Attachment 1

To: Dr. Mohamed Serageldin
Project File

From: Dave Reeves
Date: April 21, 2004

Re: Review Summary of NSRP Testing and Welding Emission Factors

We reviewed the box of supporting test data and information sent to EPA on April 16, 2004 by the shipyard industry. The documentation refers to one study for two welding technologies: shielded metal arc welding (SMAW) and submerged arc welding (SAW) and several stainless steel rods/wires. The following comments summarize my review of the information provided:

"Shipyard Welding Factor Development" by William Mener and Peter Rosen of LFR Levine-Fricke, Dana Austin of Dana M. Austin Environmental, Inc., and Wayne Holt of Atlantic Marine Inc. [NSRP 0574, Final Report, Project No. N1-98-2, September 1, 1999]

Testing conducted at the Atlantic Marine facility in Jacksonville, Florida in Sept/Oct 2000.

EPA Method 29 used for PM metals sampling in the field; lab procedure was EPA Method 5.
EPA Method 306A - Determination of Cr Emissions from Electroplating" used for Cr(VI).

1) **Welding Rod/Wire & Equipment Specifications**
   Tests 1, 2, 3, 4, 6, and 8; SMAW; 36 V, 150 A
   1. E308-16, E308L-16
   2. E309-16
   3. E309-17, E309L-17
   4. E316-16, E316L-16
   6. E308-17, E308L-17
   8. E308-16, E308H-16

   Tests 5, 7; SAW; Welding Conditions: 32 V, 300 A; Flux Type = Lincolnweld ST-100
   5. ER316, ER316L
   7. ER309, ER309L

2) LFR developed a test protocol for welding methods, types of rods, fume capture, and sampling methods; EPA reference methods were utilized for sampling and test enclosure.

3) Each test was comprised of three runs and the test mean was determined to be the arithmetic average of the results for each of three runs.

4) Copies of all field data and notebooks provided; good documentation; a couple of problems were noted where the impinger solution and rinse used on the probe and nozzle was inadvertently mixed between two samples.

5) Overall, supporting documentation is complete; no significant deficiencies or errors noted (based on a very cursory review of the submitted materials).

6) Recommend that these emission factors be included in the update to AP-42 factors for SMAW and SAW.

Attachment 2. Parametric and Nonparametric Methods Evaluated

Summary95UCL_DiffMethods04Nov04 Revised 11/29/04

No.	Metal in Fume	Sample Size	Mean (g/kg)	Recommended (g/kg)	Students'-t (g/kg)	Bootstrap "t" (g/kg)	Bootstrap Percentile (g/kg)	Bootstrap BCA (g/kg)	Bootstrap Hall's (g/kg)	H-UCL (g/kg)	Skewness
1	Cr (SMAW)	21	0.708	0.811	0.811	0.816	0.805	0.806	0.817	0.864	0.342
2	Cr (GMAW)	7	3.07	5.82	5.06	5.82	4.67	4.68	4.10	15.1	0.514
3	Cr (FCAW)	6	2.30	3.00	3.00	2.84	2.79	NC	NC	4.54	-1.37
4	Cr+6 (SMAW)	25	0.152	0.176	0.176	0.176	0.175	0.174	0.179	0.400	0.250
5	Cr+6 (GMAW)	17	0.0276	(App. G)0.0393	0.03632	0.0384	0.0361	0.0366	0.0354	0.0479	0.771
6	Cr+6 (FCAW)	13	0.0369	0.0748	0.0524	0.0587	0.0509	0.0533	0.0532	0.0637	1.38
7	Mn (SMAW)	21	0.460	(App.G)0.534	0.534	0.552	0.528	0.536	0.531	0.537	1.19
8	Mn (GMAW)	7	7.64	12.6	12.6	13.9	11.5	12.2	10.6	78	0.554
9	Mn (FCAW)	6	10.4	18.3	18.3	18.3	16.6	18.5	76.4	NC	1.017
10	Ni (SMAW)	20	0.080	0.104	0.141						
11	Ni (GMAW)	6	240	0.249	Used fume composition curves (from reference data)						
12	Ni (FCAW)	6	83.8	0.419	and max. fume formation rate from AP-42 as default.						
13	Pb (SMAW)	19	0.00882	0.215	Used fume composition curves (from reference data)						
14	Pb (GMAW)	1	0.0613	0.215	and max. fume formation rate from AP-42 as default.						
15	Pb (FCAW)	2	0.06394	0.215							

NOTE: NC = Not Calculated

Attachment 3

Figure 1: UCL Method Flow Chart

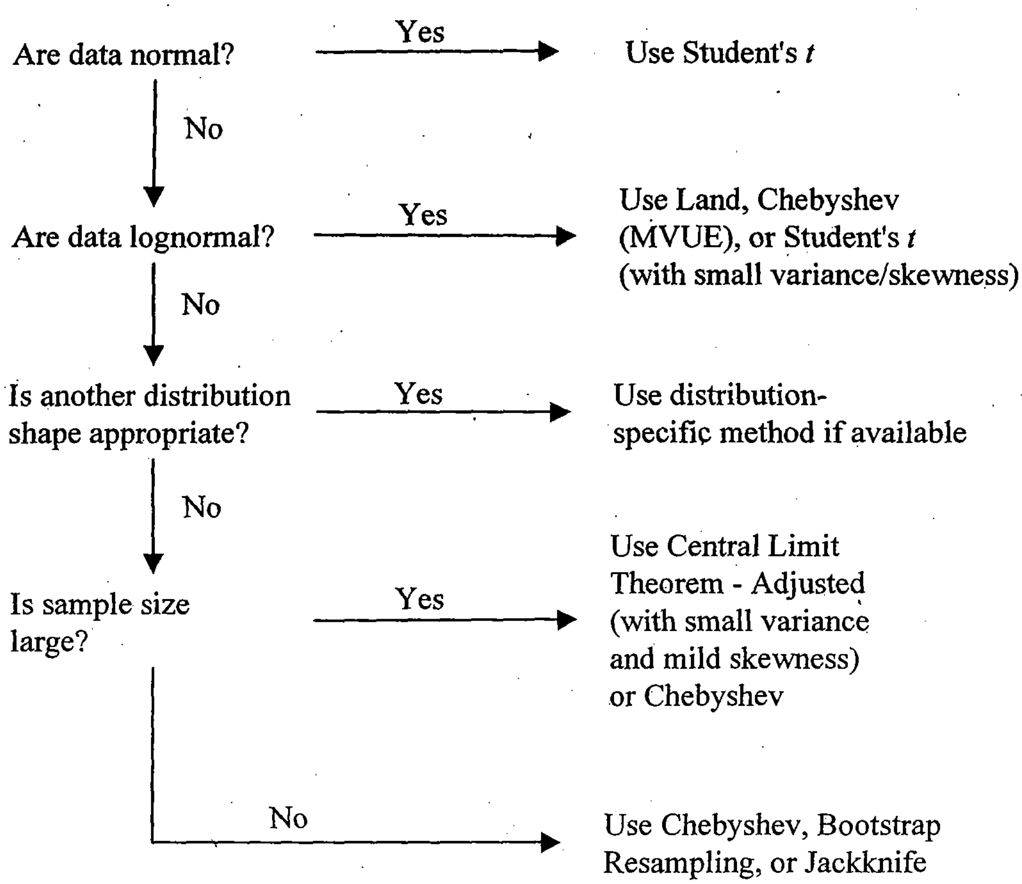

Exhibit 14
Summary of UCL Calculation Methods

Method	Applicability	Advantages	Disadvantages	Reference
For Normal or Lognormal Distributions				
Student's *t*	means normally distributed, samples random	simple, robust if *n* is large	distribution of means must be normal	Gilbert 1987; EPA 1992
Land's *H*	lognormal data, small variance, large *n*, samples random	good coverage[1]	sensitive to deviations from lognormality, produces very high values for large variance or small *n*	Gilbert 1987; EPA 1992
Chebyshev Inequality (MVUE)	skewness and variance small or moderate, samples random	often smaller than Land	may need to resort to higher confidence levels for adequate coverage	Singh et al. 1997
Wong	gamma distribution	second order accuracy[2]	requires numerical solution of an improper integral	Schulz and Griffin 1999; Wong 1993
Nonparametric/Distribution-free Methods				
Central Limit Theorem - Adjusted	large *n*, samples random	simple, robust	sample size may not be sufficient	Gilbert 1987; Singh et al. 1997
Bootstrap t Resampling	sampling is random and representative	useful when distribution cannot be identified	inadequate coverage for some distributions; computationally intensive	Singh et al. 1997; Efron 1982
Hall's Bootstrap Procedure	sampling is random and representative	useful when distribution cannot be identified; takes bias and skewness into account	inadequate coverage for some distributions; computationally intensive	Hall 1988; Hall 1992; Manly 1997; Schultz and Griffin 1999
Jackknife Procedure	sampling is random and representative	useful when distribution cannot be identified	inadequate coverage for some distributions; computationally intensive	Singh et al. 1997
Chebyshev Inequality	skewness and variance small or moderate, samples random	useful when distribution cannot be identified	inappropriate for small sample sizes when skewness or variance is large	Singh et al. 1997; EPA 2000c

[1] Coverage refers to whether a UCL method performs in accordance with its definition.
[2] As opposed to maximum likelihood estimation, which offers first order accuracy.

Table 1. Summary of UCL Calculation Methods

Attachment 5. Summary of Welding Emission Factors

Summary of Welding Information - by welding process + type of electrode - compiled on 11-22-04.
Summary includes data from 12 shipyards (1 shipyard claimed data as CBI) for baseline year - 1999.

Welding Process	Type of electrode	Proposed Emission Factors (using 95% UCL) Total Cr, g/kg	Cr+6, g/kg	Mn, g/kg	Ni, g/kg	Pb, g/kg
SMAW	E308	8.11E-01	1.76E-01	5.34E-01	1.04E-01	2.15E-01
SMAW	E309	8.11E-01	1.76E-01	5.34E-01	1.04E-01	2.15E-01
SMAW	E310	8.11E-01	1.76E-01	5.34E-01	1.04E-01	2.15E-01
SMAW	E316	8.11E-01	1.76E-01	5.34E-01	1.04E-01	2.15E-01
SMAW	E347	8.11E-01	1.76E-01	5.34E-01	1.04E-01	2.15E-01
SMAW	E429	8.11E-01	1.76E-01	5.34E-01	1.04E-01	2.15E-01
SMAW	E6010	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E6011	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E6013	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E7018	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E7024	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E70/30	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E8018	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E9018	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E10018	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E11018	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E9N10	3.64E-03	1.82E-04	1.91E+00	1.72E+00	2.15E-01
SMAW	E1N12	2.71E+00	1.35E-01	3.50E+00	1.83E+00	2.15E-01
SMAW	E8N12	1.75E+00	8.73E-02	2.83E+00	1.69E+00	2.15E-01
SMAW	ENiCl	3.64E-03	1.82E-04	1.22E-02	1.60E+00	2.15E-01
SMAW	Nickel 61	3.64E-03	1.82E-04	1.22E-02	1.67E+00	2.15E-01
SMAW	Ni-Rod 99X	3.64E-03	1.82E-04	1.22E-02	2.02E+00	2.15E-01
SMAW	ED029203	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	RN60	3.64E-03	1.82E-04	1.91E+00	1.73E+00	2.15E-01
SMAW	KOBESUS-43	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	MIL 67	3.64E-03	1.82E-04	7.61E-01	1.23E+00	2.15E-01
SMAW	Arc Rod	3.64E-03	1.82E-04	3.50E+00	1.44E-02	2.15E-01
SMAW	187N	3.64E-03	1.82E-04	1.91E+00	1.73E+00	2.15E-01
SMAW	BCUP 5	3.64E-03	1.82E-04	1.91E+00	1.73E+00	2.15E-01
SMAW	E2209	3.64E-03	1.82E-04	3.50E+00	7.00E-01	2.15E-01
SMAW	E4043	3.64E-03	1.82E-04	3.50E+00	7.00E-01	2.15E-01
SMAW	E5556	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E70S	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E80S	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	ECuSn	3.64E-03	1.82E-04	1.91E+00	1.72E+00	2.15E-01
SMAW	E12018	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	E7028	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	LIN-L70	2.21E-02	1.21E-02	1.31E+00	3.71E-02	2.15E-01
SMAW	EIA2A	2.17E-02	1.08E-03	8.61E-01	1.44E-02	2.15E-01
GMAW	E308	5.82E+00	3.92E-02	1.26E+01	2.49E-01	2.15E-01
GMAW	E309	5.82E+00	3.92E-02	1.26E+01	2.49E-01	2.15E-01
GMAW	E310	5.82E+00	3.92E-02	1.26E+01	2.49E-01	2.15E-01
GMAW	E316	5.82E+00	3.92E-02	1.26E+01	2.49E-01	2.15E-01

GMAW	E347	5.82E+00	3.92E-02	1.26E+01	2.49E-01	2.15E-01
GMAW	190093	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	(LC 33) HD/Fac	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	Arc Rod	4.00E-04	2.00E-05	3.85E-01	1.58E-03	2.15E-01
GMAW	BCUP 5	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	ECuSn	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	DS7100	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E100	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E10018	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E110	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E11018	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E2209	4.00E-04	2.00E-05	3.85E-01	7.70E-02	2.15E-01
GMAW	E4043	4.00E-04	2.00E-05	3.85E-01	7.70E-02	2.15E-01
GMAW	E5356	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E5556	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E70S	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E7018	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E80S	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E8018	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E8N12	3.74E-01	1.87E-02	6.06E-01	3.62E-01	2.15E-01
GMAW	E9018	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	E9N10	7.80E-04	3.90E-05	4.09E-01	3.68E-01	2.15E-01
GMAW	EB1	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
GMAW	ECu	1.37E-02	6.83E-04	5.92E-01	1.93E-01	2.15E-01
GMAW	ECuAl	1.37E-02	6.83E-04	5.92E-01	1.93E-01	2.15E-01
GMAW	ECuNi	7.80E-04	3.90E-05	1.63E-01	2.66E-01	2.15E-01
GMAW	ECuNiAl	1.37E-02	6.83E-04	5.92E-01	1.93E-01	2.15E-01
GMAW	ECuSi	1.37E-02	6.83E-04	5.92E-01	1.93E-01	2.15E-01
GMAW	ECuSn	7.80E-04	3.90E-05	3.08E-01	3.08E-03	2.15E-01
GMAW	ECuZn	7.80E-04	3.90E-05	5.66E-02	3.08E-03	2.15E-01
GMAW	EN60	7.80E-04	3.90E-05	4.09E-01	3.68E-01	2.15E-01
GMAW	EN625IN	7.80E-04	3.90E-05	2.62E-03	3.08E-03	2.15E-01
GMAW	EN67	7.80E-04	3.90E-05	4.09E-01	3.68E-01	2.15E-01
GMAW	ENi	7.80E-04	3.90E-05	2.62E-03	4.21E-01	2.15E-01
GMAW	ENiCrFe	4.25E-01	2.13E-02	3.75E-01	3.61E-01	2.15E-01
GMAW	ENiCu	7.80E-04	3.90E-05	2.62E-03	3.54E-01	2.15E-01
GMAW	METALLIZING	7.80E-04	3.90E-05	2.62E-03	3.08E-03	2.15E-01
GMAW	MIL 67	7.80E-04	3.90E-05	1.63E-01	2.82E-01	2.15E-01
GMAW	Monel 67	7.80E-04	3.90E-05	1.40E-01	2.62E-01	2.15E-01
GMAW	Ni-Rod 55	7.80E-04	3.90E-05	3.01E-01	4.09E-01	2.15E-01
GMAW	RN60	7.80E-04	3.90E-05	4.09E-01	3.70E-01	2.15E-01
GMAW	RN625	5.80E-01	2.90E-02	2.62E-03	3.56E-01	2.15E-01
GMAW	RN67	7.80E-04	3.90E-05	4.09E-01	3.68E-01	2.15E-01
GMAW	RN82	5.03E-01	2.51E-02	4.09E-01	3.68E-01	2.15E-01
GMAW	WELDING	8.01E-02	4.00E-03	3.96E-01	3.71E-02	2.15E-01
FCAW	E308	3.00E+00	7.48E-02	1.83E+01	4.19E-01	2.15E-01
FCAW	E309	3.00E+00	7.48E-02	1.83E+01	4.19E-01	2.15E-01
FCAW	E316	3.00E+00	7.48E-02	1.83E+01	4.19E-01	2.15E-01
FCAW	E347	3.00E+00	7.48E-02	1.83E+01	4.19E-01	2.15E-01
FCAW	MIL101TC	1.52E-01	7.60E-03	9.55E-01	2.04E-01	2.15E-01
FCAW	E101	6.67E-03	7.00E-04	9.85E-01	3.71E-02	2.15E-01
FCAW	E120S	1.52E-01	7.60E-03	9.55E-01	2.04E-01	2.15E-01

FCAW	E70S/T	6.67E-03	7.00E-04	9.85E-01	3.71E-02	2.15E-01
FCAW	E71T	6.67E-03	7.00E-04	9.85E-01	3.71E-02	2.15E-01
FCAW	E80S/T	6.67E-03	7.00E-04	9.85E-01	3.71E-02	2.15E-01
FCAW	E81T	6.67E-03	7.00E-04	9.85E-01	3.71E-02	2.15E-01
FCAW	E8AT	6.67E-03	7.00E-04	9.85E-01	3.71E-02	2.15E-01
FCAW	EM12K	6.67E-03	7.00E-04	9.85E-01	3.71E-02	2.15E-01
SAW	EL12	2.21E-03	1.21E-03	1.31E-01	3.71E-03	2.15E-01
SAW	EM12K	2.21E-03	1.21E-03	1.31E-01	3.71E-03	2.15E-01
SAW	ENi	0.00E+00	0.00E+00	0.00E+00	5.00E-02	2.15E-01
SAW	Flux F72	0.00E+00	0.00E+00	1.50E-02	0.00E+00	2.15E-01
SAW	SP/Arc 86	2.21E-03	1.21E-03	1.31E-01	3.71E-03	2.15E-01
SAW	WM1093	2.21E-03	1.21E-03	1.31E-01	3.71E-03	2.15E-01
SAW	WM1095	2.21E-03	1.21E-03	1.31E-01	3.71E-03	2.15E-01
MISC	Carbons	2.21E-03	1.21E-03	1.31E-01	3.71E-03	2.15E-01
BRAZING	GR3 Silver	2.21E-03	1.21E-03	1.31E-01	3.71E-03	2.15E-01

Stainless Steels

Mild Steels

Alloy Steels

Comment
Use new SMAW/SS factors
Use new SMAW/SS factors
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Use new GMAW/SS factors; Ni: Use AP-42 TSP, comp. curve.
Use new GMAW/SS factors; Ni: Use AP-42 TSP, comp. curve.
Use new GMAW/SS factors; Ni: Use AP-42 TSP, comp. curve.

Use new GMAW/SS factors; Ni: Use AP-42 TSP, comp. curve.
Use GMAW E70S (-3 to -6) data
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Use AP-42 TSP max. (3.9 g/kg), composition curves
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Use AP-42 TSP max. (3.9 g/kg), composition curves
Use AP-42 TSP max. (3.9 g/kg), composition curves
Use GMAW E70S (-3 to -6) data
Use new FCAW/SS factors; Ni: Use AP-42 TSP, comp. curve.
Use new FCAW/SS factors; Ni: Use AP-42 TSP, comp. curve.
Use new FCAW/SS factors; Ni: Use AP-42 TSP, comp. curve.
Use new FCAW/SS factors; Ni: Use AP-42 TSP, comp. curve.
Use AP-42 TSP max. (9.1 g/kg), composition curves
Use FCAW E70T/E71T data
Use AP-42 TSP max. (9.1 g/kg), composition curves

Use FCAW E70T/E71T data
Use FCAW E70T/E71T data
Use FCAW E70T/E71T data
Use FCAW E70T/E71T data
Use FCAW E70T/E71T data
Use FCAW E70T/E71T data
Use 10% of SMAW/7018/7028 factors.
Use 10% of SMAW/7018/7028 factors.
Use AP-42 TSP for SAW (0.05 g/kg), composition curves
Use AP-42 TSP for SAW (0.05 g/kg), composition curves
Use 10% of SMAW/7018/7028 factors.
Use 10% of SMAW/7018/7028 factors.
Use 10% of SMAW/7018/7028 factors.
Use 10% of SMAW/7018/7028 factors.
Use 10% of SMAW/7018/7028 factors.

Attachment 6

To: Dr. Mohamed Serageldin
Project File

From: Dave Reeves
Date: October 12, 2004

Re: Recommended Emission Factors for Submerged Arc Welding (SAW)

A couple of the shipyards, Jeffboat and NGSS Avondale, reported significant amounts of SAW using mild steels (e.g., EL12 and EM12K) and alloy steels (e.g., Flux F72). The total amount of SAW in the project database (involving 13 shipyards) consumed 1.1 million pounds (0.5 million kilograms) of electrodes which was 10.9 percent of the total reported electrode consumption in the database. It should be noted that Atlantic Marine Inc. did not include information on SAW processes in their questionnaire response because "SAW does not emit these HAPs according to AP-42." [While AP-42 (Section 12.19) does not include candidate HAP emission factors for SAW, it does include candidate PM-10 emission factors for SAW/EM12K1/F72-EM12K2.]

In reviewing the test data and information sent to EPA on April 16, 2004 by the shipyard industry related to "Shipyard Welding Factor Development" by William Mener and Peter Rosen of LFR Levine-Fricke, Dana Austin of Dana M. Austin Environmental, Inc., and Wayne Holt of Atlantic Marine Inc. [NSRP 0574, Final Report, Project No. N1-98-2, September 1, 1999], the report refers to a study for two welding technologies: shielded metal arc welding (SMAW) and SAW and stainless steel rods/wires (e.g., E308, E309, and E316). The following comments and table summarize the emission factor information provided in the report:

1) SAW welding process has a significantly lower fume generation rate than does SMAW.

2) Metal emissions derived from the SAW process are significantly less than from SMAW. This is likely a result of the much lower fume generation rate observed with SAW as compared to SMAW.

Excerpts from NSRP 0574 - Table 4. Metals Emission Factors (lbs/1000 lbs)

Process	**Electrode**	**Cr**	**Cr+6**	**Mn**	**Ni**	**Pb**
SMAW	E309	0.71	0.085	0.40	0.055	0.01
SAW	ER309	0.01	0.00	0.09	0.01	0.01
SMAW	E316	0.83	0.19	0.42	0.08	0.01
SAW	ER316	0.01	0.00	0.07	0.00	0.00

San Diego Air Pollution Control District (SDAPCD) guidance for welding operations and emission estimation techniques (last updated 10/16/98) states "Welding and cutting torch processes which do not consume electrodes are unquantifiable at this time. These processes may include SAW, arc spot welding, braze welding, thermal cutting, electron beam welding, and laser welding. Emissions from these processes should be identified by the facility and District as unquantifiable until preliminary estimation techniques are developed."

Per the “Final Report on Reduction of Worker Exposure and Environmental Release of Welding Emissions,” Edison Welding Institute (EWI) Project No. 43149GTH, February 5, 2003:

1) SAW is primarily a flat position welding process and is not practical for out of position welding, and

2) SAW has total fume emission factors of less than 0.0005% of the weight of the deposited weld metal.

Recommendation

Based on this information, I recommend that for purposes of this project, we assume HAP metal emission factors for SAW = 10 percent of SMAW emission factors for the same or comparable (similar HAP metal content) type of electrode.

Attachment 7

To: Dr. Mohamed Serageldin
Project File

From: Dave Reeves
Date: November 18, 2004

Re: Recommended "Default" Welding Emission Factors for Alloy Steels

Based on the limited test data for alloy steels/electrodes (i.e., those having higher compositions of Cr, Mn, and Ni), we have developed default welding emission factors. The following process was used to calculate the emission factors (EFs) for total Cr, Cr+6, Mn, Ni, and Pb:

1) EF = (fume generation rate) x (percentage of a specific metal in the fume)

2) We used EPA's "Development of Particulate and Hazardous Emission Factors for Electric Arc Welding (AP-42, Section 12.19) dated May 1995[1]and data attributed to Reference 11 (of that document) in: "Fumes From Shielded Metal Arc Welding Electrodes" by J.F. McLiwain and L.A. Neumeir (1987)[2].

   We looked at several other technical reports and test data,[3,4] but they were not as comprehensive in terms of the range(s) of metal contents evaluated for fumes generated and concentrations.

3) Fume Generation Rate - using AP-42 Table 4-15 Candidate PM-10 Emission Factors for each type of welding process.[1] We reviewed all of the electrodes reported by the shipyards in their ICR responses and selected the alloy electrode with the highest emission factor (to be conservative):
   SMAW - 18.2 g/kg
   GMAW - 3.9 g/kg
   FCAW - 9.1 g/kg
   SAW - 0.05 g/kg

4) Percentage of Metal (Cr, Mn and Ni) in Fume - using the equations and curves in AP-42 and data from AP-42 Reference 11 (McLiwain and Neumeir)[2] - pages A9 and A10:
   A - Eq. 5 calculates total Cr fraction in fume as function of Cr content of electrode:
   % Cr in fume = -0.31 + [0.66 x (% Cr in electrode)]
   B - Eq. 9 calculates Mn fraction in fume as function of Mn content of electrode:
   % Mn in fume = -0.99 + [4.60 x (% Mn in electrode)^{½}] +[0.57 x (% Mn in electrode)]
   C - Eq. 10 calculates Ni fraction in fume as function of Ni content of electrode:
   % Ni in fume = -0.78 + [1.59 x (% Ni in electrode)^{½}] +[0.04 x (% Ni in electrode)]

5) Cr+6 Emission Factors - Since there is no data for Cr+6, we opted to use the average Cr+6/Cr ratio from the Chromium File report[5] for each type of welding process:
   SMAW - 55%
   GMAW - 5%
   FCAW - 10%.

6) Pb Emission Factors - Since there is limited test data for Pb, we opted to used the highest reported data point = 0.215 g/kg as the emission factor.

Example:

1) For SMAW/8N12, we know the composition of electrode 8N12 is 7.25% Mn, 15% Cr, and 62.5% Ni (as reported by Norfolk Naval Shipyard).

2) EF = (fume generation rate) x (percentage of a specific metal in the fume)

3) SMAW Fume Generation Rate = 18.2 g/kg

4) A - using Equation 5 from Reference 11, the total Cr in fume = 9.59%
B - using Equation 9 from Reference 11, the Mn in fume = 15.53%
C - using Equation 10 from Reference 11, the Ni in fume = 9.29%

5) Emission Factors:
A - Cr = (18.2 g/kg) x (9.59/100) = 1.75 g/kg
B - Mn = (18.2 g/kg) x (15.53/100) = 2.83 g/kg
C - Ni = (18.2 g/kg) x (9.29/100) = 1.69 g/kg

6) Cr+6 Emission Factor = 55% of Cr Emission Factor = (0.55) x (1.75 g/kg) = 0.96 g/kg

7) Pb Emission Factor = 0.215 g/kg (highest value in limited data set)

REFERENCES:

1. Development of Particulate and Hazardous Emission Factors for Electric Arc Welding, United States Environmental Protection Agency, AP-42, Section 12.19, Revised Final Report, May 1995.

2. Fumes From Shielded Metal Arc Welding Electrodes by J.F. McLiwain and L.A. Neumeir, Report of Investigations 9105, United States Department of Interior, Bureau of Mines, 1987.

3. "The Effect of Oxygen on the Rate of Fume Formation in Metal Inert Gas Welding Arcs by C.N. Gray, et al., April 1980.

4. Relation Between Various Chromium Compounds and Some Other Elements in Fumes from Manual Metal Arc Stainless Steel Welding by W. Matczak and J. Chmielnicka, 1993.

5. "Chromium in Stainless Steel Welding Fumes," The Chromium File from the International Chromium Development Association, Issue No. 9, April 2002. (www.chromium-asoc.com/publications/crfile9apr02.htm)

Attachment 8A. Statistical Analysis of Stainless Steel Emission Factor Data (DRAFT - for EPA use only)

Stainless Steel Emission Factors 08-Nov-04 (revised) EFSummary95UCL_11_8_04.xls

No.	Metal in Fumes	Welding Process	Rod Type	Statistics Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	Comments
1	**Total Chromium**	SMAW	E308/E316	0.7413	1.2	14	0.8826	Student's-t
			E309	0.64	0.86	7	0.8032	Student's-t
			all data	**0.7076**	**1.2**	**21**	**0.8107**	**Student's-t**
		GMAW	E316	1.032	1.3	3	7.72	Assumed normal distribution
			E309	4.6	6.51	4	7.607	Mod-t UCL (Adjusted for skewness
			all data	**3.071**	**6.51**	**7**	**5.82**	**Bootstrap-t**
		FCAW	E316	2.45	3.04	2	2.999	Assigned UCL for "all data"
			E309	2.22	2.86	4	3.302	Mod-t UCL (Adjusted for skewness)
			all data	**2.296**	**3.04**	**6**	**2.999**	**Student's-t**
2	**Hexavalent Chromium**	SMAW	E308/E316	0.175	0.353	18	0.1998	Student's-t
			E309	0.09205	0.163	7	0.1409	Student's-t
			all data	**0.1515**	**0.353**	**25**	**0.1763**	**Student's-t**
		GMAW	E308/E316	0.02153	0.0497	13	0.02843	Student's-t
			E309	0.04752	0.06649	4	0.0801	Student's-t
			all data	**0.02765**	**0.0665**	**17**	**0.03922**	**Approx. Gamma**
		FCAW	E316	0.05587	0.0707	3	0.1049	Assumed normal distribution
			E309	0.03122	0.122	10	0.07627	95% Chebyshev (Meand, Sd)
			all data	**0.0369**	**0.122**	**13**	**0.07481**	**95% Chebyshev (Meand, Sd)**

No.	Metal in Fumes	Welding Process	Rod Type	Statistics Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	Comments
3	**Manganese**	SMAW	E308/E316	0.5005	0.861	14	0.6132	Approx. Gamma
			E309	0.3795	0.59	7	0.4569	Student's-t
			all data	**0.4602**	**0.861**	**21**	**0.534**	**Approx. Gamma**
		GMAW	E316	2.987	3.52	3	4.134	Assumed normal distribution
			E309	11.13	17.9	4	19.84	Student's-t
			all data	**7.64**	**17.9**	**7**	**12.64**	**Student's-t**
		FCAW	E316	25.85	28.5	2		
			E309	6.625		4	8.919	mod-tUCL (adjusted for skewness)
			all data	**10.35**	**28.5**	**6**	**18.3**	**Student's-t**
4	**Nickel**	SMAW	E308/E316	0.009633	0.228	14	0.1314	Approx. Gamma
			E309	0.05689	0.653	6	0.06423	Student's-t
			all data	**0.07953**	**0.2278**	**20**	**0.1041**	**Student's-t** (ESAB's data E309L = 163 g/kg was removed) (Ni content varies from 9% - 14 % by mass of rod)
		GMAW	E316	77.3	94.4	3		Calculated 95%UCL = unfeasable result;
			E309	402.7	705	3		used fume composition curves (from reference data)
			all data		**705**	**6**	**0.249**	and max fume formation rates from AP-42 as default
		FCAW	E316	190	221	2		Calculated 95%UCL = unfeasable result;
			E309	77.66	112	4		used fume composition curves (from reference data)
			all data		**221**	**6**	**0.419**	and max fume formation rates from AP-42 as default

NOTE Level of nickel in E308, E309, E310, and E316 welding rods/wires can vary between 9 to 21 % by mass

No.	Metal in Fumes	Welding Process	Rod Type	Statistics				Comments
				Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	
5	**Lead**	SMAW	E308/E316	0.00963	0.0319	13	0.01337	Lead is a trace contaminant in carbon steels;
			E309	0.007049	0.0089	6	0.008065	used default value for 95%UCL = maximim data
			all data	0.008817	0.0319	19	**0.215**	reported for any mild steel or SS = 0.215 g/kg
		GMAW	E316	ND	ND	0		Lead is a trace contaminant in carbon steels;
			E309		0.0613	1	0.0613	used default value for 95%UCL = maximim data
			all data		0.0613	1	**0.215**	reported for any mild steel or SS = 0.215 g/kg
		FCAW	E316	ND	ND	0		Lead is a trace contaminant in carbon steels;
			E309	0.0639	0.064	2	0.064	used default value for 95%UCL = maximim data
			all data		0.064	2	**0.215**	reported for any mild steel or SS = 0.215 g/kg

ND = not determined

NOTES:	11-Nov-04 Revised	Data File: EFwelding28Sep04StainlessS	Stainless Steel (s.s)
		OR EFwelding01Oct04.xls	Both s.s and mild steel

1. Single data points were used for determining the 95% UCL.

2. Q-Q plot was used to test for the appropriate parametric distribution (normal, lognormal, and Gamma), otherwise a non-parametric method was selected. Percentile bootstrap, bootstrap-t., and H-UCL were compared with the recommended value.

3. Individual Cr(6) data points received from the California Air Resource Board in August '04 were included. (In June '04 CARB report - only provided the average values and the S.D .)

4. We assumed that we could combine E308 and E316 since the rods are only used to weld s.s substrates, and the individual EF values overlapped. We analyzed E309 separately because these rods can also be used to weld stainless steel to mild steel. The substrate welded can contribute metals to the fumes.

5. We then combine the data for all the rods in a process when the statistical analysis did not indicate otherwise: (1) The QQplots for the combined data for Total Cr, Cr(6), and Mn indicated that the combined data "all data" followed a distribution that is similar to that of the the individual rod groupings, i.e., E308/E316 and E309.

6. When there were only 3 data points, we assumed the data came from a normal population to calculate a UCL. This UCL would tend to be on the protective side, because of the small data set.

7. Some of the emission factors were unusually high, e.g., ESAB's EF for Ni (SMAW/E309L). There are no AP-42 values for SMAW/E309.

8. We assigned default values when there were data gaps or inconsistencies.

9. Cr, Cr(6), and Mn are the 3 important metals in the welding fumes for RR purposes.

Attachment 8B. Statistical Analysis of Mild Steel Emission Factor Data (DRAFT - for EPA use only)

Mild Stee Steel Emission Factors 11-Nov-04 (Revised) Data from file: EFwelding01Oct04.xls

No.	Metal in Fumes	Welding Process	Rod Type	Statistics Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	Comments
1	**Total Chromium**	SMAW	E7018/28	0.0109	0.0117	2		Assigned default value based on SS value and
			E11018	ND	ND	0		rattio of total Cr in mild steel to SS:
			all data			2	**0.02206**	(0.8826 g/kg) x (0.5%/20%) = 0.02 g/kg
		GMAW	E70S(3to6)	0.00228	0.00378	3		Calculated 0.2206 using approx. Gamma dist
			E70S(6)	0.0719	0.0801	2		
			all data			5	**0.0801**	Assign max. value
		FCAW	E70T/E71T	0.00307	0.0345	40	**0.00667**	95% Chebyshev [Mean S.D]
			E71M			3		(4.10E-01 g/kg was excluded)
		(TM770)	E71T-1M			3		
			all 5 data points	0.416	0.0624	**5**	**0.05939**	Based on Student's t test
2	**Hexavalent Chromium**	SMAW	E7018/28	ND	ND	0		
			E11018	ND	ND	0		
			all data			**0**	**0.0121**	Default = 55% of Total Cr (0.022 g/kg) = 0.012
		GMAW	E70S (3to6)	ND	ND	0		
			E70S-6		0.0041	1		
			all data			**1**	**0.004**	Default = 5% of Total Cr (0.0801 g/kg) = 0.004
		FCAW	E70T/E71T	ND	ND	0	**0.0007**	Default = 10% of Total Cr (0.00667 g/kg) = 0.0007
			E71M	0.02666	0.05082	3		
		(TM770)	E71T-1M	0.00255	0.00265	2		
			all 5 data points			**5**	**0.03356**	Adj-CLT UCL (Adjusted for skewness) If we use the same default approach, then 10% of Total Cr (0.05939) = 0.0059

Mild Stee Steel Emission Factors Tabulated on 28-Oct-04 (Revisted) Data from file: EFwelding01Oct04.xls

No.	Metal in Fumes	Welding Process	Rod Type	Statistics Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	Comments
3	**Manganese**	SMAW	E7018/28	0.9972	1.72	9	1.216	Approx. Gamma
	AP-42		E11018	1.34	2.117	5	1.876	
			all data	1.12	2.117	**14**	**1.314**	Approx. Gamma
		GMAW	E70S (3to6)	0.3629	0.8216	19	0.3963	Approx. Gamma
			E70S-6	10.41	12.8	2		(Mn in welding rod is less than 2% by mass)
			all data				**0.3963**	Default based on E70S with 19 data points.
		FCAW	E70T/E71T	0.8577	2.68	62	**0.9854**	Student's-t
			E71M	17.6	21.8	2		Mn can vary from .01 to 13.5 % by mass of rod.
		(TM770)	E71T-1M	25.63	32.6	3		
			E71M/-1M	22.42	32.6	**5**	**28.98**	Student's-t (Do not use UCL)
4	**Nickel**	SMAW	E7018/28	ND	ND	0		
			E11018	ND	ND	0		
			all data				**0.03707**	Default based on FCAW/E70T/E71T data
		GMAW	E70S (3to6)		0.000619	1		
			E70S-6	ND	ND	0		
			all data			1	**0.03707**	Default based on FCAW/E70T/E71T data
		FCAW	E70T/E71T	0.01001	0.092	43	**0.03707**	99% Chebyshev (Mean, S.D)
			E71M		1.99	3		Two data points had "0.00" values (non detect).
		(TM770)	E71T-1M		12	3		(Ni can vary from .01 to 10 % by mass of rod)
			all data				**0.03707**	Default based on FCAW/E70T/E71T data

ND = Not Determined

Mild Stee Steel Emission Factors Tabulated on 28-0ct-04 (Revisted) Data from file: EFwelding01Oct04.xls

No.	Metal in Fumes	Welding Process	Rod Type	Statistics Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	Comments
5	**Lead**	SMAW	E7018/28	0.0000158	0.0000167	2		Lead is a trace contaminant in carbon steels;
			E11018	ND	ND	0		used default value for 95%UCL = maximim data
			all data				**0.215**	reported for any mild steel or SS = 0.215 g/kg
		GMAW	E70S (3to6)	ND	ND	0		Lead is a trace contaminant in carbon steels;
			E70S-6	0.141	0.215	2		used default value for 95%UCL = maximim data
			all data				**0.215**	reported for any mild steel or SS = 0.215 g/kg
		FCAW	E70T/E71T	ND	ND	0		
			E71M	0.0489	0.052	3		Lead is a trace contaminant in carbon steels;
		(TM770)	E71T-1M			3		used default value for 95%UCL = maximim data
			all data	0.0597	0.0988	6	**0.215**	reported for any mild steel or SS = 0.215 g/kg
								?? MSDS did not report lead.

ND = Not Determined

NOTES:	11/11/2004 Revised	Data File: EFwelding28Sep04StainlessS	Stainless Steel (s.s)
		OR EFwelding01Oct04.xls	Both s.s and mild steel

1. Single data points were used for determining the 95% UCL for GMAW and FCAW. The mild steel data for SMAW were mostly averages of six runs each.

2. Q-Q plot was used to test for the appropriate parametric distribution (normal, lognormal, and Gamma), otherwise a non-parametric method was selected. Percentile bootstrap, bootstrap-t., and H-UCL were compared with the recommeded values.

3. We combined some of the rods/wires within a process when the metal compositions in the original rod/wire were similar.

4. Lead was not reported for mild steel by the shpiyards in responses to EPA.

5. We assigned default values when there were data gaps or inconsistencies. We use Cr(6)/total Cr ratio to determine the amount of Cr(6). The ratio was 55% for SMAW; 5% for GMAW, and 8 % for FCAW. These are average numbers based on the literature.

6. Some of the emission factors were unusually high, as in the case of Mn and Ni.

7. Cr, Cr(6), and Mn are 3 important metals in the welding fumes in so far as RR risk is concerned.

8. In the NSRP 0587 the emission factor g/kg for Ni was twice indicated as being "0.0" for FCAW/E71-M.

Attachment 8C. Statistical Analysis of Alloy Steel Emission Factor Data (DRAFT - For EPA use only)

Mild Steel Emission Factors Tabulated on 15-0ct-04

No.	Metal in Fumes	Welding Process	Rod Type	Statistics: Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	Comments
1	**Total Chromium**	SMAW	14Mn-4CR E9N10 E1N12 E8N12 ENiCl Ni 61 several others	1.403	1.535	5	**1.595**	Mod-t adjusted for skewness (%bootstrap=1.513) No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
		GMAW	Arc Rod E2209 E4043 E8N12 E9N10 ECu several others					No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
		FCAW	Mil101TC E120S					No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
2	**Hexavalent Chromium**	SMAW	14Mn-4CR E9N10 E1N12 E8N12 ENiCl Ni 61 several others	ND	ND	0	**0.8771**	Default = 55% of Total Cr (1.5947 g/kg) = 0.8771 No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
		GMAW	Arc Rod					No test data provided, therefore used metal composition

			E2209 E4043 E8N12 E9N10 ECu several others					data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
		FCAW	Mil101TC E120S					No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
3	**Manganese**	SMAW	14Mn-4CR E9N10 E1N12 E8N12 ENiCl Ni 61 several others	23.38	32.97	5	**29.67**	Approx. Gamma distribution No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
		GMAW	Arc Rod E2209 E4043 E8N12 E9N10 ECu several others					No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
		FCAW	Mil101TC E120S					No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
4	**Nickel**	SMAW	14Mn-4CR E9N10 E1N12 E8N12	1.669	2.5	5	**2.628**	Student's-t test No test data provided, therefore used metal composition data, fume composition curves (from reference data)

			ENiCl Ni 61 several others					and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
		GMAW	Arc Rod E2209 E4043 E8N12 E9N10 ECu several others					No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
		FCAW	Mil101TC E120S					No test data provided, therefore used metal composition data, fume composition curves (from reference data) and maximum fume formation rates from AP-42 to calculate default 95% UCL for each type electrode.
5	**Lead**	SMAW GMAW FCAW	14Mn-4CR	ND	ND	0	**0.215**	Lead is a trace contaminant in carbon steels; used default value for 95%UCL = maximim data reported for any mild steel or SS = 0.215 g/kg

NOTE 12-Oct-04

Data File: EFwelding28Sep04Stainle Stainless Steel (s.s)
OR EFwelding01Oct04.xls Both s.s and mild steel

1. Only single data points were used for determining the 95% UCL.

2. Q-Q plot was used to test for the appropriate parametric distribution (normal, lognormal, and Gamma),

otherwise a non parametric method was selected.