
- 174 results, or 28%, were greater than the OSHA compliance exemption criteria but less than the OSHA Action Level of 2.5µg/m^3. Cumulatively, 83% of the results were less than the Action Level for CrVI.
- 39 results, or 6%, were greater than the OSHA Action Level but less than the OSHA permissible exposure limit (PEL) of 5µg/m^3. Cumulatively, 90% of the results were less than the PEL for CrVI.

Some general observations can be made concerning exposures to CrVI.

1. Based on the data provided by participating organizations, it appears that most occupational exposures to CrVI during work processes and activities representative of ship repair operations are well characterized and well controlled.
2. For welding activities, the filler/electrode was considered in characterizing exposures. Higher exposures were measured during the use of filler metals or electrodes that contain more than 10% chromium (Cr). Figure A summarizes CrVI exposures during welding based on the filler metal/electrode. TIG welding is not summarized by filler metal because the filler metal was not reported in several records.

Figure A – Exposure Characterization by Hot Work Activity: Welding

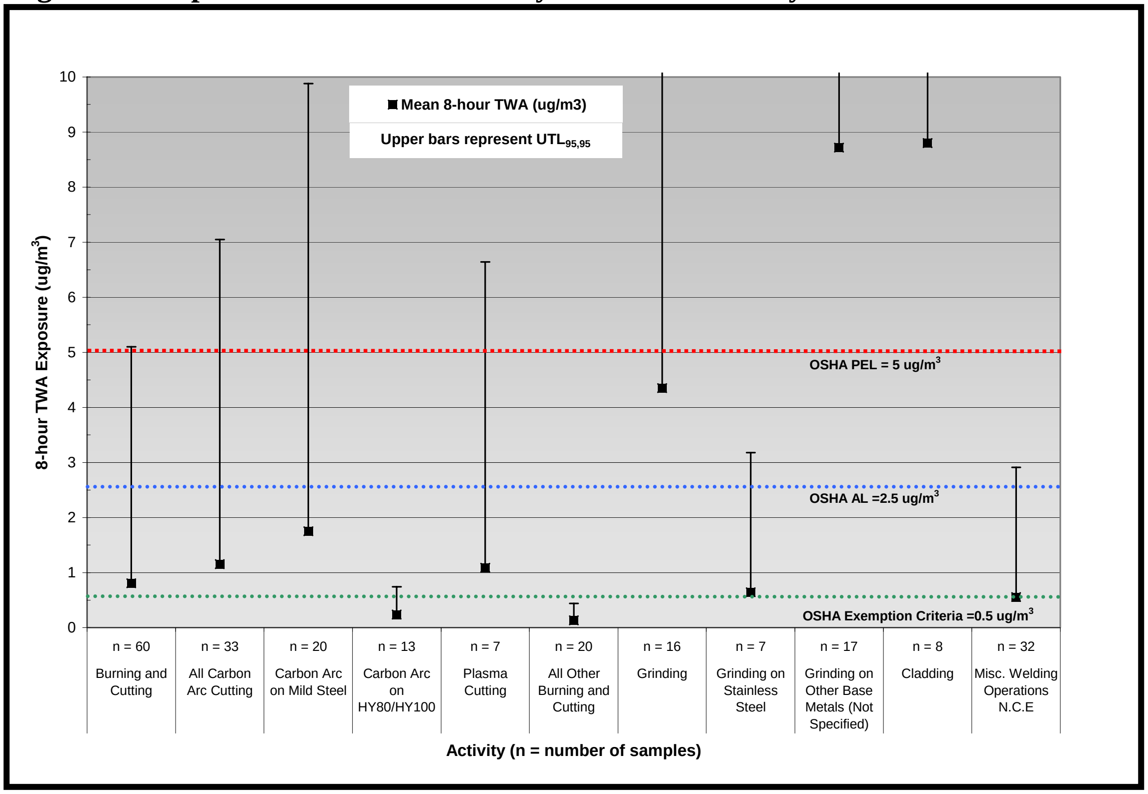


Note: data include only those records where the filler metal/electrode used was reported.

3. Relatively low exposures to CrVI were measured during carbon arc cutting on HY80 and HY100 and "Burning" or "Cutting" on AH36, carbon steel, GR B steel, and HY100. Figure B summarizes CrVI exposures during hot work activities other than welding.
4. In comparing the mean exposures to CrVI for those records where the Cr content in paint was reported, there appears to be some relationship between the Cr content and CrVI exposures. However, a more detailed analysis would need to be conducted to assess if a trend exists. Figure C summarizes CrVI exposures during paint removal and electroplating activities.
5. In comparing mean exposures based on the size of a workspace and the ventilation controls used, the following observations can be made:
   - Exposures were lower when local ventilation was used rather than natural/general ventilation in spaces smaller than 2,000 cubic feet (ft^3).
   - There was no notable difference in exposures when comparing local and natural/general ventilation in spaces between 2,000 and 5,000 ft^3.
   - Exposures were lower when local ventilation was used rather than natural/general ventilation in spaces larger than 5,000 ft^3.

   While interesting, the data provided do not allow a definitive comparative analysis of the type of ventilation used and the space configuration that yields any consistent trend.

Figure B – Exposure Characterization by Hot Work Activity: Other Hot Work Activities



Notes: "All Other Burning and Cutting" includes work on AH36, carbon steel, GR B steel, and HY100
NEC = not classified elsewhere.

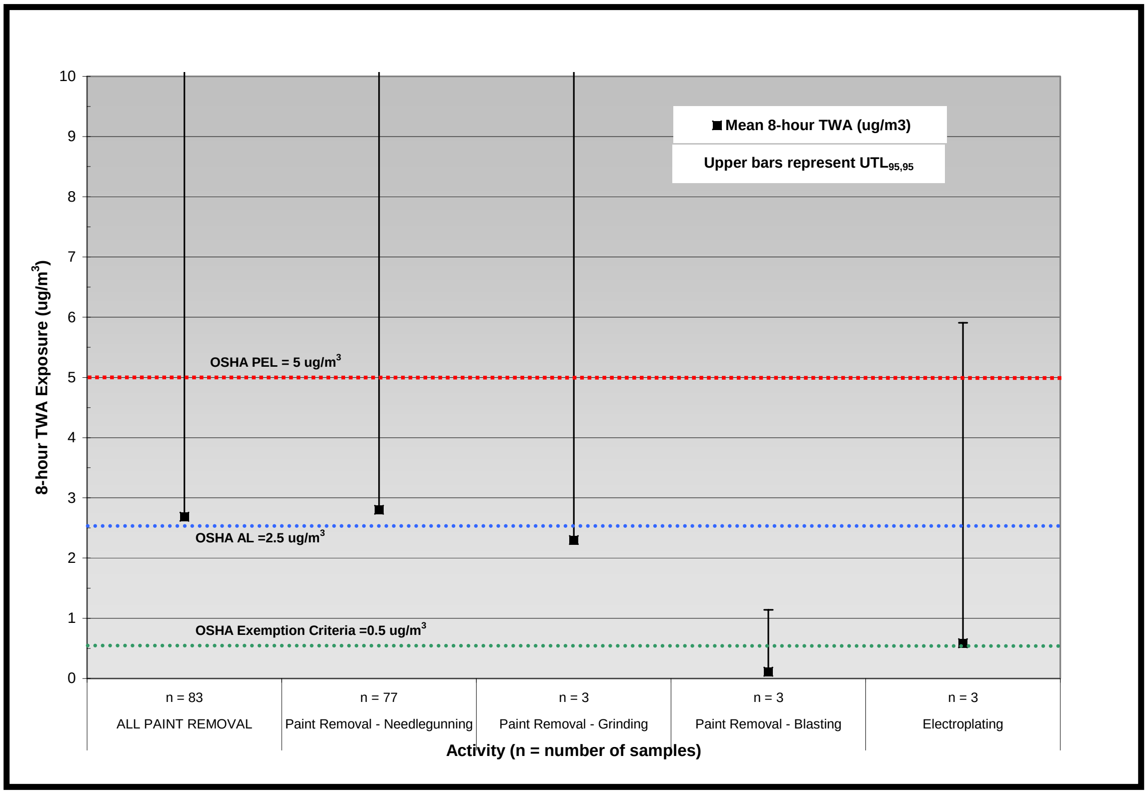
6. A comparison of the exposure data from other data sources shows similarity in the exposure distributions for most of the activities assessed in these studies. The most notable differences are seen in TIG and MIG welding, where the *Hexavalent Chromium Exposures During Hot Work* study completed in October 2006 by the American Petroleum Institute (API)[1] shows more exposures that exceeded the PEL than the previously published U.S. shipyard industry air sampling data reported in the National Shipbuilding Research Program (NSRP) January 1999 *Welding Fume Study Final Report*[2] and the Maritime Advisory Committee for Occupational Safety and Health (MACOSH) exposure studies.[3] This observation supports the value and need for industry-specific assessments and analysis of objective exposure data.
7. The data submitted for paint removal by blasting were very limited in comparison to the frequency that this activity is typically conducted in shipyards, and therefore should not be considered representative.

Survey findings and recommendations for further evaluations of industry-specific pooled objective data include:

1. For several activities, the mean 8-hour TWA CrVI exposures were less than the Action Level and the $UTL_{95\%,95\%}$ level was less than the PEL. While these activities should continue to be monitored, further routine collection of exposure data is not recommended unless processes change significantly.[4] These activities include:
   a. TIG welding;
   b. MIG welding on non-CRES metals using non-Hi-Cr electrodes;

c. FCAW on non-CRES metals using non-Hi-Cr filler metals;
d. SMAW on AH-36 using non-Hi-Cr electrodes;
e. Carbon arc cutting on HY-80/HY-100; and,
f. "Burning" or "Cutting" on AH36, carbon steel, GR B steel, and HY100.

Figure C – Exposure Characterization by Paint Removal and Electroplating Activities



2. Additional exposure monitoring may better characterize those activities with smaller sample sizes, and reduce the variability among the sample population. Those activities where additional exposure monitoring should be considered include:
   a. MIG welding on CRES base metals;
   b. FCAW on CRES base metals;
   c. SMAW on CRES base metals;
   d. Carbon arc cutting;
   e. Plasma cutting;
   f. Grinding;
   g. Cladding;
   h. Paint removal by needlegunning;
   i. Paint removal by grinding; and,
   j. Electroplating.

3. To allow for the most comprehensive analysis of industry-specific pooled objective data, a standardized industrial hygiene data collection form should be developed and used by all NSRP participants collecting exposure monitoring data.
   In collecting this information, future data collection records can be incorporated into the data set provided for this Study to enhance and expand the analysis.

4. The following relationships should be assessed further in an effort to develop standardized evaluation and industrial work practices;
   a. The relationship between the chromium content in paint and coating surfaces and CrVI exposures during routine coating removal activities including grinding and needlegunning.
   b. The relationship between the chromium content in filler metals and electrodes, base metals, and CrVI exposures.
   c. The relationship between ventilation, space size and exposure is somewhat understood, particularly in working in confined or enclosed spaces. However, the use of "push-pull" type ventilation systems and the effective working distance (capture velocity) could not be effectively assessed based on the current data. A more detailed analysis, which may require additional exposure monitoring and data collection, should be considered.

It is important to note that the limits of analyzing how ventilation and space configuration influence exposures using data provided do not negate the value of ventilation in controlling exposures. The use of ventilation (particularly localized ventilation in confined, enclosed or restricted spaces) is a very important and effective engineering control, and should be implemented when local conditions warrant its use or policies require its use.

The information from this survey should be used to promote a consistent understanding within the industry – both among and between different shipyards – of the proper and effective control methods to protect the health of shipyard employees, contractors and visitors.

The analysis of the data provided yields practical information that smaller shipyards and organizations with limited industrial hygiene resources can use to characterize and control exposures by activity. We recognize that larger shipyards and organizations with experienced industrial hygiene resources may have conducted a more thorough analysis and have better characterized and controlled CrVI exposures in their operations. In all instances, local data, exposure characterizations and established methods for controlling exposures should take precedence over an analysis of pooled objective data.

INTRODUCTION

In February 2006, the Occupational Safety and Health Administration (OSHA) promulgated an expanded health standard for workplace exposures to hexavalent chromium (CrVI), 29CFR1015.1026. This new standard became effective November 27, 2006 for large employers. This new standard has significant impact on shipbuilding industry. Compliance with the standard requires employers to assess workplace exposures through air monitoring. Collecting new data for all possible exposure-producing operations in the industry would not be feasible due to cost and time requirements. In addition, exposures during many operations are likely to be below the established Action Level of 2.5 micrograms of CrVI per cubic meter of air ($\mu g/m^3$) requiring employers to initiate compliance actions. Finally, an exemption from compliance with the standard is provided for employers who have objective data demonstrating that a material containing chromium or a specific process, operation, or activity involving chromium cannot release CrVI dusts, fumes, or mists in concentrations at or above 0.5 $\mu g/m^3$ as an 8-hour time-weighted average (TWA) under any expected conditions of use. This exception for situations where exposures are not likely to present significant risk to employees allows employers to focus their resources on exposures of greater occupational health concern.[5]

OSHA has recognized that collecting new data for all possible exposure-producing operations as a possible obstacle in characterizing exposures; and to promote a more practical application of valuable resources where needed, accepts a performance-oriented option of using “objective historical data” from industry-wide surveys for compliance with exposure determination requirements (29CFR1915.1026(d)(3)). To meet OSHA’s definition of acceptable “objective data,” the data must be representative of:

- workplace conditions closely resembling the processes;
- types of material;
- control methods;
- work practices; and,
- environmental conditions similar to current operations.

In order to promote a practical and well-directed compliance effort, the shipbuilding industry determined the need to collect and review existing historical objective CrVI exposure monitoring data. This survey was designed to be a resource that characterizes exposures by activity; and, if necessary, identifies those activities where additional monitoring may better characterize exposures. This survey is especially valuable for small businesses, which may lack the resources to conduct their own exposure monitoring in an effort to comply with the standard.

The goal of this survey was to reduce the need for undertaking costly monitoring efforts for activities where exposures are already well characterized and are known to be below the OSHA Action Level, allowing employers to focus their resources on exposures of greater occupational health concern. In addition, the data from this can be used to promote a consistent understanding within the industry – both among and between different shipyards – of the proper and effective control methods to protect the health of shipyard employees, contractors and visitors.

METHODOLOGY

Data Collection

Existing representative CrVI exposure monitoring data for the shipyard industry was identified and retrieved from those organizations that participated in this survey. To ensure consistency in the data received from participating organizations, critical data elements required to characterize existing exposure data to meet the OSHA's definition of "objective data" were identified. These critical data elements included:

- process or activity;
- job description;
- materials used;
- control methods;
- work practices; and,
- environmental conditions.

In addition to the activity-related information, data elements necessary to evaluate the monitoring results were also identified. These included:

- sample date;
- sample duration;
- sampling and analytical technique used;
- sample volume;
- sample result;
- unit of measure; and,
- full-shift time-weighted average (TWA) exposure.

Organizations that agreed to participate in this survey to collect available CrVI exposure data were contacted, and Microsoft Excel spreadsheets formatted to collect the critical data elements described above were sent to participating organizations. Copies of spreadsheets used in the data collection effort are included in Exhibit B. All requests for data were documented, and follow-up on outstanding requests was conducted as needed.

Research on other available data sources summarizing CrVI exposures measured during activities and tasks similar to those conducted in shipyards was also conducted. This research included:

- peer-reviewed studies of shipyard industry operations;
- other industry-wide studies;
- Navy studies and exposure monitoring data;
- studies conducted by the National Institute for Occupational Safety and Health (NIOSH); and,
- exposure evaluations conducted by OSHA.

Data Analysis

Once the requested data was received and research on other data sources was complete, the exposure data was compiled and analyzed. Data was sorted and analyzed by:

- job description;

- process or activity;
- location of work;
- materials used; and,
- type of ventilation used.

All proprietary or sensitive information that was not necessary for the data analysis, such as the specific shipyard or organization submitting the data and employees' personal information was removed from the database.

Because OSHA has established exposure limits for CrVI based on an 8-hour TWA, only 8-hour TWA results were analyzed. Data was analyzed using descriptive statistics to assess and characterize exposures in accordance with guidelines referenced in recognized publications. Data analysis included identifying the:

- Number of 8-hour TWA samples (n) included in each category analyzed;
- Minimum reported 8-hour TWA exposure for each category analyzed;
- Maximum reported 8-hour TWA exposure for each category analyzed;
- Range of reported 8-hour TWA exposures for each category analyzed;
- Mean (arithmetic average) of the 8-hour TWA exposures for each category analyzed;
- Geometric mean (GM) of the 8-hour TWA exposures for each category analyzed;
- Geometric standard deviation (GSD) of the 8-hour TWA exposures for each category analyzed; and,
- Upper tolerance limit ($UTL_{95\%,95\%}$) for each category analyzed. The UTL is a one-sided upper confidence limit for a selected probability level (confidence limit) and a selected coverage of the sample population. The $UTL_{95\%,95\%}$ represents the exposure level that, at 95% confidence, is greater than 95% of the measured exposures within a given category. In other words, one can be 95% confident that 95% of the exposures within a given category are below the $UTL_{95\%,95\%}$.[6]

Data from the statistical analysis was summarized to identify the following for each job description, process or activity, and materials used:

- Those categories that show exposures less than the 0.5μg/m^3 exemption criterion;
- Those categories that show exposures in the range of 0.5μg/m^3 to the OSHA Action Level of 2.5μg/m^3; and,
- Those categories that show exposures in the range of 2.5μg/m^3 to the OSHA permissible exposure limit (PEL) of 5μg/m^3; and,
- Those categories that show exposures above the PEL.

Quality Assurance and Data Verification

A review was conducted following an initial statistical analysis of all of the data collected to identify possible outliers – those sample results that were notably higher or notably lower than all other results within a given category. This review included assessing each record to verify that:

- Job descriptions, activities and materials used were consistent within the category analyzed;
- Job descriptions, activities and materials used were representative of shipyard activities;
- Work environments and engineering controls within a category were similar;
- Weapon systems and work pieces, work environments and engineering controls were representative of shipyard activities;

- Sampling and analytical methods within a category were specific for CrVI;
- Units of measure were consistent (i.e.; mg/m^3 vs. µg/m^3);
- 8-hour TWA results for full-shift consecutive samples were not reported for each sample and duplicated;
- Measured exposures were reported correctly (e.g.; decimal point location was correct).

In cases where simple conversions could address deviations (i.e.; changing results reported as mg/m^3 to µg/m^3), results were converted. In cases where job descriptions, work activities, weapons systems or work pieces were not representative of shipyard operations, or where sampling and analytical methods were not specific for CrVI, records were removed from the data set. In cases where results were considered outliers, the records were sent to the organization that submitted the data for verification.

Many of the samples results reported in the data were below the analytical limit of quantification (LOQ). Because these results provide critical information regarding the exposure profile, they were not discarded in the analysis of the data. Because of the relatively wide distribution of the results, samples reported as less than the LOQ were considered to have CrVI concentrations of 50% of the LOQ[6]. Results reported as zero (0) were not considered valid, and were not included in the statistical analysis of the data sets.

Summary of Data

Initially, 1,413 records were collected and analyzed from participating organizations and other available data sources. These records represented hot work processes, paint removal processes, and other processes where CrVI exposures were measured. Following the Quality Assurance and Data Verification process, the data set that was analyzed can be summarized as follows:

- Eleven separate job descriptions were represented by 601 discrete 8-hour TWA exposure results in the data analyzed:
  - Blasters;
  - Electricians;
  - Electroplaters;
  - Fire Watch;
  - Machinists & Sheetmetal Workers;
  - Painters;
  - Pipefitters;
  - Shipfitters and Fitters;
  - Plasma Operators
  - Welders; and,
  - Others (including Engineering Technician, Electronics Apprentice, Grinder, HAB, and Environmental).

  In instances where the job description was not reported or reported as “Unknown” in the data set, the 8-hour TWA result was not used in assessing exposures by job description.

- Thirty-two (32) separate activities were represented in 675 discrete TWA exposure results. These included:
  - For hot work activities:

  - 560 samples collected during hot work activities were verified as accurate; and,
  - 527 discrete 8-hour TWA results were represented in the 560 hot work samples collected.
- For paint removal activities:
  - 95 samples collected during paint removal activities were verified as accurate; and,
  - 83 discrete 8-hour TWA results were represented in the 95 paint removal samples collected.
- For other activities where CrVI exposures were measured:
  - 20 samples collected during other activities where CrVI exposures were measured were verified as accurate; and,
  - 16 discrete 8-hour TWA results were represented in the 20 samples collected. However, 13 of the 8-hour TWA results representing milling activities were reported as zero (0) and could not be included in the statistical analysis.

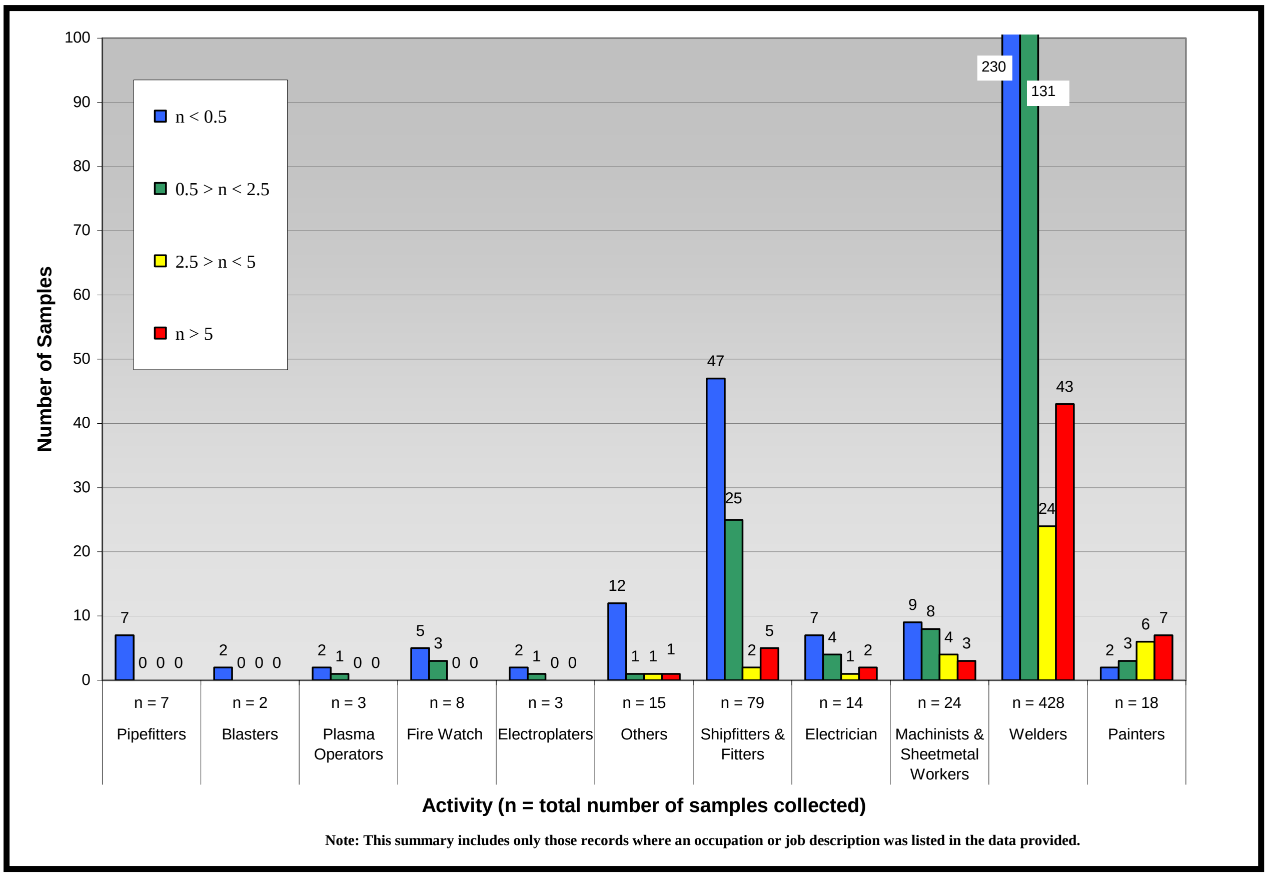
DISCUSSION

Hexavalent chromium (CrVI) fumes can be produced during welding and other hot work operations, even if the chromium present in materials or the base metal was originally in another valence state. During paint removal activities, chromates present in primers and other coatings remain in their hexavalent state even after years of exposure to weather and the environment. The coating dust generated during paint removal activities can contain CrVI. Chromic acid, a CrVI compound, is used in certain electroplating processes. These are all work processes and activities that are routinely conducted in shipyards.

Exposures by Job Description

Eleven separate job descriptions were represented by 601 discrete 8-hour TWA exposure results in the data analyzed. In instances where the job description was not reported in the data set, the 8-hour TWA result was not used in assessing exposures by job description. The category “Others” includes those job descriptions that occurred rarely in the records. Job descriptions in the “Others” category include Engineering Technician, Electronics Apprentice, Grinder, HAB, and Environmental. The distribution of 8-hour TWA exposures by job description is summarized in Figure 1. Exposure values are reported in μg/m^3.

Figure 1 – Exposure Distribution by Job Description



Descriptive statistics for each job description are summarized in Table 1. Exposure values are reported in µg/m^3.

Table 1 – Summary of Exposures by Job Description

Job Description	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%,95\%}$
Pipefitters	n = 7	0.025	0.3	0.12	0.094	2.136	0.4
Blasters	n = 2	0.050	0.3	0.15	0.112	3.121	1.2
Plasma Operators	n = 3	0.026	1.0	0.35	0.111	6.842	4.5
Fire Watch	n = 8	0.130	1.1	0.45	0.290	2.700	0.7
Electroplaters	n = 3	0.21	1.3	0.59	0.409	2.735	5.3
Others	n = 15	0.006	5.2	0.71	0.131	6.842	4.5
Shipfitters & Fitters	n = 79	0.020	11.0	1.05	0.336	4.672	5.0
Electrician	n = 14	0.037	8.8	1.73	0.531	5.351	8.9
Machinists & Sheetmetal Workers	n = 24	0.080	10.1	2.18	0.867	4.300	9.0
Welders	n = 428	0.0003	67.0	2.97	0.424	6.646	18.5
Painters	n = 18	0.080	29.1	6.63	3.192	4.538	26.2

Data analysis shows that the mean exposure for pipefitters, blasters, plasma operators, and fire watch personnel is below the OSHA criteria for exemption from the standard, which is 0.5µg/m^3. However, the UTL$_{95\%,95\%}$ for all categories except pipefitters is above this criteria. The following observations were made from the data:

1. Based on the data analyzed, there is 95% confidence that 95% of the measured exposures for the Pipefitters and Fire Watch Personnel were below the OSHA Action Level.
2. Based on the data analyzed, there is 95% confidence that 95% of the measured exposures for Plasma Operators and “Other” job descriptions were below the OSHA PEL.
3. The mean exposure for painters is above OSHA PEL.

The data submitted for abrasive blasting were very limited in comparison to the frequency that this activity is typically conducted in shipyards, and therefore should not be considered representative. Given the limited number of records provided on abrasive blasting and the information that can be extracted from the records, the application of these findings should be limited until exposures are more thoroughly characterized.

Exposures by Work Processes and Activities

<u>Hot Work</u>

Eight separate hot work processes were represented by 527 discrete 8-hour TWA exposure results in the data analyzed. Descriptive statistics for each hot work activity are summarized in Table 2. Exposure values are reported in µg/m^3.

Table 2 – Summary of Exposures by Hot Work Activity

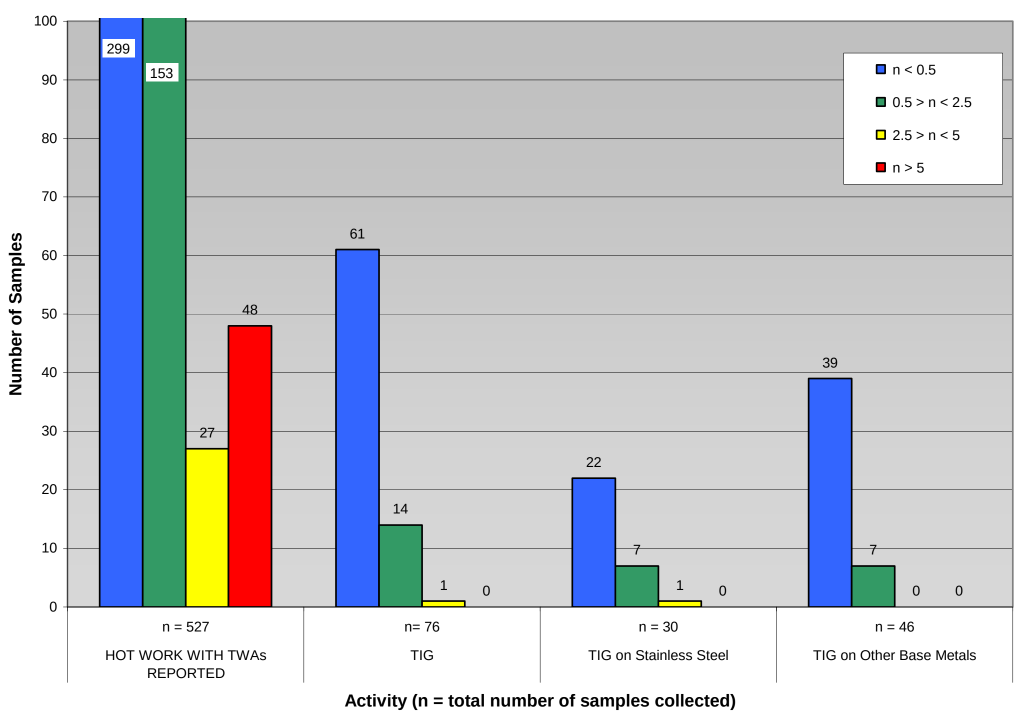
Activity	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%,95\%}$
Hot Work with TWAs Reported	527	0.0003	67.0	2.63	0.370	6.655	18.6
TIG	76	0.0003	3.50	0.30	0.117	4.614	1.3
GMAW/MIG	69	0.002	14.4	0.61	0.184	4.168	4.2
FCAW	73	0.002	36.0	2.12	0.791	4.078	12.0
SMAW	193	0.050	67.0	4.99	0.824	6.728	26.4
Burning and Cutting	60	0.020	11.0	0.81	0.173	4.443	5.1
Grinding	16	0.015	38.0	4.35	0.252	9.235	33.2
Cladding	8	0.100	57.9	8.80	1.625	6.668	72.3
Misc. Welding Operations N.C.E	32	0.002	4.60	0.56	0.144	6.721	2.9

N.C.E. = not classified elsewhere

Detailed summaries of each hot work activity are presented below.

<u>Gas Tungsten Arc Welding (GTAW)/Tungsten Inert Gas (TIG) Welding.</u> A total of 76 discrete 8-hour TWA exposure results representing GTAW/TIG welding were analyzed. TIG welding on stainless steel and on other base metals was compared to all hot work. The distribution of 8-hour TWA exposures during TIG welding is summarized in Figure 2. Exposure values are reported in µg/m^3.

Figure 2 – Exposure Distribution Comparing All Hot Work to TIG Welding by Base Metal



Descriptive statistics for TIG welding are summarized in Table 3. Exposure values are reported in µg/m^3.

Table 3 – Summary of TIG Welding Exposures

Activity	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%,95\%}$
All TIG Welding	76	0.0003	3.5	0.30	0.117	4.614	1.3
TIG on Stainless Steel	30	0.0003	3.5	0.40	0.124	6.463	1.9
TIG on Other Base Metals	46	0.006	1.3	0.23	0.113	3.612	0.9

Data analysis shows that the mean exposure during TIG welding, regardless of the base metal, is below the OSHA criteria for exemption from the standard. Based on the data analyzed, there is 95% confidence that 95% of the measured exposures during TIG welding were below the OSHA Action Level, regardless of the base metal.

TIG welding was not summarized by filler metal because the filler metal was not reported in several of the data records.

Gas Metal Arc Welding (GMAW)/Metal Inert Gas (MIG) Welding. A total of 69 discrete 8-hour TWA exposure results representing GMAW/MIG welding were analyzed. MIG welding on various base metals was compared to all hot work. The distribution of 8-hour TWA exposures during MIG welding summarized by base metal is shown in Figure 3. The distribution of 8-hour TWA exposures during MIG welding summarized by the type of electrode is shown in Figure 3A. Electrodes containing more than 10% chromium (Cr) were classified as Hi-Cr electrodes. Exposure values are reported in µg/m^3.

Descriptive statistics for MIG welding are summarized in Table 4. Exposure values are reported in µg/m^3.

Table 4 – Summary of GMAW/MIG Welding Exposures

Activity	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%,95\%}$
All MIG Welding	69	0.002	14.4	0.61	0.184	4.168	4.2
MIG on Stainless Steel	4	0.020	0.30	0.18	0.122	3.476	0.9
MIG on CRES 304	5	0.200	3.40	1.18	0.744	2.940	6.6
MIG on 316	6	0.100	14.4	3.17	0.623	8.509	24.0
MIG on Hy-80/HY-100	32	0.020	2.0	0.30	0.150	3.078	1.3
MIG on AH-36	7	0.027	0.10	0.07	0.065	1.820	0.2
MIG on Inconel	3	0.300	1.30	0.67	0.538	2.175	4.9
MIG on HTS	4	0.050	0.40	0.15	0.100	2.665	1.0
MIG on Other Metals	11	0.080	1.10	0.44	0.279	2.845	1.6
MIG using Hi-Cr Electrodes	32	0.022	14.4	0.91	0.252	4.230	6.6
MIG using Other Electrodes	24	0.020	1.40	0.27	0.145	3.043	1.0

Figure 3 – Exposure Distribution Comparing All Hot Work to MIG Welding by Base Metal

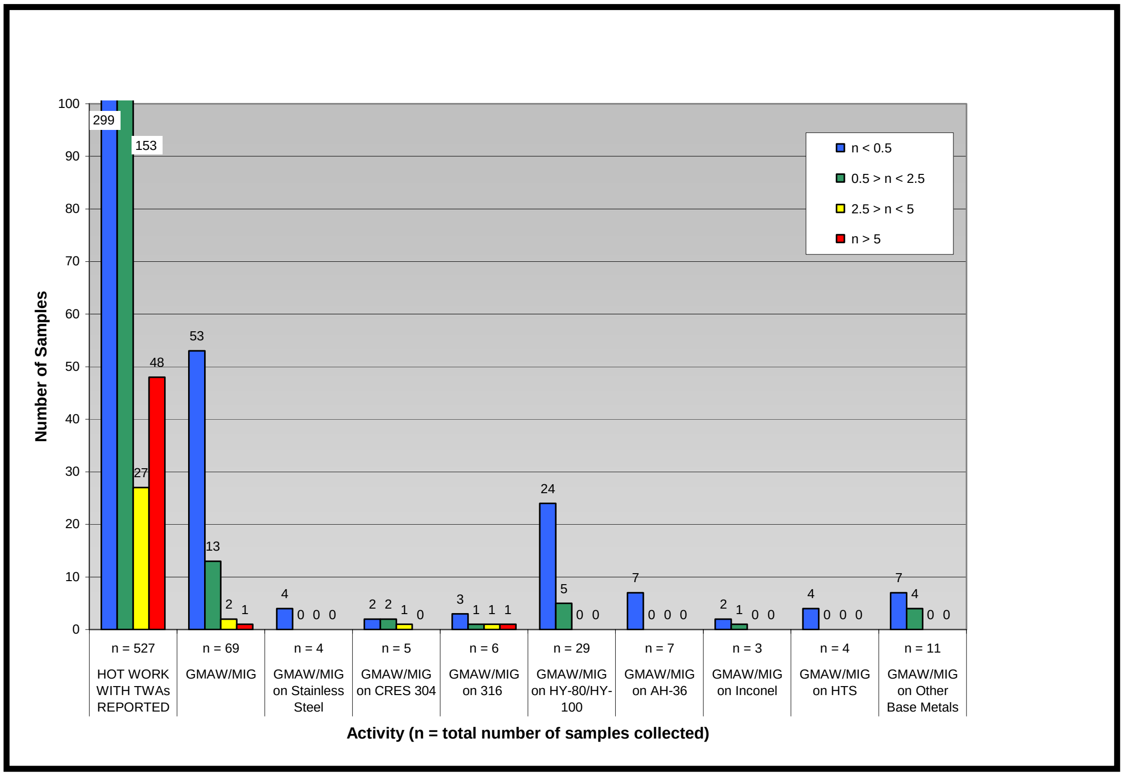
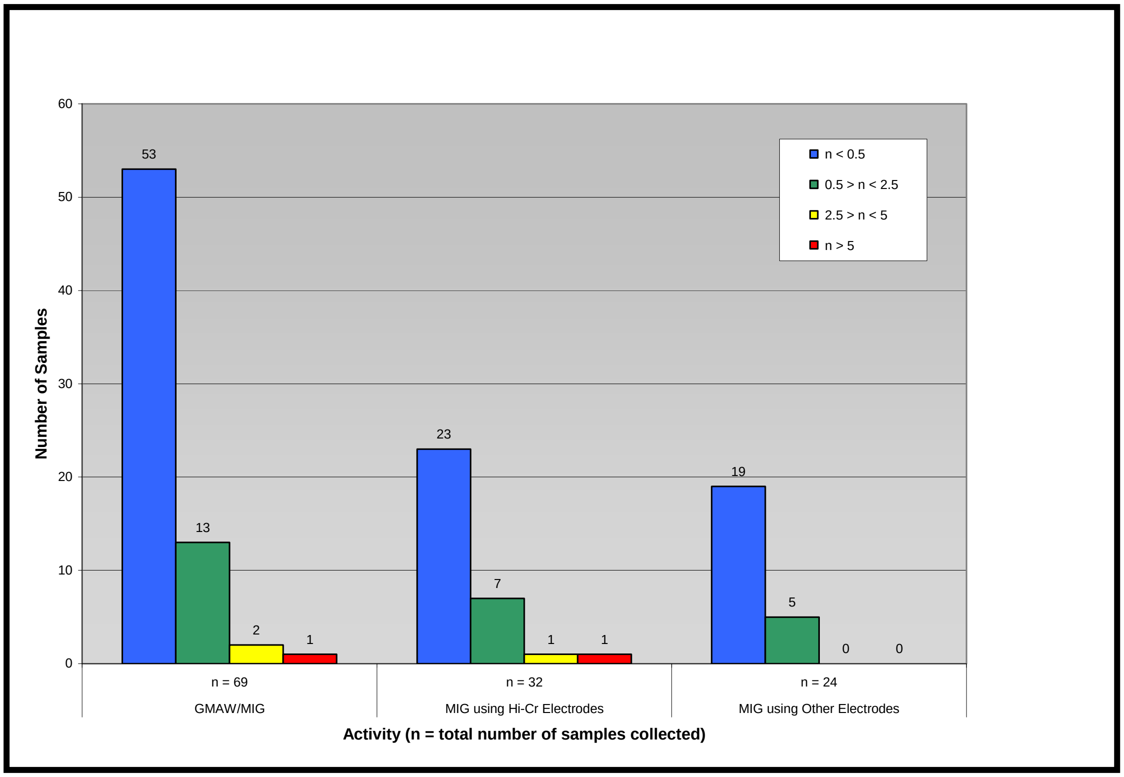


Figure 3A – Exposure Distribution of MIG Welding by Electrode Type



Data analysis shows that the mean exposure during MIG welding is below OSHA Action Level. Based on the data analyzed, there is 95% confidence that 95% of the measured exposures during MIG welding were below the OSHA Action Level for welding on HY-80, HY-100, and AH-36.

Higher exposures were measured during work on corrosion resistant (CRES) metals. While measured exposures during work on "stainless steel" were well below the OSHA Action Level, other CRES metals, including Inconel, 304, and 316 had higher measured exposures. Based on the data analyzed, there is a significant probability that measured exposures during MIG welding on CRES base metals could exceed the OSHA PEL.

Analyzing the data based on the type of electrode, it is clear that those electrodes containing more than 10% chromium (referred to as Hi-Cr electrodes in this report) result in substantially higher CrVI exposures than those that contain little or no chromium. Hi-Cr electrodes and filler metals reported in the data are shown in Table 5. Based on the data analyzed, there is 95% confidence that 95% of the measured exposures during MIG welding with electrodes that do not contain substantial amounts of chromium were well below the OSHA Action Level.

Table 5 – Summary of Hi-Cr (>10% Cr) Electrodes and Filler Metals Reported

309	308L,309L 1/8" and 3/32"
316	308L-16
625	308LT-1
30815	309-16 3/32" D
30816	309Cb
#308 L Rod	309Cb-16
#309-15	309L 3/32"
#310 Rod	316L
#310-16 Rod	8N12
1N12	ER347
30816, 7018	rods 308L

Flux Cored Arc Welding (FCAW). A total of 73 discrete 8-hour TWA exposure results representing GMAW/MIG welding were analyzed. FCAW welding on stainless steel, mild steel, AH-36, and on other base metals was compared to all hot work. The distribution of 8-hour TWA exposures during FCAW welding is summarized in Figure 4. The distribution of 8-hour TWA exposures during FCAW welding summarized by the type of filler metal is shown in Figure 4A. Filler metals containing more than 10% chromium (Cr) were classified as Hi-Cr fillers. Exposure values are reported in $\mu g/m^3$.

Descriptive statistics for FCAW welding are summarized in Table 6. Exposure values are reported in $\mu g/m^3$.

Figure 4 – Exposure Distribution Comparing All Hot Work to FCAW Welding by Base Metal

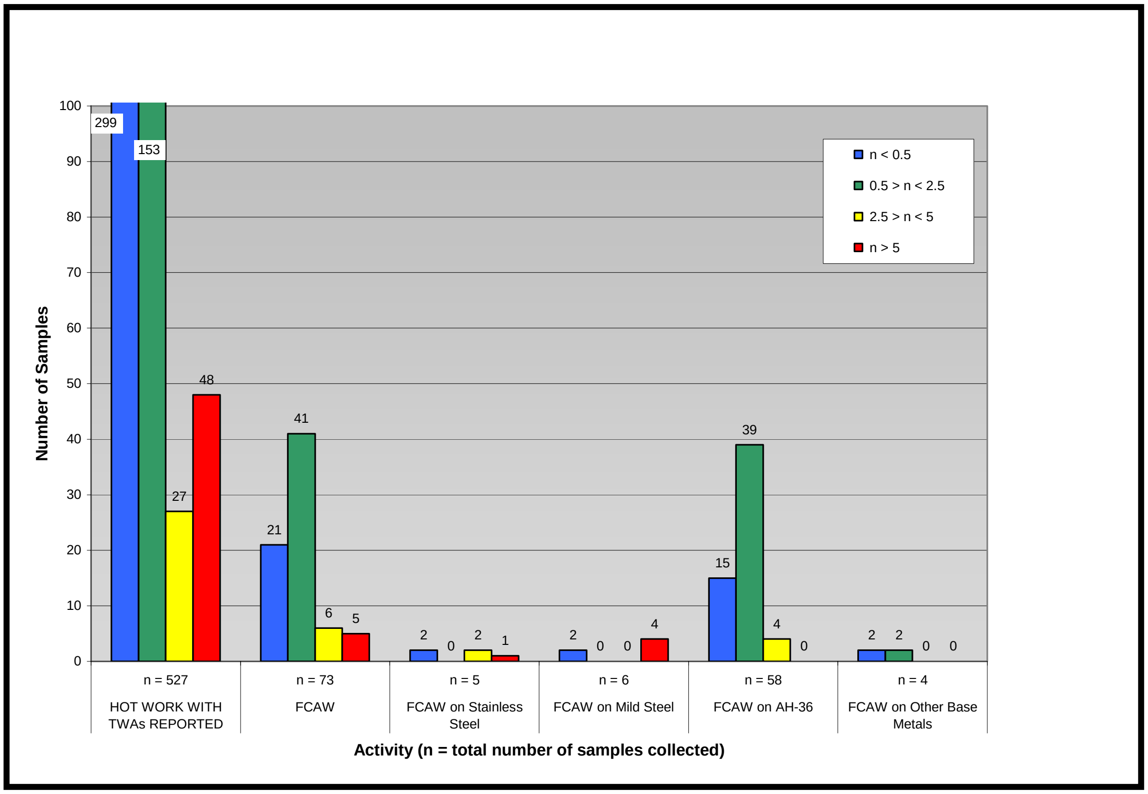


Figure 4A – Exposure Distribution of FCAW by Filler Metal Type

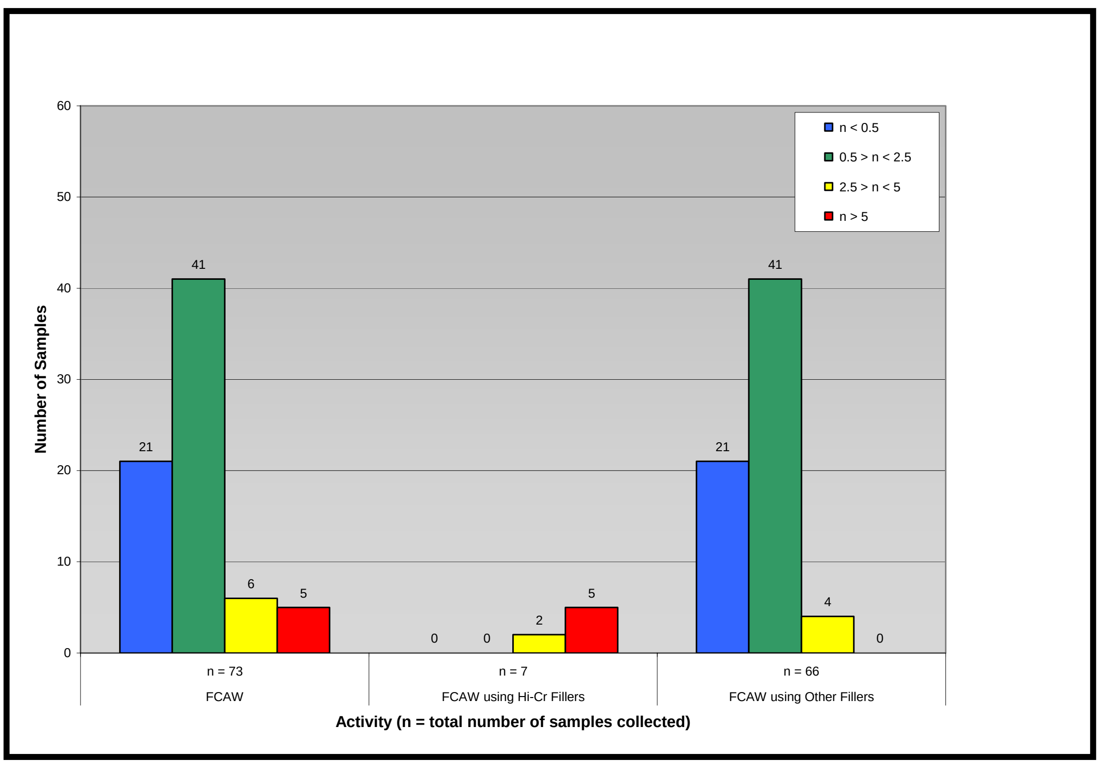


Table 6 – Summary of FCAW Welding Exposures

Activity	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%,95\%}$
All FCAW	73	0.002	48.3	2.12	0.791	4.078	12.0
FCAW on Stainless Steel	6	0.035	12.3	5.19	1.115	15.60	26.3
FCAW on Mild Steel	6	0.100	48.4	20.3	7.815	9.700	89.0
FCAW on AH-36	57	0.171	4.70	1.04	0.769	2.172	3.00
FCAW on Other Base Metals	4	0.390	1.30	0.64	0.560	1.737	2.80
FCAW using Hi-Cr Fillers	7	2.970	48.4	16.7	11.52	2.633	63.9
FCAW using Other Fillers	66	0.035	4.70	0.97	0.665	2.580	2.80

Based on the data analyzed, there is a significant probability that measured exposures during FCAW welding could exceed the OSHA PEL. One exception to this includes FCAW on AH-36; however, there is still a significant probability that measured exposures could exceed the OSHA Action Level.

Analyzing the data based on the type of filler metal, it is clear that those fillers containing more than 10% chromium (referred to as Hi-Cr fillers in this report) result in substantially higher CrVI exposures than those that contain little or no chromium. Hi-Cr electrodes and filler metals reported in the data are shown in Table 5. Based on the data analyzed, there is 95% confidence that 95% of the measured exposures during FCAW welding with filler metals that do not contain substantial amounts of chromium were below the PEL.

Shielded Metal Arc Welding (SMAW)/Stick Welding. A total of 193 discrete 8-hour TWA exposure results representing SMAW welding were analyzed. SMAW welding on stainless and mild steel, Inconel 600-625, CRES 304 and 309, AH-36, HY-80, HY-100, and on other base metals was compared to all hot work. The distribution of 8-hour TWA exposures during SMAW welding is summarized in Figure 5. The distribution of 8-hour TWA exposures during SMAW welding summarized by the type of electrode is shown in Figure 5A. Electrodes containing more than 10% chromium (Cr) were classified as Hi-Cr electrodes. Exposure values are reported in µg/m^3.

Descriptive statistics for SMAW welding are summarized in Table 7. Exposure values are reported in µg/m^3.

Table 7 – Summary of SMAW Welding Exposures

Activity	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%,95\%}$
All SMAW	193	0.050	67.0	4.99	0.824	6.728	26.4
SMAW on Stainless Steel	16	0.060	38.0	6.15	0.676	10.775	34.2
SMAW on Inconel 600-625	16	0.050	31.6	7.08	1.203	8.660	34.4
SMAW on CRES 304,309	43	0.050	67.0	11.77	2.521	8.240	50.6
SMAW on AH-36	39	0.010	3.00	0.57	0.310	3.417	1.9

Table 7 – Summary of SMAW Welding Exposures (cont.)

Activity	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%,95\%}$
SMAW on HY-80/ HY-100	43	0.050	29.5	2.65	0.675	5.620	14.8
SMAW on Mild Steel	18	0.050	7.3	1.74	0.855	4.096	6.9
SMAW on Other Base Metals	18	0.100	57.9	4.33	0.561	5.828	38.0
SMAW using Hi-Cr Electrodes	84	0.050	67.0	10.60	2.788	6.890	42.3
SMAW using Other Electrodes	109	0.050	3.1	0.63	0.332	3.501	1.9

Figure 5 – Exposure Distribution Comparing All Hot Work to SMAW by Base Metal

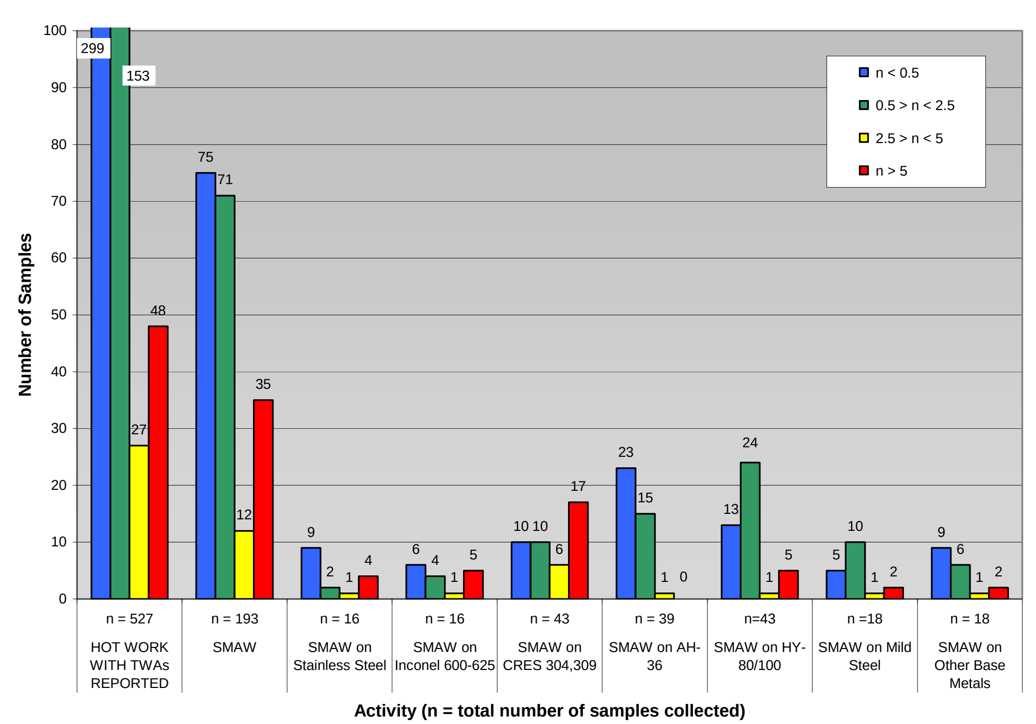
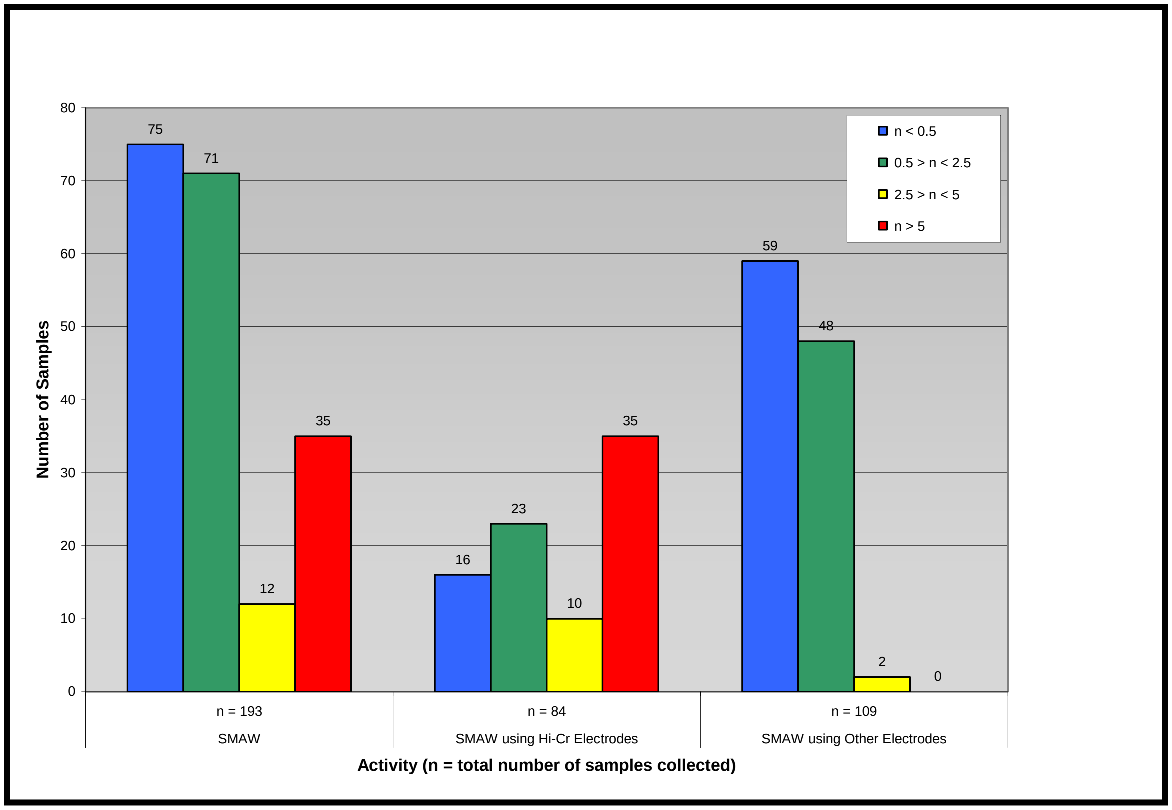


Figure 5A – Exposure Distribution of SMAW by Electrode Type



Based on the data analyzed, there is a significant probability that measured exposures during SMAW welding exceed the OSHA PEL. One exception to this includes SMAW on AH-36. The UTL for SMAW on AH-36 was less than the OSHA Action Level.

Analyzing the data based on the type of electrode, it is clear that those electrodes containing more than 10% chromium (referred to as Hi-Cr electrodes in this report) result in substantially higher CrVI exposures than those that contain little or no chromium. Hi-Cr electrodes and filler metals reported in the data are shown in Table 5. Based on the data analyzed, there is 95% confidence that 95% of the measured exposures during SMAW welding with electrodes that do not contain substantial amounts of chromium were less than the Action Level.

<u>Burning and Cutting.</u> A total of 60 discrete 8-hour TWA exposure results representing burning and cutting were analyzed. Burning and cutting activities analyzed included carbon arc cutting on mild steel and other base metals, plasma arc cutting, and other burning and thermal cutting activities. The distribution of 8-hour TWA exposures during burning and cutting is summarized in Figure 6. Exposure values are reported in µg/m^3.

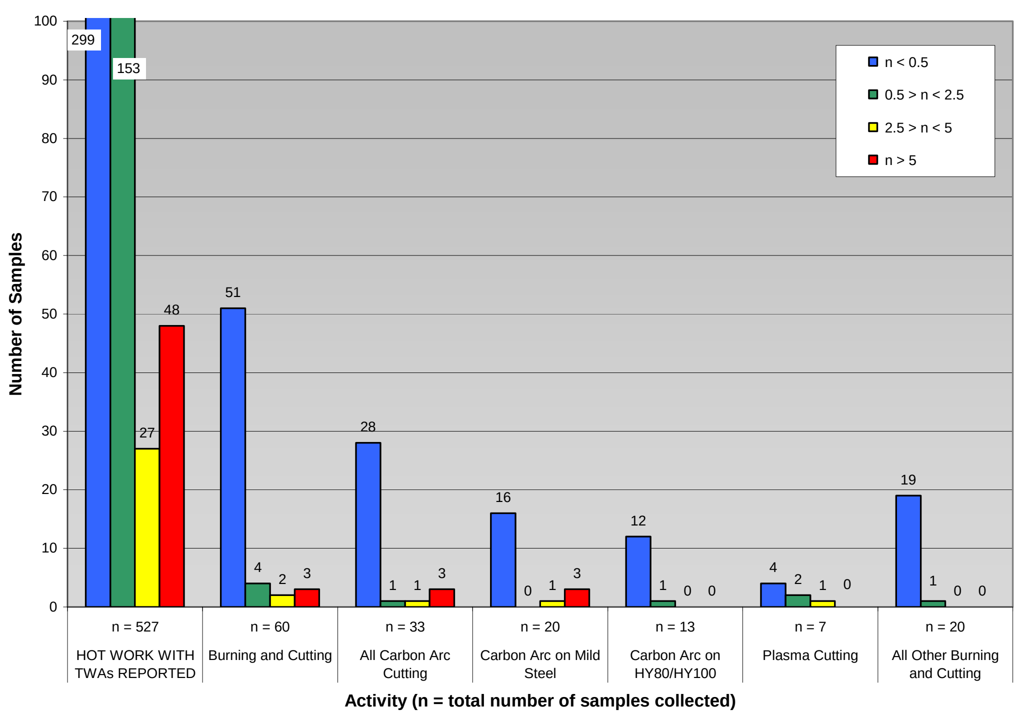
Descriptive statistics for burning and cutting are summarized in Table 8. Exposure values are reported in µg/m^3.

Table 8 – Summary of Burning and Cutting Exposures

Activity	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%,95\%}$
All Burning and Cutting	60	0.020	11.0	0.81	0.173	4.443	5.1
All Carbon Arc Cutting	33	0.030	11.0	1.16	0.243	4.651	7.1
Carbon Arc on Mild Steel	20	0.030	11.0	1.75	0.307	6.194	9.9
Carbon Arc on HY-80/HY-100	13	0.050	0.6	0.24	0.170	2.430	0.7
Plasma Cutting	7	0.020	4.3	1.09	0.185	10.347	6.6
All Other Burning and Cutting	20	0.026	0.6	0.13	0.096	2.223	0.4

Note: the category “all other burning and cutting” includes those records where the only activity descriptor was “burning” or “cutting.”

Figure 6 – Exposure Distribution Comparing All Hot Work to Burning and Cutting by Base Metal



Based on the data analyzed, there is a significant probability that measured exposures during burning and cutting exceed the PEL. Exceptions to this include carbon arc cutting on HY-80 and HY-100 and "Burning" or "Cutting" on AH36, carbon steel, GR B steel, and HY100, which were less than the Action Level.

<u>Miscellaneous Hot Work Activities.</u> A total of 56 discrete 8-hour TWA exposure results representing miscellaneous hot work activities were analyzed. These activities included grinding (for purposes other than paint removal), cladding, and welding activities not classified elsewhere or specified in the data provided. The distribution of 8-hour TWA exposures during these activities is summarized in Figure 7. Exposure values are reported in µg/m^3.

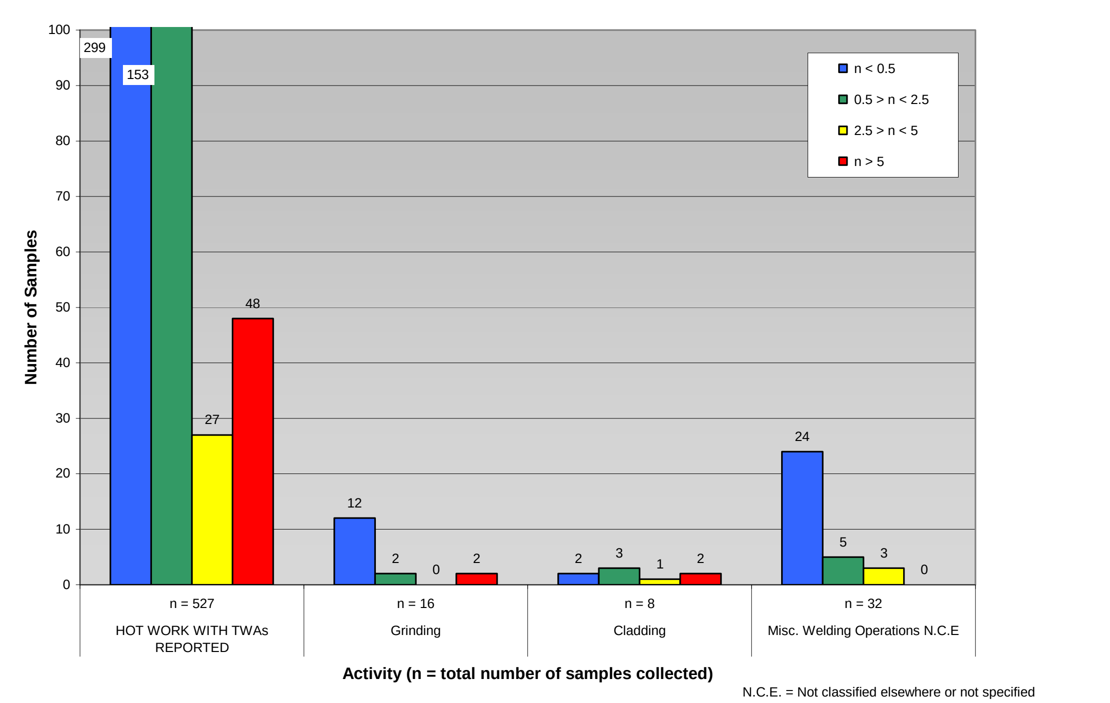
Descriptive statistics for miscellaneous hot work activities are summarized in Table 9. Exposure values are reported in µg/m^3.

Table 9 – Summary of Miscellaneous Hot Work Activity Exposures

Activity	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%,95\%}$
Grinding	16	0.015	38.0	4.35	0.252	9.235	33.2
Cladding	8	0.100	57.9	8.80	1.625	6.668	72.3
Misc. Welding Operations N.C.E.	32	0.002	4.60	0.56	0.144	6.721	2.90

N.C.E. = not classified elsewhere or not specified in the data provided.

Figure 7 – Exposure Distribution Comparing All Hot Work to Miscellaneous Hot Work Activities by Base Metal



Based on the data analyzed, there is a significant probability measured exposures during grinding and cladding exceeded the OSHA PEL.

Paint Removal and Other CrVI Activities

Three separate paint removal activities were represented by 83 discrete 8-hour TWA exposure results in the data analyzed. These activities included needlegunning, grinding, and blasting. Two separate miscellaneous activities, electroplating and milling, were represented by 16 discrete 8-hour TWA exposure results. The distribution of 8-hour TWA exposures during these activities is summarized in Figure 8. Exposure values are reported in $\mu g/m^3$.

Descriptive statistics for each paint removal and other CrVI activity are summarized in Table 10. Exposure values are reported in $\mu g/m^3$.

Table 10 – Summary of Paint Removal and Other CrVI Activity Exposures

Activity	No. Samples	Min	Max	Mean	GM	GSD	UTL $_{95\%95\%}$
All Paint Removal Activities	83	0.021	29.1	2.69	0.689	6.615	11.8
Needlegunning	77	0.021	29.1	2.80	0.717	6.627	12.2
Grinding	3	1.610	3.22	2.30	2.206	1.420	8.7
Blasting	3	0.037	0.25	0.11	0.077	2.793	1.0
Other CrVI Activities	16						
Electroplating	3	0.21	1.3	0.587	0.409	2.735	5.32
Milling	13	0	0	0	0	0	0

Although the mean exposure during all paint removal activities was below the OSHA PEL, there is a significant probability that measured exposures for the activities shown in Table 9 are above the PEL.

The data submitted for paint removal by blasting were very limited in comparison to the frequency that this activity is typically conducted in shipyards, and therefore should not be considered representative. Given the limited number of records provided on blasting and the information that can be extracted from the records, the application of these findings should be limited.

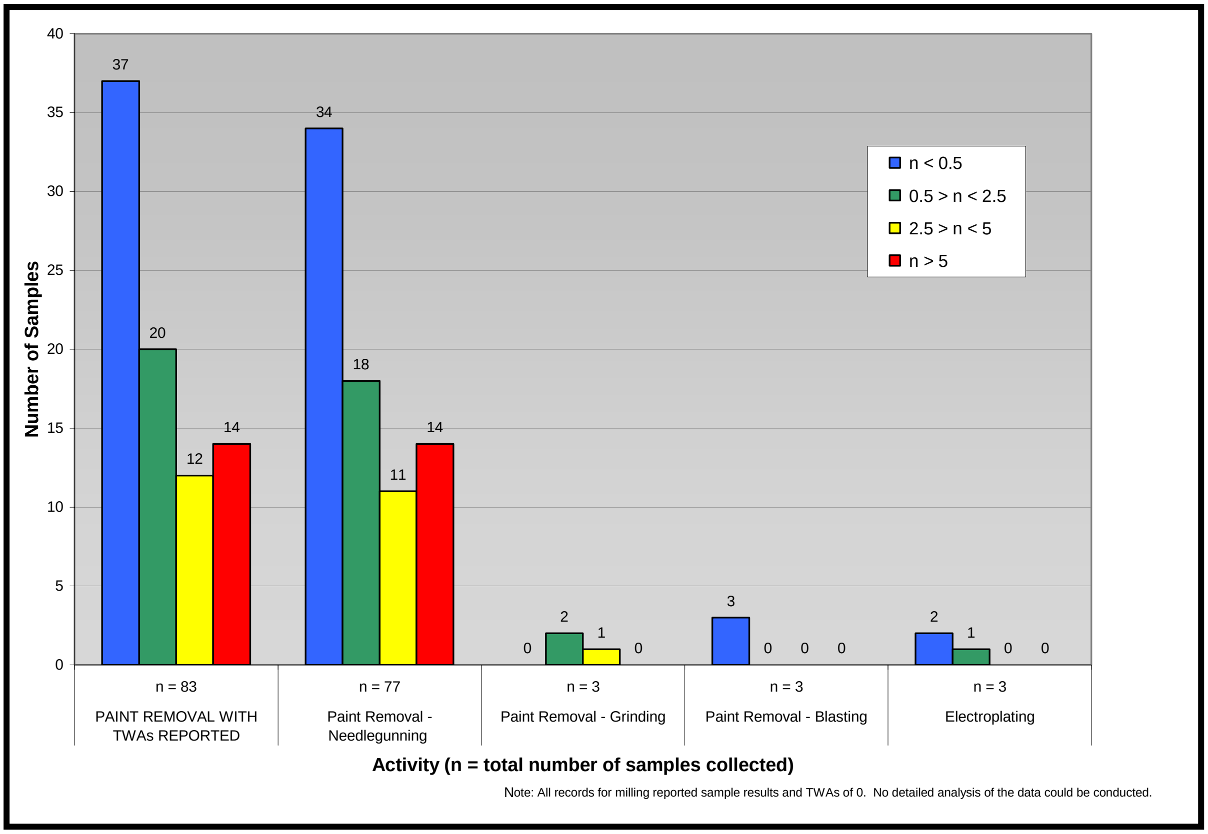
The chromium content of the paint or coating removed was reported in approximately 60% of the records. A comparison of CrVI exposures during paint removal activities to the chromium content in paint is summarized in Table 11. Values reported are in $\mu g/m^3$.

Table 11 – Comparison of CrVI Exposures and Cr Content in Paint

Chromium Content in Paint	No. Samples	Min	Max	Mean	GM
<0.1% Cr	27	0.02	15.8	1.4	0.3
0.1% to 1.0% Cr	14	0.10	8.80	3.2	1.5
1% to 5% Cr	13	0.20	10.1	3.1	1.7
>5% Cr	3	3.50	29.1	12.2	7.3

In comparing the mean exposures to CrVI for those records where the Cr content in paint was reported, there appears to be some relationship between the Cr content and CrVI exposures. However, a more detailed analysis would need to be conducted to assess if a trend exists.

Figure 8 – Exposure Distribution Comparing Paint Removal and Other CrVI Activities



Relationship of Hot Work Exposures, Ventilation and Space Size

An assessment of the relationship between CrVI exposures during hot work activities, the type of ventilation reported for the activity, and the size of the space reported was conducted. Assessing the relationship was limited by the following:

- Data collected during implementation of state-of-the-art controls limited any comparative analysis of good controls versus poor controls. For example, all of the records for hot work conducted in confined or enclosed spaces reported that local ventilation was used.
- The type of ventilation (local, natural/none, and dilution/general) was reported in approximately 84% of the hot work records. Few records included capture or face velocity of local exhaust systems, or if the system implemented was forced air (supply) or extraction (exhaust).
- With regards to space:
  - Approximately 98% of the records reported the "location" where work was conducted.
  - Approximately 49% of the records included "site" data.
  - Six indicated that work was performed in confined spaces, and all of these reported "local" as the type of ventilation used.

- Approximately 60% of the records reported space size as "NOT RECORDED" or "UNKNOWN."
- 47 records (approximately 8% of the hot work records) provided sufficient space size data for assessing the relationship between space size, ventilation and CrVI exposures during hot work.

The assessment is summarized in Table 12.

Table 12 – Relationship between CrVI Exposures, Ventilation Type and Space Size during Hot Work

Exposure Statistics	Space Size and Type of Ventilation Used							
	<2000 ft^3		2000 ft^3 - 5000 ft^3		5000 ft^3 - 10000 ft^3		>10000 ft^3	
	Local	General/ Natural	Local	General/ Natural	Local	General/ Natural	Local	General/ Natural
No. Samples	4	10	3	11	7	7	None	5
Min ($\mu g/m^3$)	0.02	0.05	0.19	0.05	0.01	0.21	NA	0.08
Max ($\mu g/m^3$)	0.05	30.2	0.39	1.20	3.29	3.10	NA	2.38
Mean ($\mu g/m^3$)	0.04	9.15	0.30	0.32	0.62	1.43	NA	0.95
GM ($\mu g/m^3$)	0.04	1.94	0.28	0.19	0.13	1.10	NA	0.59

In comparing mean exposures, the following observations can be made:

- Exposures were lower when local ventilation was used rather than natural/general ventilation in spaces smaller than 2,000 cubic feet (ft^3).
- There was no notable difference in exposures when comparing local and natural/general ventilation in spaces between 2,000 and 5,000 ft^3.
- Exposures were lower when local ventilation was used rather than natural/general ventilation in spaces larger than 5,000 ft^3.

While interesting, there is not enough data to allow a definitive comparative analysis that yields a consistent trend regarding the type of ventilation used and the space configuration.

Research on Other Available Data Sources

Research on other available data sources summarizing Cr(VI) exposures measured during activities and tasks similar to those conducted in shipyards was also conducted. The following publications were reviewed and considered:

- American Petroleum Institute (API), *Hexavalent Chromium Exposures during Hot Work*, October 2006.[1]
- National Shipbuilding Research Program (NSRP), *Welding Fume Study Final Report*, January 1999.[2]
- Maritime Advisory Committee for Occupational Safety and Health (MACOSH) exposure studies.[3]
- Gulf Coast Region Maritime Technology Center (GCRMTC)/University of New Orleans, *Evaluation of CrVI Exposure Levels in the Shipbuilding Industry*, November 1998[7].
- *2.0 Welding*, OSHA Docket.[8]
- *Feasibility of Exposure Controls*, OSHA Docket. [9]
- National Institute for Occupational Safety and Health (NIOSH) Field Survey, *Site 9 – Enclosure I, Results of Workplace Environmental Sampling*, May 2002.[10]

- NIOSH Field Survey, *Site 6 – Enclosure I, Results of Workplace Environmental Sampling*, March 2009.[11]
- Navy/Industry Task Group, *Impact Of Proposed OSHA Hexavalent Chromium Worker Exposure Standard On Navy Manufacturing And Repair Operations*, October 1995.[12]
- Navy Environmental Health Center (NEHC), *Additional Information on Hexavalent Chromium in Navy Workplaces: Addendum to the Original Report to OSHA*, November 2002.[13]

While the information in these publications was considered, several did not provide information that was comparable to the data submitted by the organizations participating in this Study because:

- Activities referenced were different from those reported in the data submitted by participating organizations;
- Sampling and analytical methods in some studies were not specific for CrVI; or
- Exposure monitoring was conducted to evaluate specific engineering controls and was not representative of real-world work activities.

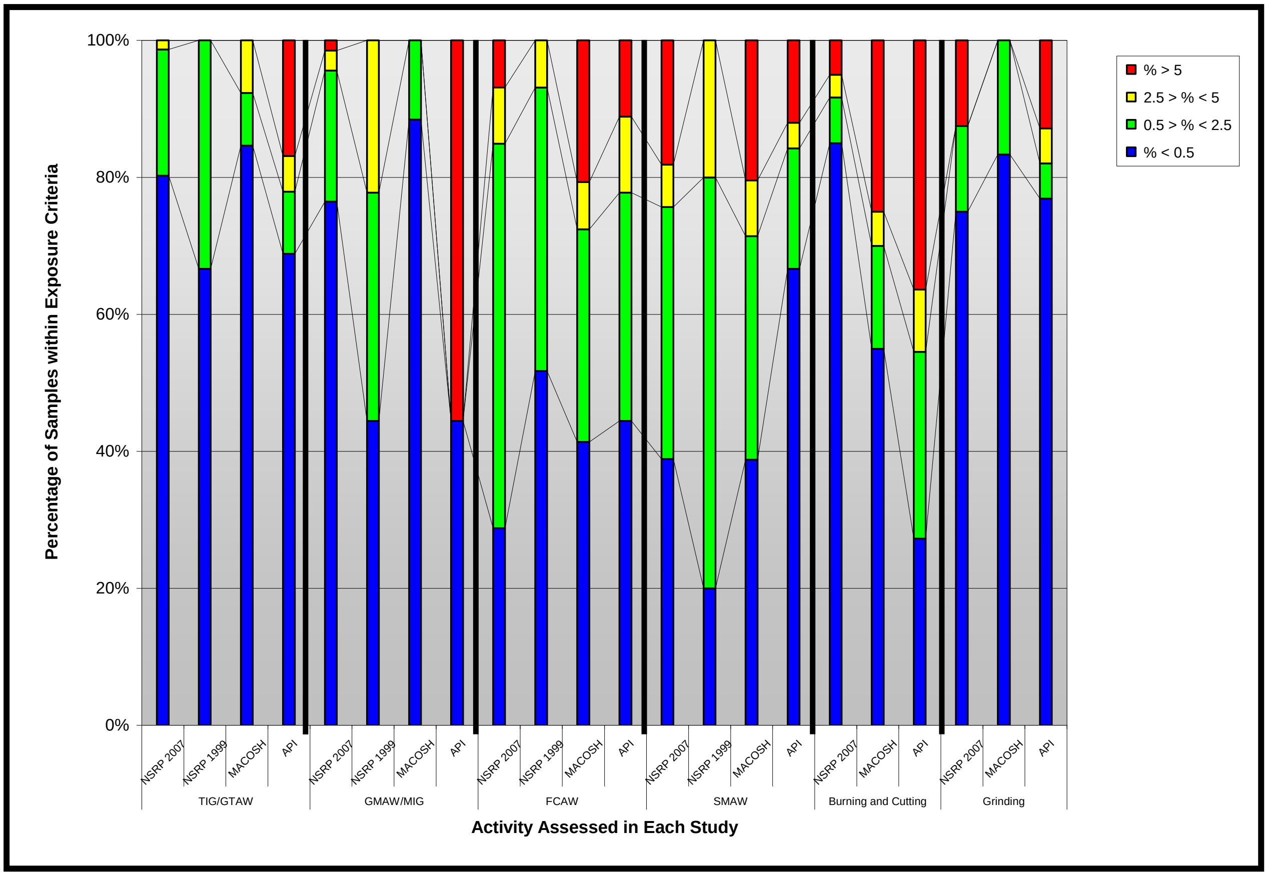
Exposure monitoring data from the following publications was compared to the data submitted for this Study:

- MACOSH data
- 2006 API Study
- 1999 NSRP Welding Fume Study

A graph depicting the distribution of exposure results by study and work activity is shown in Figure 9.

The graph shows that there was similarity in the exposure distributions for most of the activities assessed in these studies. The most notable differences are seen in TIG and MIG welding, where the API Study shows more exposures that exceeded the PEL than the NSRP and MACOSH studies. Because the API Study included welding activities in the petrochemical industry, the difference may be due to base metals, location and ventilation used, and other industry practices. There is also a notable difference in burning and cutting between the data submitted for this Study and the MACOSH and API data. The MACOSH and API data show more exposures that exceed the PEL than this NSRP Study.

Figure 9 – Exposure Distribution Comparing Similar Studies by Work Activity



CONCLUSIONS

Based on the analysis of the data provided by participating organizations, some very useful conclusions can be made concerning personal exposures to CrVI.

It is important to note that all of the exposure monitoring data is extremely valuable and useful in characterizing exposures. Although it is not a flaw in the data submitted for this Study, analysis of any pooled data set has some limitations. The exposure monitoring data were not collected specifically for this project, so some data elements that would have been helpful in additional analyses of the pooled data were not reported. Limitations included:

- Limited number of reported TWA exposures for certain activities;
- Key fields in records (base metal type, filler metal type, Cr content in paint, ventilation type, and site and space size) left blank or reported as “NA” or “UNKNOWN.”
- Inconsistencies in descriptions of base and filler metals and space size.

Only 10% of the 613 validated 8-hour TWA CrVI exposure results provided by participating organizations exceeded the OSHA PEL for CrVI of 5µg/m^3. The data can be summarized as follows:

- 337 results, or 55%, were less than the OSHA compliance exemption criterion of 0.5µg/m^3.
- 174 results, or 28%, were greater than the OSHA compliance exemption criteria but less than the OSHA Action Level of 2.5µg/m^3. Cumulatively, 83% of the results were less than the Action Level for CrVI.
- 39 results, or 6%, were greater than the OSHA Action Level but less than the OSHA permissible exposure limit (PEL) of 5µg/m^3. Cumulatively, 90% of the results were less than the PEL for CrVI.

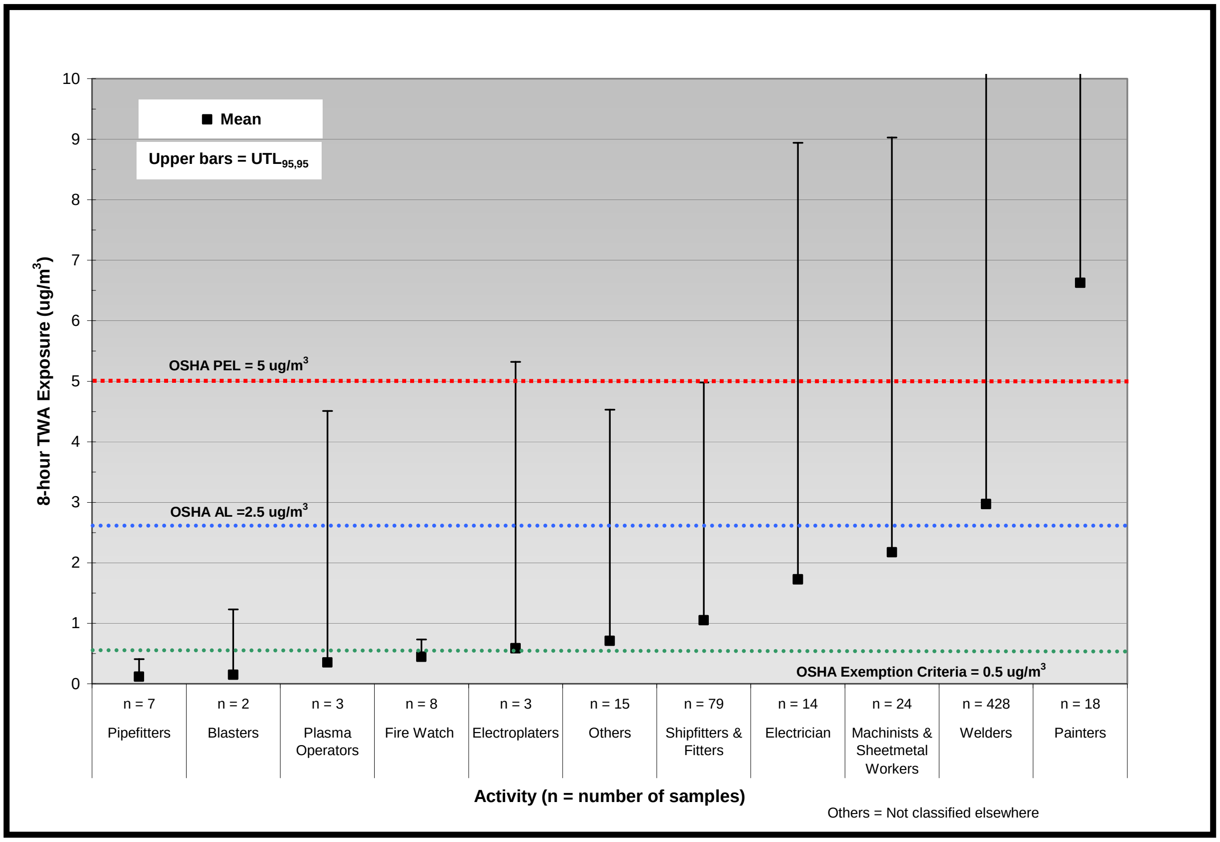
The arithmetic mean, or average, exposure was used as the primary statistic to characterize exposures. The majority of the data sets analyzed showed highly variable results, with a large number of very low exposure results and few higher exposure results. This lognormal distribution is characteristic of most data sets of occupational exposures. Although the sample distribution of data sets is lognormal, the arithmetic mean, not the geometric mean, is the best descriptor of average exposure.[6] For similar exposure groups or activities, an arithmetic mean 8-hour TWA exposure that is appreciably below an established occupational exposure limit (such as the compliance exemption criterion, Action Level or PEL for CrVI) is a clear indication that workplace controls are effective.[4]

The statistical analysis of the sample results collected during this survey was completed to determine the upper tolerance limit (UTL). The UTL is a one-sided upper confidence limit for a selected probability level (confidence limit) and a selected coverage of the sample population. For this survey, the $UTL_{95\%,95\%}$ was used to assess the upper confidence limit of a given data set. This provides 95% confidence that 95% of the exposures are lower than the calculated upper confidence limit. For example, if the calculated $UTL_{95\%,95\%}$ for a group of CrVI exposures was 2.5µg/m^3, one can be 95% confident that 95% of the CrVI exposures for that group are less than 2.5µg/m^3.[6] It is important to note that the calculated $UTL_{95\%,95\%}$ is highly sensitive to sample size. The tolerance factor (K) used to calculate the $UTL_{95\%,95\%}$ is based on sample size. The K value is relatively large for data sets with fewer than six samples.

Exposure Characterization by Job Description

Figure 10 shows CrVI exposure characterization by job description. This figure also shows how the mean exposure and $UTL_{95\%,95\%}$ for each job category compares to the OSHA compliance exemption criterion of 0.5µg/m^3, the Action Level of 2.5µg/m^3, and the PEL of 5µg/m^3.

Figure 10 – Exposure Characterization by Job Description



When evaluating mean exposures, the data submitted by participating organizations shows:

1. The mean 8-hour TWA CrVI exposure is less than the OSHA exemption criterion of 0.5µg/m^3 for the following job descriptions:
    a. Pipefitters;
    b. Plasma operators; and,
    c. Fire watch personnel.

   The data sets for blasters and plasma operators are small (less than six samples); and the exposure results for plasma operators was highly variable (GSD >3).[6]

2. The mean 8-hour TWA CrVI exposure is greater than the OSHA exemption criterion but less than the OSHA Action Level of 2.5µg/m^3 for the following job descriptions:
    a. Electroplaters;
    b. Engineering Technician, Electronics Apprentice, Grinder, HAB, and Environmental (Others);
    c. Shipfitters and Fitters;
    d. Electricians; and,

   e. Machinists and sheetmetal workers.

   The data set for electroplaters is small (less than six samples); and the exposure results for the other groups were highly variable (GSD >3).

3. The mean 8-hour TWA CrVI exposure is greater than the OSHA Action level but less than the OSHA PEL of 5µg/m^3 for welders. The exposure results for this group were highly variable (GSD >3).

4. The mean 8-hour TWA CrVI exposure exceeds the OSHA PEL for painters.

When evaluating exposures compared to the calculated $UTL_{95\%,95\%}$, the data submitted by participating organizations shows there is a significant probability that measured 8-hour TWA CrVI exposures:

1. Were less than the OSHA exemption criterion of 0.5µg/m^3 for Pipefitters.

2. Were less than the OSHA Action Level of 2.5µg/m^3 for Fire Watch personnel.

3. Were less than the OSHA PEL of 5µg/m^3 for:
   a. Plasma operators; and,
   b. Engineering Technician, Electronics Apprentice, Grinder, HAB, and Environmental (Others).

4. Were less than 50µg/m^3, or 10 times the PEL, for:
   a. Electroplaters;
   b. Electricians;
   c. Pipe and shipfitters;
   d. Machinists and sheetmetal workers;
   e. Welders; and,
   f. Painters.

   The OSHA assigned protection factor for a half-face air purifying respirator with appropriate filter cartridges is 10.[14] Therefore, a properly fitted half-face air purifying respirator would be expected to provide to employees protection in work environments with CrVI aerosol concentrations up to 50µg/m^3.

Exposure Characterization by Work Processes and Activities

Figures 11 through 16 show CrVI exposures characterized by work processes and activities. These figures also show how the mean exposure and $UTL_{95\%,95\%}$ for each process and activity compares to the OSHA compliance exemption criterion of 0.5µg/m^3, the Action Level of 2.5µg/m^3, and the PEL of 5µg/m^3. For welding activities, it appears that the filler metal or electrode used is a better variable for characterizing CrVI exposures than the base metal. Therefore, exposures by filler metal and electrodes are shown in Figures 11 through 13, and are summarized in Figure 14.

Figure 11 – Exposure Characterization by Hot Work Activity: TIG and MIG Welding

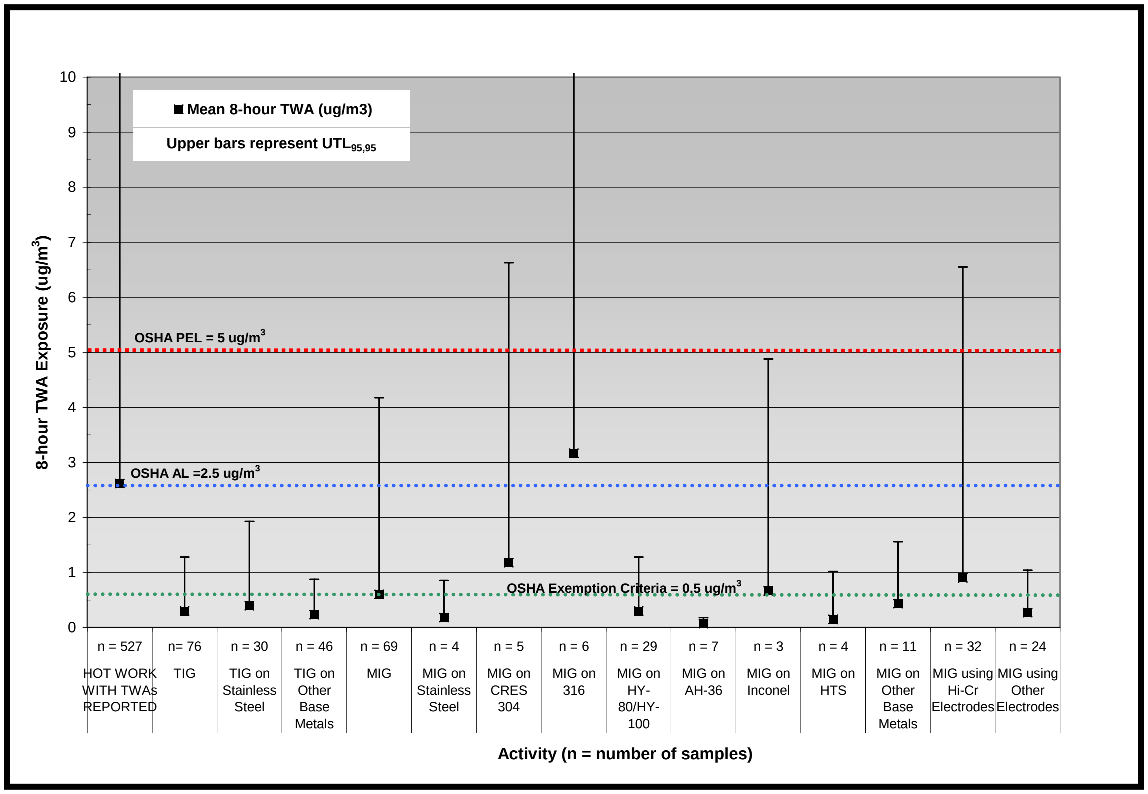


Figure 12 – Exposure Characterization by Hot Work Activity: FCAW

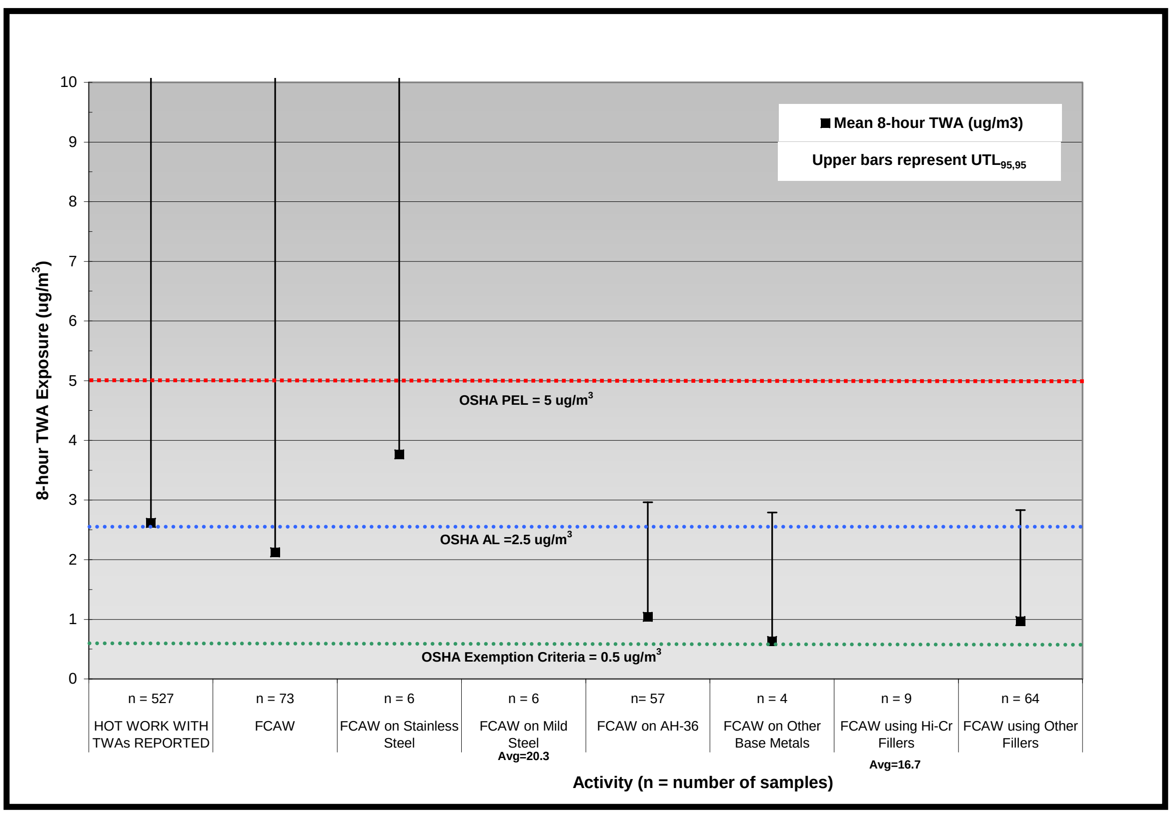


Figure 13 – Exposure Characterization by Hot Work Activity: SMAW

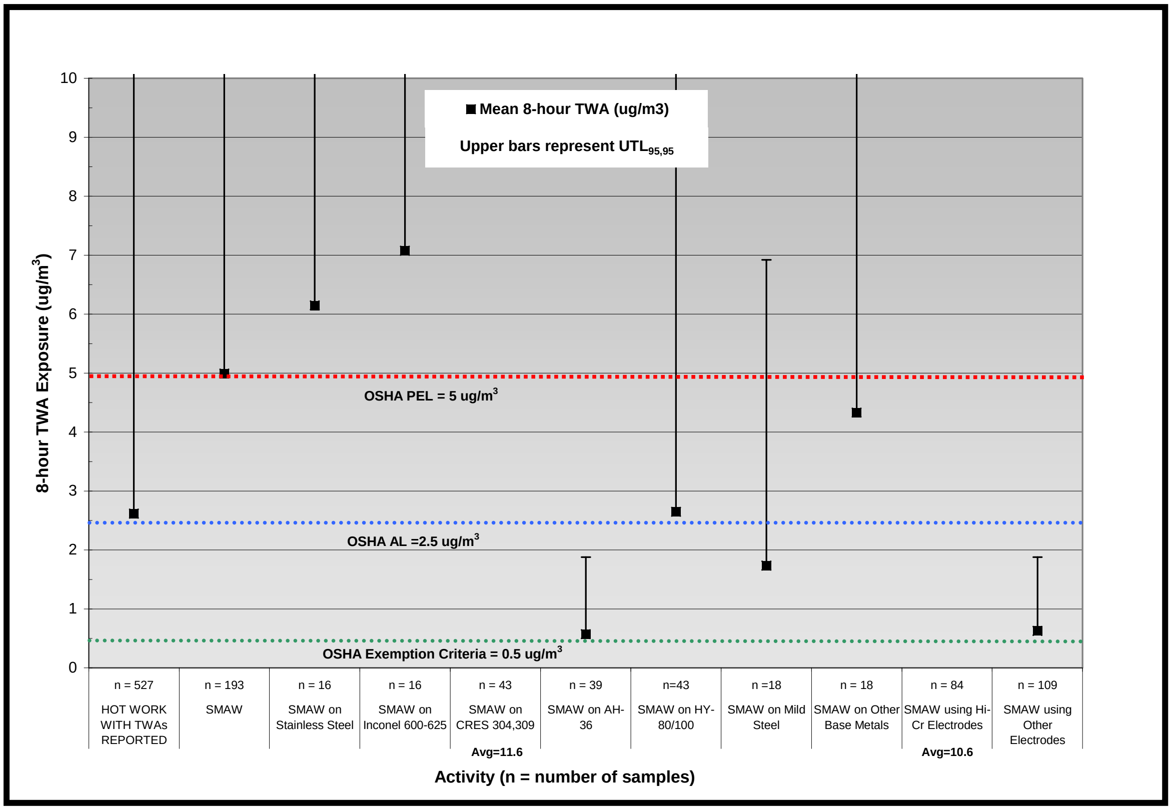


Figure 14 – Exposure Characterization by Filler Metal or Electrode

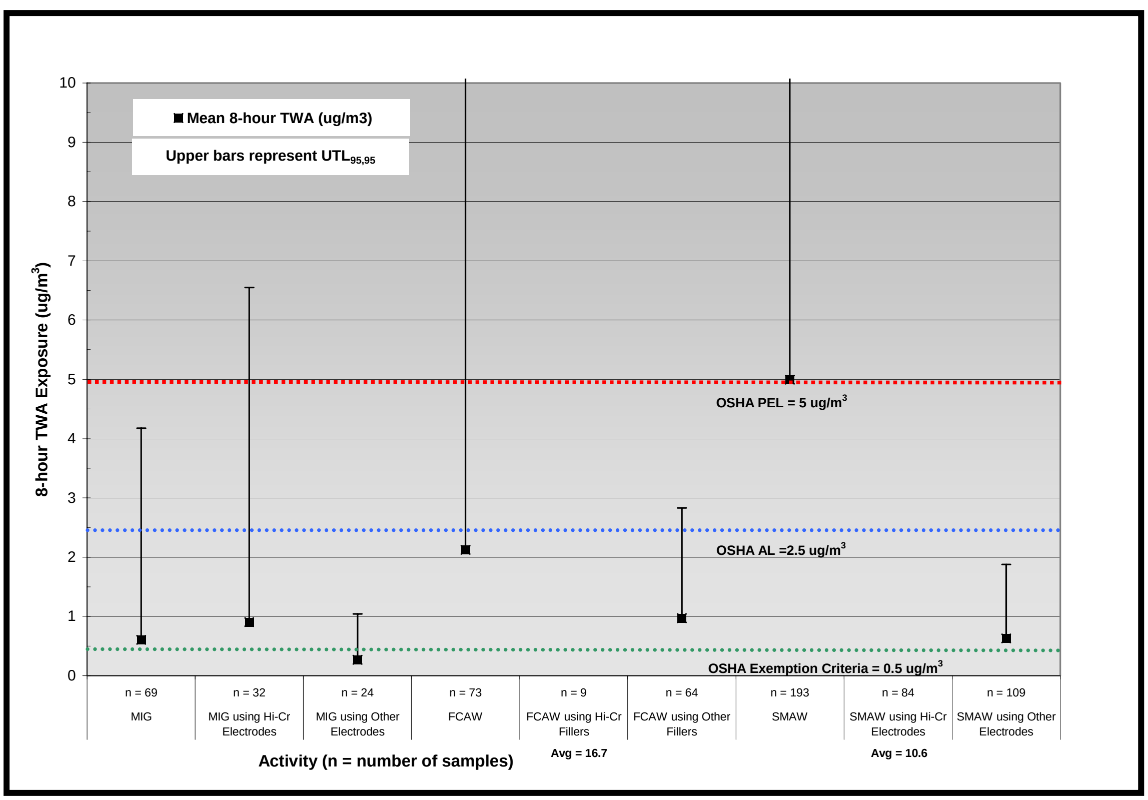


Figure 15 – Exposure Characterization by Hot Work Activity: Other Hot Work Activities

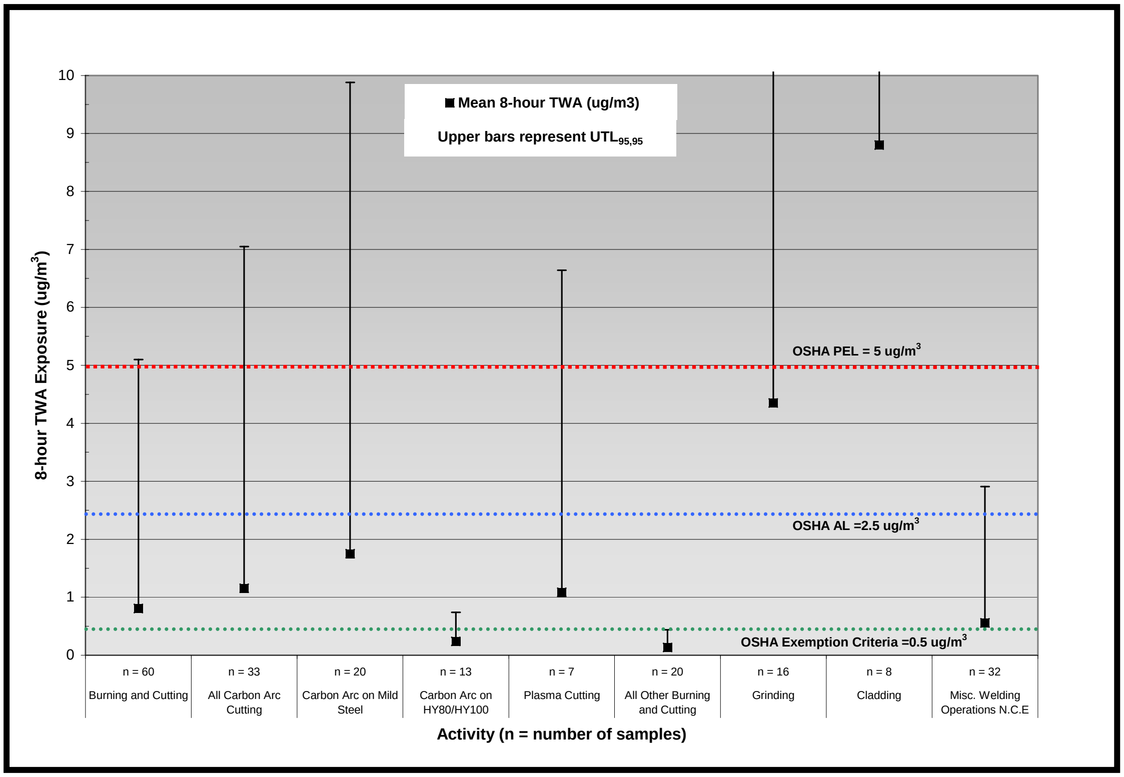
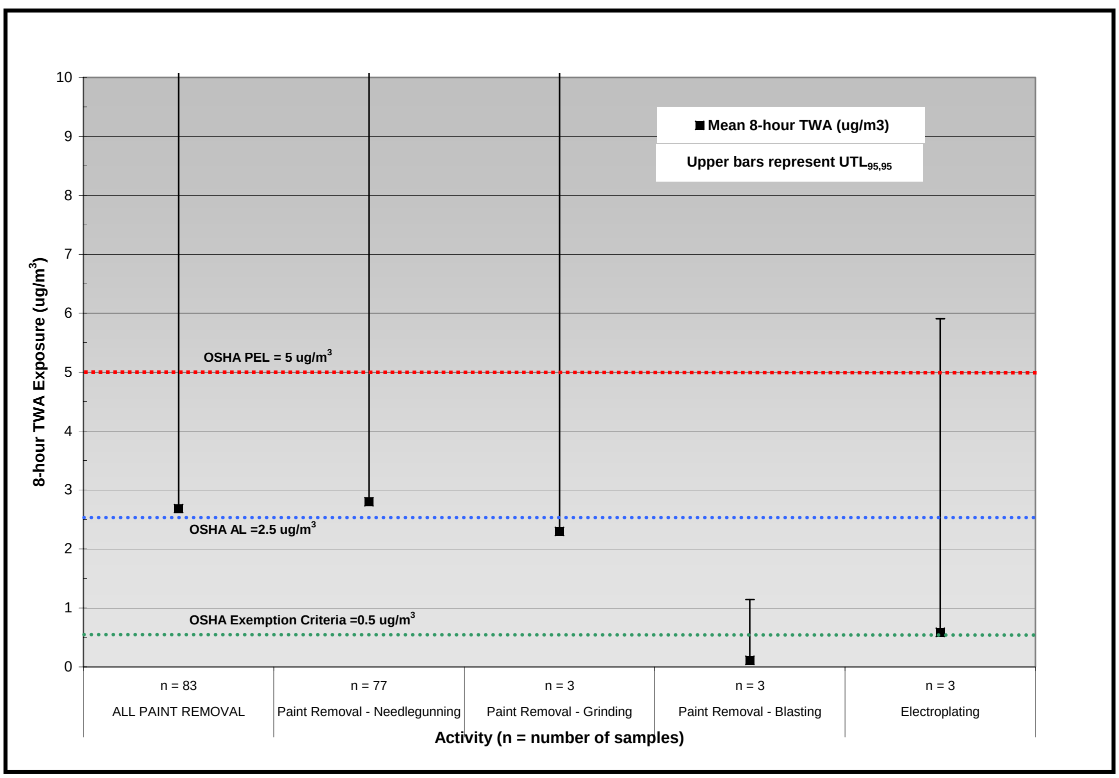


Figure 16 – Exposure Characterization by Other Hot Work, Paint Removal and Electroplating Activities



When evaluating mean exposures, the data submitted by participating organizations shows:

1. The mean 8-hour TWA CrVI exposure is less than the OSHA exemption criterion of 0.5µg/m^3 during:
   a. TIG welding, regardless of the base metal;
   b. MIG welding on non-CRES base metals;
   c. MIG welding using non-Hi-Cr electrodes;
   d. Carbon arc cutting on HY-80/HY-100; and,
   e. "Burning" or "Cutting" on AH36, carbon steel, GR B steel, and HY100.

2. The mean 8-hour TWA CrVI exposure is greater than the OSHA exemption criterion but less than the OSHA Action Level of 2.5µg/m^3 during:
   a. MIG welding using Hi-Cr electrodes;
   b. FCAW on non-CRES base metals;
   c. FCAW using non-Cr fillers;
   d. SMAW using non-Cr electrodes;
   e. Burning and Cutting
   f. Grinding (Paint Removal)
   g. Plating

   The data sets for paint removal by grinding and electroplating were small (less than six samples).

3. The mean 8-hour TWA CrVI exposure is greater than the OSHA Action Level but less than the OSHA PEL of 5µg/m^3 during:
   a. MIG welding on CRES base metals;
   b. SMAW on non-CRES base metals;
   c. Needlegunning
   d. Grinding (Hot Work)

   The exposure results for these groups were highly variable (GSD >3).

4. The mean 8-hour TWA CrVI exposure exceeds the OSHA PEL during:
   a. FCAW on CRES base metals;
   b. FCAW using Hi-Cr filler metals;
   c. SMAW on CRES base metals;
   d. SMAW using Hi-Cr electrodes; and,
   e. Cladding.

When evaluating exposures compared to the calculated $UTL_{95\%,95\%}$, the data submitted by participating organizations shows there is a significant probability that measured 8-hour TWA CrVI exposures:

1. Were less than the OSHA exemption criterion of 0.5µg/m^3 during "Burning" or "Cutting" on AH36, carbon steel, GR B steel, and HY100 (non-CRES) metals.

2. Were less than the OSHA Action Level of 2.5µg/m^3 during:
   a. TIG welding, regardless of the base metal;
   a. MIG welding on non-CRES base metals;
   b. MIG welding using non-Hi-Cr electrodes;
   c. SMAW when using non-Cr electrodes; and,

   b. Carbon arc cutting on HY-80/HY-100.

3. Were less than the OSHA PEL of 5µg/m^3 during:
   a. FCAW on non-CRES base metals; and,
   b. FCAW using non-Cr fillers.

4. Were less than 50µg/m^3, or 10 times the PEL, during:
   a. MIG welding on CRES base metals;
   b. MIG welding using Hi-Cr electrodes;
   c. SMAW on non-CRES base metals;
   d. SMAW using Hi-Cr electrodes;
   e. Carbon arc cutting on mild steel;
   f. Plasma cutting;
   g. Grinding;
   h. Paint removal by needlegunning;
   i. Paint removal by grinding; and,
   j. Electroplating.

   The OSHA assigned protection factor for a half-face air purifying respirator with appropriate filter cartridges is 10.[14] Therefore, a properly fitted half-face air purifying respirator would be expected to provide to employees protection in work environments with CrVI aerosol concentrations up to 50µg/m^3.

5. Were less than 125µg/m^3, or 25 times the PEL, during:
   a. FCAW on CRES base metals;
   b. FCAW using Hi-Cr filler metals;
   c. SMAW on CRES base metals; and,
   d. Cladding.

   The OSHA assigned protection factor for a supplied air respirator with a hood, helmet or loose-fitting facepiece is 25.[14] The OSHA assigned protection factor for a full-face air purifying respirator with appropriate filter cartridges is 50. Therefore, a properly fitted full-face air purifying respirator or a supplied air respirator with a hood, helmet or loose-fitting facepiece would be expected to provide to employees protection in work environments with CrVI aerosol concentrations up to 125µg/m^3.

Many of the activities where exposures were the highest were data sets with fewer validated 8-hour TWA exposure monitoring results. Those processes and activities with smaller data sets are summarized in Table 13.

Table 13 – Summary of Activities with Smaller Exposure Data Sets

Process or Activity	No. of Validated 8-hour TWA Results
Cladding	8
Electroplating	3
FCAW on stainless steel	6
FCAW on mild steel	6
Paint removal by grinding	3
Plasma cutting	7

Other Observations

1. In comparing the mean exposures to CrVI for those records where the Cr content in paint was reported, there appears to be some relationship between the Cr content and CrVI exposures. However, a more detailed analysis would need to be conducted to assess if a trend exists.

2. In comparing mean exposures based on the size of a workspace and the ventilation controls used, the following observations can be made:
   - Exposures were lower when local ventilation was used rather than natural/general ventilation in spaces smaller than 2,000 cubic feet (ft^3).
   - There was no notable difference in exposures when comparing local and natural/general ventilation in spaces between 2,000 and 5,000 ft^3.
   - Exposures were lower when local ventilation was used rather than natural/general ventilation in spaces larger than 5,000 ft^3.

   While interesting, there is not enough data to allow a definitive comparative analysis that yields a consistent trend regarding the type of ventilation used and the space configuration.

3. A comparison of the exposure data from other data sources shows similarity in the exposure distributions for most of the activities assessed in these studies. The most notable differences are seen in TIG and MIG welding, where the API Study shows more exposures that exceeded the PEL than the NSRP and MACOSH studies. Because the API Study included welding activities in the petrochemical industry, the difference may be due to base metals, location and ventilation used, and other industry practices. This observation supports the value and need for industry-specific assessments and analysis of objective exposure data.

Recommendations

1. Based on the data provided by participating organizations, it appears that most occupational exposures to CrVI during work processes and activities representative of shipyard operations are well characterized and well controlled. For several activities, the mean 8-hour TWA CrVI exposures were less than the Action Level and the $UTL_{95\%,95\%}$ level was less than the PEL. While these activities should continue to be monitored, further routine collection of exposure data is not needed for the purposes of this evaluation unless processes change significantly.[4] These activities include:
   a. TIG welding;
   b. MIG welding on non-CRES metals using non-Hi-Cr electrodes;
   c. FCAW on non-CRES metals using non-Hi-Cr filler metals;
   d. SMAW on AH-36 using non-Hi-Cr electrodes;
   e. Carbon arc cutting on HY-80/HY-100; and,
   f. “Burning” or “Cutting” on AH36, carbon steel, GR B steel, and HY100.

2. Additional exposure monitoring may better characterize those activities with smaller sample sizes, and reduce the variability among the sample population. Many of the activities where the highest mean exposures and $UTL_{95\%,95\%}$ were identified had highly variable sample results (GSD >3). Additional exposure monitoring may reduce the variability of the

distribution, resulting in a more representative mean and $UTL_{95\%,95\%}$ value. Those activities where additional exposure monitoring should be considered include:

a. MIG welding on CRES base metals;
b. FCAW on CRES base metals;
c. SMAW on CRES base metals;
d. Carbon arc cutting;
e. Plasma cutting;
f. Grinding;
g. Cladding;
h. Paint removal by needlegunning;
i. Paint removal by grinding; and,
j. Electroplating.

3. To allow for the most comprehensive analysis of industry-specific pooled objective data, it is important to ensure that future data collection efforts collect key data elements. Therefore, a standardized industrial hygiene data collection form should be developed and used by all NSRP participants collecting exposure monitoring data. This standardized data collection form should include:
   a. Calculated TWA exposures that represent a full 8-hour work shift to allow for direct comparison to OSHA exposure criteria;
   b. Variables such as:
      - workspace configuration;
      - workspace size (in cubic feet);
      - base metal type,
      - filler metals and electrode type;
      - ventilation controls implemented, including capture velocity and working distance; and,
      - Cr content in paint.
   c. Consistent descriptions:
      - work space configurations;
      - base metals;
      - filler metals and electrodes; and,
      - ventilation controls.
   d. Collection of other process-related information, such as:
      - amperage during welding;
      - welding arc time (in minutes or percent of shift); and,
      - description if shrouded or ventilated equipment is used.

   In collecting this information, future data collection records can be incorporated into the data set provided for this Study to enhance and expand the analysis.

4. The following relationships should be assessed further in an effort to develop standardized evaluation and industrial work practices:
   a. The relationship between the chromium content in paint and coating surfaces and CrVI exposures during routine coating removal activities including grinding and needlegunning.
   b. The relationship between the chromium content in filler metals and electrodes, base metals, and CrVI exposures. While the data show that welding on CRES metals and using Hi-Cr fillers/electrodes results in higher exposures, the prevalence and reason for

using of Hi-Cr fillers/electrodes on non-CRES base metals (and vice versa) is not clear. While this practice may be somewhat less frequent in routine production, it may help in better assessing exposures during cladding activities.

c. The relationship between ventilation, space size and exposure is somewhat understood, particularly in working in confined or enclosed spaces. However, the use of “push-pull” type ventilation systems and the effective working distance (capture velocity) could not be effectively assessed based on the current data. A more detailed analysis, which may require additional exposure monitoring and data collection, should be considered.

It is important to note that the limits of analyzing how ventilation and space configuration influence exposures using data provided do not negate the value of ventilation in controlling exposures. The use of ventilation (particularly localized ventilation in confined, enclosed or restricted spaces) is a very important and effective engineering control, and should be implemented when local conditions warrant its use or policies require its use.

The information from this survey should be used to promote a consistent understanding within the industry – both among and between different shipyards – of the proper and effective control methods to protect the health of shipyard employees, contractors and visitors.

The analysis of the data provided yields practical information that smaller shipyards and organizations with limited industrial hygiene resources can use to characterize and control exposures by activity. We recognize that larger shipyards and organizations with experienced industrial hygiene resources may have conducted a more thorough analysis and have better characterized and controlled CrVI exposures in their operations. In all instances, local data, exposure characterizations and established methods for controlling exposures should take precedence over an analysis of pooled objective data.

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[1] American Petroleum Institute (API), *Hexavalent Chromium Exposures during Hot Work*, API Publication 4629, October 2006.

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[3] Maritime Advisory Committee for Occupational Safety and Health (MACOSH) exposure study data, January 2007.

[4] Formisano Jr., J.A., Still, K., Alexander, W. and Lippman, M. (2001), *Application of Statistical Models for Secondary Data Usage of the U.S. Navy's Occupation Exposure Database (NOED)*, Applied Occupational and Environmental Hygiene, 16:2, 201-209

[5] U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), *Small Entity Compliance Guide for the Hexavalent Chromium Standards*, OSHA 3320-10N, 2006

[6] Mulhausen, J.R., and J. Damiano, Quantitative Exposure Data: Interpretation, Decision Making, and Statistical Tools. In *A Strategy for Assessing and Managing Occupational Exposures*, AIHA Press, Fairfax, VA, 1998.

[7] Gulf Coast Region Maritime Technology Center (GCRMTC)/University of New Orleans, *Evaluation of CrVI Exposure Levels in the Shipbuilding Industry*, GMRTC Project No. 32, November 1998, OSHA Docket H054A, Exhibit 35-396 .

[8] *2.0 Welding*, OSHA Docket H054A, Exhibit 35-390-6

[9] *Feasibility of Exposure Controls*, OSHA Docket H054A, Exhibit 38-106-2

[10] Letter to Caroline Freeman, U.S. DOL/OSHA from Jennifer Topmiller, National Institute for Occupational Safety and Health (NIOSH) regarding *Site 9 – Enclosure I, Results of Workplace Environmental Sampling* dated May 30, 2002, OSHA Docket H054A, Exhibit 35-45-9.

[11] Letter to Maureen Ruskin, Occupational Safety and Health Administration, from Amir Kahn, National Institute for Occupational Safety and Health (NIOSH) regarding *Site 6 – Enclosure I, Results of Workplace Environmental Sampling* dated March 26, 2003, OSHA Docket H054A, Exhibit 35-45-16.

[12] Navy/Industry Task Group, *Impact of Proposed OSHA Hexavalent Chromium Worker Exposure Standard on Navy Manufacturing and Repair Operations*, October 1995, OSHA Docket H054A, Exhibit 31-8-3.

[13] Navy Environmental Health Center (NEHC), *Additional Information on Hexavalent Chromium in Navy Workplaces: Addendum to the Original Report to OSHA*, November 2002, OSHA Docket H0054A, Exhibit 31-8-1.

[14] "Respiratory Protection," Code of Federal Regulations, Title 29, Part 1910.134, 71 FR 50187, August 24, 2006.

EXHIBIT A

DATA COLLECTION SPREADSHEETS

Hot Work Operations

Sample ID	Job Title	Date	Location	Site	Size of Space	Operation	Shield Gas	Base Metal	Filler Metal/ Electrode	Shift Hours	Operation Time	Ventilation	Capture Velocity (ft/min)	Sampling Method	Analytical Method	Sample Time	Sample Result	TWA	Full Shift TWA	Respirator Worn?	Respirator Type*
			ship	deck	units = ft^3	FCAW					How long the operation was actually conducted during the shift	local								Yes	HF
			shop	bulkhead		SMAW						general								No	FF
			open	overhead		MIG						natural									PA
			other			TIG															AL
						Carbon arcing															SC
						Grinding															
						Burning															

***Respirator Type**

HF	Half Face
FF	Full Face
PA	Powered Air Purifying
AL	Airline (Supplied Air)
SC	Self-Contained Breathing Apparatus

Paint Removal

Sample ID	Job Title	Date	Location	Site	Size of Space	Operation	Blast Media	Amount of Paint Removed	Paint Color	% Total Cr in Paint	Shift Hours	Removal Time	Ventilation	Capture Velocity (ft/min)	Sampling Method	Analytical Method	Sample Time	Sample Result	TWA	Full Shift TWA	Respirator Worn?	Respirator Type*
			ship	deck	units = ft^3	grinding	garnet	units = ft2				How long the operation was actually conducted during the shift	local								Yes	HF
			shop	bulkhead		needlegunning	water						general								No	FF
			open	overhead		chipping	sponge						natural									PA
			other			hand sanding	coal slag															AL
						blasting	steel shot															SC
						mechanical sanding																

Painting, Plating & Other CrVI Activities

Sample ID	Job Title	Date	Location	Site	Size of Space	Operation	Product Used	% CrVI	Tools Used	Shift Hours	Operation Time	Ventilation	Capture Velocity (ft/min)	Sampling Method	Analytical Method	Sample Time	Sample Result	TWA	Full Shift TWA	Respirator Worn?	Respirator Type*
			ship	deck	units = ft^3	Be as descriptive as possible					How long the operation was actually conducted during the shift	local								Yes	HF
			shop	bulkhead								general								No	FF
			open	overhead								natural									PA
			other																		AL
																					SC