Developing Emissions Factors for Electrodes Commonly used within the Shipbuilding Industry for use in Regulator Reporting Procedures

Final Project Technical Report

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Distribution authorized to project participants and NSRP ASE Program Representatives

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EXECUTIVE SUMMARY

The United States (U.S.) Environmental Protection Agency (EPA) published an Advanced Notice of Proposed Rule Making (ANPRM) in the Federal Register on March 23, 2007, indicating that the shipbuilding and ship repair industry would be included in their Residual Risk Ruling (RRR) process. To ensure that the industry was proactively working with the U.S. EPA during this process, the National Shipbuilding Research Program (NSRP) established several initiatives to provide the industry with technical support to assist them in preparing for and complying with this upcoming RRR. These initiatives have identified several Hazardous Air Pollutants (HAPs) found in welding operations as a primary risk driver for the industry. The U.S. EPA and industry are in agreement that the U.S. EPA's current Air Pollutant Emission Factors Data Set (AP-42) is limited in terms of quantity and quality of emission factors. Since this is the primary data set used by industry for estimating welding emissions for regulatory reporting, shipyard representatives are concerned that their emissions are being inaccurately quantified. This inaccuracy is resulting in either artificially high risk results for the industry, followed by the unnecessary promulgation of additional more stringent and costly regulations, or artificially low risk results that could result in undiscovered, unregulated and uncontrolled real potential risk to human health and the environment.

As a result of the industry taking a proactive approach with this ruling, U.S. EPA representatives have expressed interest in obtaining scientifically valid data to update the existing emissions data set. Under an NSRP funded panel project entitled "Developing Emission Factors for Electrodes Commonly used within the Shipbuilding Industry for use in Regulatory Reporting Procedures", *CTC*, as the prime contractor, along with consultants, The Applied Research Laboratory at the Pennsylvania State University (ARL-PSU), Soft*Tek* Systems, Inc. and ALS Laboratory Group (formerly DataChem Labs), and various shipbuilding and ship repair representatives who provided valuable information as part of the project team, established a methodology to generate this data for the shipbuilding industry. This data can then be used by industry as the industry continues to work with the U.S. EPA. Past NSRP projects have demonstrated that the actual composition of HAPs in welding emissions may, in some cases, be lower than what are calculated using current published emission factors.

This panel project expanded on the work completed under past NSRP projects to assist the industry in addressing the need for high quality emission factors for welding operations. The project was designed so that multiple fume samples were collected to provide reproducibility of results, which will increase the accuracy and quality of the calculated emission factors.

The primary objectives of this project were to:

1. Select five welding process/electrode combinations of importance to the shipyards based on their overall volume of use in the shipyards, their lack of current high quality emission factors and their potential for emitting Hexavalent Chromium (Cr(VI)) and Manganese (Mn); the primary constituents that drive shipyard offsite public health risks.

2. Measure and analyze the welding emissions from the electrodes in accordance with analytical methods developed by the National Institute for Occupational Safety and Health (NIOSH), and the Occupational Safety and Health Administration (OSHA) to determine the total concentrations of Cr(VI), and total Chromium (Cr), Nickel (Ni), Lead (Pb) and Mn. The Sampling and Analysis Plan (SAP) used in this study is attached as Appendix C.

3. Use the resulting analytical data, along with the process data collected during testing to calculate high quality emission factors in terms of mass of pollutant per mass of electrode consumed.

Emission factors have been determined for total fume, total Cr, Mn, Ni, Pb, and Cr(VI) for the five selected welding process/electrode combinations. These emission factors and the emission factors from recent, related studies were compared to U.S. EPA AP-42 and U.S. EPA proposed emission factors. The following findings were identified:

- The emission factors for Cr that were measured in this study for the two stainless steel flux cored electrodes were significantly lower than emission factors proposed by the U.S. EPA.
- The Cr(VI)/Cr ratios generated for four of the electrodes in this study varied from 3 to 35%, indicating that the U.S. EPA proposed 34% "default speciation profile" (that assumes 34% of all reported "Chromium Compounds" are Cr(VI)), cannot be accurately applied to all electrodes. The ratio varies significantly from electrode to electrode demonstrating that it is not appropriate or accurate to establish an overall “default” ratio, and the use of the 34% ratio for all electrodes would greatly overestimate the actual Cr(VI) emissions from some electrodes.

  Using the average Cr emission factor and Cr(VI) ratio measured in this study rather than currently proposed U.S. EPA values, the reported Cr emissions from a shipyard using 50,000 pounds per year (lbs/year) of FCAW 309 would be reduced from 150 lbs to 35 lbs while the Cr(VI) emissions would be reduced from 51 lbs to two lbs. This represents a 77% reduction in Cr emissions and a 96% reduction in Cr(VI) emissions for one key shipyard electrode.
- For all of the five electrodes evaluated, the U.S. EPA proposed emission factor for Pb was approximately two orders of magnitude higher than what was found in this study.
- The emission factor measured for Ni for the SMAW 7018M carbon steel electrode is significantly lower that the U.S. EPA proposed factor.

All other emission factors measured in this study (with the exception of one unexplained data point) are generally consistent within the data sets and are consistent with the U.S. EPA AP-42 and U.S. EPA proposed emission factors.

The data provided within this report, together with the supporting data from previous NSRP/*CTC* studies and from ESAB testing of the same electrode materials, provide valuable additional data to the U.S. EPA that can be used in establishing more accurate

and defensible emission factors for welding emissions for key shipyard welding processes. It is recommended that this data be used by the U.S. EPA to a) augment their data sets where appropriate to improve the quality and confidence of future proposed emission factors, b) set new emission factors where none currently exists, and c) initiate gathering of additional data where data are inconclusive or inconsistent.

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ACRONYMS AND ABBREVIATIONS

µg	microgram
µg/g	micrograms per gram
µg/m^3	microgram per cubic meter
AES	Atomic Emission Spectrophotometry
AIHA	American Industrial Hygiene Association
AMA	Atlantic Marine Alabama
ANPRM	Advanced Notice of Proposed Rule Making
ARL	Applied Research Laboratory
ASA	American Shipbuilding Association
AWS	American Welding Society
BIW	Bath Iron Works
CARB	California Air Resources Board
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations
Cr	Chromium
Cr(III)	Trivalent Chromium
Cr(VI)	Hexavalent Chromium
CTC	Concurrent Technologies Corporation
CTWD	Contact Tip-To-Work Distance
DOP	Diameter of Particle
DPM	Diesel Particulate Matter
EH&S	Environmental, Health and Safety
EPA	Environmental Protection Agency
ETF	Environmental Technology Facility
FCAW	Flux Cored Arc Welding
g	grams
g/kg	gram per kilogram
GD	General Dynamics
HAP	Hazardous Air Pollutant
HEPA	High-Efficiency Particulate Air
ICP	Inductively Coupled Plasma
IPM	inches per minute
JSA	Job Safety Analyses
lbs	Pounds
mg/g	milligrams per gram
ml	milliliters
Mn	Manganese
Mo	Molybdenum
MSDS	Material Safety Data Sheet

ACRONYMS AND ABBREVIATIONS (CONTINUED)

NA	Not Applicable or not set by user
Na_2CO_3	sodium carbonate
$NaHCO_3$	sodium bicarbonate
NASSCO	National Steel and Shipbuilding Company
NAVSEA	Naval Sea Systems Command
NELAP	National Environmental Laboratory Accreditation Program
NGNN	Northrop Grumman Newport News
NGSS	Northrop Grumman Ship Systems
NESHAP	National Emissions Standards for Hazardous Air Pollutants
Ni	Nickel
NIOSH	National Institute for Occupational Safety and Health
nm	nanometer
NMAM	NIOSH Manual of Analytical Methods
NSRP	National Shipbuilding Research Program
NSWCCD	Naval Surface Warfare Center Carderock Division
OSHA	Occupational Safety and Health Administration
Pb	Lead
PSNY	Puget Sound Naval Shipyard
PSU	Pennsylvania State University
PTR	Program Technical Representative
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
QFF	Quartz Fiber Filter
RRR	Residual Risk Ruling
RSD	Relative Standard Deviation
SAP	Sampling and Analysis Plan
SCA	Shipbuilders Council of America
SMAW	Shielded Metal Arch Welding
SOP	Standard Operating Procedure
U.S.	United States
UV	Ultraviolet
VPP	Voluntary Protection Programs
XRF	X-ray Fluorescence

1.0 SCOPE AND APPLICATION

1.1 Background

The U.S. EPA published an ANPRM in the Federal Register on March 23, 2007, indicating that the shipbuilding and ship repair industry would be included in their RRR process. To ensure that the industry was proactively working with the U.S. EPA during this process, the NSRP established an initiative entitled, "Shipbuilding and Ship Repair Industry Initiative to prepare for and comply with the NESHAP Residual Risk Ruling" to provide the industry with technical support to assist them in preparing for and complying with the upcoming RRR. As a result of the RRR project, the U.S. EPA and industry reached the agreement that the U.S. EPA's current Air Pollutant emission factors data set (AP-42) was limited, and contained low quality emission factors which were generated through the use of statistical analysis versus direct scientific data. Because U.S. EPA representatives expressed interest in utilizing data collected during the project to update the existing AP-42 emissions data set, *CTC* developed several emission factors as part of the project. When these emission factors were compared to current AP-42 emission factors, they appeared to be lower in terms of "microgram (μg)" emitted per "gram (g)" of electrode consumed. A limitation identified to the emission factors developed during the RRR project was the fact that the emission factors were based on a single data point.

Consequently, the SP-1 Environmental Technology Panel submitted the data from the RRR project to the U.S. EPA. They responded by saying that after internal discussions regarding the best fit for addressing HAPs emissions under the part 63 NESHAP statutes, the U.S. EPA has decided that developing a separate NESHAP for HAPs from welding operations is the best approach to air quality management (*Driscoll*). The rationale is that several distinct industries, including shipbuilding and aerospace, all have welding operations and thus a NESHAP for all of them would be beneficial for both the U.S. EPA and industry. The U.S. EPA has stated that the data generated from the RRR project would be very helpful in characterizing the industries' chromium emissions in the development of a NESHAP for welding operations (*Driscoll*). The U.S. EPA is encouraging additional sampling campaigns, even though it is unclear when development of such a NESHAP would commence.

This panel project entitled, "Developing Emission Factors for Electrodes Commonly used within the Shipbuilding Industry for use in Regulatory Reporting Procedures", expanded on the work completed under the earlier NSRP RRR project to assist the industry in addressing the need for high quality emission factors. It was designed so that multiple fume samples were collected to provide reproducibility of results, which will increase the accuracy and quality of the calculated emission factors.

1.2 Purpose

This purpose of this project was to develop scientifically defensible emission factors that accurately represent the emissions from electrodes commonly used in the various types of shipbuilding activities (repair, new construction, submarine, surface vessel, etc.).

This Final Project Technical Report details the experimental materials, equipment, procedures, analytical methods, and controls that were used to collect the weld fume emissions data. It also provides the calculated emission factors, along with a discussion on how these emission factors compare to emission factors from various other sources such as: the previous RRR project, the U.S. EPA, and ESAB.

1.3 Objectives

The primary objectives of this project were the following:

1. Select five welding process/electrode combinations based on their a) overall use in the shipbuilding industry; b) lack of current high quality emission factors; and c) potential for emitting Cr(VI) and Mn, the primary constituents that drive shipyard offsite public health risks. Additional information regarding the electrode selection process for this study can be found in the Electrode Usage Summary and Selection Report attached as Appendix D.
2. Collect the emissions produced from these five welding process/electrode combinations in accordance with American Welding Society (AWS) F1.2:2006, *Laboratory Method for Measuring Fume Generation and Total Fume Emission of Welding and Allied Processes* (*AWS F1:2*).
3. Analyze the emissions in accordance with analytical methods developed by NIOSH and OSHA to determine the total concentrations of Cr(VI), and total Cr, Ni, Pb and Mn. The SAP used in this study is attached as Appendix C.
4. Use the resulting analytical data, along with the process data collected during the testing (amount of electrode consumed), to calculate emission factors for the electrode in terms of mass of pollutant per mass of electrode consumed.

1.4 Organization

This study was conducted through the NSRP SP-1 Environmental Technology Panel with *CTC* acting as the primary contractor. *CTC* teamed with The ARL-PSU, and Soft*Tek* Systems, Inc. as consultants for the project, and ALS Laboratory Group (formerly DataChem Labs) as the analytical laboratory for sample analysis. The contact information for the study participants are provided in Table 1.1 below.

Table 1.1. Study Participants

Name	Organization	Role	Contact Information
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Rand Potter	ALS Laboratory Group (formerly DataChem Labs)	Sample Analysis	E-mail: potter@datachem.com Phone: (801) 904-4277

The panel project organization is outlined in Figure 1.1 below.

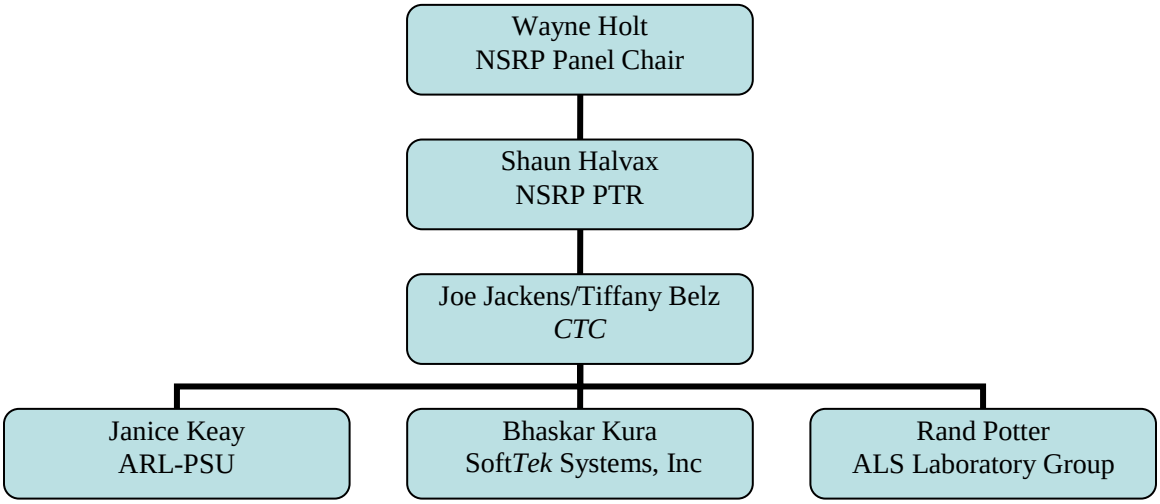

Figure 1.1. Panel Project Organization

2.0 SUMMARY OF METHOD

The goal of this testing was to determine scientifically valid emission factors for the selected welding process/electrode combinations. Welding fumes were collected from

five different process/electrode combinations on appropriate analytical fiber filters. The filters were submitted to an American Industrial Hygiene Association (AIHA) accredited industrial hygiene testing laboratory for the analysis of: Cr(VI), Cr, Mn, Pb, Ni, and mass of total fume, via standardized OSHA and NIOSH methods. The analytical results were used to calculate emission factors for each of these five welding process/electrode combinations.

The five process/electrode combinations were selected based on input received from shipyard surveys, a review of current AP-42 emission factor data gaps and quality indicators, and a review of electrode composition to determine the potential to emit Cr(VI) and/or Mn, the primary constituents that drive shipyard offsite public health risks.

CTC utilized past studies conducted in support of the NSRP to collect baseline information on shipyard welding processes and materials. *CTC* then applied this information to develop a survey instrument that was intended for the collection of current data to assist in the prioritization and down-selection process of ten potential welding process/electrode combinations. Three surveys were distributed to 46 U.S. commercial and naval shipyards for the identification of electrodes that are used most often, and which electrodes present the greatest potential challenge to the shipyards in terms of emissions reporting requirements. This challenge could be due to the characteristic emissions from the specific electrode, the availability and accuracy of AP-42 emission factors, or the relative usage rate within the shipyard. The incorporation of input from the shipyard survey's ensured that the data is representative of the overall industry. *CTC* then researched the industry identified electrodes to determine if they currently have high quality emission factors assigned to them by the U.S. EPA, and to identify their potential for emitting CR(VI) and Mn, the primary constituents that drive shipyard off-site health risks. These factors helped to provide the justification to make a final selection of the five process/electrode combinations for evaluation under this project. Additional information regarding the electrode selection process can be found in Appendix D .

The five selected combinations were as follows:

- Flux Cored Arc Welding (FCAW) 308
- FCAW 309
- Shielded Metal Arc Welding (SMAW) 11018
- SMAW 309
- SMAW 7018

Welding with each of these process/electrode combinations was conducted within a conical test chamber meeting the requirements of the AWS test method AWS F1.2:2006, *Laboratory Method for Measuring Fume Generation and Total Fume Emission of Welding and Allied Processes* (Appendix L). The specific chamber that was used for this study was constructed in accordance with AWS F1.2:2006, with the exception that the top of the chamber was reduced to a diameter of 8" (rather than the specified 12") to

allow for the use of 8" high volume fiber filters that were required for analytical analysis via the OSHA and NIOSH methodologies.

Eighteen welding runs were conducted within the weld fume chamber for each of the five selected welding process/electrode combinations (Table 2.1), and the weld fumes were collected on 8" fiber filters, which were analyzed as follows:

- Welding fumes for six runs were collected on glass fiber filters (Pall A/E glass fiber filters) that were pre-weighed by the analytical laboratory. After fume collection, the filters were reweighed back at the analytical laboratory, completing the gravimetric analysis in accordance with NIOSH Method 0500 to determine total mass of fume generated. Each filter was then analyzed according to NIOSH Method 7300 to determine total Cr, total Mn, total Pb and total Ni.

- Welding fumes for six runs were collected on quartz fiber filters (Pall Tissuquartz™) pre-weighed by the analytical laboratory. Again, the gravimetric analysis was completed back at the analytical laboratory in accordance with NIOSH Method 0500 to determine total mass of fume generated. The gravimetric analysis for the quartz fiber filters had to be completed as a separate set of runs due to the fact that the Cr(VI) samples required field preservation in a vial of sodium bicarbonate/sodium carbonate solution, making post-weighing impossible.

- Welding fumes for six of these runs were collected on quartz fiber filters (Pall Tissuquartz). Each of these filters was inserted immediately after sampling into a vial containing sodium bicarbonate/sodium carbonate solution ($NaHCO_3/Na_2CO_3$) to quench the conversion of Cr(VI) to Trivalent Chromium (Cr(III)). The quenched filters were then analyzed for Cr(VI) using OSHA Method ID-215.

Table 2.1. Test Matrix

				# of Runs	# of Samples Analyzed		
Process	Electrode	Base Metal	Filter	Welding	Mass on Filter	Total Metals: Cr, Mn, Ni, Pb	Cr(VI)
FCAW	308	304 SS	TissuQuartz	6	6	---	---
	308	304 SS	TissuQuartz	6	---	---	6
	308	304 SS	Glass Fiber	6	6	6	---
FCAW	309	304 SS	TissuQuartz	6	6	---	---
	309	304 SS	TissuQuartz	6	---	---	6
	309	304 SS	Glass Fiber	6	6	6	---
SMAW	309	304 SS	TissuQuartz	6	6	---	---
	309	304 SS	TissuQuartz	6	---	---	6
	309	304 SS	Glass Fiber	6	6	6	---
SMAW	7018	DH 36	TissuQuartz	6	6	---	---
	7018	DH 36	TissuQuartz	6	---	---	6
	7018	DH 36	Glass Fiber	6	6	6	---
SMAW	11018	DH 36	TissuQuartz	6	6	---	---
	11018	DH 36	TissuQuartz	6	---	---	6
	11018	DH 36	Glass Fiber	6	6	6	---

This sampling strategy provided the following:

- Six data points per process/electrode combination, for Cr, Cr(VI), Mn, Pb, and Ni.
- Twelve data points (six on quartz fiber filters and six on glass fiber filters) per process/electrode combination for total mass of fume generated.

The data from each of the six individual sampling runs was combined with the mass of electrode consumed during that specific run, to calculate an emission factor in units of micrograms of pollutant emitted per gram of electrode consumed (µg/g). The six emission factors values were then averaged to produce a representative emission factor for that specific pollutant, produced from that specific process/electrode combination.

Using this procedure, emission factors were generated specific to each of the five process/electrode combinations, for pollutants including: total fume; total Cr, Mn, Pb, and Ni; and Cr(VI).

Details for this sampling and testing methodology are presented in this report, along with the presentation and discussion of the resulting emissions data and emission factors.

3.0 DEFINITIONS

3.1 Welding Processes

3.1.1 Shielded Metal Arc Welding

SMAW utilizes heat produced by an electric arc to melt a covered electrode and the welding joint at the base metal. During operation, the rod core both, conducts electric current to produce the arc and provides filler metal for the joint. The core of this covered electrode consists of either a solid metal rod of drawn or cast material or a solid metal rod fabricated by encasing metal powders in a metallic sheath. The electrode covering provides stability to the arc and protects the molten metal by creating shielding gases by vaporization of the cover (*AP-42*).

3.1.2 Flux Cored Arc Welding

FCAW is a consumable electrode welding process that uses the heat generated by an arc between the continuous filler metal electrode and the weld pool to bond the metals. This flux cored electrode consists of a metal sheath surrounding a core of various powdered materials. During the welding process, the electrode core material produces a slag cover on the face of the weld bead. The welding pool can be protected from the

atmosphere either by self-shielded vaporization of the flux core or with a separately supplied shielding gas (*AP-42*).

3.2 Filter Media

3.2.1 Tissuquartz™ Filter, Quartz, No Support Pad, 8" x 10"

- Autoclavable, binder-free, heat-treated to remove trace organic impurities, high-purity microfibers for collecting diesel particulates and trace-level environmental pollutants.
- Superior purity for collection of elemental/organic carbon, Diesel Particulate Matter (DPM), and trace-level contaminants.
    - Heat-treated to reduce trace organics
    - Low-metal background
    - Binder-free
    - High flow rate and filtration efficiency
    - Withstand temperature up to 1832º F (1000ºC)
- Specified in NIOSH method 5040 for Elemental Carbon (Diesel Particulates (*SKC Website (1)*).

3.2.2 Type AE Glass, Glass Fiber, No Support Pad, 1.0 micrometer (µm), 8" x 10"

- High-temperature tolerant
- Liquid nominal pore size of 1.0 µm
- High-particle retention (*SKC Website(2)*)

3.3 Electrodes

3.3.1 Avesta Stainless Steel Flux Core Wire E308LT1

The Material Safety Data Sheet (MSDS) (Avesta E308LT1-1 in Appendix J) states the approximate composition of the tube and the flux core separately as:

- 19% Cr in the tube, 0-40% Cr in the Flux core
- 10% Ni in the tube, 0-20% Ni in the Flux core

- 1% Mn in the tube, 0-10% Mn in the Flux core
- <0.3% copper in the tube, not specified in the flux core
- <0.3% molybdenum (Mo) in the tube, 0.8-15% Mo in the flux core
- Up to 68% iron in the tube, "balance" of iron and various other constituents in the flux core

3.3.2 Shield Bright Flux Cored Stainless Steel Electrode 309LT1

Shield-Bright 309L was developed for welding stainless steel to carbon or low alloy steels and for the first layer cladding of carbon and low alloy steels. It was designed for welding in all positions and performs particularly well in the vertical position with excellent slag removal.

For joining thick sections, it is preferred that the non-stainless steel be buttered with a layer of Shield-Bright 309L and the joint completed with Shield-Bright 316L or 308L. The service temperature should not exceed approximately 750ºF (399ºC) (Appendix J).

The MSDS (7968-X in Appendix J) states the approximate composition as:

- 21-24% Cr
- 10-12% Ni
- 1-3% Mn
- 0.2-2% silicon
- <1% copper and Molybdenum (Mo)
- <20% various other constituents
- Balance (>45%) iron

3.3.3 Arcaloy SMAW Stainless Steel Welding Electrode 309L

Arcaloy 309L-16 is used for welding carbon and low alloy steels to stainless steels. This can be done provided the service temperature does not exceed about 700ºF (315ºC). Post weld heat treatment should only be performed after due consideration (Appendix J).

The MSDS (7967-O in Appendix J) states the approximate composition as:

- 18-20% Cr

- 8-10% Ni
- 2-4% Mn
- <0.5% silicon
- 40-50% iron
- With the balance (<30%) being a mixture of fluorides, calcium salts, silicates, silicon dioxide and mineral silicates, and titanium dioxide

3.3.4 Atom Arc Low Hydrogen Welding Electrode E7018M

Atom Arc 7018 is an all-position low hydrogen moisture resistant electrode. The wider operating ranges and smooth weld metal transfer minimizes post weld clean up. This premium quality electrode meets a multitude of codes and welding specifications. Atom Arc 7018 was developed to weld carbon and low-alloy steel, including a variety of hardenable steel (Appendix J).

The MSDS (7970-T in Appendix H) states the approximate composition as:

- 1.0-2.0 % Mn
- 70-85% iron
- With the balance (<30%) being a mixture of calcium salts, silicon, silicon dioxide and mineral silicates, and titanium dioxide

3.3.5 Atom Arc Low Hydrogen Welding Electrode E11018-M

Atom Arc T (E11018-M) was developed for welding T-1 steel in all applications. Mechanical properties of the welded joints equal or exceed the properties of the base steel in either the as welded or stress relieved condition, thus giving 100% design joint efficiency. In addition, Atom Arc T electrodes are suitable for many other applications, particularly where high-strength welds with excellent low-temperature impact properties are required (Appendix J).

The MSDS (7970-T in Appendix H) states the approximate composition as:

- 2-3 % Mn
- 1-2% Ni
- <0.5% Cr

- 65-80% iron
- With the balance (<30%) being a mixture of calcium salts, silicon, silicon dioxide and mineral silicates, and titanium dioxide

4.0 INTERFERENCES

4.1 OSHA ID-215 Cr(VI)

The OSHA ID-215 uses alkaline extraction condition which prevents the reduction of Cr(VI) to Cr(III) and includes the addition of phosphate buffer/magnesium sulfate to the extraction media to reduce interferences from iron (II). Cr(VI) is then separated from any Cr(III) that is present in the sample using ion chromatography. Finally, post-column derivatization of the Cr(VI) with 1,5-diphenyl carbazide is performed to allow analysis using Ultraviolet (UV)-vis detection at 540 nanometers (nm) (*OSHA ID-215*). The combination of stabilization, separation and derivatization provides for a very specific analysis with a minimum of interference.

4.2 NIOSH 7300 Elements by Inductively Coupled Plasma (ICP)

The NIOSH 7300 method states that spectral interferences are the primary interferences encountered in ICP Atomic Emission Spectrophotometry (AES) analysis. NIOSH 7300 uses alkaline extraction conditions which prevent the reduction of Cr(VI) to Cr(III), and includes the addition of phosphate buffer/magnesium sulfate to the extraction media to reduce interferences from iron (II). In addition, this is an ion chromatography method with post column derivatization and detection by visible spectroscopy. The combination of these two techniques makes the method very specific for Cr(VI).

5.0 SAFETY

5.1 General Testing Safety

All welding and sampling activities were completed at *CTC's* Environmental Technology Facility (ETF) which has been designated by OSHA as a Voluntary Protection Programs (VPP) Star site. *CTC* ensured that all *CTC* and non-*CTC* employees were aware of and followed the established Environmental, Health and Safety (EH&S) regulations and procedures. This testing event was evaluated for EH&S risks and controls through the use of *CTC's* International Organization for Standardization ISO procedures (Form 3014: Legal and Other Requirements and Form 3013: Environmental Aspects & Impact Evaluation). These forms were reviewed and approved by *CTC's* Senior EH&S Engineer, Mr. Tom Monito.

5.2 Welding Safety

A qualified *CTC* welder completed all welding activities for this testing event. The *CTC* welder was properly trained and all activities were conducted in accordance with applicable OSHA regulation, including 29 Code of Federal Regulations (CFR) 1910 Subpart Q - Welding, Cutting, and Brazing, as well as established *CTC* Work Instructions and Job Safety Analyses (JSA). Other study participants were protected from the welder's flash by the chamber.

The study participants were not exposed to the weld fumes because the fume chamber system is designed to capture and contain all welding fumes. The fumes were pulled from the chamber through a filter designed to capture, at a minimum, 99.9% of the hazardous constituents. However, as an added safety precaution, a local exhaust ventilation system was placed at the chamber's blower outlet to capture and remove all exhaust air from the work environment.

5.3 Contractor Safety

One contractor (non-*CTC* employee) from PSU ARL was present during this testing event. This contractor was briefed on applicable *CTC's* EH&S Policies including building evacuation procedures and outside emergency meeting areas. In addition, this contractor signed in and out using the ETF building attendance log in accordance with *CTC* policy and was escorted by *CTC* personnel at all times.

5.4 Sample Collection Safety

Study participants were required to wear the nitrile gloves when handling any filter media and/or preservation solutions. In addition, all study participants were required to wear safety glasses and safety shoes during the testing event.

6.0 EQUIPMENT AND SUPPLIES

6.1 Welding Test Chamber

The specific chamber that was used for this study was constructed following the guidelines of AWS F1.2:2006, with the exception that the top of the chamber has been reduced to a diameter of 8" (rather than the specified 12") to allow the use of 8" high volume fiber filters with compositions that are suitable for the analytical analysis via the OSHA and NIOSH methodologies. The modified weld fume chamber that was used is shown in Figure 5.1.

Figure 5.1. *CTC* Weld Fume Chamber

An AMETEK ROTON® Blower Model DR454R72M, Part # 080480 pulled the weld fumes that were generated up through the fume chamber exhaust duct at a flow of 709 to 989 liters/minute (25 to 35 cubic feet per minute [CFM]) as specified in Section 4.2.2 of the AWS F1.2:2006. The flow was controlled using a Lenze AC Tech adjustable frequency drive that controls the blower speed. The flow rate was measured in CFM using a ROTRON air flow meter and displayed on a gauge that is located on the control panel of the weld fume chamber.

A pressure drop gauge which reports the pressure drop across the filter in inches of water was also located on the control panel. This pressure drop gauge indicated the amount to which the filter is loading.

The control panel with gauges is shown in Figure 5.2. A detailed description of all the equipment installed on the weld fume chamber can be found in the Weld Fume Chamber Manual that is attached in Appendix K.

Figure 5.2. Control Panel with Gauges

The exhaust flow rate was monitored to make sure that the flow through the chamber did not drop below the minimum 25 CFM specified in AWS F1.2:2006. This purpose of this requirement is to ensure that all fumes are drawn up through the filter where they are captured, and that none of the fume escapes through the access ports or the bottom of the chamber. Reproducibility of the mass of fume captured/mass of electrode consumed for each process/electrode combination was calculated upon receipt of the gravimetric results from the lab. This data, presented in Section 10.1, indicates the combined precision of welding fume generation and fume capture.

6.2 Filters

The selection of filters for the capture of weld fume in the AWS weld fume chamber involved the consideration of a number of factors:

- Ability to filter fine fume particulates from the air,
- Capacity to handle high flow rates through the filter for use in the AWS chamber,
- Suitability for use in the selected OSHA and NIOSH methods for the analysis of heavy metals Cr, Mn, Pb, Ni and Cr(VI), and
- Available in sizes of at least 8" diameter.

AWS F1.2:2006 calls for the use of a pad of glass fiber insulation to filter the fume from the test chamber exhaust stream. The use of the glass fiber insulation pad allows for gravimetric analysis of the total mass of fume, but not for quantitative chemical analysis of individual metal components in the fume.

In addition, Mr. Chris Halm at the California Air Resources Board (CARB) reports that the AWS-recommended filter pad does not efficiently capture all fumes that are generated; at times over 10% of the fume mass passes through the glass fiber filter pad (*Halm*). Halm therefore recommends the use of Whatman Glass Microfiber filters, EPM-2000 for more complete capture of particulates.

Whatman Glass Microfiber EPM-2000 filter, Pall Tissuquartz™ quartz fiber filter, and Pall A/E glass fiber filter are all specifically designed for use with high volume air samplers (*VWR, Pall*). They all capture greater than 99.9% of Diameter of Particle (DOP) 0.3µm particulates, and they are all available in 8" x 10" sheets, which are large enough to capture the fumes from the cross-sectional area of the 8" diameter openings in the AWS fume chamber.

OSHA method ID-215 for Cr(VI) analysis calls for the use of Polyvinyl Chloride (PVC) or quartz filters. Because PVC membrane filters are not available in sizes larger than 4" diameter, they are not suitable for this application. However, the Pall quartz membrane filters can be used provided that they are inserted into an $NaHCO_3/Na_2CO_3$ solution immediately after sampling in order to quench the conversion of Cr(VI) to Cr(III) on the filters.

NIOSH method 7300 for heavy metals analysis allows for the use of glass fiber filters, making the 8" x 10" Pall A/E glass fiber filters acceptable for the Cr, Mn, Pb and Ni analysis.

Based on the filter criteria and method restrictions listed above, Pall Tissuquartz quartz fiber filters were used to collect fume samples for Cr(VI) analysis via OSHA ID-215 and Pall A/E glass fiber filters were used to collect fume samples for total metals via NIOSH 7300. Both filters were used for gravimetric analysis of total fume by NIOSH Method 0500.

Prior to the testing events, the 8" x 10" filters were cut into 8" diameter circles, using an aluminum cutting die. These were then sent to the laboratory where they were conditioned, pre-weighed and placed individually in labeled storage bags and envelopes (Figures 6.1 and 6.2).

Figure 6.1. Filter in Labeled Bag

Figure 6.2. Filter Envelopes

6.3 Electrodes

A total of five different welding process/electrode combinations, including both mild steels and stainless steels, were evaluated during the testing event. These were:

- FCAW 308
- FCAW 309
- SMAW 11018
- SMAW 309
- SMAW 7018

These electrodes were selected based on a.) shipyard recommendation, b.) lack of current high quality emission factors, and c.) potential for emitting Cr(VI) and Mn, the primary constituents driving shipyard offsite public health risks.

Shipyards involved in all aspects of shipbuilding activates (repair, new construction, submarine, surface vessel, etc.) were provided with three separate surveys that requested information on the electrodes that they would like to see evaluated under this project. The results of these surveys were tabulated, and a prioritized list of shipyard recommended electrodes was developed. The electrodes from this list were researched to determine if current AP-42 emission factors were available, and if so, what quality ratings were currently assigned to them. In addition, the composition of the these electrodes was obtained from MSDSs to evaluate their potential to emit Cr(VI) and/or Mn, the two primary constituents that drive shipyard offsite public health risks. As a result of this evaluation and down-selection process, the five process/electrode combinations listed above emerged as those most in need of evaluation to develop high quality welding emission factors. This approach and down-selection process was documented in the project report entitled *Electrode Usage Summary and Selection Report* (Appendix D).

6.4 Base Metals

The mild steel electrodes were used in combination with DH-36 mild steel base metal. The stainless steel electrodes were used in combination with 304 stainless steel base metal. Base metals were selected based on their overall use, which was indicated on the surveys completed by the shipyards (Appendix D).

7.0 REAGENTS AND STANDARDS

7.1 Sampling Reagents

A $NaHCO_3/Na_2CO_3$ solution, prepared by ALS Laboratory Group (formerly DataChem Labs), was used to quench the conversion of Cr(VI) to Cr(III) in the field after sampling (*OSHA ID-215*, Appendix G).

7.2 Analytical Reagents

ALS Laboratory Group used the reagents and standards required by OSHA ID-215 and NIOSH 7300 analytical methodologies. These methodologies can be found in Appendices G and H, respectively.

8.0 SAMPLE COLLECTION, PRESERVATION, STORAGE AND TRANSPORT

The study was conducted over a two-day sampling event (September 22-23, 2009) at *CTC's* ETF, located in Johnstown, PA. A *CTC* welder completed all welding activities.

Test Run Data Log sheets were used during the testing to document information relevant to the testing. Information recorded on these sheets included: welding times; fume chamber run times; sampling times; flow rate; pressure drop; volts, and amps; shielding gases and base metals; electrode weights; filter types; ambient room temperature and humidity; and any special circumstances, problems or changes from the SAP. The Test Run Data Logs completed during this study are provided in Appendix E.

The welding materials proposed for this study are listed in Table 8.1, along with the parameters recommended by the suppliers in the Technical Product Data Sheet, which were included in the SAP (Appendix C). As much as possible, these recommended welding parameters were used during the testing.

Table 8.1. Proposed Welding Materials and Parameters

Process	AWS Classification	Electrode Diameter	Base Metal	Supplier Recommendations				
				Amps	Volts	CTWD*	Wire Feed Speed (ipm)	Shielding Gas
FCAW	**E308HT1-1 E308HT1-4**	0.045"	304 SS	190	28	5/8" - 3/4"	445	75% Ar/25% CO_2
FCAW	**E309HT1-1 E309HT1-4**	0.045"	304 SS	190	28	5/8" - 3/4"	445	75% Ar/25% CO_2
SMAW	**E309-15 E309H-15**	1/8"	304 SS	65-120	NA	NA	NA	NA
SMAW	**E7018**	1/8"	DH 36	90-160	NA	NA	NA	NA
SMAW	**E11018-M**	1/8"	DH 36	90-160	NA	NA	NA	NA

NA = Not applicable or not set by user
*CTWD = Contact Tip-To-Work Distance
ipm = inches per mintue

Some of the electrodes received by the project team were not consistent with electrodes proposed for use in Table 3 above. Deviations from this table are as follows:

- The ESAB 308 HT1 electrode provided was a solid wire electrode. It was replaced with an Avesta 308 LT1electrode that was available in-house because the study was designed to evaluate flux cored electrodes.
- 309 LT1was received in place of 309H.
- 309L-16 was received in place of 309H-15.

According to the AWS, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, the H indicates that the allowable weld metal carbon content is restricted to 0.04 to 0.08 % to provide higher tensile and creep strength at elevated temperature. The

L indicates the allowable weld metal carbon content is restricted to 0.04 % maximum, to reduce the possibility of intergranular carbide precipitation to increase the resistance to intergranular corrosion. It appears that these designations are related to the use of the electrode, and only alters the composition slightly.

The actual electrodes and welding parameters used in the study are presented in Table 8.2.

Table 8.2. Welding Materials and Parameters Used for Testing

Process	Electrode	Company	Size	Base Metal	Amps	Volts	Wire Feed Speed (ipm)	Shielding Gas
FCAW	**308LT1**	Avesta	0.045"	304 SS	198	28	375.8	75% Ar/ 25% CO_2
FCAW	**309L**	ESAB	0.045"	304 SS	198	28	387.2	75% Ar/ 25% CO_2
SMAW	**309L-16**	ESAB	1/8"	304 SS	110	28	NA	NA
SMAW	**7108-M**	ESAB	1/8"	DH 36	134	25	NA	NA
SMAW	**11018-M**	ESAB	1/8"	DH 36	135	25	NA	NA

NA = Not Applicable or not set by user
ipm = inches per minute

The welding process and electrode was set up within the weld fume chamber. The base metal was ground down to the bare metal to ensure no coatings were present (Figure 8.1).

Figure 8.1. Clean Base Metal Prior to Conducting Welding Test Run

When using the stick electrodes (SMAW), an initial and final rod weight were recorded in the Test Run Data Log to determine the amount of electrode consumed (Figure 8.2).

Figure 8.2. Weighing of Stick Electrodes

When using wire electrodes (FCAW), the wire feed rate was determined (inches/15 seconds) and the wire mass per unit length was determined (grams/inch) and recorded prior to welding. The welding time was recorded on the Test Run Data Log sheet. Using this information, the mass of weld wire consumed for each test run was calculated.

Based on the type of analysis, an appropriate filter from Table 2.1 was selected and assigned a field identification name and number that correspond to the welding process (FCAW or SMAW), electrode type (e.g., 309 or 7018) and the run number (1-6). The field identification name and number were recorded in the Test Run Data Log.

The filter was removed from its labeled sampling container and placed on the bottom side of the gasketed sampling cage and clamped in place with a gasketed locking ring. The cage and filter were inserted into the top of the weld fume chamber. A gasketed top was put into place and clamped down. Figure 8.3 provides illustrations of the process that was used to install the filter into the weld fume cage and chamber.

Figure 8.3. Placing Filter in Weld Fume Chamber

After inserting the filter into the weld fume chamber, the welder positioned himself for welding. The turntable and blower were started, and the flow rate (in CFM) and pressure drop (in "inches of water") were recorded. The initial flow rate varied between 29 and 52 CFM. The initial pressure varied between 16 and 30 inches of water. The CFM and pressure drop were dependent on the filter type, and the speed at which the blower was operated. The blower speed was adjusted slightly throughout the testing event to maximize run times, while being cautious not to damage the filters.

After achieving a steady flow rate, the timekeeper signaled the welder to start welding (Figure 8.4), and the stopwatch was started when the arc was made between the electrode and base metal.

Figure 8.4. Welding Inside the Chamber During a Test Run

As the filter loaded with particulates from the fume, the flow rate continued to decrease and the pressure drop across the filter continued to increase by approximately eight to ten inches of water. Welding was stopped prior to the flow rate dropping below 25 CFM, which is the minimum specified in AWS F1.2:2006 to ensure fume does not escape the chamber.

As the testing progressed, the project team noted that some of the quartz fiber filters were developing tears and/or small holes (Figure 8.5) when using the flow reduction as a stopping point for the run.

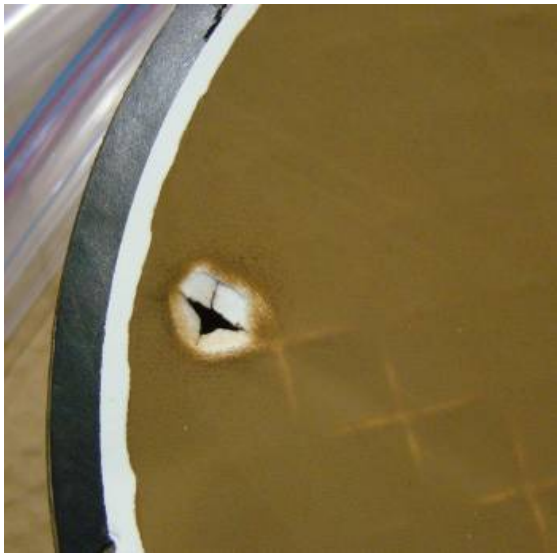

Figure 8.5. Small Hole Noted in a Filter due to Increased Pressure

This was due to the fact that the pressure drop increased to a level these filters could not handle. To resolve this issue, the project team limited the run time for quartz fiber filters to ensure the pressure drop did not become high enough to tear or damage the filter. Welding times ranged from 16 to 59 seconds based on the rate of increase in pressure drop, and decrease in flow rate, which were both dependent on the fume generation rate of the process/electrode combination. Fume generation rates depend on the type of welding process, electrode, and process conditions.

NOTE: It is important to note that whenever any sign of damage to the filter was observed, that filter was discarded and the test was performed again using a new filter.

For all runs, the blower was left operational for an additional 60 seconds after the welding was stopped in order to capture all weld fumes from the chamber, as specified in the AWS F1.2:2006.

After the blower was turned off, the filter cage was removed from the chamber, and the filter was inspected for any signs of fume loss. This inspection included ensuring that there were no holes or tears in the filter, and that the outer ring of the filter was clean, indicating that there was a tight seal on the filter cage and that no fume had escaped around the sides. Figure 8.6 demonstrates a filter that passed this inspection because a solid white ring is visible around the filter.

Figure 8.6. Filter that Passed Inspection Demonstrating that No Fume was Lost

For comparison purposes, Figure 8.7 demonstrates a filter that did not pass this inspection. This filter was discarded and the test was re-run.

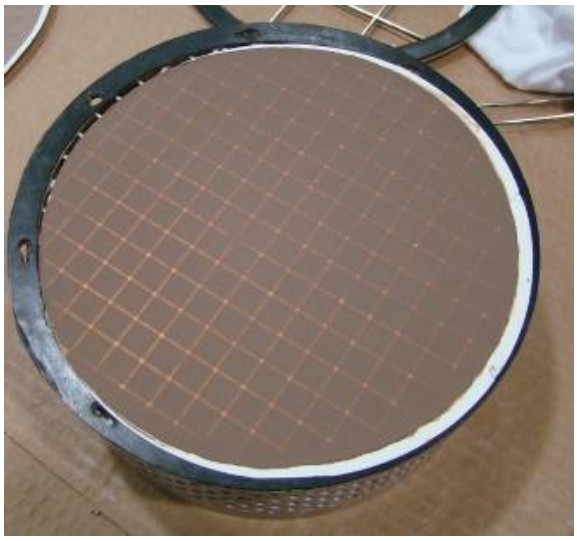

Figure 8.7. Filter that Did Not Pass Inspection Indicating Fume May Have Been Lost

The quartz fiber filters, intended for gravimetric analysis, and all glass fiber filters were removed from the cage, folded into quarters, and inserted back into the labeled sample bags and envelope (Figure 8.8).

Figure 8.8. Folding Filters for Shipment to the Laboratory

The quartz fiber filters used for Cr(VI) analysis were also folded into quarters, then inserted into individual labeled vials (Figures 8.9 and 8.10) .

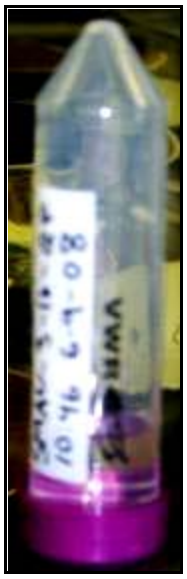

Figure 8.9. Vial for Cr(VI) Samples

Figure 8.10. Placing Folded Filter into Vial

Twenty to 25 milliliters (ml) of a $NaHCO_3/Na_2CO_3$ buffer solution was added to wet the filters and quench the conversion of Cr(VI) to Cr(III) on the filters (Figure 8.11) (*OSHA ID-215* and *Chang et. al.*).

Figure 8.11. Addition of the $NaHCO_3/Na_2CO_3$ Solution

The vials were stored in a freezer below the U.S. EPA recommended 4°C to further inhibit the conversion of Cr(VI). The following day the vials were packed into a cooler with dry ice and all samples were shipped to ALS Laboratory Group , using overnight or next-day delivery.

The procedures listed above were carried out using each of the five process/electrode combinations listed above. The inside of the chamber was blown out with an air hose and wiped clean before starting a new process/electrode combination (Figure 8.12).

Figure 8.12. Cleaning the Chamber Between Runs

9.0 QUALITY CONTROL (QC)

9.1 Sampling Control Blanks

Field Blanks

One Tissuquartz fiber filter was placed in the weld fume chamber during a blank fume chamber run. The blower was turned on and run for 110 seconds without any welding activity. This filter was labeled Quartz Fiber Filter (QFF)-Equip Blank. The filter was folded and inserted into a vial containing the $NaHCO_3/Na_2CO_3$ solution. The vial was analyzed for Cr(VI) via the OSHA ID-215 method to determine if there was any Cr(VI) contamination in the chamber or in the filter media itself.

One separate Tissuquartz fiber filter was placed in the weld fume chamber during a blank fume chamber run. The blower was turned on and run for 80 seconds without any welding activity. This filter was labeled QFF-Equip Blank2. The filter was analyzed gravimetrically via the NIOSH 0500 method to determine if any residual particulates in the chamber or air would affect the gravimetric results.

One glass fiber filter was placed in the weld fume chamber for a blank fume chamber runs. The blower was turned on and run for 80 seconds without any welding activity. This filter was labeled GFF-Equip Blank2. This filter was analyzed gravimetrically via the NIOSH 0500 method again for quality assurance on the gravimetric results. This filter was also analyzed using the NIOSH 7300 method to determine if there was any metal contamination present in the fume chamber, or in the filter media itself.

9.2 Sample Control

Each sample collected was assigned a unique sample identification number that clearly distinguished it from other similar samples and provided information necessary to trace the sample to relevant field data sheets. Immediately after sample collection, each sample was placed in a suitable storage container and labeled with the unique sample identification number, the date and the initials of the person packaging the sample.

Chain-of-custody records were kept for each sample set, documenting all transfers in the possession of the samples, and documenting that the samples were in constant custody from collection at *CTC* to analysis at ALS Laboratory Group (formerly DataChem Labs).

9.3 Records and Document Control

Test Run Data Logs were used to provide sufficient experimental details, data, and observations to enable reconstruction of events that occurred during test and sampling activities. All entries in the Test Run Data Logs or in the Field Data Notebook were made with indelible ink and are legible, accurate and complete. All entries include sample identification numbers to correlate the samples collected to the recorded test information. Any errors made when recording test data were corrected by drawing a line through the error and entering the correct information. The erroneous information was not obliterated. All corrections were initialed and dated. A copy of the Test Run Data Logs is included in Appendix E to this report, and the original Test Run Data Logs are being stored in a manner that protects them from loss or damage, and have become part of the project record file at *CTC*.

A copy of the chain-of-custody form is being retained in the project record file for traceability.

9.4 Analytical Laboratory Quality Assurance (QA)/QC

Filtrate samples were analyzed by ALS Laboratory Group , an American Industrial Hygiene Association (AIHA) accredited industrial hygiene testing laboratory, following established U.S. EPA protocols. QA and QC procedures cited within the specified OSHA and NISOH methods were followed. ALS Laboratory Group also followed and adhered to their own established and documented Standard Operating Procedures (SOPs) and QA/QC procedures.

9.5 Data Review and Reporting

All data collected during the testing event was entered into a Microsoft™ Excel spreadsheet and organized for calculation of emission factors. Data included in the spreadsheet was verified as accurate through the analytical laboratory's

QA/QC process. Emission factors were calculated and reported in units of mass of fume or HAP per mass of electrode consumed.

A hard copy of the spreadsheet data is included in Appendix F of this summary report. An electronic version of the data is part of the project record file at *CTC*.

This final testing summary report has been reviewed and approved by the project team and *CTC* prior to its release. A hard copy and an electronic copy of the final report are part of the project record file at *CTC*.

10.0 CALIBRATION/STANDARDIZATION

10.1 Fume Chamber Standardization and Flow Checks

The exhaust flow rate through the weld fume chamber was monitored and recorded before and after each welding test run to ensure that the flow through the chamber did not drop below the minimum 25 CFM specified in AWS F1.2:2006. The purpose of this requirement was to ensure that all fumes were drawn up through the filter where they were captured, and that none of the fume escaped through the access ports or the bottom of the chamber.

Reproducibility of the mass of fume captured/mass of electrode consumed for each process/electrode combination was calculated upon receiving the gravimetric results from the lab. These data, presented in Table 5, indicate the combined precision of welding fume generation, fume capture and the gravimetric analysis.

Table 10.1. Reproducibility of Total Fume Emission Factors

Total Fume Emission Factors	FCAW 308LT1	FCAW 309LT1	SMAW 309L-16	SMAW 7018M	SMAW 11018-M
$MEAN_{12}$ (mg fume/g rod)	5.5	6.3	10.4	20.5	17.3
STDEV	1.0	1.1	1.9	2.0	1.8
RSD	18	18	18	10	10

For the stainless steel electrodes, where the total fume emission factors ranged from 5.5 to 10.4 milligrams per gram (mg/g) electrode, the Relative Standard Deviation (RSD) for each of the three sets of 12 runs was consistently 18%. For the carbon steel electrodes, where the total fume emission factors were higher, at 17.3 and 20.5 mg/g electrode, the RSD for each of the two sets of 12 runs was 10%. These relative standard deviations indicate that the fume generation and capture by the AWS fume hood was reproducible.

Each run was timed from when the arc was ignited on the base metal to when the arc was extinguished as recommended by Section 7.5 of the AWS F1.2:2006.

The AWS specification explains that the weld times will vary depending on the amount of fume generated and the corresponding filter loading. To be confident that the entire fume was collected on the filter and that the filters were not overloaded, the welding was stopped when the flow rate dropped to 25 CFM, which is the minimum flow rate listed in Section 4.2.2 of the AWS F1.2:2006.

After the welding process was complete, the blower remained on for one additional minute to clear the chamber of all fumes. This exceeds the recommendation of Section 7.3 of the AWS F1.2:2006, which states that the blower should be left on for an additional 30 seconds after the welding has stopped.

10.2 Analytical Calibration/Standardization

ALS Laboratory Group followed the selected OSHA and NIOSH methodologies for the analysis of the samples collected during this testing. These methods provided the requirements for the calibration and standardization of the analytical equipment. The laboratory ensured that all of the method requirements were met, and documented such in the QC report that accompanied their final report to *CTC*. This report is part of the project record file at *CTC*.

11.0 ANALYTICAL PROCEDURES

11.1 Gravimetric Analysis

The samples collected on the pre-weighed glass fiber filters and quartz fiber filters were returned to the same environmentally controlled laboratory where the filters were pre-weighed before the sampling event. The analytical laboratory recorded the post weights on these samples using the NIOSH Manual of Analytical Methods (NMAM) 0500 method for gravimetric analysis. A copy of the NMAM 0500 method is included in Appendix I for reference.

11.2 Total Metals Analysis

Upon completion of the NIOSH 0500 gravimetric analysis, the glass fiber filters were digested and analyzed in accordance with the NIOSH 7300 *Elements by ICP* (Nitric/Perchloric Acid Ashing) (Appendix H), adjusting solution volumes and dilutions as necessary for the filter size, total fume mass, and expected metals mass of the filtrate. One major modification to the test method was that the 8" filters were cut in half by the laboratory and each half was digested separately. Equal portions of the two (half-filter) digested solutions were mixed together before analysis. A detailed description of the actual (modified) sample preparation procedure that was used by the laboratory is also included in Appendix H.

11.3 Cr(VI) Analysis

The quartz fiber filters that were quenched in the field with the $NaHCO_3$ solution were analyzed for Cr(VI) in accordance with the OSHA ID-215 *Hexavalent Chromium* method (Appendix G). This method uses alkaline extraction conditions which prevent the reduction of Cr(VI) to Cr(III), and includes the addition of phosphate buffer/magnesium sulfate to the extraction media to reduce interferences from iron (II). In addition, it is an ion chromatography method with post column derivatization and detection by visible spectroscopy. The combination of these two techniques makes the method very specific for Cr(VI). The quantitative detection limit for this method is 0.003 microgram per cubic meter ($\mu g/m^3$). Solution volumes and dilutions were adjusted as necessary for the filter size, total fume mass, and expected metals mass of the filtrate. A detailed description of the actual (modified) sample preparation procedure that was used by the laboratory is included in Appendix G.

12.0 CALCULATIONS AND DATA ANALYSIS

12.1 Calculation of Electrode Usage

12.1.1 SMAC – Calculation for Stick Electrode Mass

Grams of electrode consumed = (mass of rod_{final}) – (mass of $rod_{initial}$).

12.1.2 FCAW – Calculation for Wire Electrode Mass

When using wire electrodes for FCAW, the wire feed speed in "inches per minute" was determined, along with the wire unit weight in "grams per inch". In addition to the wire information, the welding times were also recorded. Using this information, the mass of weld wire consumed for each test run will be calculated using the following equations:

12.1.3 FCAW – Calculation for Wire Feed Speed

Inches wire / minute = (inches of wire / 15 seconds) * (60 seconds / minute).

12.1.4 FCAW – Calculation for Wire Electrode Mass

Grams wire consumed = (inches of wire / minute) * (grams wire / inch) * (minutes of welding).

12.2 Calculation of Emission Factors

Emission factors have been calculated in units of microgram/gram (μg/g) of electrode consumed. AP-42 lists emission factors in units of gram/kilogram (g/kg) for total fume and 10^{-1} g/kg (10^{-1} g/kg) of electrode consumed for HAPs (*AP-42*), and the U.S. EPA proposed emission factors (*Serageldin*) are expressed in units of g/kg. Because these units result in a wide range of exponential factors

which are difficult to visually compare in a table, this report presents the emission factors in units of μg/g of electrode consumed; this is being used for ease of comparison and review.

Emission Factor = (μg of metal or fume in sample) / (g of electrode consumed)

NOTE: In order to convert the emission factors reported here (in μg/g) to g/kg, divide μg/g by 1000. In order to convert from μg/g to 10^{-1} g/kg, divide μg/g by 10,000.

12.3 Sample Calculations

Sample calculations for all of the above items using, and referenced to, the data generated in this study, are detailed in Appendix A.

13.0 PRESENTATION OF RESULTS

Emission factors for total fume (in mg/g of electrode consumed) and for Cr, Cr(VI), Pb, Mn, and Ni (in μg/g of electrode consumed) for each individual sample were calculated and are tabulated in Appendix B. The individual results were averaged and the standard deviation and relative standard deviation for each set was calculated; average of 12 data points were used for total fume and six data points were used for the metal species. These data for each of the five welding process/electrode combinations are presented in Table 13.1. The minimum and maximum emission factors and the median for each sample set are also included in the table.

The ratio (%) of Cr(VI) to Cr was calculated for each data set, using the average Cr and average Cr(VI) emission factors. These ratios are included in Table 13.1. as well.

The data is discussed further in the following sections.

Table 13.1. Emission Factors and Summary Statistics

		Total Fume	Cr	Cr(VI)	Pb	Mn	Ni	Cr(VI)/Cr
		mg/g wire	µg/g wire	µg/g wire	µg/g wire	µg/g wire	µg/g wire	Ratio, %
FCAW 308LT1	**$MEAN_{6 \text{ or } 12}$**	5.50	426	12	1.5	440	56	3
	STDEV	0.97	130	9	0.2	103	16	
	RSD	18	30	70	15	23	28	
	MIN	3.97	317	6.1	1.3	344	42	
	MAX	7.35	643	26.2	1.9	597	78	
	MEDIAN	5.51	386	7.5	1.5	423	52	
FCAW 309LT1	**$MEAN_{6 \text{ or } 12}$**	6.27	696	37	0.8	416	131	5
	STDEV	1.10	213	33	0.1	42	75	
	RSD	18	31	90	8	10	57	
	MIN	5.12	469	6.0	0.8	354	51	
	MAX	8.43	1001	72.5	0.9	479	216	
	MEDIAN	5.82	636	36.2	0.8	416	120	
SMAW 309L-16	**$MEAN_{6 \text{ or } 12}$**	10.4	716	252	3.3	736	64	35
	STDEV	1.89	201	106	0.3	153	18	
	RSD	18	28	42	10	21	29	
	MIN	8.17	493	99	2.8	545	43	
	MAX	13.5	983	382	3.8	917	92	
	MEDIAN	10.1	729	251	3.3	758	61	
SMAW 7018M	**$MEAN_{6 \text{ or } 12}$**	20.5	6	1.2	3.2	771	1	21
	STDEV	2.0	1	0.5	0.3	74	0	
	RSD	10	19	44	10	10	26	
	MIN	17.0	5	0.6	2.8	679	1	
	MAX	23.3	8	1.8	3.5	858	2	
	MEDIAN	21.0	6	1.4	3.2	778	1	
SMAW 11018-M	**$MEAN_{6 \text{ or } 12}$**	17.3	21	71	2.3	1004	46	339
	STDEV	1.79	3	35	0.1	109	7	
	RSD	10	13	50	5	11	16	
	MIN	13.8	17	32.4	2.2	860	37	
	MAX	19.7	24	125	2.4	1128	58	
	MEDIAN	17.2	22	70.8	2.3	1035	47	

14.0 DISCUSSION OF RESULTS

14.1 Field Blanks

The three field blanks discussed in Section 9.1 were tested as appropriate by OSHA ID-215, NIOSH 7300 and NIOSH 0500, and the results are included with the Tabulated Analytical Data in Appendix F. All field blank test results were

either very low or were below the limits of detection for the method; therefore, no total fume or HAP emission results were corrected for these blanks.

14.2 Total Fume

The average (mean of 12) total fume emission factors for the two stainless steel FCAW electrodes, 308LT1 and 309LT1, were 5.5 and 6.27 mg/g, respectively. The average total fume emission factor for the stainless steel SMAW electrode, 309L-16, was 10.4 mg/g.

The total fume emission factors for the two carbon steel SMAW electrodes, 7018M and 11018-M, were 20.5 and 17.3 mg/g, respectively.

For the stainless steel electrodes, where the total fume emission factors ranged from 5.5 to 10.4 mg/g electrode, the RSD for each of the three sets of 12 runs was consistently 18%. For the carbon steel electrodes, where the total fume emission factors were higher, at 17.3 and 20.5 mg/g electrode, the RSD for each of the two sets of 12 runs was 10%.

The median values for each set were generally consistent with the mean for the set.

14.3 Metals

For the metals Cr, Pb, Mn, and Ni, the reported emission factors represent the average of six data points. One data point for Pb in SMAW 7018 was rejected as an outlier using a Q-test at the 90% confidence level (See Appendix B). With the exception of Ni in FCAW 309LT1 (RSD 57%), all emission factor results have an RSD of 31% or lower, and the median values for each set were consistent with the mean for the set.

Cr - The average Cr emission factors for the two stainless steel FCAW electrodes, 308LT-1 and 309LT1, were 426 and 696 μg/g, respectively, and for the stainless steel SMAW electrode, 309L-16, was 716 μg/g.

The average Cr emission factors for the two carbon steel SMAW electrodes, 7018M and 11018-M, were six and 21 μg/g, respectively. As expected, these values are lower than those for the stainless steel electrodes.

Pb - The average Pb emission factors for all of the electrodes ranged from 0.8 to 3.3 μg/g.

Mn - The average Mn emission factors for the two stainless steel FCAW electrodes, 308LT-1 and 309LT1, were 440 and 416 μg/g, respectively, and for the stainless steel SMAW electrode, 309L-16, was 736 μg/g.

The average Mn emission factors for the two carbon steel stick (SMAW) electrodes, 7018M and 11018-M, were 771 and 1004 μg/g, respectively.

Ni - The average Ni emission factors for the two stainless steel FCAW electrodes, 308LT-1 and 309LT1, were 56 and 131 μg/g, respectively, and for the stainless steel SMAW electrode, 309L-16, was 64 μg/g.

The average Ni emission factors for the two carbon steel stick (SMAW) electrodes, 7018M and 11018-M, were 1 and 46 μg/g, respectively.

14.4 Cr(VI)

For Cr(VI), the reported emission factors represent the average of six data points. Relative standard deviations for the five data sets ranged from 42 to 90%, higher than for the metal species discussed above. The reason for this difference was not investigated within the scope of this project. One possible explanation is the fact that Cr(VI), unlike the other metal species, is not physically present in the electrodes themselves. It is produced by the oxidation of Cr to Cr(VI) during welding process. The variability of the production of Cr(VI) during the welding process will add variability to the sample, and therefore to the data.

The median values for each set were generally consistent with the mean for the set.

The average Cr(VI) emission factors for the 2 stainless FCAW electrodes, 308LT-1 and 309LT1, were 12 and 37 μg/g, respectively, and for the stainless steel SMAW electrode, 309L-16, was 252 μg/g.

The average Cr(VI) emission factors for the 2 carbon steel SMAW electrodes, 7018M and 11018-M, were 1.2 and 71 μg/g, respectively.

It should be pointed out that the Cr(VI) emission factor (71 +/- 35μg/g) for the SMAW11018-M electrode is statistically higher than the (total) Cr emission factor of 21 +/- 3 μg/g. It is not possible to obtain a Cr(VI) value higher than the total Cr value. The project team investigated the several potential sources for this discrepancy in the data, but a definite cause for this could not be determined.

- The project team conducted a second review of the raw data provided by the laboratory, along with the internal emission factors calculations, and no errors were identified.
- The field data sheets were reviewed to check for abnormal weld parameters, and to determine if there were any problems documented for the runs associated with the questionable results. Again, nothing was found.

- The project team ruled out the possibility of varying electrode composition causing these results based on the fact that one electrode was used to complete two runs. For this to have been the source of this questionable result, the project team would have had to randomly select three electrodes with abnormally high composition of Cr for the six Cr(VI) runs, and then randomly selected three electrodes with a low or normal composition of Cr for the total Cr runs. This combination of events is highly unlikely.

- Although the time at which base plates were changed was not documented, it is unlikely that the incorrect base metal (stainless steel used instead of carbon steel) was used for the testing. It is unlikely that a stainless steel base metal was used because the Cr(VI) sample runs for SMAW 11018-M were completed immediately following the SMAW 7018 runs, which were completed on a carbon steel base metal. In addition, the Cr sample runs for SMAW 11018-M were completed immediately following the Cr(VI) runs; therefore, if a stainless steel plate had been inadvertently used, the Cr values would be comparable to the Cr(VI) values. The only scenario in which an incorrect base metal could have been used would be if the project team changed the base metal after the completing the SMAW 7018 sample runs, conducted the 6 SMAW 11018-M Cr(VI) sample runs, and then changed the plate again before completing the total Cr sample runs for the SMAW 11018-M. This scenario is highly unlikely because it was not a common practice to change base metals during a run. Additionally, all base metals were marked to identify their type.

The project team believes that the Cr(VI) value is unexplainably high for this electrode because it is a carbon steel electrode and contains a minimal amount of Cr. Because there is a lack of scientific data to support this assumption, the project team cannot recommend that the Cr(VI) data point be disregarded. There is the alternative possibility that the Cr value is artificially low for some unidentified reason. The project team recommends that additional data be collected to better determine valid emission factors for Cr and Cr(VI) for the SMAW11018-M electrode/process combination.

14.5 Cr(VI)/Cr Ratio

The Cr(VI)/Cr emission factor ratio for the two stainless steel FCAW electrodes, 308LT-1 and 309LT1, were three and 5%, respectively, and for the stainless steel SMAW electrode, 309L-16, was 35%.

The Cr(VI)/Cr emission factor ratio for the two carbon steel stick (SMAW) electrodes, 7018M and 11018-M, were 21 and 339%, respectively.

This SMAW11018-M ratio of 339% must be disregarded as scientifically impossible and the results of an obvious discrepancy in either the Cr or the Cr(VI) results, as discussed in Section 14.3 above.

When a shipyard reports emissions generically as “Chromium Compounds”, the U.S. EPA is currently applying a default “speciation profile” that assumes 34% of the reported “Chromium Compounds” are Cr(VI), with the remaining 66% being Cr(III) (*ANPRM*). Based on the data presented in Table 15.1, the proposed 34% ratio is clearly not a ratio representative of all electrodes across the board. For the two FCAW electrodes used in this study, the Cr(VI)/Cr ratios were found to be only three and 5%. The use of a 34% ratio to calculate the total Cr(VI) emissions from these two commonly used electrodes would greatly overstate the actual shipyard Cr(VI) emissions.

The SMAW 309L and 7018 values of 35 and 21% Cr(VI) values respectively are closer to the default ratio of 34%, but even in this process subset, there is variability in the ratio between specific electrodes.

The data presented above demonstrates that the ratio of Cr(VI) to total Cr are highly dependent on the processes and electrodes being used. A default value cannot be applied to welding emission in general. Additional data on each welding process/electrode combination should be generated in order to determine whether a process-specific ratio or an electrode-specific ratio would result in the most accurate emissions reporting.

15.0 COMPARISON TO PREVIOUS DATA AND PUBLISHED VALUES

This section provides a comparison of the emission factors that were generated under this study, referred to as *CTC*-09, to the following emission factor sources:

- *CTC* testing at BIW for Residual Risk Project in 2008, referred to as BIW
- *CTC* testing at AMA for Residual Risk Project in 2008, referred to as AMA
- Testing at *CTC* for Cr(VI) study, referred to as *CTC*-Cr(VI)-08
- AP-42
- U.S. EPA proposed

Not all electrodes were included in all of the testing protocols and not all electrodes and metal species are included in AP-42 or the U.S. EPA proposed document.

The number of replicates for each set of data is indicated in the two right-hand columns of the Table.

15.1 Stainless Steel Electrodes

The comparison for the stainless steel emission factors is presented in Table 15.1, and represented graphically in Figures 15.1, 15.2 and 15.3.

Table 15.1. Emission Factors for Stainless Steel Electrodes

			mg/g electrode	µg/g electrode					# of replicates	
Process	**Electrode**	**Source**	**total fume**	**Cr**	**Cr(VI)**	**Mn**	**Ni**	**Pb**	**total fume**	**metals**
FCAW	308LT1	CTC-09	5.5	426	12	440	56	2	12	6
FCAW	308	EPA Proposed	ND	3000	59	521	516	215	---	---
FCAW	308	AP-42	9.1 (308LT)	ND	ND	ND	ND	ND	---	---
FCAW	309L	BIW	5.1	285	26	241	74	0.8	5	1
FCAW	309L	AMA	3.4	176	78	169	29	0.6	4	1
FCAW	309L	CTC-CrVI-08	6.7	127	31	199	71	ND	6	3
FCAW	309LT1	CTC-09	6.3	696	37	416	131	0.8	12	6
FCAW	309L	EPA Proposed	ND	3000	59	521	516	215	---	---
FCAW	309L	AP-42	ND	ND	ND	ND	ND	ND	---	---
SMAW	309	BIW	6.6	298	255	284	46	3	5	1
SMAW	309	AMA	11.1	551	375	325	62	2	4	1
SMAW	309L-16	CTC-09	10.4	716	252	736	64	3	12	6
SMAW	309L	EPA Proposed	ND	811	168	534	104	215	---	---
SMAW	309L	AP-42	ND	ND	ND	ND	ND	ND	---	---
ND = No data available or presented in the reference										

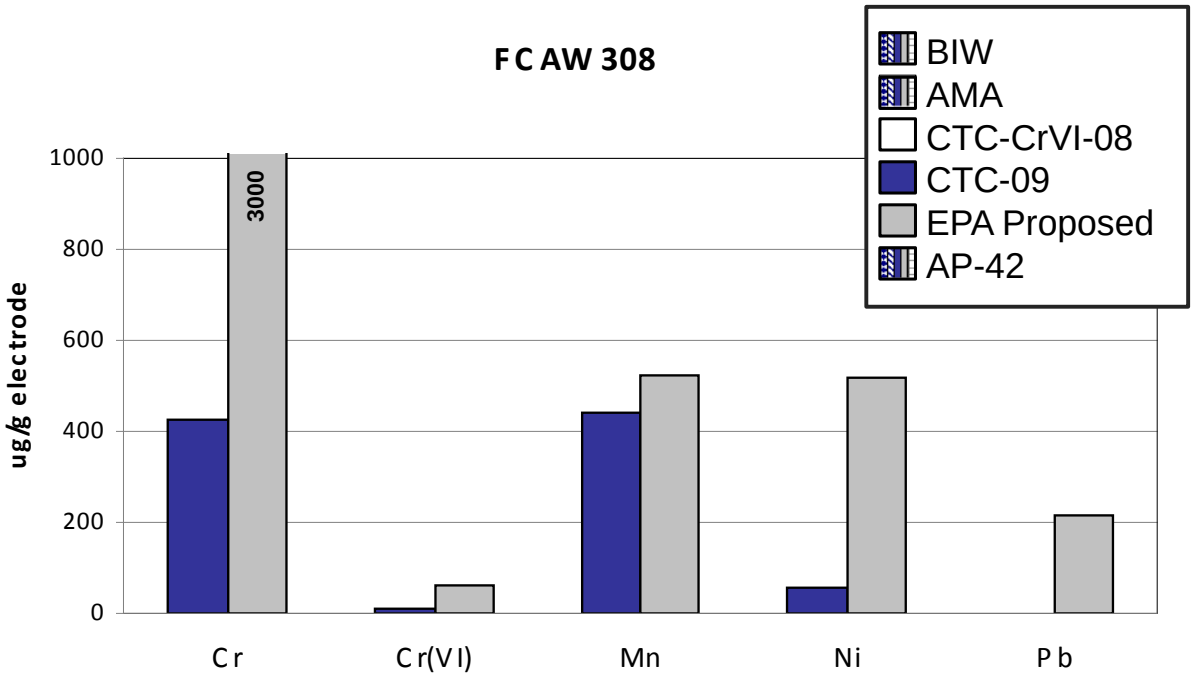

Figure 15.1. Comparison of FCAW 308 Emissions Factors

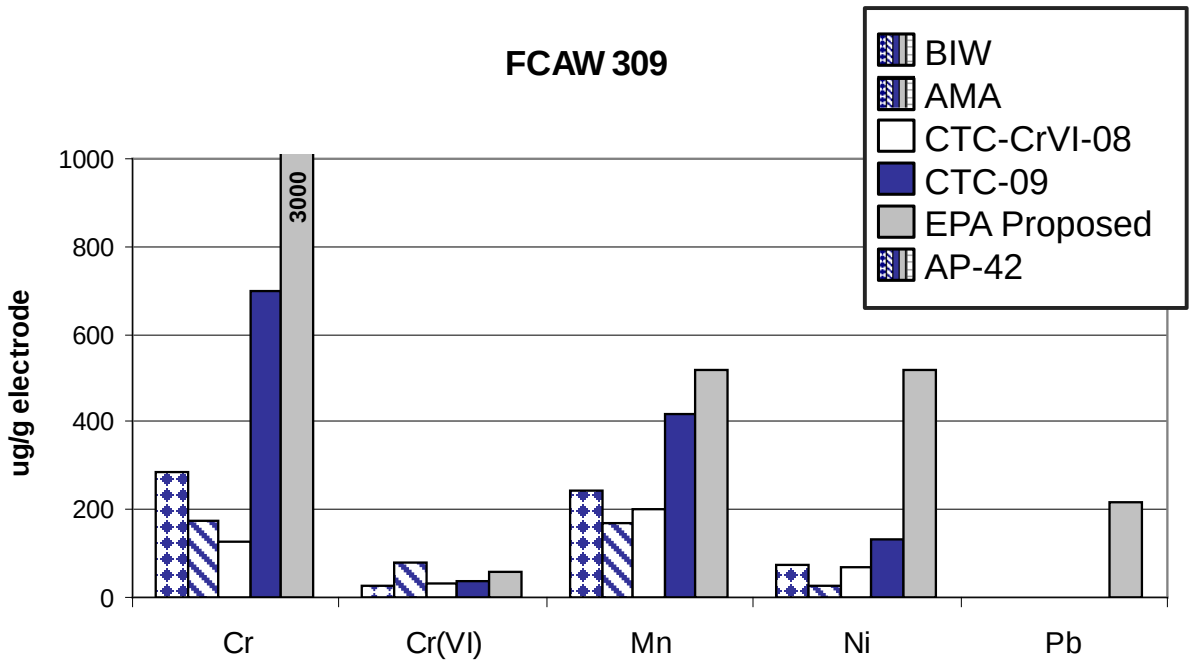

Figure 15.2. Comparison of FCAW 309 Emissions Factors

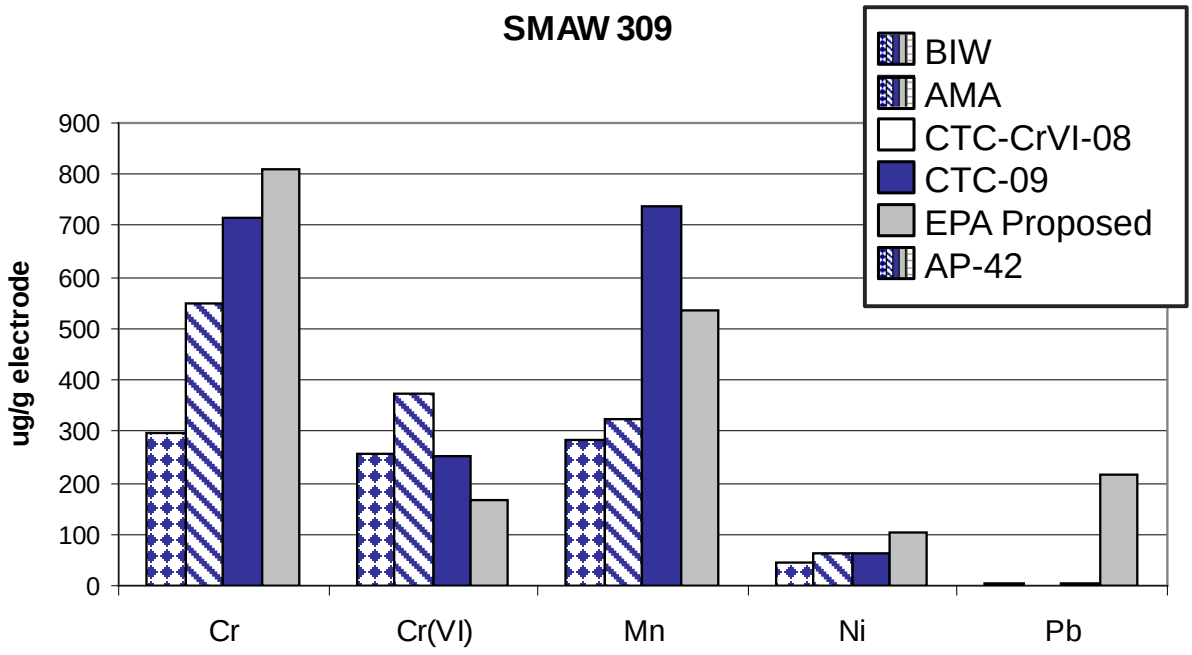

Figure 15.3. Comparison of SMAW 309 Emissions Factors

Based on the graphs presented above, the following observations were made:

- The emission factors generated in the various studies represented in these comparisons are consistent from study to study (within the same order of magnitude) for all metals.

- There are currently no U.S. EPA AP-42 emission factors for the selected stainless steel electrodes used in this study.

- The U.S. EPA proposed Cr emission factor of 3000 µg/g for both FCAW electrodes appears high relative to the data generated in various studies.

- The U.S. EPA proposed Pb emission factor of 215 µg/g for all stainless steel electrodes, appears to be high relative to the data generated in the various studies.

- The U.S. EPA proposed emission factors for Cr(VI), Mn, and Ni appear consistent (within the same order of magnitude) with the emission factors generated in these studies.

The data presented above demonstrates that using current emission factors and the default speciation profile provided by the U.S. EPA may contribute to the overestimation of Cr(VI) emissions as compared to using the emission factors and profile generated in this study. An example of the effect that this difference in factors could have on reported emissions is presented below.

For example purposes only:

- Assume that a shipyard consumes 50,000 lbs of FCAW 309 electrode.
    - Calculating emissions using the U.S. EPA proposed Cr emission factor of 3000 µg/g, and the default speciation profile that assumes 34% of the reported "Chromium Compounds" are Cr(VI), with the remaining 66% being Cr(III) (*ANPRM*).
        - 50,000 lbs equals 22,700,000 g of electrode
        - 22,700,000 g of electrode * 3000 µg/g = 6.81E+10 µg or 150 lbs of Cr emitted
        - 150 lbs *0.34 = 51 lbs assumed to be Cr(VI)
    - Calculating emissions using the average Cr emission factor generated in this study of 696 µg/g, and the speciation profile developed in this study that 5% of the emissions reported as Cr are actually Cr(VI).
        - 22,700,000 g of electrode * 696 µg/g = 1.6E+10 µg or 35 lbs of Cr emitted

- 35 lbs *0.05 = 2 lb assumed to be Cr(VI)

These calculated results are summarized and compared in Table 15.2 below.

Table 15.2. Comparison of Cr and Cr(VI) Emissions

Calculation Method	Cr Emissions	Cr(VI) Emissions
Calculated using U.S. EPA Data	150	51
Calculated using data generated from this study	35	2

15.2 Carbon Steel Electrodes

The comparison for the carbon steel emission factors is presented in Table 15.3, and represented graphically in Figures 15.4 and 15.5.

Table 15.3. Emission Factors for Carbon Steel Electrodes

			mg/g electrode	µg/g electrode					# of replicates	
Process	Electrode	Source	total fume	Cr	Cr(VI)	Mn	Ni	Pb	total fume	metals
SMAW	7018M	BIW	12.3	4	2	454	1	1	5	1
SMAW	7018M	AMA	13.3	5	2	489	2	1.5	4	1
SMAW	7018M	CTC-09	20.5	6	1	771	1	5	12	6
SMAW	7018M	EPA Proposed	ND	7	4	1180	37	215	---	---
SMAW	7018M	AP-42	18.4	6	ND	1030	2	ND	---	---
SMAW	11018-M	CTC-09	17.3	21	71	1004	46	2	12	6
SMAW	11018	EPA Proposed	ND	7	4	1180	37	215	---	---
SMAW	11018	AP-42	16.4	ND	ND	1380	ND	ND	---	---
ND = No data available or presented in the reference										

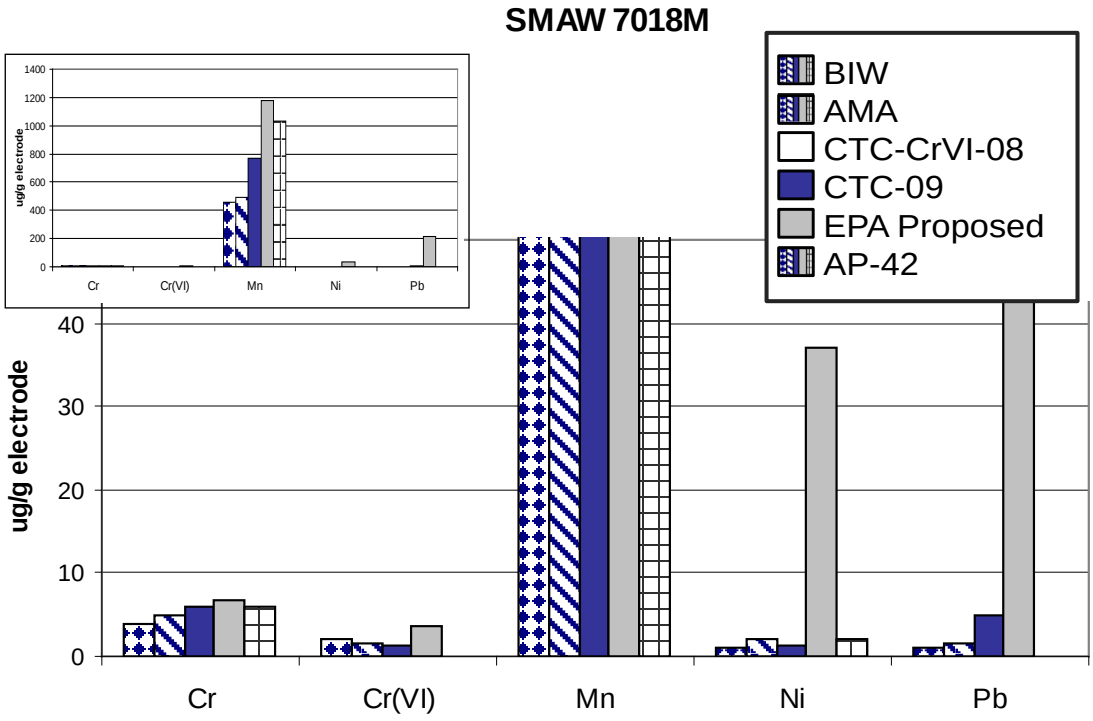

Figure 15.4. Comparison of SMAW 7018M Emissions Factors

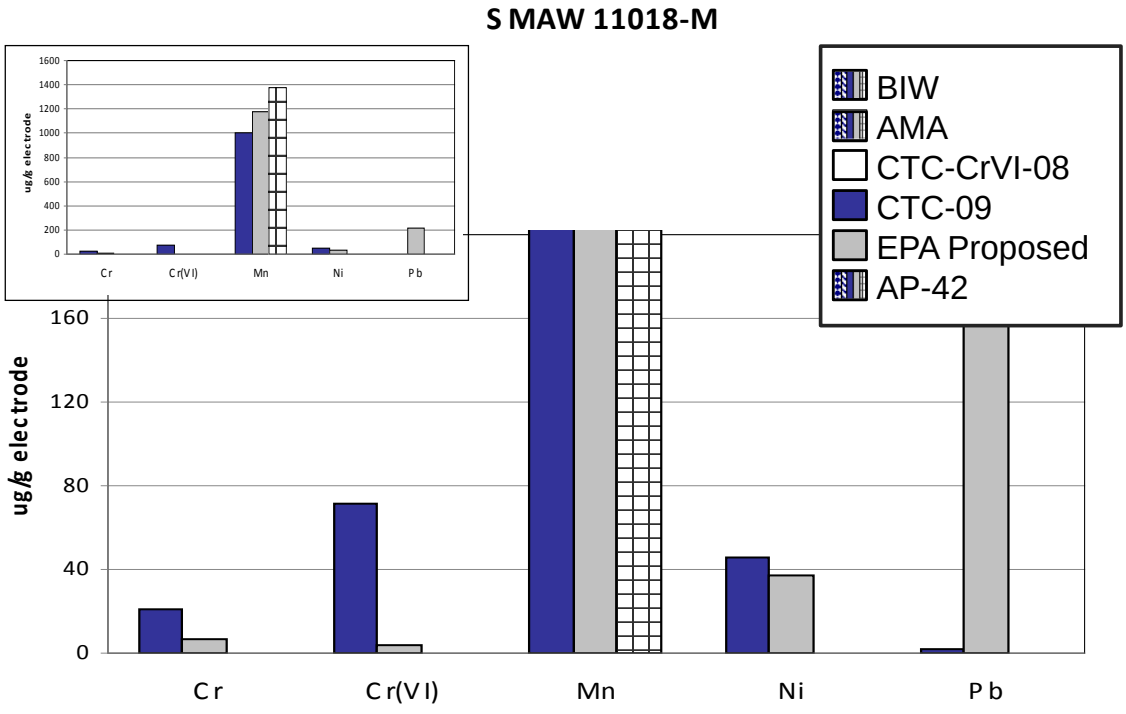

Figure 15.5. Comparison of SMAW 11018-M Emissions Factors

Based on the graphs presented above, the following observations were made:

- The values generated for SMAW 7018M in the three studies represented in this comparison show similar emission factors from study to study (within the same order of magnitude) for all metals.

- The U.S. EPA proposed Pb emission factor of 215 μg/g for all stainless steel electrodes appears to be high relative to the data generated in the various studies.

- The U.S. EPA proposed Ni emission factor of 37 μg/g for SMAW 7018M is high relative to the three studies used for comparison, and the current AP-42 value.

- The U.S. EPA proposed and AP-42 emission factors for Cr, Cr(VI), and Mn, appear consistent (within the same order of magnitude) with the emission factors generated in these studies.

16.0 ESAB DATA

As a result of the project presentation provided at the NSRP SP-3 Welding Panel meeting in the spring of 2009, the welding material supplier, ESAB, expressed an interest in providing their support at no cost to the project. This support included providing valuable information related to the ESAB welding products that were evaluated in this study, and completing comparative testing of the selected electrodes. This comparative testing was completed using the same batches of electrodes that were used in this study, but used different processes for sample preparation and analysis (Appendix L). The major differences between this study and the study completed by ESAB were as follows:

- The filer media used by ESAB to collect fume using the AWS F1.2:2006 chamber was different from the filter media used in this panel project study.

- ESAB conducted three welding runs of each process/electrode combination until enough fume was collected to complete all of their testing, then brushed the particulates off the filter, combined and dried them, and then analyzed a portion of the composite fume sample by each of the methods. In this study, one filter was used per test and the entire filter and fume sample were digested.

- The ESAB study used an in-house Wavelength Dispersive X-Ray Fluorescence (XRF) Spectrophotometric method to analyze for Cr, Mn, Ni, and Pb, while this panel project study used NIOSH 7300.

- The ESAB study used OSHA W4001 to analyze the fume samples for Cr(VI), while this study used OSHA ID-215.

- The ESAB results for metals are the result of a single analytical sample run, while the results in this panel project study are an average of six sample runs.

- The ESAB results for total fume are an average of three sample runs, while the results of this study are an average of 12 sample runs.

Because numerous differences exist between the ESAB and panel project studies, the data was not combined with the data from this study, and was not used in any way in the development of the emission factors presented in this report. The purpose of this testing was to compare emission data from an alternative procedure to determine the comparability of results.

The results from the testing completed by ESAB are presented in Table 16.1 below, along with the results from this study.

Table 16.1. ESAB Data as Compared to *CTC*-09 Data

				mg/g electrode[1]	µg/g electrode[2]				
Process	Electrode	Electrode Type	Source	total fume	Cr	Cr(VI)	Mn	Ni	Pb
FCAW	308LT1	Stainless	CTC-09	5.5	426	12	440	56	2
FCAW	308LT1	Stainless	ESAB	3.1	200	27	258	23	2
FCAW	309LT1	Stainless	CTC-09	6.3	696	37	416	131	0.8
FCAW	309LT1	Stainless	ESAB	4.5	452	45	313	62	1.5
SMAW	309L-16	Stainless	CTC-09	10.4	716	252	736	64	3
SMAW	309L-16	Stainless	ESAB	6.8	460	291	494	37	5
SMAW	7018M	Carbon Steel	CTC-09	21	6	1	771	1	5
SMAW	7018M	Carbon Steel	ESAB	16	15	2	704	11	4
SMAW	11018-M	Carbon Steel	CTC-09	17	21	71	1004	46	2
SMAW	11018-M	Carbon Steel	ESAB	14	19	10	831	32	3

[1] CTC-09 value for total emission factor is the average of 12 replicates; ESAB value is the average of 3 replicates

[2] CTC-09 value for HAP emission factor is the average of 6 replicates; ESAB value is based on a single analysis

Based on the results presented in Table 16.1 above, it was determined that the two methods resulted in comparable data, within one order of magnitude. Again, it is important to note that the ESAB data was generated from the analysis of one composite sample, while this study is representing the average of the analysis of six individual samples. As discussed in Section 14 above, a variation is observed in multiple samples collected over several runs. In addition, ESAB used different techniques for sample preparation and analysis.

Even given these procedural differences, the ESAB data supports the data generated in this study, which increases the confidence that the emission data presented in this report accurately reflects the composition of the fume generated from the selected electrodes.

17.0 CONCLUSIONS

Emission factors were determined for total fume, total Cr, Mn, Ni, Pb, and Cr(VI) for the five welding process/electrode combinations that are of greatest concern to the shipyards. These emission factors were generated by capturing the fumes from welding runs conducted in a weld fume chamber built to meet the requirements of AWS F1.2:2006 and the fumes were analyzed using OSHA and NIOSH analytical methods in a AIHA accredited laboratory. Six replicate welding runs were conducted for each process/electrode combination and for each HAP species tested.

The emission factors are presented and compared to values determined in the RRR project, and to AP-42 and U.S. EPA proposed emission factors. They are also compared to ESAB emission factors that were generated using the same electrode and base metals.

There is a high degree of confidence in the emission factors generated in this study for the following reasons.

- The testing was completed according to the AWS specification AWS F1.2:2006, and using OSHA and NIOSH analytical test methods. All testing procedures were outlined in the SAP which was reviewed and approved by the NSRP project team and the U.S. EPA prior to conducting the study.

- Six replicate welding runs were conducted for each process electrode combination for each HAP analysis and 12 replicate welding runs were conducted for each total fume analysis.

- The relative standard deviation for all total fume emission factors was less than 20%, and for Cr, Mn, Ni, and Pb were generally less than 30%. Relative standard deviations for Cr(VI) ranged from 42 to 90%; however higher variation is expected in the Cr(VI) results because it includes the variability from the production of Cr(VI) from Cr in the welding process itself, as well as the analytical variability of the capture and analytical procedures.

- The emission factors generated in this study are consistent with emission factors that were generated in the previous NSRP Residual Risk Project (*NSRP, July 18 and July 29, 2008*).

- The emission factors generated in this study are within one-order of magnitude when compared to the ESAB generated emission factors using the same welding materials but different procedures for sample preparation and analysis.

The three most significant findings of this study, each of which would significantly reduce emissions reported by shipyards, are the following:

- The emission factors for Cr that were measured in this study for the two stainless steel flux cored electrodes were 426 +/- 130 μg/g for FCAW 308 and 696 +/-

213 μg/g for FCAW 309. Both of these emission factors are significantly lower than the U.S. EPA proposed emission factor of 3000 μg/g.

- The Cr(VI)/Cr ratios generated for four of the electrodes were three, five, 21 and 35%. This range of values from electrode to electrode clearly indicates that the U.S. EPA proposed 34% "default speciation profile" that assumes 34% of all reported "Chromium Compounds" are Cr(VI), would lead to the reporting of significantly high emissions in some cases. Based on the data presented, there should NOT be a "default" Cr(VI)/Cr ratio; the ratio clearly varies from electrode to electrode. In fact, for the two FCAW stainless steel electrodes tested in this study, the ratios are only three and 5%. The use of the 34% ratio to calculate Cr(VI) emissions from these two commonly-used stainless steel electrodes would greatly overstate the actual shipyard Cr(VI) emissions.

  In an example presented in this report in Section 15.1, using the average Cr emission factor and Cr(VI) ratio measured in this study rather than currently proposed U.S. EPA values and for a shipyard using 50,000 lbs/year of FCAW 309, reported Cr emissions would be reduced from 150 lbs to 35 lbs and Cr(VI) emissions would be reduced from 51 lbs to two lbs. This is a 77% reduction in Cr emissions and a 96% reduction in Cr(VI) emissions for two key shipyard electrodes.

  The proposed 34% "default" speciation has been shown by this study to be inaccurate. It is recommended that additional data on each process/electrode combination should be generated in order to determine process-specific or electrode-specific ratios that would result in the most accurate Cr(VI) emissions reporting.

- For all of the five electrodes tested, the U.S. EPA proposed the emission factor for Pb (215 μg/g) to be about two orders of magnitude higher than what was found in this study. It is recommended that the emission factor for lead for all electrodes should be reviewed and revised by the U.S. EPA.

Additional findings of this study include:

- Total fume emission factors measured in this panel project are consistent with those generated in the previous RRR project, with U.S. EPA proposed emission factors where available, and are corroborated by the ESAB data presented in this report. It is recommended that the data be reviewed by the U.S. EPA and used to establish more accurate emission factors for these five process/electrode combinations.

- For the stainless steel electrodes, Cr(VI), Mn and Ni emission factors measured in this project are generally consistent with those generated in the previous RRR project, with U.S. EPA proposed emission factors where available, and are corroborated by the ESAB data presented in this report. It is recommended that the data be reviewed by the U.S. EPA and used to establish more accurate emission factors for these five process/electrode combinations.

- For the carbon steel electrode SMAW 7018, Cr, Cr(VI), and Mn emission factors measured in this project are generally consistent with those generated in the previous RRR project, with U.S. EPA proposed emission factors where available, and are corroborated by the ESAB data presented in this report. The emission factor for Ni that was measured (1 μg/g) is significantly lower that the U.S. EPA proposed value of 37 μg/g and should be reviewed for modification. It is recommended that the data be reviewed by the U.S. EPA and used to establish more accurate emission factors for these five process/electrode combinations.

- For the carbon steel electrode SMAW 11018, Mn and Ni emission factors measured in this project are generally consistent with those generated in the previous RRR project, with U.S. EPA proposed emission factors where available, and are corroborated by the ESAB data presented in this report. The Cr(VI) emission factor and possibly the Cr emission factor determined in this study are suspect because they result in a Cr(VI)/Cr ratio of 339% and the Cr(VI) factor is inconsistent with the ESAB results. It is recommended that additional data be generated and reviewed by the U.S. EPA in order to establish more accurate emission factors for this electrode.

18.0 POLLUTION PREVENTION

The filters used in the fume chamber are designed to capture 99.9% of the particulates from the exhaust air stream. To ensure that hazardous particulates were captured in the event that the filter failed in the chamber, a local exhaust ventilation system with a High-Efficiency Particulate Air (HEPA) filtration system was placed at the exhaust of the fume chamber blower to capture the exhaust air.

19.0 WASTE MANAGEMENT

19.1 Material Disposal

The base metals used in this study were recycled by a local scrap metal recycler.

19.2 Sample Disposal

ALS Laboratory Group was responsible for the proper disposal of any remaining samples after the metals analyses were completed. The disposal of these samples was conducted through the laboratory's standard sample disposal procedures.

20.0 REFERENCES

AP-42, Fifth Edition, *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*, Section 12.19: Development of Particulate and Hazardous Emission Factors for Electric Arc Welding. Office of Quality Planning and

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APPENDIX A

SAMPLE CALCULATIONS

SMAW Emission Factors, AWS Chamber

Test performed at *CTC* in AWS chamber, September 23, 2009, Run #4
SMAW, weld rod 7018, 1/8" d., on carbon steel DH36

Data:	Weld time = 32 sec	= 0.53 minutes
	Weld rod initial	= 22.32 g
	Weld rod final	= 8.19 g
	Filter ID = GFF-27	
	Filter weight initial	= measured by contract test lab
	Filter weight final	= measured by contract test lab

Calculations:

Grams rod consumed = *Mass of rod$_{final}$ – mass of rod$_{initial}$*
= 22.32 g – 8.19 g
= 14.13 g

Mass of fume on filter = *Mass of filter$_{final}$ – mass of filter$_{initial}$*
= calculated by contract test lab
= 260 mg

EF(Total Fume)$_{unc}$ = *Mass of fume on filter / mass weld rod consumed*
= 260 / 14.13
= 18.40 mg/g, or 20.49 mg/g for average of 12 runs

Data: **<u>For total Cr</u>**: Run #4, Filter ID = GFF-27, Weld time = 32 sec,
Mass of weld rod consumed = 14.13 g, Mass of total Cr on filter = 70 µg

<u>For Cr(VI)</u>: Run # 3, Filter ID = QFF-28, Weld time = 30 sec,
Mass of weld rod consumed = 13.40g, Mass of total Cr(VI) on filter = 24 µg

EF(Cr)$_{unc}$ = *Mass Cr on filter / mass weld rod consumed*
= 70 / 14.13
= 4.95 µg/g

EF(Cr(VI))$_{unc}$ = *Mass Cr(VI) on filter / mass weld rod consumed*
= 24 / 13.4
= 1.8 µg/g

The calculations for the Emission Factors for Mn, Pb, and Ni are the same.

FCAW Emission Factors, AWS Chamber

Test performed at *CTC* in AWS chamber, September 22, 2009, GFF Run #2
FCAW, weld wire 308LT, 0.045" d., on stainless steel 304SS

Data:	Weld time = 25 sec	= 0.417 minutes
	Weld wire	= 93.96 inches / 15 seconds (average of 3)
	Weld wire	= 0.183 g/inch (average of 3)
	Filter ID = GFF-11	
	Filter weight initial	= measured by contract test lab
	Filter weight final	= measured by contract test lab

Calculations:

Inches wire / minute = *Inches of wire in 15 sec * 4 intervals / minute*
= 93.96 * 4
= 375.8 inches/min

Grams wire consumed = *Inches of wire / minute * grams wire / inch * minutes of welding*
= 375.8 * 0.183 * 0.417
= 28.68 g

Mass of fume on filter = *Mass of filter*$_{final}$ – *mass of filter*$_{initial}$
= calculated by contract test lab
= 130 mg

EF(Total Fume)$_{unc}$ = *Mass of fume on filter / mass weld wire consumed*
= 130 mg / 28.68 g
= 4.54 mg/g, or 5.50 mg/g for average of 12 runs

Data: **For total Cr**: GFF Run # 2, Filter ID = GFF-11, Weld time = 25 sec,
Mass of weld rod consumed = 28.68 g, Mass of total Cr on filter = 9200 µg

For Cr(VI): QFF Run # 1, Filter ID = QFF-7, Weld time = 23 sec,
Mass of weld rod consumed = 26.36 g, Mass of total Cr(VI) on filter = 160 µg

EF(Cr)$_{unc}$ = *Mass Cr on filter / mass weld rod consumed*
= 9200 / 28.68
= 321 µg/g

EF(Cr(VI))$_{unc}$ = *Mass Cr(VI) on filter / mass weld rod consumed*
= 160 / 26.36
= 6.1 µg/g

The calculations for the Emission Factors for Mn, Pb, and Ni are the same.

APPENDIX B

INDIVIDUAL EMISSION FACTORS AND SUMMARY STATISTICS

Tabulation of Individual Sample Emissions Factors and Summary Statistics							
		Total Fume	**Cr**	**Cr(VI)**	**Pb**	**Mn**	**Ni**
		mg fume/g rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod
FCAW 308LT1	1	3.97	317	6.1	1.3	344	42
	2	4.36	336	7.5	1.4	369	44
	3	4.54	321	6.6	1.3	349	42
	4	5.95	436	7.5	1.7	476	59
	5	6.43	505	20.8	1.7	505	69
	6	7.35	643	26.2	1.9	597	78
	7	6.54					
	8	5.23					
	9	5.05					
	10	5.51					
	11	5.51					
	12	5.51					
	MIN	3.97	317	6.1	1.3	344	42
	MAX	7.35	643	26.2	1.9	597	78
	MEDIAN	5.51	386	7.5	1.5	423	52
	$MEAN_{6 \text{ or } 12}$	5.50	426	12	1.5	440	56
	STDEV	0.97	130	8.7	0.2	103	16
	RSD	18	30	70	15	23	28
		Total Fume	**Cr**	**Cr(VI)**	**Pb**	**Mn**	**Ni**
		mg fume/g rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod
FCAW 309LT1	1	6.60	566	8.0	0.8	424	75
	2	5.82	537	6.0	0.8	408	67
	3	5.54	469	64.5	0.8	354	51
	4	8.43	1001	6.4	0.8	479	216
	5	7.90	896	66.0	0.9	432	211
	6	7.54	707	72.5	0.8	396	165
	7	5.17					
	8	5.82					
	9	5.12					
	10	5.54					
	11	5.97					
	12	5.82					
	MIN	5.12	469	6.0	0.8	354	51
	MAX	8.43	1001	72.5	0.9	479	216
	MEDIAN	5.82	636	36.2	0.8	416	120
	$MEAN_{6 \text{ or } 12}$	6.27	696	37	0.8	416	131
	STDEV	1.10	213	33	0.1	42	75
	RSD	18	31	90	8	10	57

		Total Fume	Cr	Cr(VI)	Pb	Mn	Ni
		mg fume/g rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod
SMAW 309L-16	1	13.11	983	335.0	2.8	917	92
	2	12.48	854	382.5	3.2	854	79
	3	11.78	824	190.3	3.4	824	65
	4	10.37	634	202.4	3.1	692	58
	5	8.96	493	98.6	3.8	582	49
	6	8.57	506	300.5	3.6	545	43
	7	10.53					
	8	8.17					
	9	8.89					
	10	9.90					
	11	8.66					
	12	13.50					
	MIN	8.17	493	98.6	2.8	545	43
	MAX	13.50	983	382.5	3.8	917	92
	MEDIAN	10.14	729	251.5	3.3	758	61
	$MEAN_{6 \text{ or } 12}$	10.41	716	252	3.3	736	64
	STDEV	1.89	201	106	0.3	153	18
	RSD	18	28	42	10	21	29

		Total Fume	Cr	Cr(VI)	Pb	Mn	Ni
		mg fume/g rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod
SMAW 7018M	1	21.0	8	1.6	3.2	752	2
	2	22.0	6	0.6	3.5	836	1
	3	18.1	5	1.8	3.0	696	1
	4	18.4	5	1.7	2.8	679	1
	5	20.9	5	1.2	11.7*	803	2
	6	22.4	6	0.6	3.5	858	1
	7	21.7					
	8	22.5					
	9	23.3					
	10	20.0					
	11	18.5					
	12	17.0					
	MIN	17.0	5	0.6	2.8	679	1
	MAX	23.3	8	1.8	3.5	858	2
	MEDIAN	21.0	6	1.4	3.2	778	1
	$MEAN_{6 \text{ or } 12}$	20.5	6	1.2	3.2	771	1
	STDEV	2.0	1	0.5	0.3	74	0.4
	RSD	10	19	44	10	10	26

*Observation rejected using Q test: Q=0.92, which is greater than 90% Rejection Quotient of 0.56

		Total Fume	Cr	Cr(VI)	Pb	Mn	Ni
		mg fume/g rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod	µg/gm rod
SMAW 11018-M	1	18.1	22	33.4	2.4	997	46
	2	18.6	24	91.6	2.3	1077	58
	3	19.7	23	125.1	2.4	1128	47
	4	19.7	22	71.3	2.3	1072	50
	5	16.3	17	70.2	2.2	891	39
	6	15.8	18	32.4	2.2	860	37
	7	16.0					
	8	18.7					
	9	17.4					
	10	17.1					
	11	15.8					
	12	13.8					
	MIN	13.8	17	32.4	2.2	860	37
	MAX	19.7	24	125.1	2.4	1128	58
	MEDIAN	17.2	22	70.8	2.3	1035	47
	$MEAN_{6 \text{ or } 12}$	17.3	21	71	2.3	1004	46
	STDEV	1.79	2.7	35	0.1	109	7.4
	RSD	10	13	50	5	11	16

Raw laboratory data is on file at: Concurrent Technologies Corporation, 100 CTC Drive, Johnstown, PA 16904, (800) 282-4392.
Reference Task Name: *Shipbuilding and Ship Repair Industry Initiative to Prepare for and Comply With the NESHAP Residual Risk Ruling*

APPENDIX C

SAMPLING AND ANALYSIS PLAN

C -
NSRP_Weld_Emission

APPENDIX D

ELECTRODE USAGE SUMMARY AND SELECTION REPORT

D - Electrode Usage
Summary and Selectic

APPENDIX E

ON-SITE TEST RUN DATA LOGS

E - Welding Test Logs Sept09.pdf

APPENDIX F

TABULATED ANALYTICAL DATA

Tabulated Laboratory Analytical Data

Process	Electrode		Lab/Filter ID	CTC ID	Type	Mass Fume mg	Cr µg/spl	Cr(VI) µg/spl	Pb µg/spl	Mn µg/spl	Ni µg/spl
Media Blank			Q	QFF-EquipBlank	quartz	NA		<0.3			
Media Blank			QFF-A09-3	QFF-EquipBlank2	quartz	<8	---	---	---	---	---
Media Blank			GFF-A09-2	GFF-EquipBlank2	glass	<8	21	---	<14	12	3.3
FCAW	308LT1	1	GFF-A09-9	FCAW308-1GF	glass	150.0	12000	---	51	13000	1600
		2	GFF-A09-10	FCAW308-2GF	glass	130.0	10000	---	41	11000	1300
		3	GFF-A09-11	FCAW308-3GF	glass	130.0	9200	---	38	10000	1200
		4	GFF-A09-12	FCAW308-4GF	glass	150.0	11000	---	43	12000	1500
		5	GFF-A09-14	FCAW308-5GF	glass	140.0	11000	---	36	11000	1500
		6	GFF-A09-15	FCAW308-6GF	glass	160.0	14000	---	41	13000	1700
		1	QFF-A09-13	FCAW308-1QFG	quartz	120.0	---	---	---	---	---
		2	QFF-A09-14	FCAW308-2QFG	quartz	120.0	---	---	---	---	---
		3	QFF-A09-15	FCAW308-3QFG	quartz	110.0	---	---	---	---	---
		4	QFF-A09-16	FCAW308-4QFG	quartz	120.0	---	---	---	---	---
		5	QFF-A09-17	FCAW308-5QFG	quartz	120.0	---	---	---	---	---
		6	QFF-A09-18	FCAW308-6QFG	quartz	120.0	---	---	---	---	---
		1	QFF-7	FCAW308-1CrVI	quartz	NA	---	160	---	---	---
		2	QFF-8	FCAW308-2CrVI	quartz	NA	---	190	---	---	---
		3	QFF-9	FCAW308-3CrVI	quartz	NA	---	190	---	---	---
		4	QFF-10	FCAW308-4CrVI	quartz	NA	---	190	---	---	---
		5	QFF-11	FCAW308-5CrVI	quartz	NA	---	500	---	---	---
		6	QFF-12	FCAW308-6CrVI	quartz	NA	---	690	---	---	---
FCAW	309LT1	1	GFF-A09-6	FCAW309-4GF	glass	140.0	12000	---	18	9000	1600
		2	GFF-A09-7	FCAW308-5GF	glass	130.0	12000	---	18	9100	1500
		3	GFF-A09-8	FCAW308-6GF	glass	130.0	11000	---	18	8300	1200
		4	GFF-A09-38	FCAW308-8GF	glass	160.0	19000	---	15	9100	4100
		5	GFF-A09-39	FCAW308-9GF	glass	150.0	17000	---	18	8200	4000
		6	GFF-A09-40	FCAW308-10GF	glass	160.0	15000	---	17	8400	3500
		1	QFF-A09-6	FCAW309-2QFG	quartz	150.0	---	---	---	---	---
		2	QFF-A09-7	FCAW309-3QFG	quartz	130.0	---	---	---	---	---
		3	QFF-A09-9	FCAW309-4QFG	quartz	120.0	---	---	---	---	---
		4	QFF-A09-10	FCAW309-5QFG	quartz	130.0	---	---	---	---	---
		5	QFF-A09-11	FCAW309-6QFG	quartz	120.0	---	---	---	---	---
		6	QFF-A09-12	FCAW309-7QFG	quartz	130.0	---	---	---	---	---
		1	QFF-1	FCAW309-1CrVI	quartz	NA	---	160	---	---	---
		2	QFF-2	FCAW309-2CrVI	quartz	NA	---	160	---	---	---
		3	QFF-3	FCAW309-3CrVI	quartz	NA	---	1800	---	---	---
		4	QFF-4	FCAW309-4CrVI	quartz	NA	---	150	---	---	---
		5	QFF-5	FCAW309-5CrVI	quartz	NA	---	1400	---	---	---
		6	QFF-6	FCAW309-6CrVI	quartz	NA	---	1700	---	---	---
SMAW	309L-16	1	GFF-A09-17	SMAW309-1GF	glass	200.0	15000	---	43	14000	1400
		2	GFF-A09-18	SMAW309-2GF	glass	190.0	13000	---	49	13000	1200
		3	GFF-A09-19	SMAW309-3GF	glass	200.0	14000	---	57	14000	1100
		4	GFF-A09-21	SMAW309-4GF	glass	180.0	11000	---	54	12000	1000
		5	GFF-A09-22	SMAW309-5GF	glass	200.0	11000	---	84	13000	1100
		6	GFF-A09-23	SMAW309-6GF	glass	220.0	13000	---	92	14000	1100

Tabulated Laboratory Analytical Data, pg 2

Process	Electrode		Lab/Filter ID	CTC ID	Filter Type	Mass Fume mg	Cr µg/spl	Cr(VI) µg/spl	Pb µg/spl	Mn µg/spl	Ni µg/spl
SMAW	7018M	1	GFF-A09-24	SMAW7018-1GF	glass	260.0	100	---	39	9300	25
		2	GFF-A09-25	SMAW7018-2GF	glass	250.0	69	---	40	9500	15
		3	GFF-A09-26	SMAW7018-3GF	glass	250.0	71	---	42	9600	14
		4	GFF-A09-27	SMAW7018-4GF	glass	260.0	70	---	40	9600	15
		5	GFF-A09-28	SMAW7018-5GF	glass	250.0	65	---	140	9600	18
		6	GFF-A09-29	SMAW7018-6GF	glass	240.0	63	---	38	9200	15
		1	QFF-A09-27	SMAW7018-1QFG	quartz	220.0	---	---	---	---	---
		2	QFF-A09-28	SMAW7018-2QFG	quartz	200.0	---	---	---	---	---
		3	QFF-A09-29	SMAW7018-3QFG	quartz	200.0	---	---	---	---	---
		4	QFF-A09-30	SMAW7018-4QFG	quartz	220.0	---	---	---	---	---
		5	QFF-A09-31	SMAW7018-5QFG	quartz	180.0	---	---	---	---	---
		6	QFF-A09-32	SMAW7018-6QFG	quartz	190.0	---	---	---	---	---
		1	QFF-19	SMAW7018-1CrVI	quartz	NA	---	23.0	---	---	---
		2	QFF-20	SMAW7018-2CrVI	quartz	NA	---	7.5	---	---	---
		3	QFF-21	SMAW7018-3CrVI	quartz	NA	---	24.0	---	---	---
		4	QFF-22	SMAW7018-4CrVI	quartz	NA	---	22.0	---	---	---
		5	QFF-23	SMAW7018-5CrVI	quartz	NA	---	16.0	---	---	---
		6	QFF-24	SMAW7018-6CrVI	quartz	NA	---	8.0	---	---	---
SMAW	11018-M	1	GFF-A09-30	SMAW11018-1GF	glass	200.0	240	---	27	11000	510
		2	GFF-A09-31	SMAW11018-2GF	glass	190.0	240	---	23	11000	590
		3	GFF-A09-32	SMAW11018-3GF	glass	210.0	240	---	26	12000	500
		4	GFF-A09-33	SMAW11018-4GF	glass	220.0	250	---	26	12000	560
		5	GFF-A09-35	SMAW11018-5GF	glass	220.0	230	---	30	12000	530
		6	GFF-A09-36	SMAW11018-6GF	glass	220.0	250	---	30	12000	520
		1	QFF-A09-33	SMAW11018-1QFG	quartz	220.0	---	---	---	---	---
		2	QFF-A09-34	SMAW11018-2QFG	quartz	220.0	---	---	---	---	---
		3	QFF-A09-35	SMAW11018-3QFG	quartz	230.0	---	---	---	---	---
		4	QFF-A09-37	SMAW11018-4QFG	quartz	190.0	---	---	---	---	---
		5	QFF-A09-39	SMAW11018-5QFG	quartz	150.0	---	---	---	---	---
		6	QFF-A09-40	SMAW11018-6QFG	quartz	190.0	---	---	---	---	---
		1	QFF-25	SMAW11018-1CrVI	quartz	NA	---	390	---	---	---
		2	QFF-26	SMAW11018-2CrVI	quartz	NA	---	1400	---	---	---
		3	QFF-27	SMAW11018-3CrVI	quartz	NA	---	1500	---	---	---
		4	QFF-28	SMAW11018-4CrVI	quartz	NA	---	1000	---	---	---
		5	QFF-29	SMAW11018-5CrVI	quartz	NA	---	980	---	---	---
		6	QFF-30	SMAW11018-6CrVI	quartz	NA	---	390	---	---	---

NA = Not Applicable

APPENDIX G

OSHA ID-215 AND LABORATORY MODIFICATIONS

G - OSHA ID-215 for
CrVI and lab mods.pd

APPENDIX H

NIOSH 7300 AND LABORATORY MODIFICATIONS

H - NIOSH 7300 and lab mods.pdf

APPENDIX I

NIOSH METHOD 0500

I - NMAM Method 0500.pdf

APPENDIX J

MSDS AND TECHNICAL DATA SHEETS FOR WELDING ELECTRODES

J - MSDS and
Technical Data Sheets

APPENDIX K

WELD FUME CHAMBER MANUAL

L - Weld Fume
Chamber User Guide

APPENDIX L

SUMMARY OF ESAB PROCEDURES FOR WELD FUME ANALYSIS

Summary of ESAB Procedures for Weld Fume Emissions Analysis

Information provided by ESAB personnel in e-mails and telephone meetings September – October 2009

Fume Capture:
AWS F1.2:2006 with adapters to allow use of either 6" or 12" filters for fume capture

Filters:

Cr(VI):	Whatman (Schleicher & Schuell) TE 38 Membrane Filter (PTFE, supported), 5 □m poresize, 150 mm (6") dia., Cat no. 10411130
Cr, Mn, Ni, Pb:	Whatman (Schleicher & Schuell) 40 Quantitative, 32 cm (12") dia, Cat no. 1440-320

Filtrate Collection:
Number of welding runs per electrode: 3 runs on (Whatman 40 filter) for gravimetric analysis and XRF analysis; and 1 run (on Whatman TE 38 Teflon filter) for Cr(VI) analysis
Welding times: Varied from 59 to 226 seconds for each filter sample collected
Pressures: Start of run: 1 inch H_20; End of run: 3 inches H_20
Fume weights: Mass of fume collected on each filter varied from 0.3 g to 0.56 g

Filtrates for gravimetric analysis: Using a camel hair brush the filtrates were carefully brushed off the filters from 3 separate welding runs into separate tared glass beakers, dried at 105°C to constant weight.

Filtrates for Cr, Mn, Ni, and Pb analysis: After weighing, the filtrates collected for the gravimetric analysis were combined and mixed well.

Filtrates for Cr(VI) analysis: Filtrate was carefully brushed off of the filters using a camel hair brush and transferred to a glass vial. The samples were tested within 24 hours.

Sample Preparation and Analysis:
For Cr(VI): Tested by modified OSHA W4001 by ALS Group Laboratories

For Cr, Mn, Ni, and Pb: The well-mixed powder fume sample was mixed at an appropriate ratio with a borate salt such as lithium borate, and heated until the flux melted and the fume sample dissolved in it, yielding a homogeneous melt. The melt was then poured into a mold and annealed to form a glass disk. The borate fusion sample disk was then analyzed using a Wavelength Dispersive XRF Spectrometer.