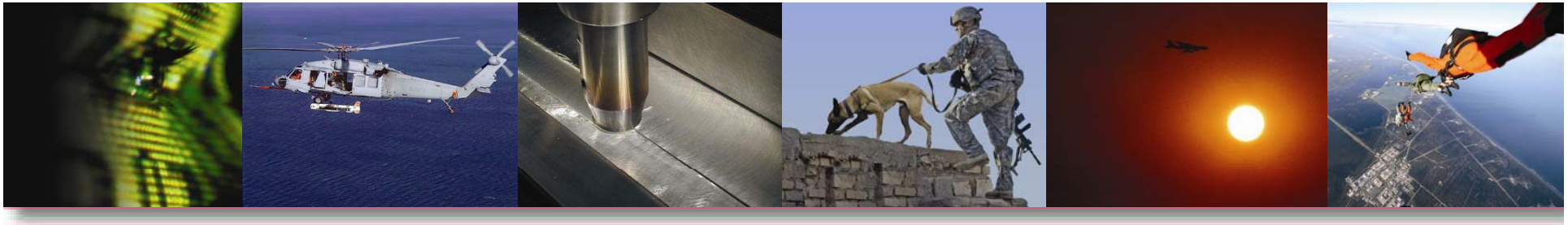


Developing Emissions Factors for Shipyard Welding Operations

Joe Jackens – *CTC*

Environmental Technologies Panel Meeting
New Orleans, LA
February 10, 2010

Presentation Outline

- Overview of the Project
  - Industry Need
  - Project Team
  - Objectives
  - Approach
- Project Accomplishments
  - Task 1
  - Task 2
  - Task 3
- Conclusions
- Acknowledgments
- Questions?

Industry Need

- The previous NSRP RRR project identified the industry need for high quality emissions factors for welding operations
- This result was based on the following:
  - Limitations and data gaps were discovered in the current AP-42 data set
  - Current emissions factors were developed statistically using data from multiple studies in which sampling methods varied
  - Lack of data was forcing the U.S. EPA to use conservative assumptions in regulatory decisions
  - Data collected during the NSRP RRR project demonstrated lower emissions than current AP-42 and proposed RRR emissions factors
  - U.S. EPA expressed interest in obtaining data to update the existing AP-42 emissions factors data set

With the eventual release of new welding regulations, it is critical that shipyard emissions be reported accurately to avoid non-compliance issues.

Response to Industry Need

- *CTC* developed and submitted a white paper to respond to this need through the development of high quality emissions factors for the industry
  - *CTC* received support in development of the white paper from various members of the previous NSRP RRR project team
  - The white paper team included:
    - BAE Systems Norfolk Ship Repair – Shipyard project support and cost share contributor
    - Bath Iron Works – Shipyard project support
    - Penn State University (PSU) Applied Research Laboratory (ARL) – Technical support
    - SofTek Systems, Inc. – Emission factor SME oversight
- The panel project was awarded by ATI on January 1, 2009

Panel Project Team

- **Supporting Organizations**
  - National Shipbuilding Research Program (NSRP)
  - Advance Technology Institute (ATI)
  - Naval Sea Systems Command (NAVSEA)
  - Naval Surface Warfare Center Carderock Division (NSWCCD)
  - Shipbuilders Council of America (SCA)
  - American Shipbuilding Association (ASA)

- **Primary Contractor and Subcontractors/Consultants**
  - Concurrent Technologies Corporation *(CTC)*
  - Applied Research Laboratory (ARL) - Penn State Univ.
  - SofTek Systems Inc. (SSI)
  - ALS Laboratory Group (formerly DataChem Laboratories, Inc)

- **Shipyards**
  - Atlantic Marine Alabama (AMA)
  - Atlantic Marine Jacksonville,
  - Bath Iron Works (BIW)
  - BAE Systems Norfolk Ship Repair
  - BAE Systems San Diego
  - Bollinger Shipyard
  - General Dynamics (GD) Electric Boat
  - GD National Steel and Shipbuilding Company (NASSCO)
  - Jeffboat, LLC
  - Norfolk Naval Shipyard
  - Northrop Grumman Newport News (NGNN)
  - Northrop Grumman Shipbuilding Gulf Coast, Avondale Facility
  - Northrop Grumman Shipbuilding Inc., Pascagoula Operations
  - Northrop Grumman Ship Systems (NGSS)
  - Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility
  - Portsmouth Naval Shipyard
  - Puget Sound Naval Shipyard (PSNY)
  - Shipbuilders Council of America (SCA)
  - Signal International
  - Southwest Shipyard LP
  - Trinity Marine Products, Inc.

Project Objectives

- Identify commonly used shipyard welding electrodes that currently lack high quality emissions factors
- Develop an electrode selection process based on:
  - Shipyard request
  - Current lack of high quality emissions factors
  - Potential to emit Hexavalent Chromium and/or Manganese, the primary constituents driving shipyard offsite public health risks
- Develop high quality emissions factors for the selected electrodes that can be submitted to the U.S. EPA for use in regulatory reporting procedures

Project Approach

- **Task 1 – Identify Electrodes for Evaluation**
  - Survey the industry
  - Prioritize the electrodes, based on the following:
    - Number shipyard requests
    - Lack of high quality emission factors
    - Potential to drive shipyard offsite public health risks
- **Task 2 – Collect and Analyze Weld Fume Samples**
  - Develop a Sampling and Analysis Plan
  - Conduct weld fume sampling and analysis
- **Task 3 – Develop Emissions Factors for Tested Electrodes**
  - Develop emissions factors based on analyzed data
  - Prepare detailed Final Project Technical Report
  - Provide report to the NSRP for submittal to the U.S. EPA

Task 1 Accomplishments
Electrode Selection

- **Developed and distributed three surveys**
  - Survey 1: Electrode Identification
    - 18 out of 46 shipyards responded; 39% response rate
  - Survey 2: Electrode Prioritization
    - 13 out of 18 shipyards responded; 72% response rate
  - Survey 3: Electrode Supplier Identification
    - 5 out of 18 shipyards responded; 28% response rate
- **Identified five process/electrode combinations for development of emissions factors based on:**
  - Shipyard request
  - Current lack of high quality emission factors
  - Potential to drive shipyard offsite public health risks
- **Prepared <u>Electrode Usage Summary and Selection Report</u>**
  - Submitted on to ATI on May 28, 2009

Task 1 Accomplishments

Electrode Selection

Rank	Shipyard Request	Emission Factor Need	Potential to Drive Max. Individual Risk for Cancer	Potential to Drive Hazard Indices for Non-Cancer Risks
1	**SMAW 7018**	**SMAW 309**	**SMAW 309**	**SMAW 11018**
2	FCAW 71T	GMAW 100S-1	**FCAW 309**	**FCAW 308** / **FCAW 309** / FCAW 316
3	**FCAW 309**	**FCAW 309**	SMAW 308	SMAW 308 / **SMAW 309**
4	**SMAW 11018**	**FCAW 308**	**FCAW 308** / FCAW 316	**SMAW 7018** / GMAW 70S / GMAW 100S-1
5	**FCAW 308**	SMAW 308	GMAW 100S-1	FCAW 71T
6	**SMAW 309**	**SMAW 11018** / **SMAW 7018**	**SMAW 11018**	
7	GMAW 70S	FCAW 71T / FCAW 316		
8	SMAW 308 / GMAW 100S-1	GMAW 70S		
9	FCAW 316			

Task 1 Accomplishments

Electrode Selection

- **Identified the following Process/Electrodes for evaluation:**
  - FCAW 308
  - FCAW 309
  - SMAW 309
  - SMAW 7018
  - SMAW 11018

Task 2 Accomplishments

Fume Sampling and Analysis

- **Developed <u>Sampling and Analysis Plan (SAP)</u>**
  - Submitted to U.S. EPA for review and comment on 6/09/09
  - Submitted to ATI on 6/25/09
  - Received comments on 8/03/09
  - Responded to comments 9/11/09
- **Completed weld fume sampling event**
  - September 22-23, 2009 at *CTC*, Johnstown, PA
- **Coordinated with ESAB to complete additional fume analysis**
  - October, 2009

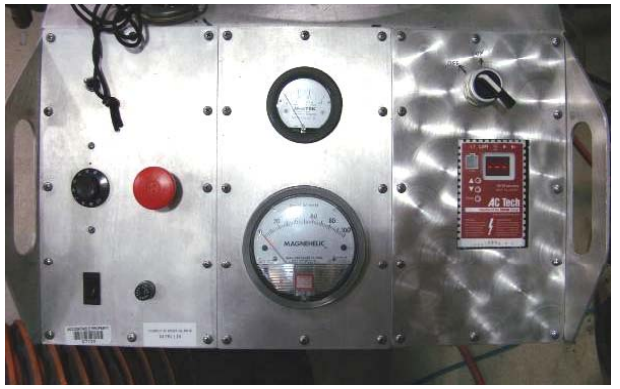
Task 2 Accomplishments

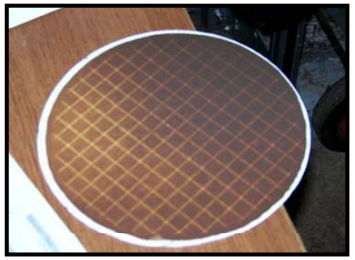
Fume Sampling












Concurrent Technologies Corporation

Task 3 Accomplishments

Calculation of Emissions Factors

- **Calculated emissions 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**
  - Determined emissions factors for each individual sample collected
  - Averaged Individual sample results to develop representative emissions factors
    - 12 data points used for total fume
    - 6 data points used for the metal species
    - Calculated Standard deviation and relative standard deviation for each set
- **Calculated the ratio (%) of Cr(VI) to Cr for each data set, using the average Cr and average Cr(VI) emissions factors**

Task 3 Accomplishments

Development of Emissions Factors

		Total Fume mg/g wire	Cr µg/g wire	Cr(VI) µg/g wire	Pb µg/g wire	Mn µg/g wire	Ni µg/g wire	Cr(VI)/Cr Ratio, %
FCAW308LT1	MEAN 6 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	
FCAW309LT1	MEAN 6 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	
SMAW309L-16	MEAN 6 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	
SMAW7018M	MEAN 6 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	
SMAW11018-M	MEAN 6 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	

Task 3 Accomplishments

Total Fume Emissions Factors

- Stainless steel electrodes
  - Total fume emissions factors ranged from 5.5 to 10.4 mg/g electrode
    - 5.5 mg/g for FCAW 308LT1
    - 6.27 mg/g for FCAW 309LT1
    - 10.4 mg/g for SMAW 309L
  - RSD for each of the three sets of 12 runs was consistently 18%
- Carbon steel electrodes
  - Total fume emissions factors were 17.3 and 20.5 mg/g electrode
    - 20.5 mg/g for SMAW 7018
    - 17.3 mg/g for SMAW 11018-M
  - 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

Task 3 Accomplishments

Total Cr and Cr(VI) Emissions Factors

- Cr
  - Stainless steel electrodes
    - 426 µg/g for FCAW 308LT-1
    - 696 µg/g for FCAW 309LT1
    - 716 µg/g for SMAW 309L-16
    - RSD for each of the three sets of 6 runs were 30, 31, and 28.
  - Carbon steel electrode
    - 6 µg/g for SMAW 7018M
    - 21 µg/g for SMAW 11018-M
    - RSD for each of these sets of 6 runs were 19 and 13.
- Cr(VI)
  - Stainless steel electrodes
    - 12 µg/g for FCAW 308LT-1
    - 37 µg/g for FCAW 309LT1
    - 252 µg/g for SMAW 309L-16
    - RSD for each of the three sets of 6 runs were 70, 90, and 42%
  - Carbon steel electrodes
    - 1.2 µg/g for SMAW 7018M
    - 71 µg/g for SMAW 11018-M
    - RSD for each of these sets of 6 runs were 44 and 50%

Task 3 Accomplishments

Investigation of the SMAW 11018-M Emissions Factors

- The Cr(VI) emissions factor 71 +/- 35 µg/g is higher than the Cr emission factor of 21 +/- 3 mg/g
- Investigated potential sources for this discrepancy in the data, but a definite cause for this could not be determined
  - Second review of the raw data, internal emissions factors calculations
  - Second review of the field data sheets to check for abnormal weld parameters, and to determine if there were any problems documented for the runs
  - Ruled out the source being varying electrode composition
  - Ruled out the source being the use of an incorrect base metal
- 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
- Due to the lack of scientific data to support this assumption, the Cr(VI) data point cannot be discarded
- Additional data must be collected to better determine valid emissions factors for Cr and Cr(VI) for the SMAW11018-M electrode/process combination

Task 3 Accomplishments

Total Ni, Mn and Pb, Emissions Factors

- Mn
  - Stainless steel electrodes
    - 440 µg/g for FCAW 308LT-1
    - 416 µg/g for FCAW 309LT1
    - 736 µg/g for SMAW 309L-16
    - RSD for each of the three sets of 6 runs were 23, 10, and 21%
  - Carbon steel electrodes
    - 771 µg/g for SMAW 7018M
    - 1004 µg/g for SMAW 11018-M
    - RSD for each of these sets of 6 runs were 10 and 11%
- Ni
  - Stainless steel electrodes
    - 56 µg/g for FCAW 308LT-1
    - 131 µg/g for FCAW 309LT1
    - 64 µg/g for SMAW 309L-16
    - RSD for each of the three sets of 6 runs were 26, 57, and 29%
  - Carbon steel electrodes
    - 1 µg/g for SMAW 7018M
    - 46 µg/g for SMAW 11018-M
    - RSD for each of these sets of 6 runs were 26 and 16%
- Pb
  - Emissions factors for all of the electrodes ranged from 0.8 to 3.3 µg/g

Task 3 Accomplishments

Cr(VI)/Cr Ratio

- Stainless steel electrodes
  - 3% for FCAW 308LT-1
  - 5% for FCAW 309LT1
  - 35% for SMAW 309L-16
- Carbon steel electrodes
  - 21% for SMAW 7018M
  - 339% for SMAW 11018-M
- SMAW11018-M ratio of 339% must be discarded as the results of an obvious discrepancy in the Cr or the Cr(VI) results

Task 3 Accomplishments

Cr(VI)/Cr Ratio Discussion

- 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)
- Based on the data generated in this study, the proposed 34% ratio is clearly not a ratio representative of all electrodes across the board
  - FCAW electrodes used in this study, were found to be only 3 and 5%
  - SMAW 309L and 7018 values of 35 and 21% 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 from this study demonstrates that the ratio of Cr(VI) to total Cr is highly dependent on the processes and electrodes being used
- A default value cannot be applied to welding emissions in general
- Additional data on each welding process/electrode combination should be generated to determine whether a process-specific ratio or an electrode-specific ratio would result in the most accurate emissions reporting

Task 3 Accomplishments

Comparison of Stainless Steel Electrode Emissions Factors

- Current U.S. EPA emissions factors and the default speciation profile may contribute to the overestimation of Cr(VI) emissions as compared to the emissions factors and profile generated in this study
- Assume a shipyard consumes 50,000 lbs of FCAW 309 electrode
  - Emissions calculated using the U.S. EPA proposed Cr emissions factor of 3000 µg/g, and the default speciation profile of 34% Cr(VI)
  - Emissions calculated using the average Cr emissions factor generated in this study of 696 µg/g, and the speciation profile of 5% Cr(VI)

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

Task 3 Accomplishments

Comparison of Emissions Factors

- The emissions factors generated under this project were compared 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
  - *CTC* testing in house for Cr(VI) study, referred to as *CTC*-Cr(VI)-08
  - AP-42
  - U.S. EPA proposed

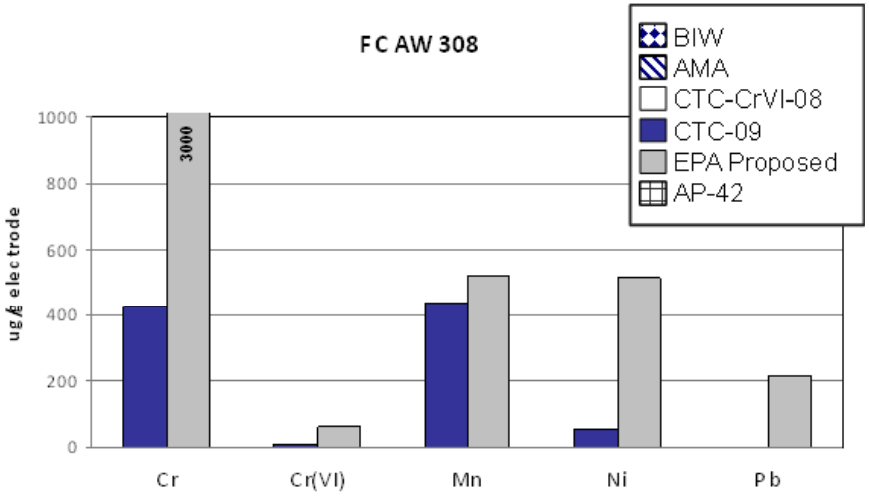
Task 3 Accomplishments

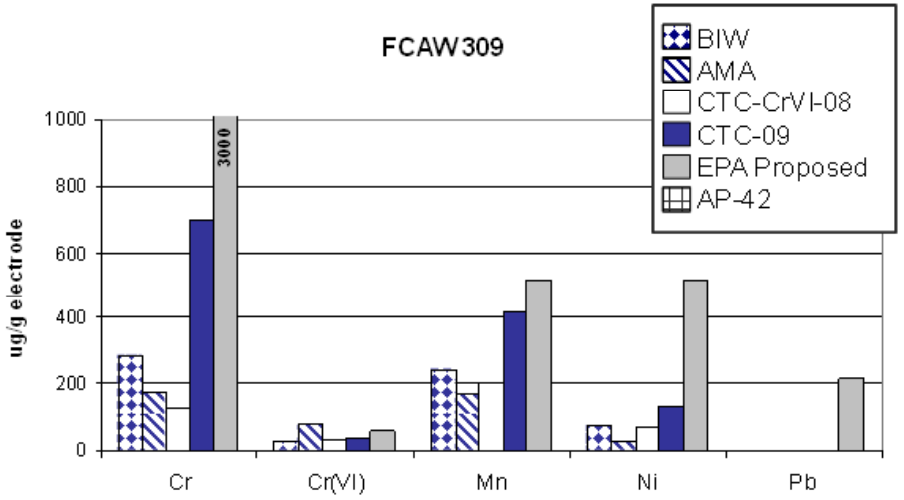
Comparison of Emissions Factors

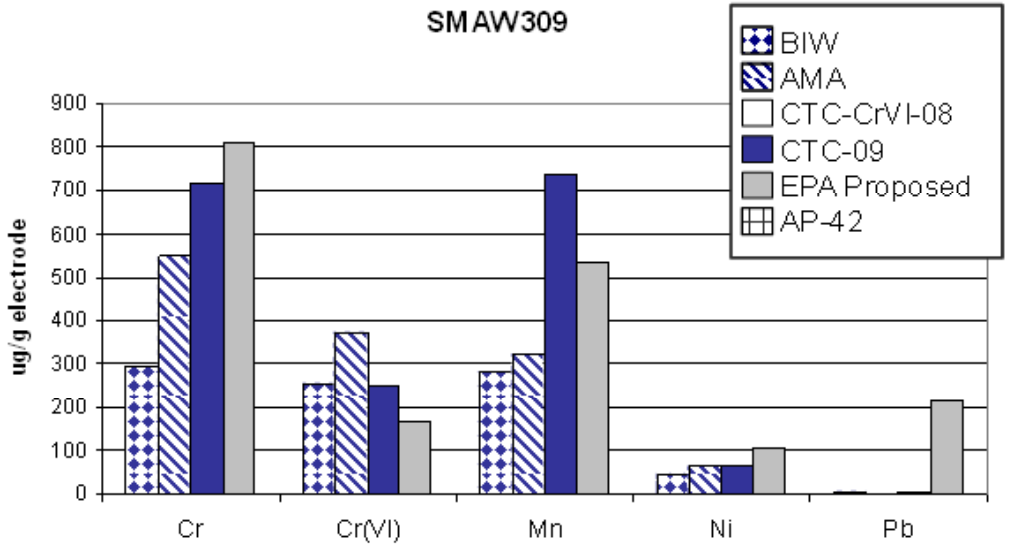
			mg/g electrode	µg/g electrode					# of replicates	
Process	Electrode	Source	total fume	Cr	Cr(VI)	Mn	Ni	Pb	total fume	metals
FCAW	308LT1	CTC-09	5.5	426	12	440	56	2	12	6
FCAW	308	EPA Proposed	ND	3000	59	521	516	215	--	--
FCAW	308	AP-42	9.1 (308LT)	ND	ND	ND	ND	ND	--	--
FCAW	309L	BIW	5.1	285	26	241	74	0.8	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										

Task 3 Accomplishments

Comparison of Stainless Steel Electrode Emissions Factors







Task 3 Accomplishments

Comparison of Stainless Steel Electrode Emissions Factors

- Based on the graphs, the following observations were made:
  - Emissions factors generated in the various studies were consistent from study to study (within the same order of magnitude) for all metals
  - No U.S. EPA AP-42 emission factors currently exist for the selected stainless steel electrodes used in this study
  - 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
  - U.S. EPA proposed Pb emissions factor of 215 mg/g for all stainless steel electrodes appears high relative to the data generated in the various studies
  - U.S. EPA proposed emissions factors for Cr(VI), Mn, and Ni appear consistent (within the same order of magnitude) with the emissions factors generated in these studies

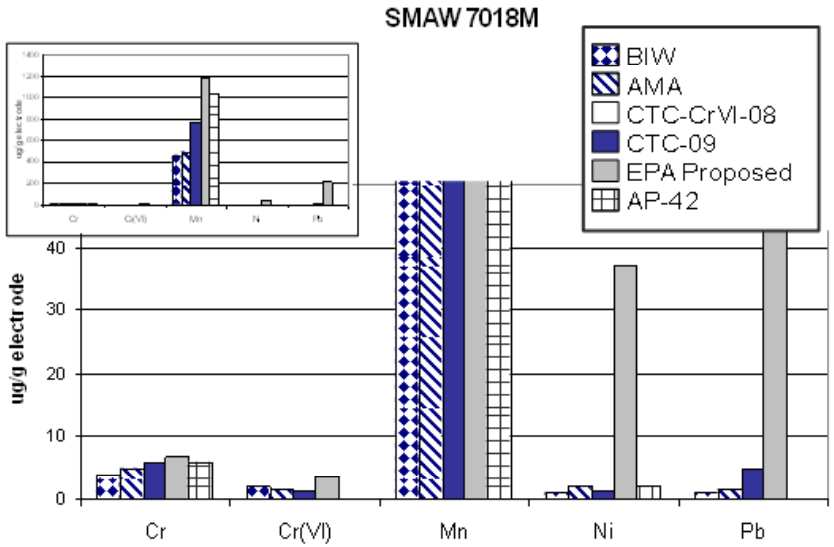
Task 3 Accomplishments

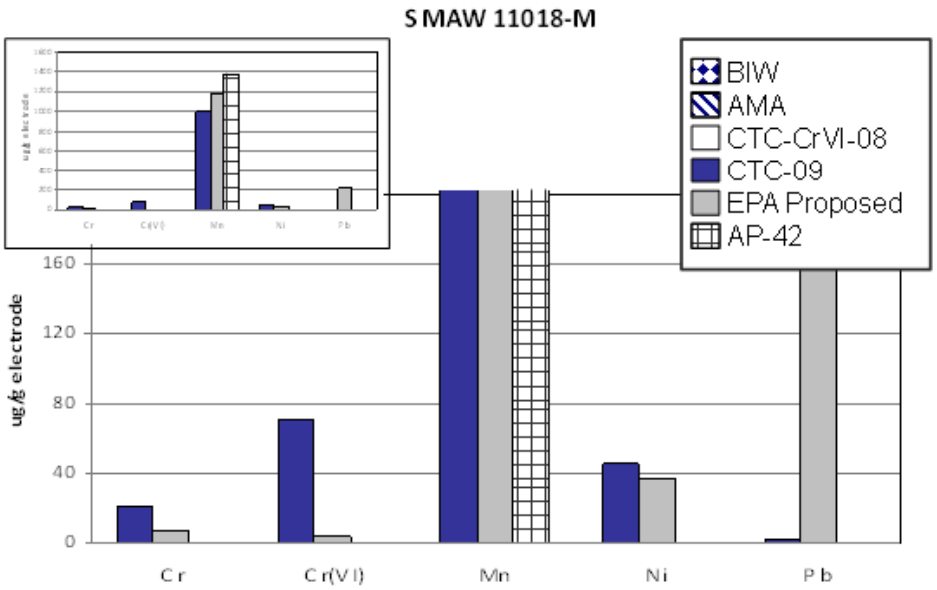
Comparison of Carbon Steel Electrode Emissions Factors

			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										

Task 3 Accomplishments

Comparison of Carbon Steel Electrode Emissions Factors





Task 3 Accomplishments

Comparison of Carbon Steel Electrode Emissions Factors

- Based on the graphs, the following observations were made:
  - Emissions factors generated for SMAW 7018M show similar emissions factors from study to study (within the same order of magnitude) for all metals
  - U.S. EPA proposed Pb emissions factor of 215 µg/g for all carbon steel electrodes appears high relative to the data generated in the various studies
  - U.S. EPA proposed Ni emissions factor of 37 µg/g for SMAW 7018M is high relative to the three studies used for comparison, and the current AP-42 value
  - U.S. EPA proposed and AP-42 emissions factors for Cr, Cr(VI), and Mn, appear consistent (within the same order of magnitude) with the emissions factors generated in these studies

Task 3 Accomplishments

Comparison to ESAB Data

- As a result of briefing at the Spring 2009 Weld Panel meeting, ESAB expressed interest in supporting the project. This support included:
  - Providing information related to the ESAB welding products evaluated in this study
  - Completing comparative testing of the selected electrodes
- The major differences between this study and the ESAB study were as follows:
  - Filer media used
  - Number of welding runs (3 per process/electrode)
  - Sample preparation (brushed particulates off the filter)
  - Analytical methods (used an in-house Wavelength Dispersive X-Ray Fluorescence (XRF) Spectrophotometric for Cr, Mn, Ni, Pb, and OSHA W4001 to analyze the fume samples for Cr(VI))
  - Results for metals are the result of a single analytical sample run
  - Results for total fume are an average of three sample runs

Task 3 Accomplishments

Comparison to ESAB Data

Process	Electrode	Electrode Type	Source	mg/g electrode[1] total fume	µg/g electrode[2] 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 of6 replicates; ESAB value is based on a single analysis

Task 3 Accomplishments

Comparison to ESAB Data

- Given the procedural differences, the two methods still resulted in comparable data, within one order of magnitude
- The ESAB data supports the assumption that the Cr(VI) value for the SMAW 11018-M electrode is unexplainably high

				mg/g electrode[1]	µg/g electrode[2]				
Process	Electrode	Electrode Type	Source	total fume	Cr	Cr(VI)	Mn	Ni	Pb
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

Conclusions

- Significant findings of this study:
  - Emissions factors generated for FCAW 308 (426 +/- 130 µg/g) and FCAW 309 (696 +/- 213 µg/g) are both significantly lower than the U.S. EPA proposed emission factor of 3000 mg/g
  - Cr(VI)/Cr ratios generated for four of the electrodes (3, 5, 21, and 35%) clearly indicates that the U.S. EPA's 34% "default speciation profile" would greatly overstate the actual Cr(VI) emissions
    - Example assuming 50,000 lbs/year of FCAW 309, reported Cr emissions would be reduced by 77% and Cr(VI) emissions by 96%
  - U.S. EPA proposed emissions factor for Pb (215 µg/g) is approximately two orders of magnitude higher than what was discovered in this study
  - Ni emissions factor of 1 µg/g generated for SMAW 7018 is significantly lower that the U.S. EPA proposed value of 37 µg/g
- Project information was summarized in the Final Project Summary Report and was submitted to ATI on December 30,2009

Acknowledgements

The project team would like to thank those who provided outstanding support during the coordination and completion of this project

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  - Environmental Technologies Panel under direction of the panel chair, Mr. Wayne Holt, for its sponsorship and support
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Questions?