To: Shipbuilding and Ship Repair Residual Risk Docket

Submitted by: Dr. Mohamed Serageldin
EPA/ESD/CCPG
U. S. Environmental Protection Agency
Research Triangle Park, NC 27701

Date: February 7, 2005 [1]

Project: Development of Residual Risk Standards for the Shipbuilding and Ship Repair Industry - Surface Coating.

Re: Minutes from January 25, 2005 Meeting with the Shipbuilding Industry (Including the Material Presented at the Meeting)

I. Participants

Shipbuilding Industry
Frank Losey, American Shipbuilding Association
Mike Chee, NASSCO
Shaun Halvax, Southwest Marine
Frank Thorn, Newport News
Page Ayres, Newport News
Vince Dickinson, Bath Iron Works
John Wittenborn, Collier Shannon Scott
Valorie Thompson, SRA
Wayne Holt, Atlantic Marine
Philip (Mike) Host, Norfolk Naval Shipyard
Daniel Youhas, Shipbuilders Council of America
Jim Bourque, Jeffboat (call-in)
Ron Shipley, Shipley Associates (call-in)

Others
Mark Lee, ICF Consulting
Chris Halm, California Air Resources Board (CARB) (call-in)
Bhaskar Kura, MERIC/UNO (call-in)

EPA
Mohamed Serageldin, OAQPS/ESD/CCPG (OAR)
Roy Smith, OAQPS/ESD/REAG (OAR)
Maria Pimentel, OAQPS/ESD/REAG (OAR)
Shana Harbour, SSD/OBCI/OPEI (AO)

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[1] This memo emailed to the industry on July 12, 2005.

Barrett Parker, OAQPS /EMAD (OAR)
Elaine Manning, OAQPS/ESD/CCPG (OAR)
Carey Johnston, OST/EAD/EEB (OW) (call-in)
Amanda Evans, OSP/(ORD) (call-in)
Bill Linak, NRMRL/APPCD (ORD)
Len Lazarus, OC/CAMPD/AHWTB (OECA) (call-in)
Paula Hirtz, OAQPS/ESD/CCPG (OAR)

RTI International
Dave Reeves
Mark Bahner
Roy Neulicht

(See Attachment A: Meeting Sign-In Sheet with more information on participants.)

II Opening Statement

Dr. Serageldin started the meeting by greeting the participants. He recognized the role played by the EPA project work group during the review phase of the proposed emission factors. He also acknowledged the assistance of Dr. Nagaraj Neerchal (UMBC, Baltimore) during the early phase of the welding emission factor development work.[2]

III. Risk Assessment Overview - Roy Smith (see Powerpoint presentation, Attachment B)[3]

Dr. Smith stated that the objective of his presentation was to generate new questions for discussion in the afternoon. He noted that emission factors for welding and abrasive blasting were crucial inputs to the risk analysis, and would therefore get a great deal of scrutiny. He also stated that the same emission factors would be used (for the same processes and materials) at all facilities, so that facilities that reported high emission factors would not be "punished" by that fact.

Dr. Smith noted that, if the true means of the various emission factor data were known, those true means would be used. However, EPA does not know what the true means are, due to: 1) uncertainty (e.g., as caused by limited samples) and 2) variability (as measured by the standard deviation of the data). Therefore, upper confidence limits (UCLs) will be used for the risk analysis.

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[2] Dr. Neerchal was assisted in Summer 2004 by his Graduate Student Justin Newcomer.

[3] The document can be downloaded from the shipbuilding/repair website: (http://epa.gov/ttn/atw/shipb/shipbpg.html). Appendix 2 provides a brief description of the attachments.

The model that will be used for the risk analysis will be Industrial Source Complex, Short Term, Version 3 (ISCST) which is an air dispersion model. EPA's Human Exposure Model will not be used for the risk analysis. This means the risk analysis will deal exclusively with inhalation risk.

Dr. Smith said that pollutant transformation or deposition were not expected, and so had not been included in the risk analysis (note that the risk analyses conducted to date have not included abrasive blasting). Mark Lee commented that dry deposition was a function of particle size and density. He observed that no deposition would be expected for welding, but that there might be significant deposition for abrasive blasting.

An example risk analysis that was done for Jeffboat was reviewed. It was cautioned that the analysis was just to establish modeling procedures, rather than to develop any final analysis. Jeffboat was chosen because they are a large facility in terms of welding rod usage and had populations close to the property boundaries of the facility.

Dr. Smith reviewed the "points of departure," the decision points that would likely be used to evaluate whether risk was significant. For noncancer risk, the Hazard Quotient (HQ) will be 1.0 (rather than 0.2, the value used in the May 2003 residual risk test report). For cancer risk, the following general guidelines would be used:

- If risk is less than 1 x 10^{-6}, nothing will be done.
- If risk is greater than 1 x 10^{-4}, something will be done.
- If risk falls between these two levels, it's uncertain what action will be taken.

IV. Welding Emission Factors - Mohamed Serageldin (see Powerpoint presentation)

Dr. Serageldin noted that the AP-42 electric arc welding chapter was last revised in 1995, and contains data that date back to approximately 1990, so the data are quite old. Therefore, welding data from testing by ESAB (2000), CARB (2004) and NSRP (1999 and 2000) were also used.

Dr. Serageldin outlined the projected schedule for the project:

- Refined risk analysis (February 2005)
- Evaluate available and potential risk reduction options (April 2005)
- Regulatory decision(s) (September 2005)
- Proposed rule (December 2005)

Dr. Serageldin noted that air dispersion modeling involves both uncertainty in the model and uncertainty in the input data to the model. It is to address the uncertainty in the inputs that 95% UCLs are being used. Dr. Smith then commented that there had been discussions at EPA, with some people advocating using 95th percentile values (rather than 95% UCLs on the means); he considered the 95% UCLs to be very reasonable.

Dr. Serageldin handed out a copy of Figure 1 which compared the upper UCL and 95th percentile of a normal distribution. He indicated that as the data gets better, the UCL of the mean moves closer to the (true) mean, whereas the 95th percentile remains at the upper end of the distribution. Dr. Serageldin then reviewed 95% UCL emission factors as shown in Attachment 8A provided during the 1/25/05 meeting (see handout listing in Appendix 2), commenting specifically on the emission factor for total chromium from SMAW for stainless steel. He noted that the recommended 95% UCL emission factor of 0.811 g/kg is very close to the calculated mean of 0.708 g/kg, and stated that this result was typical when sufficient sample sizes and closely matching data existed. He then referred to Attachment 2, which lists the recommended 95%UCL for welding HAP data from SMAW, GMAW, and SMAW for stainless steels, together with 95% UCL derived using six other UCL statistical methods. He mentioned that the value of 0.0748 g/kg for Cr+6 from FCAW exceeded the maximum value in the data set and that this value should be replaced by 0.064 g/kg, which represents the H-UCL value in Attachment 2 . (That value was selected rather than the maximum value, because there were sufficient data points to run the UCL test.)

Valorie Thompson and Vince Dickinson commented that the recommended emission factors of 12.6 g/kg and 18.3 g/kg for manganese from stainless steels using SMAW and FCAW (respectively) were likely above the manganese content in the rods, which they characterized to be 1 percent (i.e. 10 g/kg if all the manganese were vaporized, and none delivered to the weld). Both Dr. Serageldin and Dr. Smith noted that EPA had thrown out some other test data where that result had occurred. Specifically, ESAB's data for SMAW using 309L stainless steel resulted in an emission factor of 163 g/kg nickel, which was greater than the 9-14%– 90 to 140 g/kg-- nickel content of the rod.) They said that any such obviously incorrect test data would not be used, and urged the shipbuilding industry to send supporting data for cases where they thought the emission factors were too high. Dr. Serageldin suggested that industry try to approach CARB to get unpublished data for manganese and chromium for those rods CARB had reported hexavalent chrome information in their 2004 report.

V. Default Emission Factors for SAW and Alloy Steels - Dave Reeves

Mr. Reeves opened his remarks by mentioning that during lunchtime, it had come to his attention that some shipyards apparently did not report SAW emissions in their ICR responses (due to expected low emissions from the SAW process and not being reported as part of their annual emissions inventory for States and TRI). Dr. Serageldin noted that the ICR required shipyards to report all welding activity, which would include all SAW.

Mr. Reeves related how he had come up with the recommendation metallic hazardous air pollutant (HAP) emissions that SAW emissions be considered as 10 percent of SMAW emissions. He referred to Attachment 6, and noted that the ratio for SAW to SMAW emissions for the metals in the table in Attachment 6 varied from essentially zero percent to twenty percent (for manganese, which was the only metal with a ratio of over 10 percent). He said he had made the estimate of 10 percent expecting that SAW emissions were not going to be significant. He noted that changing the emission factor estimates to the metal-specific ratios in the table in Attachment 6 would result in much lower emissions for Cr, Cr+6, and Ni. He also noted that using a PM-10 emission factor of 0.05 g/kg for SAW, as shown in Attachment 7, Item 3, would also result in much lower HAP emission factors. He urged the shipbuilding industry to provide input to EPA on appropriate HAP emission factors for SAW.

Mr. Reeves then related how “default” emission factors had been developed for alloy steels (where no electrode-specific test data existed). He referred to Attachment 7, which explains the procedures in detail. Specifically, the procedure involved taking fume generation rates from AP-42, and applying equations for the percentage of metals (Cr, Mn, and Ni) in the fume from AP-42 Reference 11. He noted that a similar procedure could be used for estimating manganese from stainless steels using SMAW and FCAW.

VI. Abrasive Blasting - Mohamed Serageldin (see Powerpoint presentation)

Dr. Serageldin reviewed the procedures that had been used for calculating emissions from abrasive blasting. The results for abrasive blasting from coal slag were specifically shown in his presentation. The steps used to calculate HAP emissions from abrasive blasting for coal slag were:

- Determine the amount of abrasive blasting material used.
- Use the particulate emission factors developed during testing by Dr. Bhaskar Kura (MERIC/UNO) [ref. 1].
- Use metallic HAP concentration data from a 1999 U.S. EPA Office of Solid Waste report to Congress [ref. 2].

Valerie Thompson pointed out that the total particulate emission factors developed by Dr. Kura were significantly higher than the particulate emission factors reported by others (including testing by NSRP). Dr. Serageldin referred to Addendum 5 and explained that the flow of the 2005 UNO study was 0.335 miles/h, whereas that for the 1999 NSRP study was 0.026 miles/hr. That may explain why the NSRP tests reported lower total particulate emissions. Ms. Thompson offered the opinion that the respirable fraction (PM-10) would be a more appropriate metric for inhalation risk than total PM. The availability of data on particulate sizing data for abrasive blasting emissions was discussed. Dr. Serageldin agreed and said that EPA would review available data to arrive at a suitable value for PM10/Total PM ratio that would be used to adjust emission factors based on total particulate matter.

Several shipbuilding representatives offered the opinion that the Cr+6 concentration in the Report to Congress seemed much too high. The mean value for Cr+6 was 592 ppm. (No value for total chrome was in the Report to Congress.) Mike Host and others offered the opinion that the value might actually be total chrome. Mike Host noted that he had data for coal slag for abrasive blasting that indicated a total chromium content of 662 ppm, but a hexavalent chromium content of 17.4 ppm. Mark Bahner and Dave Reeves reported that the manufacturer of Black Beauty™ (coal slag blast medium) had been contacted, and had reported the total chromium results for 10 samples. Data for hexavalent chromium were not available. The total chromium[4] results indicated:

Mean = 37.0 ppm
Minimum = 3.5 ppm
Maximum = 150 ppm
Median = 19.5 ppm

VII. Questions (from Industry) and Responses (from EPA)

Q1: If all shipbuilding facilities are found to be below levels of concern regarding risk, will there still be regulations.
A1a: No, EPA will publish a notice in the Federal Register announcing the results of the risk analysis. (It is uncertain with such a notice will simply be a proposal, or a final notice.)
A1b: However, it should be noted that Section 112d of the CAAA of 1990 requires the EPA to perform the eight year MACT review.

Q2: Suppose only one shipbuilding facility has risk. Would EPA issue regulations for the whole industry?
A2: It's more likely that EPA would work with that one facility.

VIII. Action Items

Shipbuilding Industry

A) Welding Operations

1) Vince Dickinson will coordinate and provide EPA with Mil Spec composition information on the rods that are most commonly used for mild steel welding.

[Note: On January 26, Dave Reeves provided the following usage information on the most common mild steel electrodes: 71T (45%), 70S (13%), 7018 (12%), 7024 (10%), and 6011 (4%).]

2) Mike Chee will attempt to gather further trace metal welding emissions information from CARB (e.g., total chrome and manganese).

3) The industry should provide supporting information where they think emission factors proposed by EPA are currently too high (e.g. manganese from welding stainless steels using FCAW and SMAW).

B) Abrasive Blast Cleaning:

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[4] . The manufacturer was not able to provide us with the composition of the coals used to manufacture the coal slags pertaining to the total chromium data.

4) Any shipyards that did not provide abrasive blasting information on their 2003 questionnaire responses should do so. This is especially important for shipyards that use coal slag as an abrasive medium. If the shipyards use controls for abrasive blasting emissions, such as venting to baghouses or cyclones, this data should be provided.

5) If the shipbuilding industry has any data that justifies that shrouds provide control of PM-10 emissions from abrasive blasting, they will provide it to EPA. Otherwise, EPA plans to assume that shrouds (without the exhaust being sent to a control device such as a baghouse) do not control PM-10 emissions from abrasive blasting.

6) Mike Host will provide data on the concentration of trace metals in coal slag used for abrasive blasting.

NOTE: Friday, February 11, 2005 deadline agreed upon with the industry during the 1/25/05 meeting, for them to submit additional data listed above in sections A and B.

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C) Economic Valuation:

7) The shipbuilding industry should provide control cost data, as requested in the 2003 EPA questionnaire. That information should be provided by April 2005, in complete form.

EPA

1) EPA will make a decision on the PM-10 /Total PM ratio that will be used for abrasive blasting. Once this decision has been made, the shipbuilding industry will be informed.

2) EPA presently has emission factors for GTAW as being equal to emission factors for GMAW. EPA will change the emission factors for GTAW to equal those for SAW (which are lower than for GMAW).

3) EPA will review the use of metallic HAP emissions from SAW being 10 percent of emissions from SMAW.

4) Within two weeks of the receipt of final shipbuilding industry data listed above, EPA plans to release the raw data that will be used to conduct its emission factors statistical analyses.

IX. References

1) Kura, Bhaskar, “Environmentally-Friendly Abrasives,” UNO/GCMTC, Final Report, 2005.

2) Technical Background document for a U.S. EPA “Report to Congress on Remaining Wastes from Fossil Fuels,” EPA OSWER, March 15, 1999, (http://www.epa.gov/epaoswer/other/fossil/ffc2_399.pdf).

Attachment A

Meeting Participants: Contact Information

Participant	**Affiliation**	**Phone Number**	**E-Mail Address**	**Fax**
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Valorie Thompson	SRA	858-488-2987	vltsra@earthlink.com	
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Julian Bingham	Atlantic Marine	251-690-7031	jbingham@atlanticmarine.com	
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Paula Hirtz	EPA/OAQPS/CCPG	919-541-2618	hirtz.paula@epa.gov	
Mark Lee	ICF Consulting	919-406-1392	Mlee@icfconsulting.com	
Dave Reeves	RTI	919-316-3739	dwreeves@rti.org	919-541-7155
Mark Bahner	RTI	919-541-6016	bahner@rti.org	919-541-7155
Roy Neulicht	RTI	919-316-3736	rmneulicht@rti.org	919-541-7155
Call- In Participants	**Affiliation**	**Phone Number**	**E-Mail Address**	**Fax**
Jim Bourque	Jeffboat	812-288-1728	Jim.Bourque@acbl.net	812-288-0398
Chris Halm	CARB	916-323-8372	chalm@arb.ca.gov	
Bhaskar Kura	MERIC/UNO	202-342-8514	bkura@uno.edu	504-280-5586
Ron Shipley	Shipley Associates	301-540-0315	ron@rshipleylaw.com	
Amanda Evans	EPA	202-564-2208	evans.amanda@epa.gov	
Len Lazarus	EPA	202-564-6369	lazarus.leonard@epa.gov	

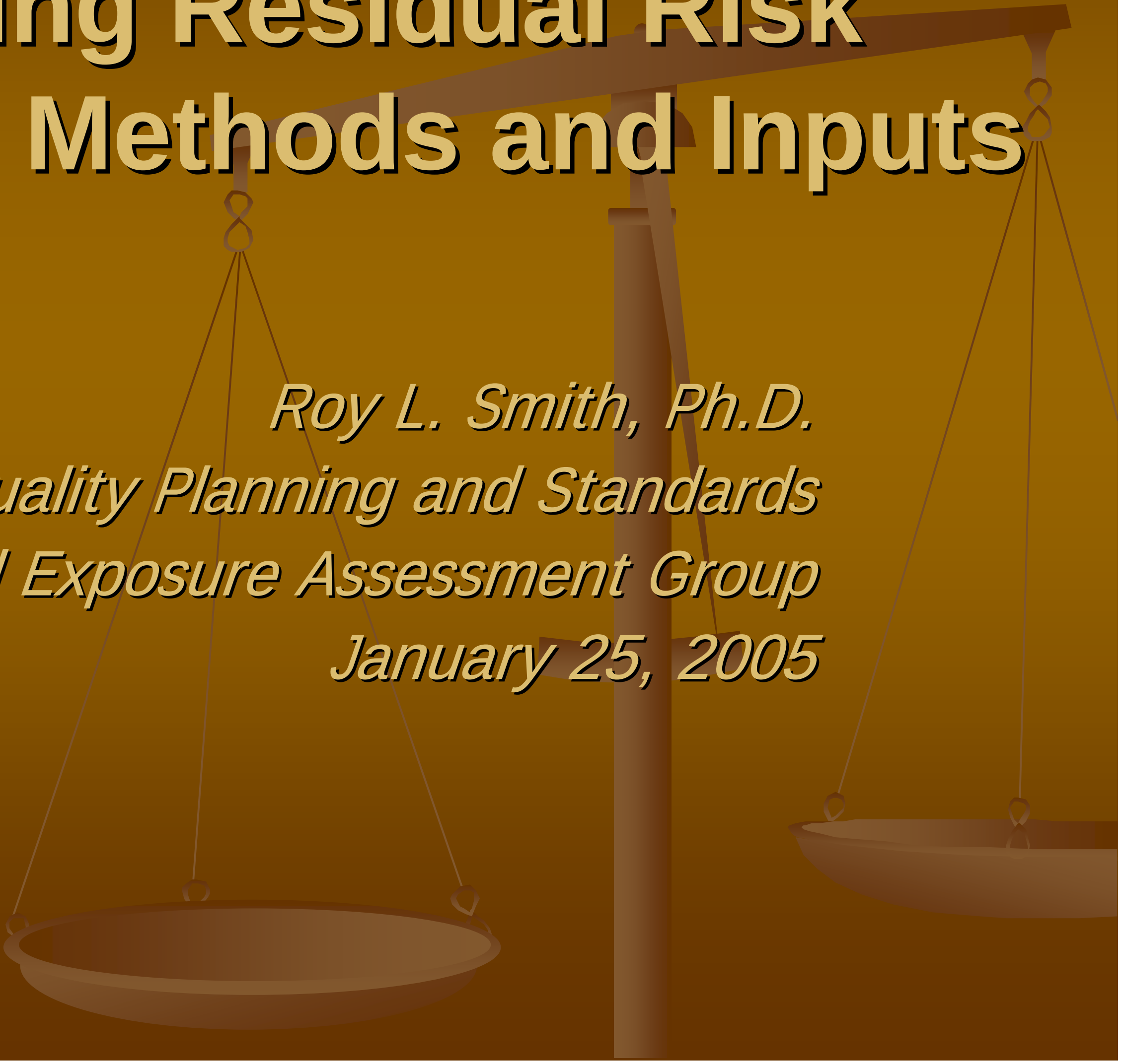
Shipbuilding and Ship Repair NESHAP Residual Risk Phase

Industry Meeting - January 25, 2005

Revised Agenda

I.	**Initiate Conference Call/Meeting**		**10:00**
II.	**Introductions**		**10:00 - 10:15**
III.	**Project Status/Overview**		**10:15 - 11:15**
IV.	**Review Proposed Welding Emission Factors**		**11:15 - 12:15**
V.	**Lunch**	**(EPA Cafeteria)**	**12:15 - 1:00**
VI.	**Review Abrasive Blasting Data/Emission Factors**		**1:00 - 2:15**
VII.	**Break**	**(Optional)**	**2:15 - 2:30**
VIII.	**Questions/Comments/Schedule**		**2:30 - 3:45**
IX.	**Review Action Items**		**3:45 - 4:00**
X.	**Meeting Adjourned**		**4:00**

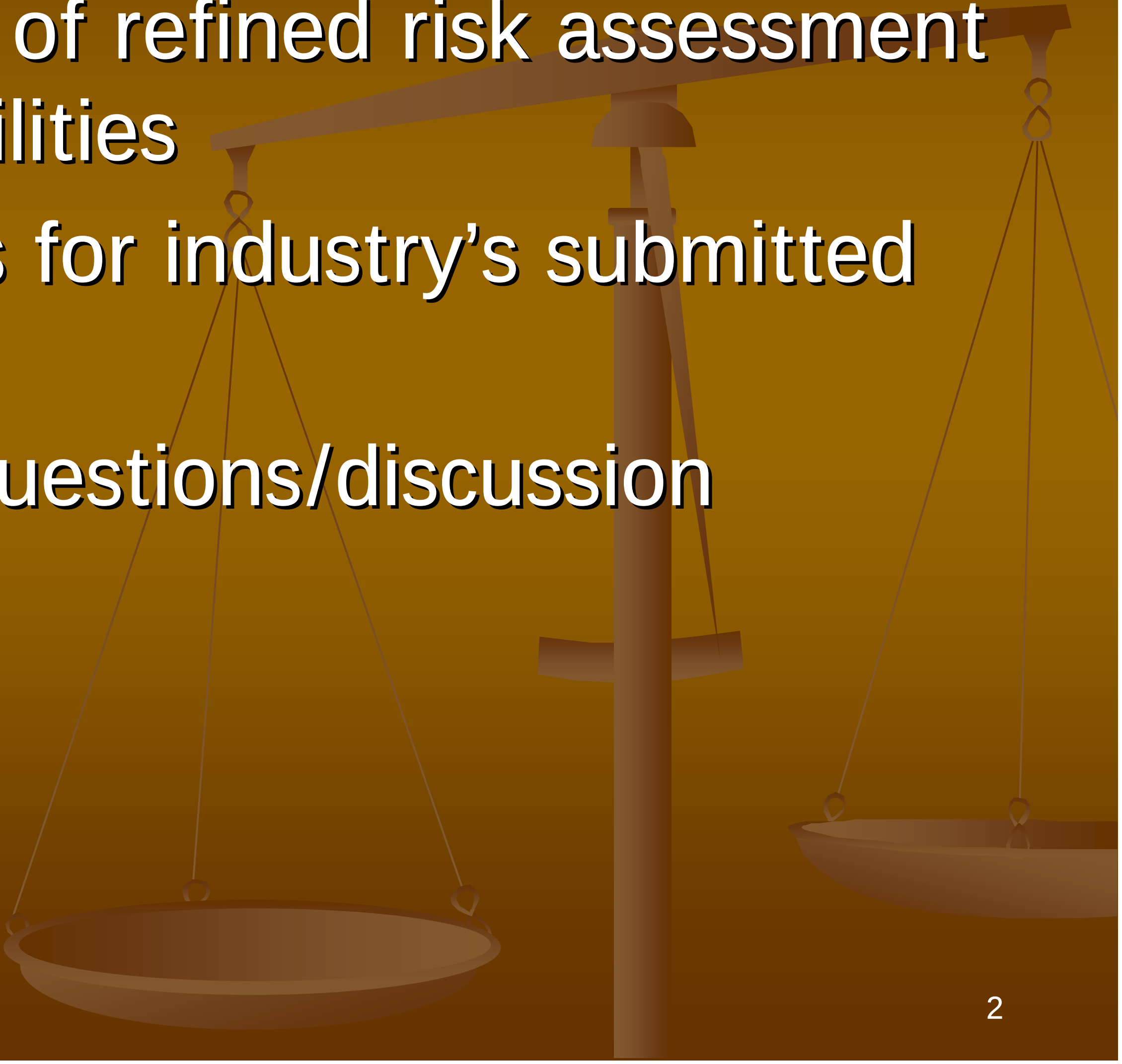
Shipbuilding Residual Risk Assessment: Methods and Inputs



Roy L. Smith, Ph.D.
Office of Air Quality Planning and Standards
Risk and Exposure Assessment Group

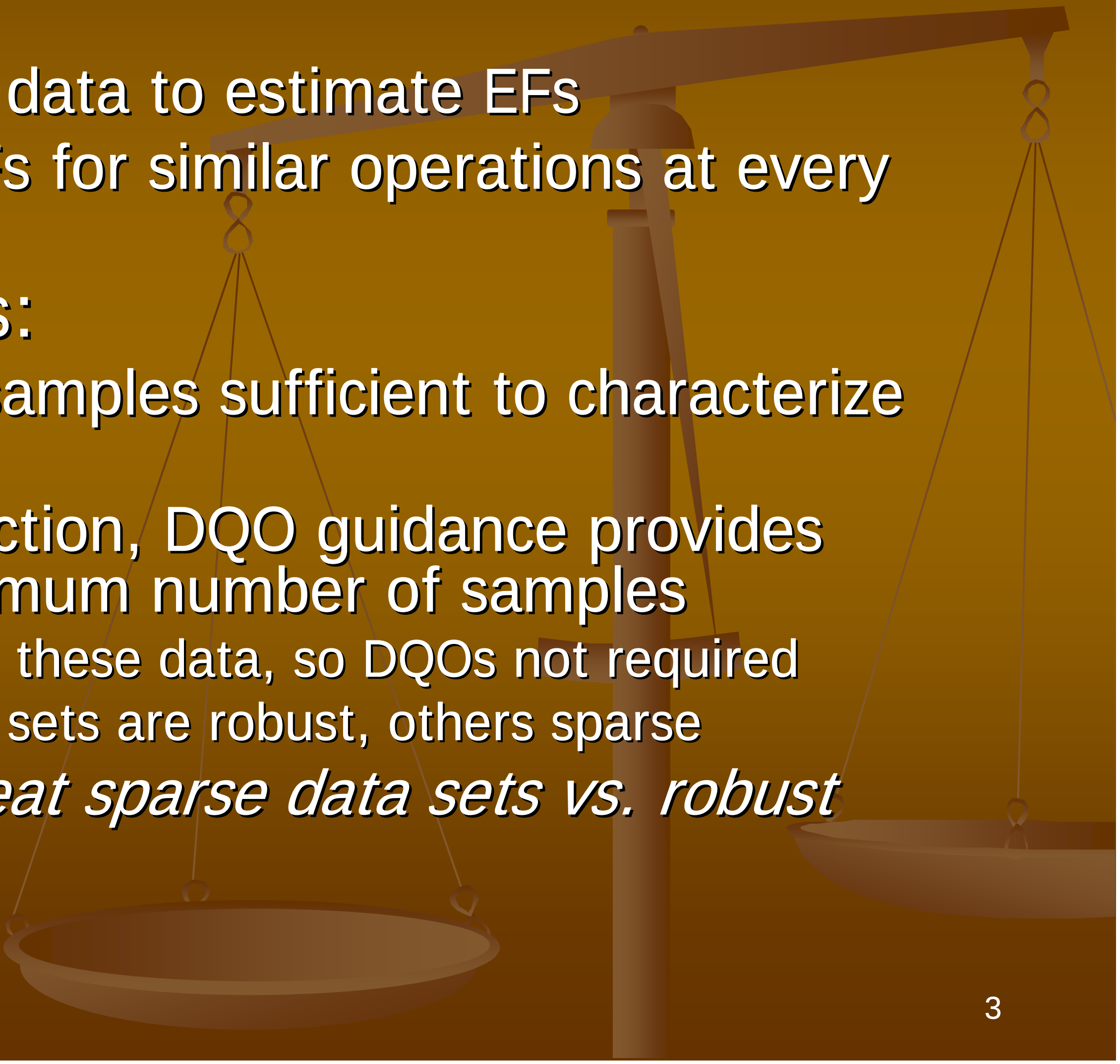
January 25, 2005

Objectives



- Describe details of refined risk assessment of individual facilities
- Provide answers for industry’s submitted questions
- Generate new questions/discussion

Development of Emission Factors



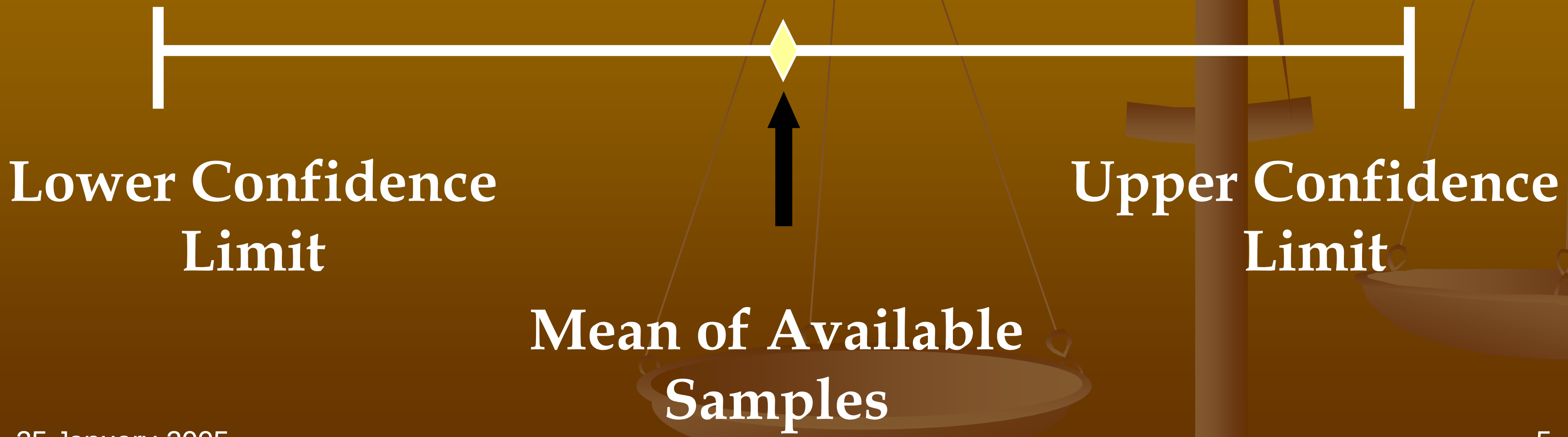
- Goals
  - Use best available data to estimate EFs
  - Apply the same EFs for similar operations at every facility
- Data quality issues:
  - Is the number of samples sufficient to characterize the emission?
  - For EPA data collection, DQO guidance provides calculation of minimum number of samples
    - EPA did not collect these data, so DQOs not required
    - Some EF test data sets are robust, others sparse
  - *How should we treat sparse data sets vs. robust ones?*

Treatment of Sparse vs. Robust Datasets

- Statistics 101:
  - There exists a “true mean” for every set of EF data
    - The average of ALL possible samples
    - We would use this number if we knew it
  - But all we know is what our group of samples tells us:
    - Average of the samples available to us
    - Number of samples available (uncertainty)
    - The standard deviation of the samples (variability)

Statistical Treatment of Uncertainty and Variability: Confidence Limits

- Provide a range of likely values for the mean
- Provide a likelihood that the true mean of ALL samples will lie within that range



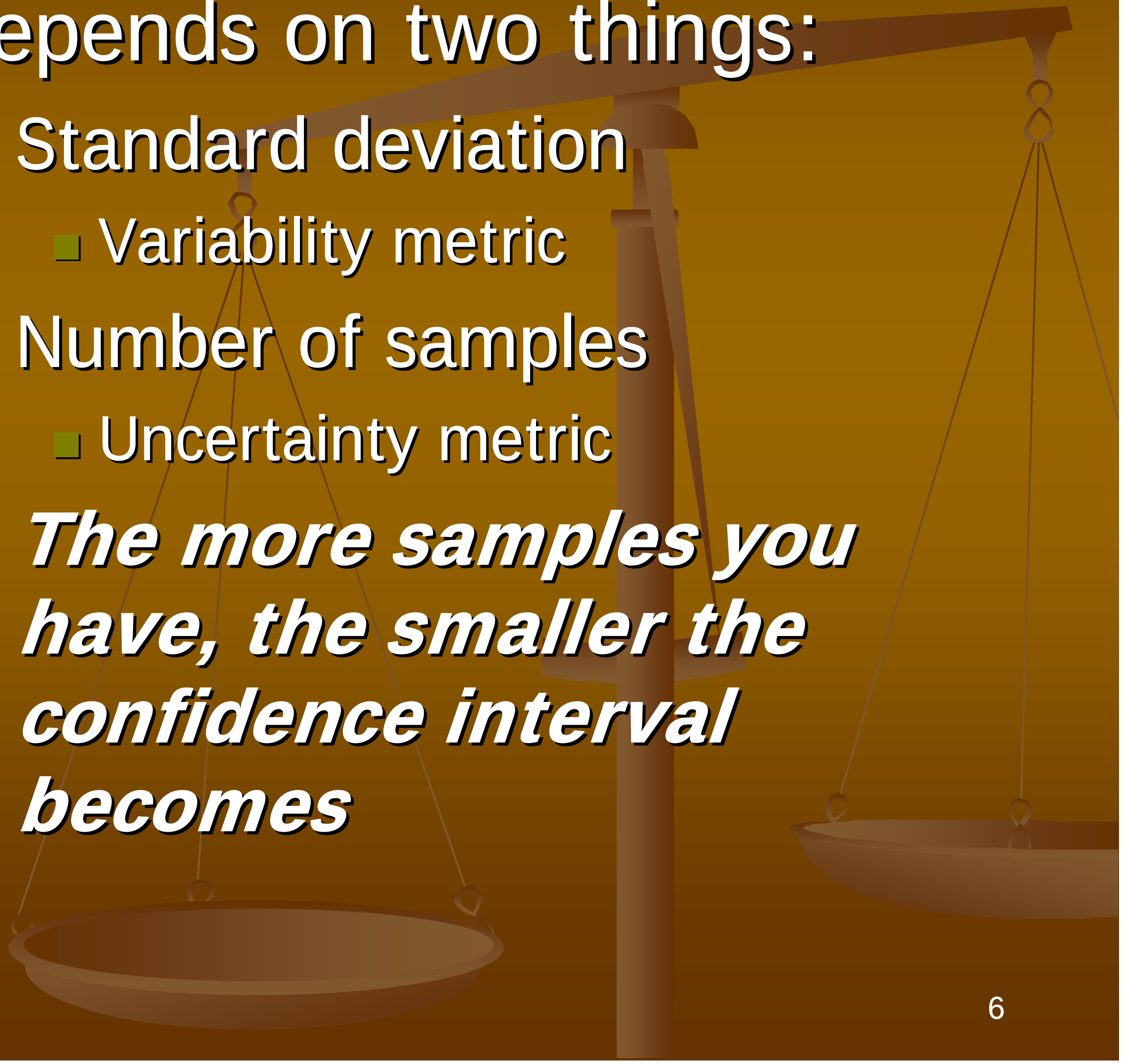
Lower Confidence Limit

Upper Confidence Limit

Mean of Available Samples

Example: Upper Confidence Limits for a Normal Distribution

$$UCL = \bar{x} + t\frac{\sigma}{\sqrt{n}}$$



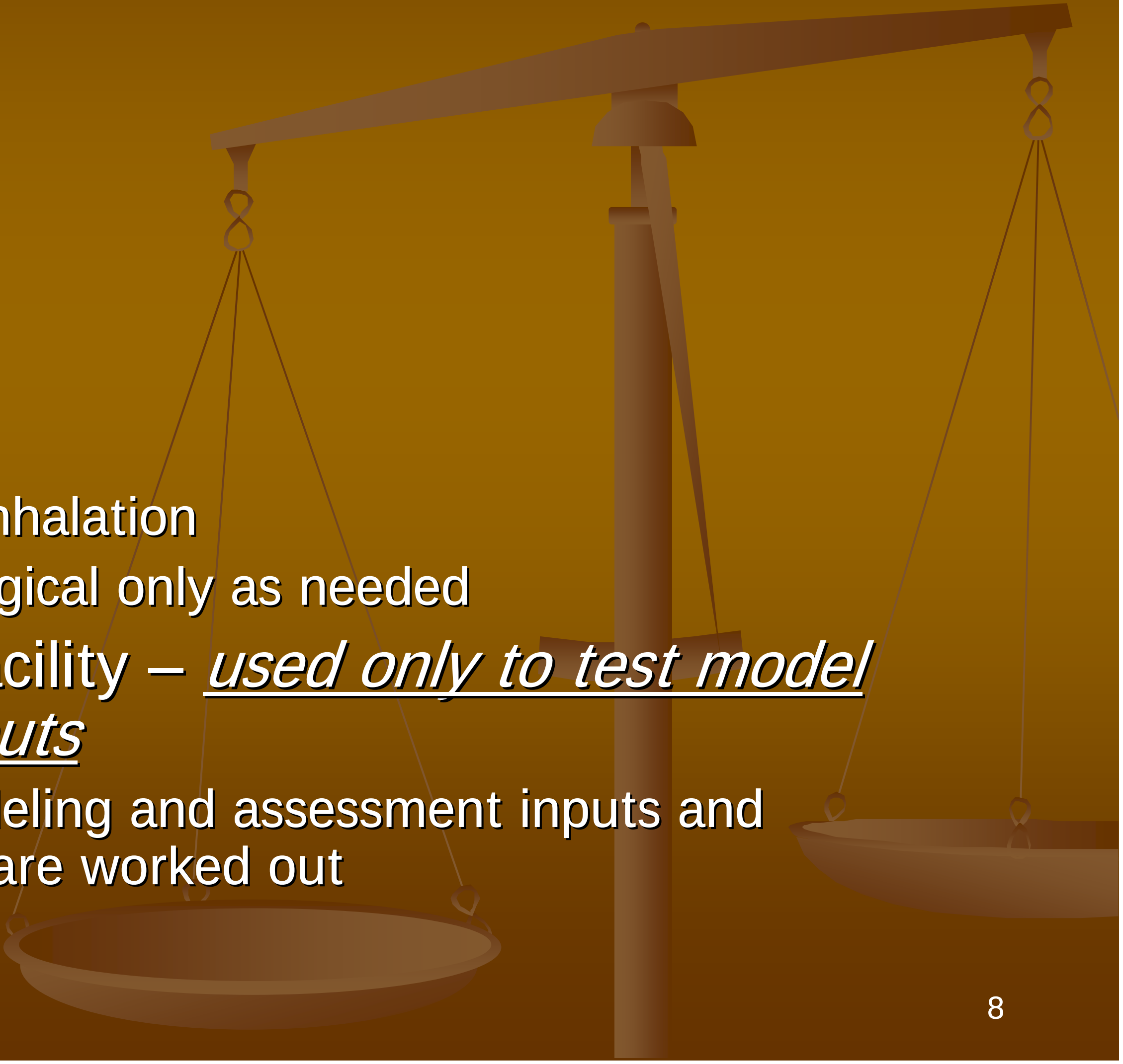
- Depends on two things:
  - Standard deviation
    - Variability metric
  - Number of samples
    - Uncertainty metric
  - ***The more samples you have, the smaller the confidence interval becomes***

What This Means for the Risk Assessment

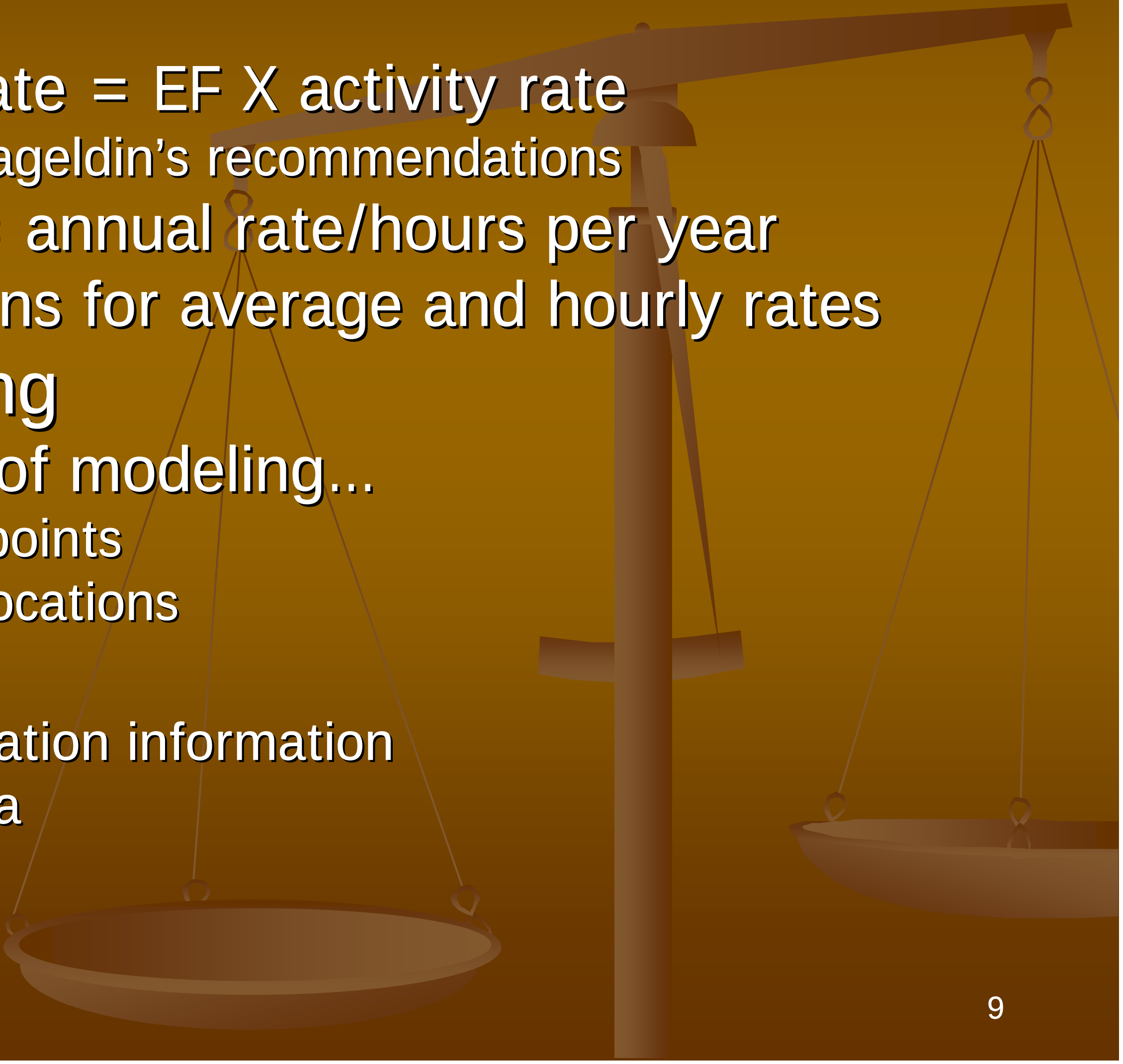
- For shipbuilding EFs, we're proposing to use:
  - Where data are adequate, the 95% UCL
  - Where data are sparse or absent, the EF selected for the closest combination or welding rod and apparatus

Scope

- Sources evaluated
  - Welding
  - Coating
  - Painting
  - Blasting
  - Cleaning operations
- Exposure pathways
  - Main focus – human inhalation
  - Multipathway or ecological only as needed
- Test case: Jeffboat facility – *<u>used only to test model configuration and inputs</u>*
  - Data used to test modeling and assessment inputs and capabilities while EFs are worked out

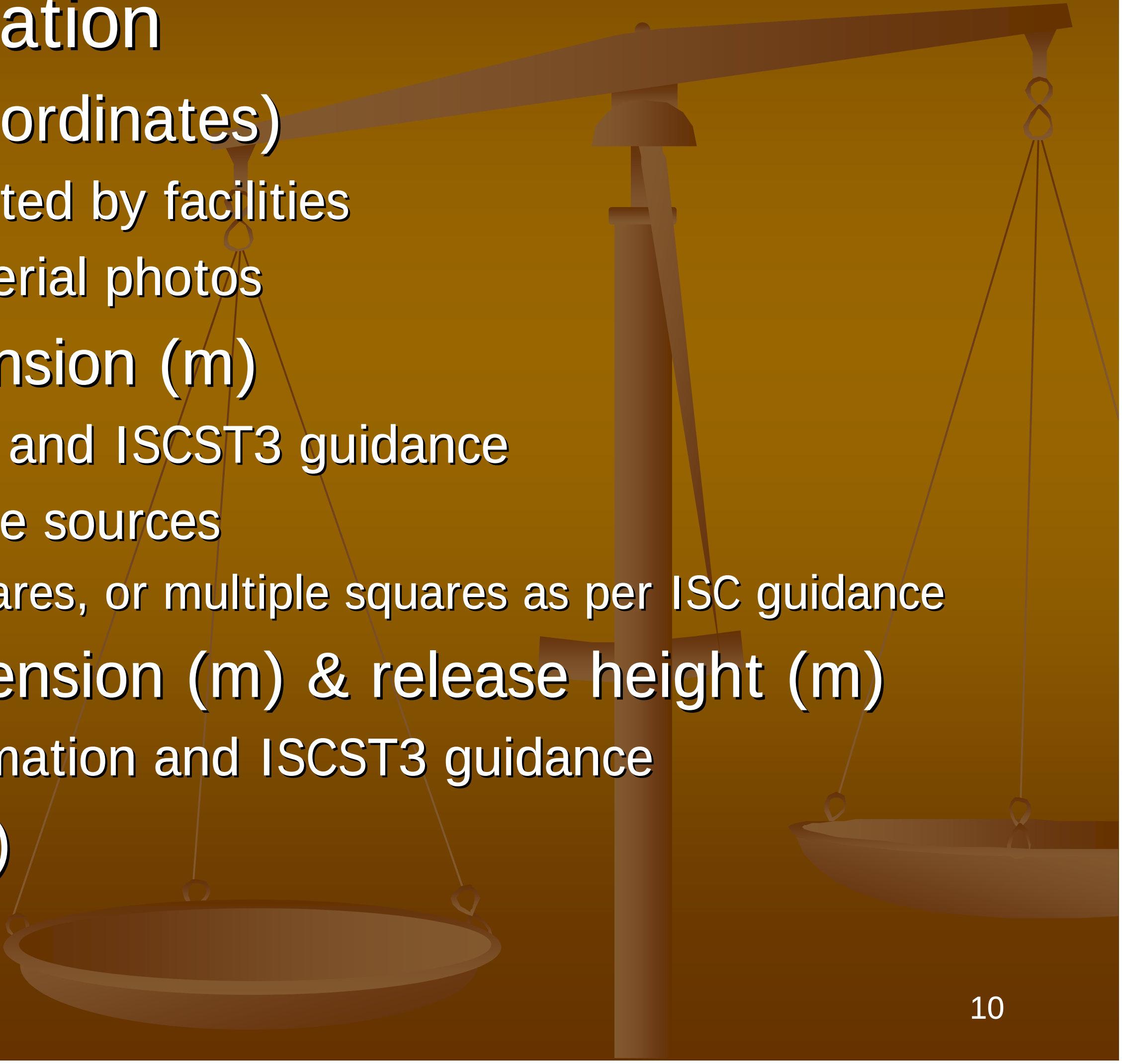


Release Parameters



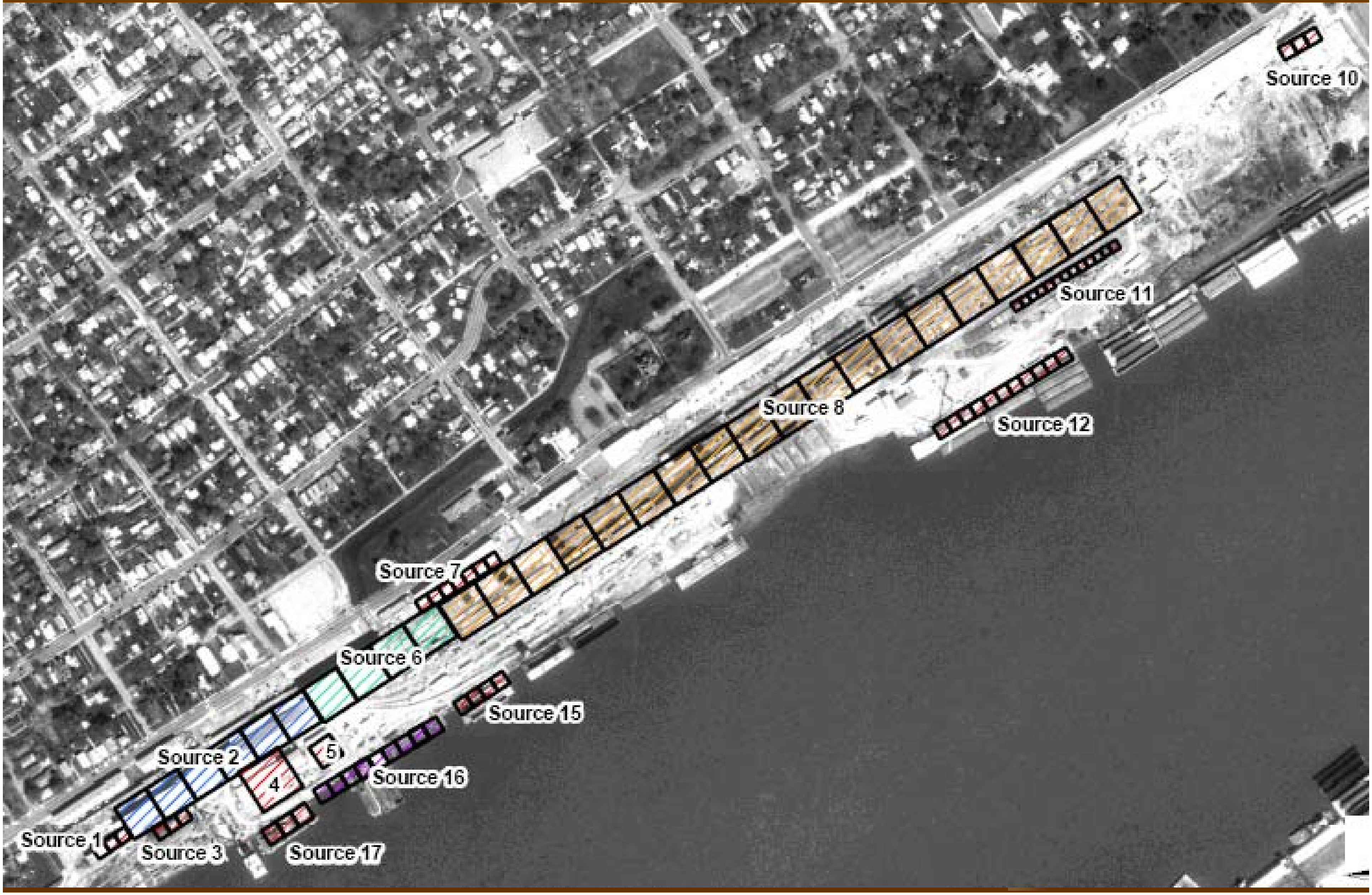
- Emissions data
  - Annual emission rate = EF X activity rate
    - EFs as per Dr. Serageldin's recommendations
  - Max. hourly rate = annual rate/hours per year
  - Separate model runs for average and hourly rates
- Dispersion modeling
  - ISCST3 – capable of modeling...
    - Multiple emission points
    - Multiple receptor locations
  - Required inputs
    - Source characterization information
    - Meteorological data
    - Receptor locations

Release Parameters (cont'd)



- Source characterization
  - Locations (UTM coordinates)
    - From maps submitted by facilities
    - Confirmed using aerial photos
  - Initial lateral dimension (m)
    - From facility maps and ISCST3 guidance
    - Most will be volume sources
      - Modeled as squares, or multiple squares as per ISC guidance
  - Initial vertical dimension (m) & release height (m)
    - From source information and ISCST3 guidance
  - Emission rate (g/s)

Source Characterization



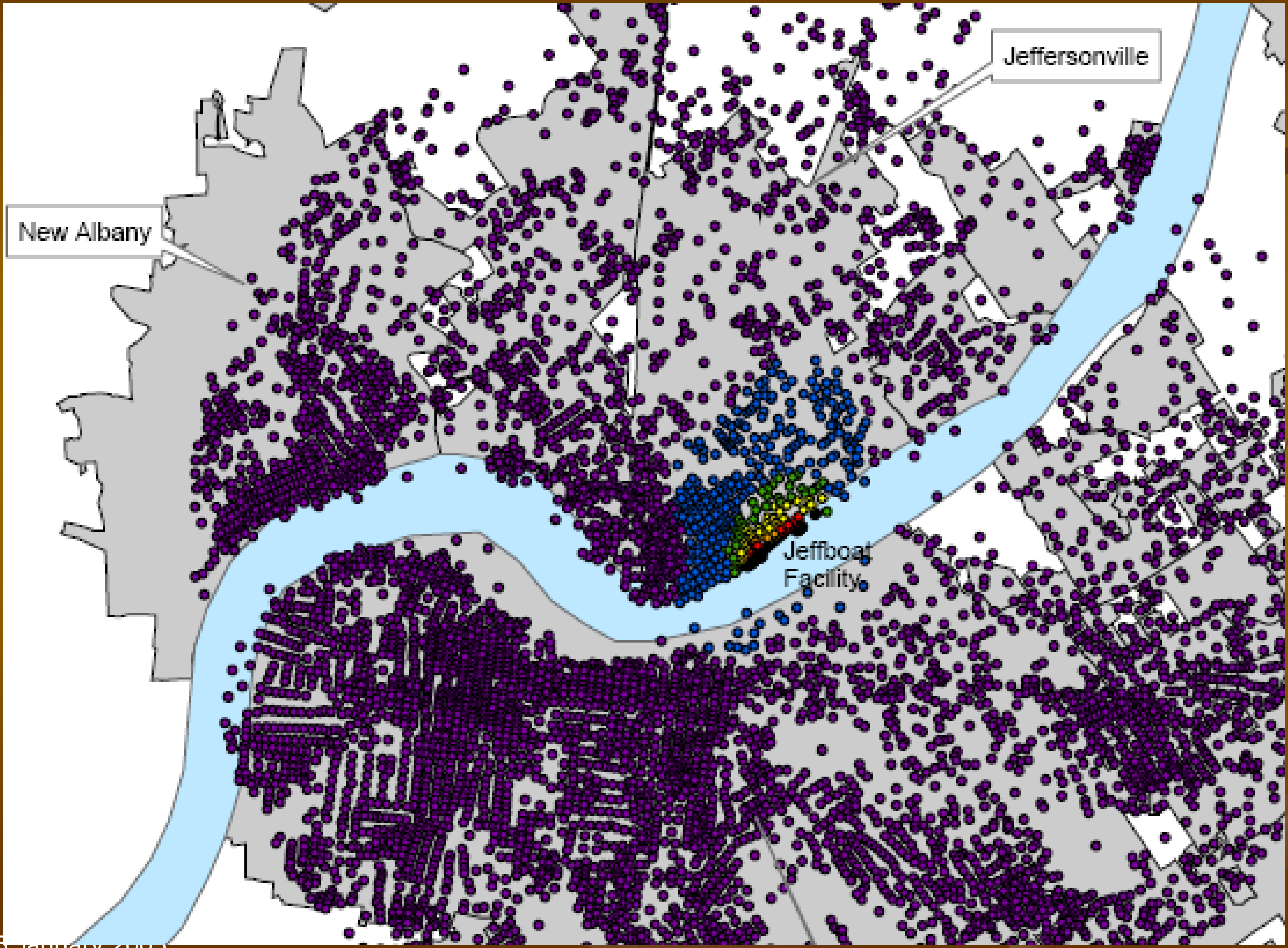
Meteorological Data

- Sources
  - EPA Support Center for Regulatory Air Models (SCRAM) – first choice
  - Surface data from Hourly US Weather Observations (HUSWO) & upper air data from Radiosonde Data of North America CD/ROMs
- Types
  - Mixing height/ upper atmosphere data
  - Surface data
  - May need to use different locations for two types (because more locations have surface data than upper air data)
- Locations – in order of preference
  - Immediate area (within 50 miles of facility)
  - In-state or nearby state with similar climate (i.e., rainfall, temp, land use, proximate water bodies)
  - Choose surface station first, then match upper atmosphere
- 5 consecutive years of data used in model runs

Model Configuration

- Regulatory default configuration of model
- No pollutant transformation or deposition
- Receptor network: ambient concentrations
  - At each block centroid (2000 Census) within 10-km radius
  - At homes closer to the facility than the nearest centroid
- Averaging of exposures
  - Cancer – average exposure for all 5 years
  - Chronic noncancer – highest of 5 annual averages
  - Acute noncancer – highest hourly estimate

Map of Census Blocks



Dose-Response Assessment

- Chronic: values recommended on AT website

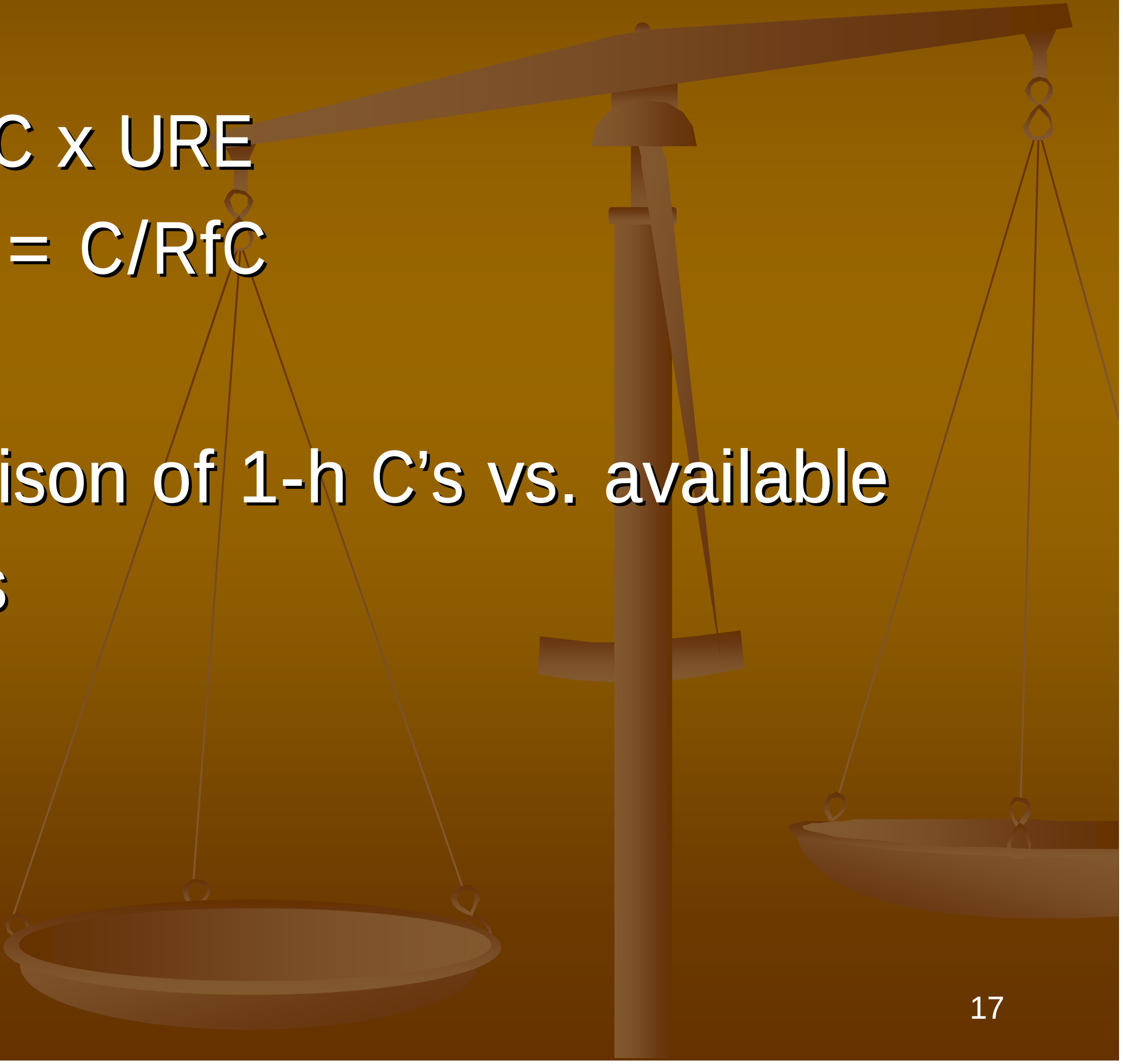
Pollutant	URE (per µg/m^3)	RfC (mg/m^3)
Chromium VI	1.2e-2	0.0001
Nickel	4.8e-4 (Ni_3S_2)	0.0001 (NiO)
Manganese	NA	0.00005
Xylene	NA	0.1

Dose-Response Assessment

- Acute: range of available acute benchmarks

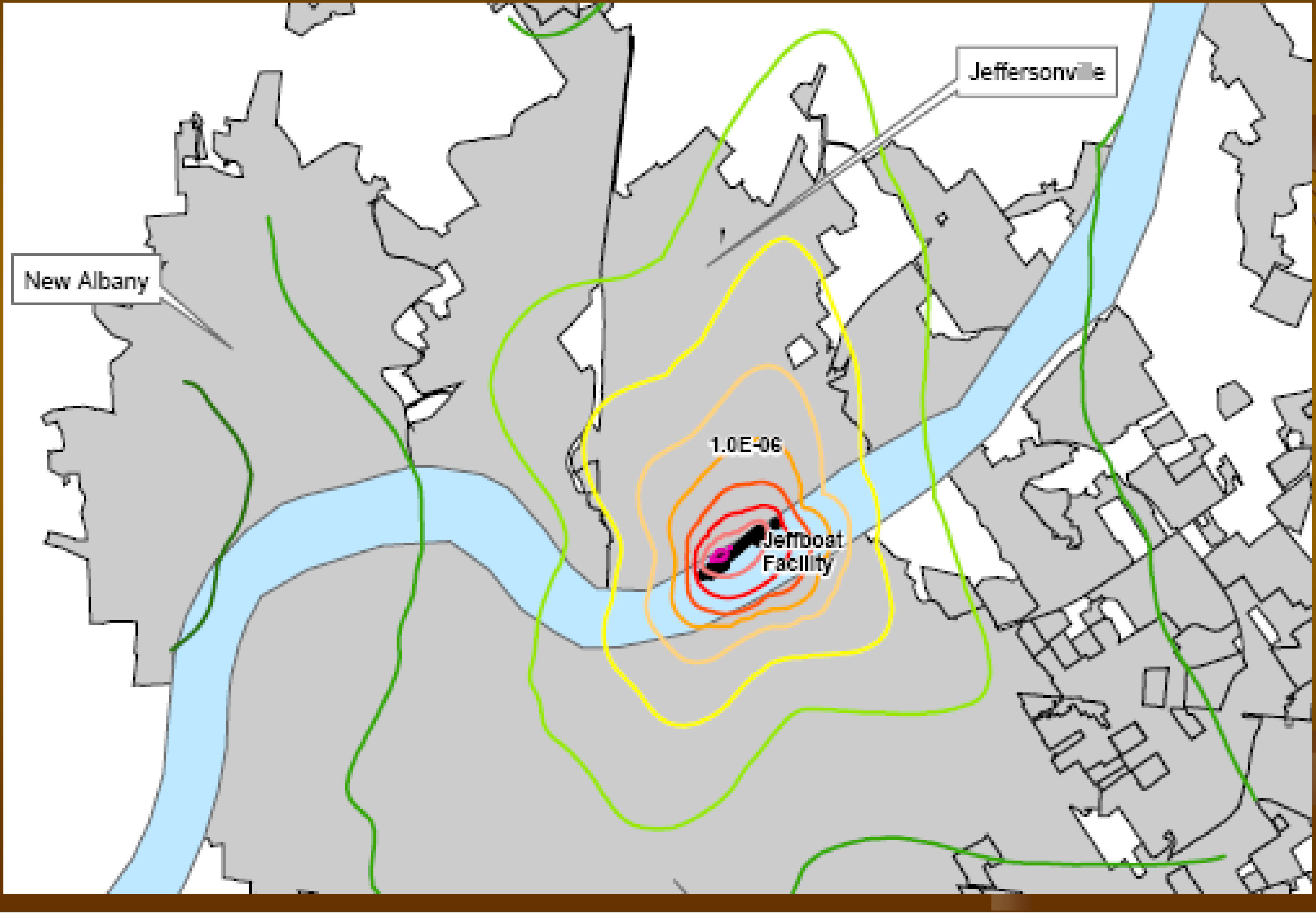
Pollutant	Benchmarks
Chromium VI	IDLH/10
Nickel	CA aREL, IDLH/10
Manganese	IDLH/10
Xylene	AEGL-1, ATSDR MRL, CA aREL, IDLH/10

Quantitative Risk Estimates

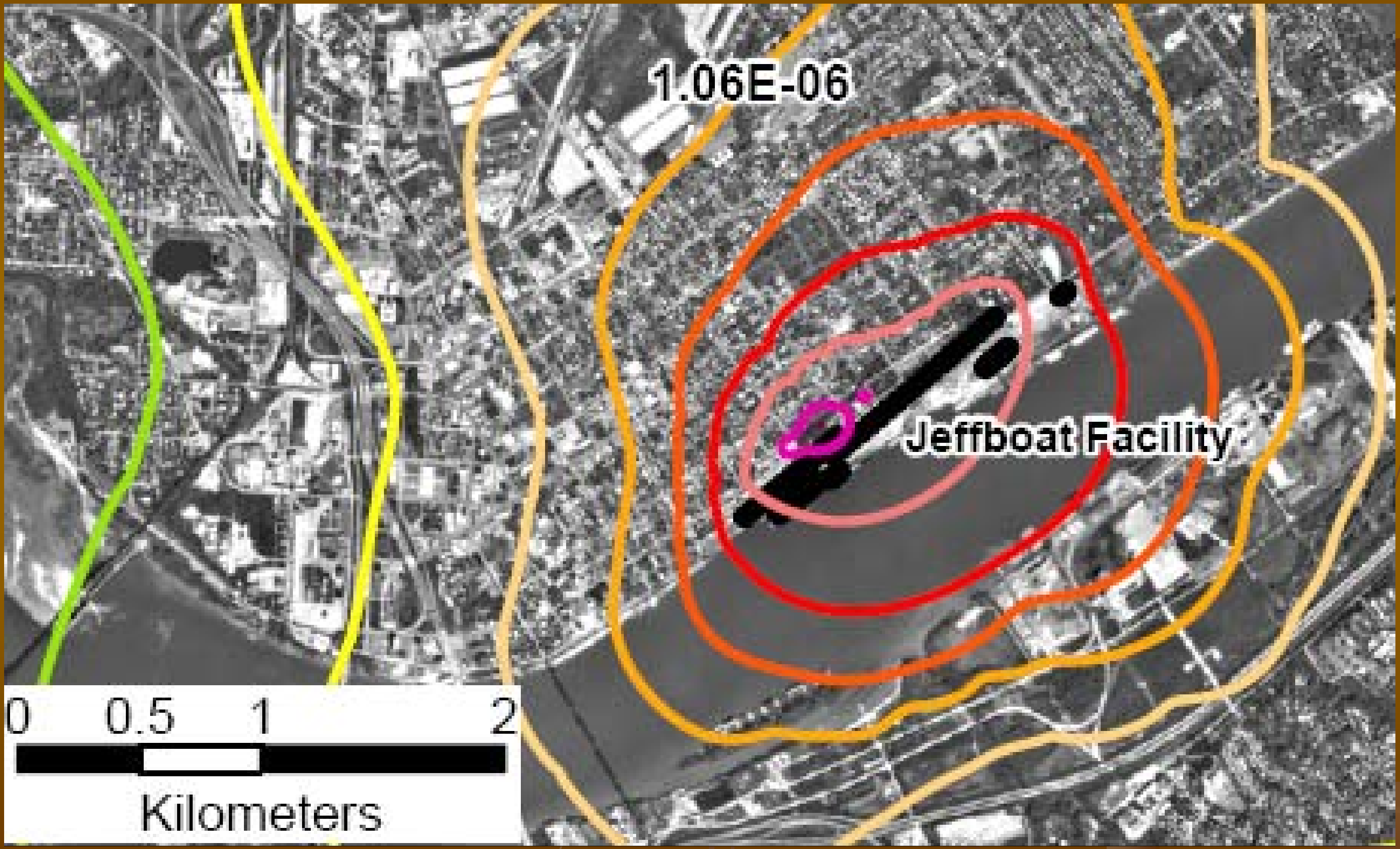


- Chronic
  - Cancer: Risk = C x URE
  - Noncancer: HQ = C/RfC
- Acute
  - Graphic comparison of 1-h C’s vs. available 1-h benchmarks

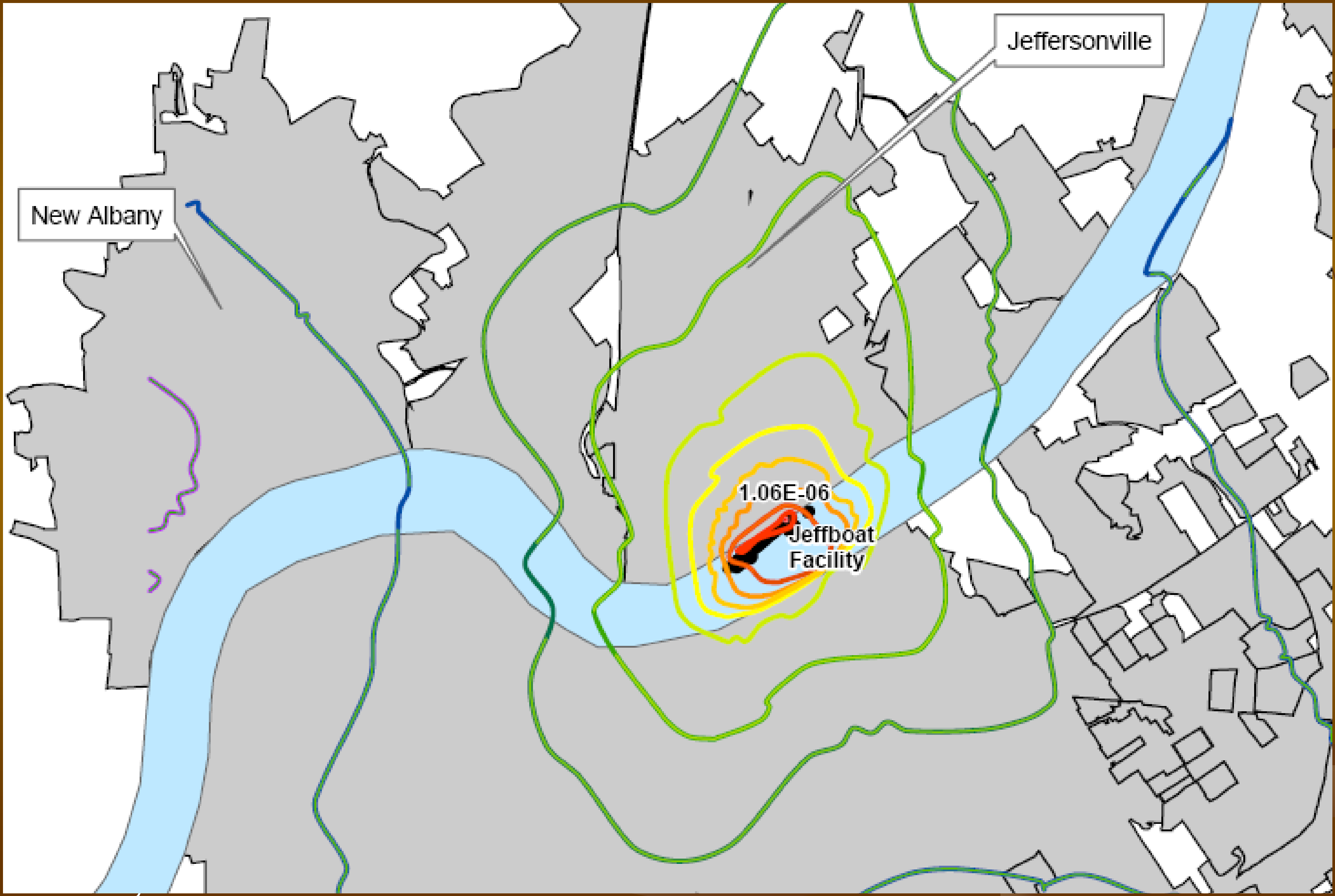
Welding Risk Isopleths: 95% UCL



Welding Risk Isopleths: 95% UCL



Welding Risk Isopleths: AP-42



Welding Risk Isopleths: AP-42

Preliminary Model Results; Effect of Different Welding EFs

	Max Individual Cancer Risk		
Emission Factors	**Cr(VI)**	**Ni**	**Total**
AP-42 **	6.32E-06	4.81E-07	6.80E-06
95% UCL (Nov '04)	3.14E-05	6.52E-06	3.79E-05
Mean (Nov '04)	2.62E-05	1.81E-06	2.80E-05

** AP-42 data did not include data for alloy steels, but the Nov. '04 data used for calculating 95% UCL of mean did.

	Max Individ. Chronic Noncancer HQ (Metals)		
Emission Factors	**Cr(VI)**	**Mn**	**Ni**
AP-42 **	5.63E-03	5.61E+00	1.07E-02
95% UCL (Nov '04)	2.71E-02	8.96E+00	1.42E-01
Mean (Nov '04)	2.26E-02	7.79E+00	3.95E-02

Shipbuilding and Ship Repair (Surface Coating) NESHAP – Residual Risk Analysis

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Industry Meeting/Conference Call

January 25, 2005

EPA

Shipbuilding NESHAP – Residual Risk

- Overview of residual risk project
- Review data analysis for proposed welding factors
- Review abrasive blasting proposed factors
- Refined risk assessment modeling
- Status/schedule

Shipbuilding NESHAP – Residual Risk

- REAG's residual risk test report (May 28, 2003) showed 7 out of 10 modeled shipyards either had cancer risk >1x10^{-6} or chronic hazard index (HI) > 0.2
  - Based on available data and several conservative assumptions
  - Cr was the primary cancer risk driver
  - Mn was the primary noncancer risk driver

- ICRs sent out to 9 entities (12 shipyards) and Norfolk Naval Shipyard to collect additional information in order to obtain
  - more accurate Cr, Cr^{+6}, Mn, Ni, Pb emission rates
  - site specific release locations and stack parameters

- 52 potential major source shipyards

Shipbuilding NESHAP – Residual Risk

- ICR questionnaires sent out – August/September 2003
- Responses received through May 2004
- Follow-up welding test information from CARB
  - average Cr+6 data received in July 2004
  - single test Cr+6 data received in August 2004
- Emission Sources Considered
  - Surface Coating
  - Solvent Cleaning
  - Abrasive Blasting
  - Welding

Shipbuilding NESHAP – Residual Risk

- 13 Shipyards responded – Newport News claimed most of their welding and location data as CBI
- 12 Shipyards – 10,183,000 lbs of welding rods consumed (1999)
  [(Range = 2,760,000 lbs (Jeffboat) to 26,500 lbs (Norfolk Naval)]
- Primary Welding Processes
  - SMAW (29.3%)
  - FCAW (54.5%)
  - GMAW (4.8%)
  - SAW (11%)
  - GTAW (0.3%)
- Stainless Steels (e.g., 308, 309, 316) = 1.3% of total usage
- Mild Steels (e.g., 70S, 70T, 71T, 7018, 7024) = 90%
- Alloy Steels (e.g., 8N12, EN60, Monel 67, RN82) = 8.6%

Shipbuilding NESHAP – Residual Risk

- Industry Meetings
  - December 2002
  - February 2003 (conference call)
  - October 2003
  - January 2005

- Site Visits (June/July 2003)
  - NASSCO and Southwest Marine, San Diego, CA
  - Jeffboat, Jeffersonville, IN

- Industry representatives have continued monthly contact (phone calls) with EPA

Shipbuilding NESHAP – Residual Risk

- Questionnaire Recipients (large- and middle-sized shipyards doing ship construction and/or repair)

Company	Shipyard	Location
American Commercial Lines	Jeffboat	Jeffersonville, IN
General Dynamics	NASSCO Bath Iron Works	San Diego, CA Bath, ME
Northrop Grumman	Newport News Shipyard Ingalls Avondale – LA Avondale – MS	Newport News, VA Pascagoula, MS New Orleans, LA Gulfport, MS
Atlantic Marine	Atlantic Marine Alabama Shipyard	Mobile, AL Mobile, AL
Greenbrier Companies	Gunderson	Portland, OR
U.S. Marine Repair	NORSHIPCO San Francisco Drydock	Norfolk, VA San Francisco, CA
U.S. Navy	Norfolk Naval Shipyard	Norfolk, VA

Shipbuilding NESHAP – Residual Risk Welding Emission Factors

- AP-42 (Section 12.19) – Development of Particulate and Hazardous Emission Factors for Electric Arc Welding (1994)
  - No data/factors for some new processes/electrodes (e.g., FCAW/309)
  - Missing/incomplete information (e.g., Cr, Cr^{+6}, Mn, Ni, Pb)
- Obtained additional test data from shipyards, ESAB (2000), CARB (2004), and National Shipyard Research Program (NSRP) reports (1999 and 2000)
- Revising/updating Emission Factors based on new test data

Shipbuilding NESHAP – Residual Risk

- Schedule
  - Refined risk analysis (February 2005)
  - Evaluate available and potential risk reduction options (April 2005)
  - Regulatory decision(s) (September 2005)
  - Proposed rule (December 2005)

Shipbuilding NESHAP – Residual Risk

- Abrasive Blasting Issues
  - Limited test data and information on how much PM is emitted (media specific emission factors)
  - Limited information on HAP metal concentrations of specific media (e.g., coal slag)
  - Missing or incomplete usage and location data from shipyards

Shipbuilding NESHAP – Residual Risk

- **Abrasive Blasting: Total PM Emission Factors (as reported*)**

TNRCC	**0.29%**	**(5.8 lb PM/ton)**
Texas (NSRP)	**0.23%**	**(4.6 lb PM/ton)**
Newport News	**2%**	**(40 lb PM/ton)**
Norfolk Naval	**0.4%**	**(8 lb PM/ton)**
Gunderson	**3.15%**	**(63 lb PM/ton)**
NORSHIPCO	**5%**	**(100 lb PM/ton)**
GCRMTC/UNO	**5 - 9 %**	**(100 -180 lb PM/ton)**

*__Method for estimating PM emission factors was not explained.__

Shipbuilding NESHAP – Residual Risk

- Abrasive Blasting: PM 10 Emission Factors

– SCAQMD	1%	(20 lb PM10/ton)
– TNRCC	0.14%	(40 lb PM10/ton)
– Texas (NSRP)	0.06%	(1.2 lb PM10/ton)
- Gunderson	0.9%	(18 lb PM10/ton)
- NSRP 0552	0.24%	(4.9 lb PM10/ton)

Shipbuilding NESHAP – Residual Risk

- Uncontrolled TPM Emission Factor:
  - Using GCRMTC/UNO 1995 report by Dr. Kura for coal slag abrasive media
  - Mean = 7.73% (155 lb PM/ton) for uncontrolled abrasive blasting with coal slag
  - Calculated 95% UCL = 8.38% (167.6 lb PM/ton) for uncontrolled abrasive blasting with coal slag

Shipbuilding NESHAP – Residual Risk

- Example Emission Calculation for Uncontrolled Abrasive Blasting:
  - 9,093 tons of coal slag abrasive media

    x 8.38% = 762 tons PM = 1,524,000 lbs PM
  - 1,524,000 lbs PM x 592 ppm Cr+6*

    = 902 lbs of Cr+6 emitted

(* March 15, 1999 Technical Background Document for Report to Congress on Remaining Wastes from Fossil Fuel Combustion: Waste Characterization)

Shipbuilding NESHAP – Residual Risk

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Supplemental Guidance to RAGS: Calculating the Concentration Term

Office of Emergency and Remedial Response
Hazardous Site Evaluation Division, OS-230

Intermittent Bulletin
Volume 1 Number 1

The overarching mandate of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) is to protect human health and the environment from current and potential threats posed by uncontrolled releases of hazardous substances. To help meet this mandate, the U.S. Environmental Protection Agency's (EPA's) Office of Emergency and Remedial Response has developed a human health risk assessment process as part of its remedial response program. This process is described in the *Risk Assessment Guidance for Superfund: Volume I — Human Health Evaluation Manual (RAGS/HHEM).* Part A of RAGS/HHEM addresses the baseline risk assessment, and describes a general approach for estimating exposure to individuals from hazardous substance releases at Superfund sites.

This bulletin explains the concentration term in the exposure/intake equation to remedial project managers (RPMs), risk assessors, statisticians, and other personnel. This bulletin presents the general intake equation as presented in RAGS/HHEM Part A, discusses basic concepts concerning the concentration term, describes generally how to calculate the concentration term, presents examples to illustrate several important points, and lastly, identifies where to get additional help.

THE CONCENTRATION TERM

How is the concentration term used?

RAGS/HHEM Part A presents the Superfund risk assessment in four "steps": (1) data collection and evaluation; (2) exposure assessment; (3) toxicity assessment; and, (4) risk characterization. The concentration term is calculated for use in the exposure assessment step. **Highlight 1** presents the general equation Superfund uses for calculating exposure, and illustrates that the concentration term (C) is one of several parameters needed to estimate contaminant intake for an individual.

For Superfund assessments, the concentration term (C) in the intake equation is an estimate of the arithmetic average concentration for a contaminant based on a set of site sampling results. Because of the uncertainty associated with estimating the true average concentration at a site, the 95 percent upper confidence limit (UCL) of the arithmetic mean should be used for this variable. The 95 percent UCL provides reasonable confidence that the true site average will not be underestimated.

Why use an average value for the concentration term?

An estimate of average concentration is used because:

Supplemental Guidance to RAGS is a bulletin series on risk assessment of Superfund sites. These bulletins serve as supplements to *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual.* The information presented is intended as guidance to EPA and other government employees. It does not constitute rulemaking by the Agency, and may not be relied on to create a substantive or procedural right enforceable by any other person. The Government may take action that is at variance with these bulletins.

Highlight 1
GENERAL EQUATION FOR ESTIMATING EXPOSURE TO A SITE CONTAMINANT

$$I = C \times \frac{CR \times EFD}{BW} \times \frac{1}{AT}$$

where:

I = Intake (i.e., the quantitative measure of exposure in RAGS/HHEM)
C = Contaminant Concentration
CR = Contact (Intake) Rate
EFD = Exposure Frequency and Duration
BW = Body Weight
AT = Averaging Time

(1) carcinogenic and chronic noncarcinogenic toxicity criteria[1] are based on lifetime average exposures; and,

(2) Average concentration is most representative of the concentration that would be contacted at a site, over time.

For example, if you assume that an exposed individual moves randomly across an exposure area, then the spatially-averaged soil concentration can be used to estimate the true average concentration contacted over time. In this example, the average concentration contacted over time would equal the spatially averaged concentration over the exposure area. While an individual may not actually exhibit a truly random pattern of movement across an exposure area, the assumption of equal time spent in different parts of the area is a simple but reasonable approach.

When should an average concentration be used?

The two types of exposure estimates now being required for Superfund risk assessments, a reasonable maximum exposure (RME) and an average, should both use an average concentration. To be protective, the overall estimate of intake (see **Highlight 1**) used as a basis for action at Superfund sites should be an estimate in the high-end of the intake/dose distribution. One high-end option is the RME used in the superfund program. The RME, which is defined as the highest exposure that could reasonably be expected to occur for a given exposure pathway at a site, is intended to account for both uncertainty in the contaminant concentration and variability in exposure parameters (e.g., exposure frequency, averaging time). For comparative purposes, agency guidance (U.S. EPA, *Guidance on Risk Characterization for Risk Managers and Risk Assessors*, February 26, 1992) states that an average estimate of exposure also should be presented in risk assessments. For decision-making purposes in the Superfund program, however, RME is used to estimate risk.[2]

Why use an estimate of the arithmetic mean rather than the geometric mean?

The choice of the arithmetic mean concentration as the appropriate measure for estimating exposure derives from the need to estimate an individual's long-term average exposure. Most Agency health criteria are based on the long-term average daily dose, which is simply the sum of all daily doses divided by the total number of days in the averaging period. This is the definition of an arithmetic mean. The

---

[1] When acute toxicity is of most concern, a long-term average concentration generally should not be used for risk assessment purposes, as the focus should be to estimate short-term, peak concentrations.

[2] For additional information on RME, see RAGS/HHEM Part A and the National Oil and Hazardous Substances Pollution contingency plan (NCP), 55 *Federal Register* 8710, March 8, 1990.

arithmetic mean is appropriate regardless of the pattern of daily exposures over time, or the type of statistical distribution that might best describe the sampling data. The geometric mean of a set of sampling results, however, bears no logical connection to the cumulative intake that would result from long-term contact with the site contaminants, and it may differ appreciably from—and be much lower than—the arithmetic mean. Although the geometric mean is a convenient parameter for describing central tendencies of lognormal distributions, it is not an appropriate basis for estimating the concentration term used in Superfund exposure assessments. The following simple example may help clarify the difference between the arithmetic and geometric mean, when used for an exposure assessment:

> Assume the daily exposure for a trespasser subject to random exposure at a site is 1.0, 0.01, 1.0, 0.01, 1.0, 0.01, 1.0, and 0.01 units/day, over an 8-day period. Given these values, the cumulative exposure is simply their summation, or 4.04 units. Dividing this by 8 days of exposure results in an arithmetic mean of 0.505 units per day. This is the value we would want to use in a risk assessment for this individual, not the geometric mean of 0.1 units per day. Viewed another way, multiplication of the geometric mean by the number of days equals 0.8 units, considerably lower than the known cumulative exposure of 4.04 units.

UCL AS AN ESTIMATE OF THE AVERAGE CONCENTRATION

What is a 95 percent UCL?

The 95 percent UCL of a mean is defined as a value that, when calculated repeatedly for randomly drawn subsets of site data, equals or exceeds the true mean 95 percent of the time. Although the 95 percent UCL of the mean provides a conservative estimate of the average (or mean) concentration, it should not be confused with a 95th percentile of site concentration data (as shown in **Highlight 2**).

Why use the UCL as the average concentration?

Statistical confidence limits are the classical tool for addressing uncertainties of a distribution average. The 95 percent UCL of the arithmetic mean concentration is used as the average concentration, because it is not possible to know the true mean. The 95 percent UCL, therefore, accounts for uncertainties due to limited sampling data at Superfund sites. As sampling data become less limited at a site, uncertainties decrease, the UCL moves closer to the true mean, and exposure evaluations using either the mean or the UCL produce similar results. This concept is illustrated in **Highlight 2**.

Should a value other than the 95 percent UCL be used for the concentration?

A value other than the 95 percent UCL can be used, provided the risk assessor can document that high coverage of the true population mean occurs (i.e., the value equals or exceeds the true population mean with high probability). For exposure areas with limited amounts of data or extreme variability in measured or modeled data, the UCL can be greater than the highest measured or modeled concentration. In these cases, if additional data cannot practicably be obtained, the highest measured or modeled value could be used as the concentration term. Note, however, that the true mean still may be higher than this maximum value (i.e., the 95 percent UCL indicates a higher mean is possible), especially if the most contaminated portion of the site has not been sampled.

CALCULATING THE UCL

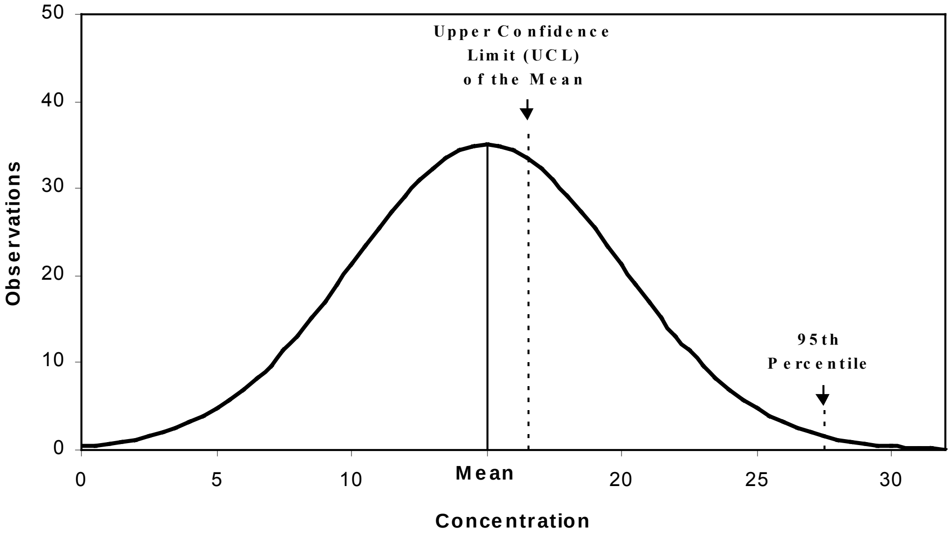
How many samples are necessary to calculate the 95 percent UCL?

Sampling data from Superfund sites have shown that data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration (i.e., there is a large difference between the sample mean and the 95 percent UCL), while data sets with 10 to 20 samples per exposure are provide somewhat better estimates of the mean, and data sets with 20 to 30 samples provide fairly consistent estimates of the mean (i.e., the 95 percent UCL is close to the sample mean). Remember that, in general, the UCL approaches the true mean as more samples are included in the calculation.

Should the data be transformed?

EPA's experience shows that most large or "complete" environmental contaminant data sets

Highlight 2
COMPARISON OF UCL AND 95th PERCENTILE



As sample size increases, the UCL of the mean moves closer to the true mean, while the 95th percentile of the distribution remains at the upper end of the distribution.

from soil sampling are lognormally distributed, rather than normally distributed (see **Highlights 3 and 4**, for illustrations of lognormal and normal distributions). In most cases, it is reasonable to assume that Superfund soil sampling data are lognormally distributed. Because transformation is a necessary step in calculating the UCL of the arithmetic mean for a lognormal distribution, the data should be transformed by using the natural logarithm function (i.e., calculate ln(*x*), where *x* is the value from the data set). However, in cases where there is a question about the distribution of the data set, a statistical test should be used to identify the best distributional assumption for the data set. The W-test (Gilbert, 1987) is one statistical method that can be used to determine if a data set is consistent with a normal or lognormal distribution. In all cases, it is valuable to plot the data to better understand the contaminant distribution at the site.

How do you calculate the UCL for a lognormal distribution?

To calculate the 95 percent UCL of the arithmetic mean for a lognormally-distributed data set, first transform the data using the natural logarithm function as discussed previously (i.e., calculate ln(x)). After transforming the data, determine the 95 percent UCL for the data set by completing the following four steps:

(1) Calculate the arithmetic mean of the transformed data (which is also the log of the geometric mean);

(2) Calculate the standard deviation of the transformed data;

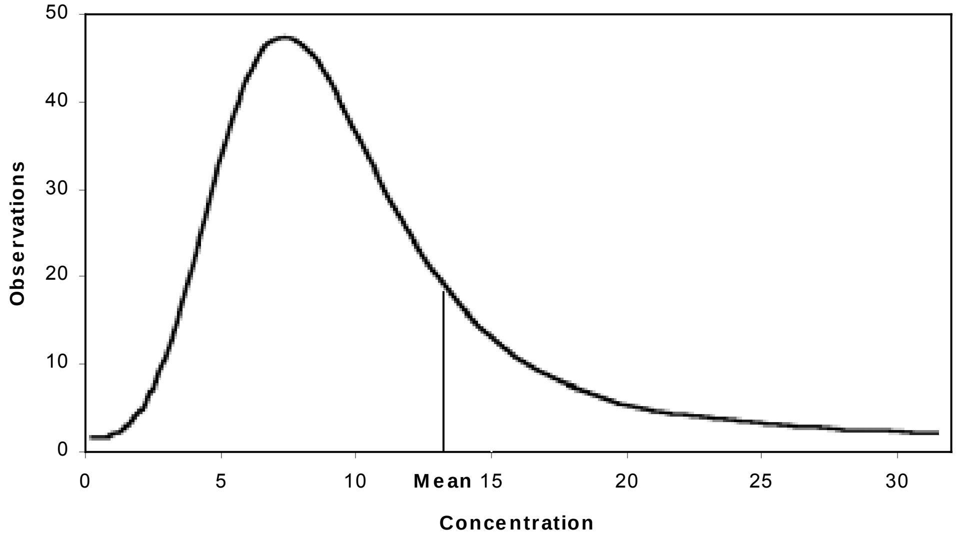
(3) Determine the H-statistic (e.g., see Gilbert, 1987); and,

(4) Calculate the UCL using the equation shown in **Highlight 5**.

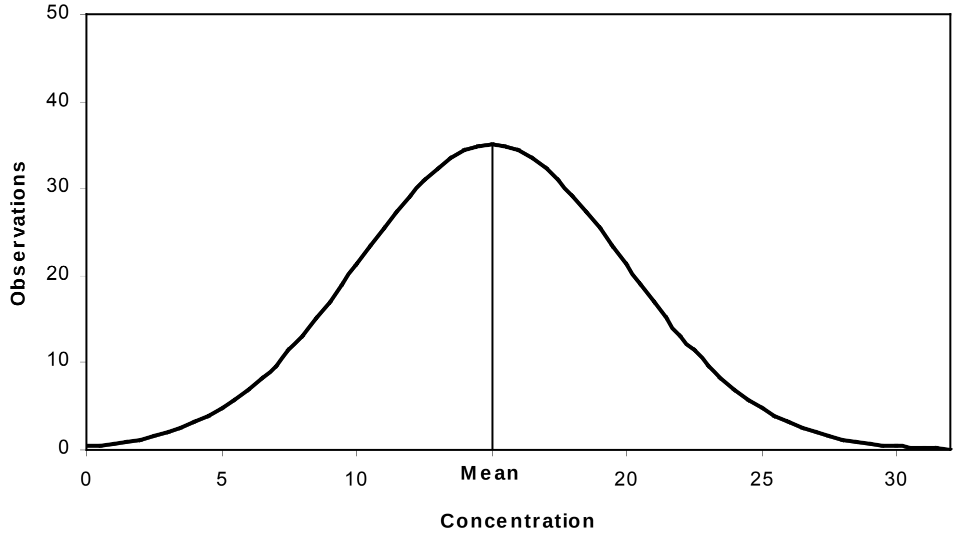
How do you calculate the UCL for a normal distribution?

If a statistical test supports the assumption that the data set is normally distributed, calculate the 95 percent UCL by completing the following four steps:

Highlight 3
EXAMPLE OF A LOGNORMAL DISTRIBUTION



Highlight 4
EXAMPLE OF A NORMAL DISTRIBUTION



Highlight 5
CALCULATING THE UCL OF THE ARITHMETIC MEAN FOR A LOGNORMAL DISTRIBUTION

$$UCL = e^{(\overline{x} + 0.5s^2 + sH / \sqrt{n-1})}$$

where:

UCL = upper confidence limit
e = constant (base of the natural log, equal to 2.718)
$\overline{x}$ = mean of the transformed data
s = standard deviation of the transformed data
H = H-Statistic (e.g., from table published in Gilbert, 1987)
n = number of samples

Highlight 6
CALCULATING THE UCL OF THE ARITHMETIC MEAN FOR A NORMAL DISTRIBUTION

$$UCL = \overline{x} + t(s / \sqrt{n})$$

where:

UCL = upper confidence limit
$\overline{x}$ = mean of the untransformed data
s = standard deviation of the untransformed data
t = Student-t statistic (e.g., from table published in Gilbert, 1987)
n = number of samples

(1) Calculate the arithmetic mean of the untransformed data;

(2) Calculate the standard deviation of the untransformed data;

(3) Determine the one-tailed t-statistic (e.g., see Gilbert, 1987); and,

(4) Calculate the UCL using the equation shown in **Highlight 6**.

Use caution when applying normal distribution calculations, if there is a possibility that heavily contaminated portions of the site have not been adequately sampled. In such cases, a UCL from normal distribution calculations could fall below the true mean, even if a limited data set at a site appears normally distributed.

EXAMPLES

The examples show in **Highlights 7 and 8** address the exposure scenario where an individual at a Superfund site has equal opportunity to contact soil in any sector of the contaminated area over time. Even though the examples address only soil exposures, the UCL approach is applicable to all exposure pathways. Guidance and examples for other exposure pathways will be presented in forthcoming bulletins.

Highlight 7 presents a simple data set and provides a stepwise demonstration of transforming the data—assuming a lognormal distribution—and calculating the UCL. **Highlight 8** uses the same data set to show the difference between the UCLs that would result from assuming normal and lognormal distribution of the data. These

Highlight 7
EXAMPLE OF DATA TRANSFORMATION AND CALCULATION OF UCL

This example shows the calculation of a 95 percent UCL of the arithmetic mean concentration for chromium in soil at a Superfund site. This example is applicable only to a scenario in which a spatially random exposure pattern is assumed. The concentrations of chromium obtained from random sampling in soil at this (in mg/kg) are 10, 13, 20, 36, 41, 59, 67, 110, 110, 136, 140, 160, 200, 230, and 1300. Using these data, the following steps are taken to calculate a concentration term for the intake equation:

(1) Plot the data and inspect the graph. (You may need the help of a statistician for this part, as well as other parts, of the calculation of the UCL.) The plot (not shown, but similar to **Highlight 3**) shows a skew to the right, consistent with a lognormal distribution.

(2) Transform the data by taking the natural log of the values (i.e., determine ln(x)). For this data set, the transformed values are: 2.30, 2.56, 3.00, 3.58, 3.71, 4.08, 4.20, 4.70, 4.70, 4.91, 4.94, 5.08, 5.30, 5.44, and 7.17.

(3) Apply the UCL equation in **Highlight 5**, where:

$\bar{x}$ = 4.38
s = 1.25
H = 3.163 (based on 95 percent)
n = 15

The resulting 95 percent UCL of the arithmetic mean is thus found to equal $e^{(6.218)}$, or 502 mg/kg.

Highlight 8
COMPARING UCLs OF THE ARITHMETIC MEAN ASSUMING DIFFERENT DISTRIBUTIONS

In this example, the data presented in **Highlight 7** are used to demonstrate the difference in the UCL that is seen if the normal distribution approach were inappropriately applied to this data set (i.e., if, in this example, a normal distribution is assumed).

ASSUMED DISTRIBUTION:	Normal	Lognormal
TEST STATISTIC:	Student-t	H- statistic
95 PERCENT UCL (mg/kg):	325	502

examples demonstrate the importance of using the correct assumptions.

WHERE CAN I GET MORE HELP?

Additional information on Superfund's policy and approach to calculating the concentration term and estimating exposures at waste sites can be obtained in:

- U.S. EPA, *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002, December 1989.
- U.S. EPA, *Guidance for Data Usability in Risk Assessment*, EPA/540/G-90/008, (OSWER Directive 9285.7-05), October 1990.
- U.S. EPA, *Risk Assessment Guidance for Superfund (Part A—Baseline Risk Assessment) Supplemental Guidance/ Standard Exposure Factors*, OSWER Directive 9285.6-03, May 1991.

Useful statistical guidance can be found in many standard textbooks, including:

- Gilbert, R.O., *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York, New York, 1987.

Questions or comments concerning the concentration term can be directed to:

- Toxics Integration Branch
  Office of Emergency and Remedial
  Response
  401 M Street, SW.
  Washington, DC 20460
  Phone: 202-260-9486

EPA staff can obtain additional copies of this bulletin by calling EPA's Superfund Document Center at 202-260-9760. Others can obtain copies by contacting NTIS at 703-487-4650.

NOTE

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Additional information about the Oregon DEQ can be found on the internet at:

www.deq.state.or.us

DEQ
State of Oregon
Department of
Environmental
Quality

Shipbuilding and Ship Repair - Residual Risk
Industry Meeting – January 25, 2005

1. Purpose and Objectives

The purpose of this January 2005 meeting is to review the process that we (EPA) used to develop the welding emission factors for several welding process/electrode (rod or wire) combinations and to respond to any questions you may have. The emission factors will be used to estimate HAP metal emissions from welding operations, which will then be used in the risk analysis for each individual shipyard. We have delayed the refined risk analysis calculation in response to the shipbuilding industry's request that EPA not complete the analysis until we first share with the shipbuilding and repair industry the emission factors we plan to use as input to the risk model. We have complied with that request, and unless there are serious issues with the process used by EPA, we plan to start the refined risk analysis after our meeting in January 2005.

When reviewing the shipyard questionnaire responses, we found that some shipyards used different emission factors (or assumptions) to calculate metal HAP emissions from welding operations. For example, some shipyards estimated that one percent of the electrode is emitted to the air and used the metal composition of the electrode to estimate metal emissions, while other shipyards identified several "generic" emission factors and selected the lowest factor to estimate emissions. Our analysis shows that the 12 shipyards responding to the 2003 questionnaire consumed 10.2 million pounds of welding electrodes in 1999. (Usage data for a 13th facility [Newport News Shipyard] was not included because EPA is still reviewing the facility's claim that all their data needs to be protected as confidential business information.) The breakdown by welding process is shielded metal arc welding (SMAW), 29.3 percent; gas metal arc welding (GMAW), 5.1 percent; flux core arc welding (FCAW), 54.5 percent; and submerged arc welding (SAW), 10.8 percent. All stainless steel electrodes combined account for approximately 1.3 percent of the reported welding usage (by mass).

The primary objectives of the meeting are to (1) present the information and procedures used to develop a set of welding emission factors to be used in the residual risk analysis, (2) allow shipbuilding industry representatives the opportunity to review and comment on the presented information and raise questions, and (3) document a final set of emission factors to be used in the residual risk analysis for all shipyard welding operations. The following write-up and attachments describe how we developed emission factors for the welding process/electrode (rod or wire) combinations. Several attachments are referenced throughout this summary and a listing of all attachments is provided at the end of this document.

2. Emission Rate Calculation

Knowledge of the emission rate and release characteristics is necessary for estimating pollutant fate and transport. Because emission measurements at the fenceline of a shipyard facility are generally <u>not</u> available, we are using emission factors to estimate the quantity of pollutants typically released to the atmosphere from welding and blasting operations.

3. Single Test Data

For the statistical computations that are discussed in the following sections, we used data for single test runs when that was available. However, we have taken a different approach for estimating emission factors for other welding material/process combinations for which we could not identify test data.

4. Sources of Emission Factor Data

In addition to the information related to welding emission factors provided by the shipyards in response to the 2003 questionnaire, we reviewed our emission inventories and contacted state and local air toxics agencies. To obtain data for individual test runs, we started by reviewing original references mentioned in Table 4-16 of EPA's AP-42 document [1]. The EPA AP-42 emission factors were published in 1995 and the test reports referenced in that document account for most of the emission factor information we have evaluated. The summary emission data listed in Table 4-16 provide candidate emission factors based on weighted average values from 12 references, which included test reports. The weighted averages are based on the number of replicate runs. Some of the references provided emission factors based on 1 test run; however, 3 to 6 replicate (repeat) runs were performed on average. In one case, the experimenters undertook more than 15 runs to generate an average emission factor. Table 4-16 of AP-42 did not include emission factors for stainless steel electrodes E309 (or several new alloy steels), which some of the shipyards indicated are now being used in significant quantities. Also, only 6 out of 34 process/electrode combinations in AP-42 included data on hexavalent chromium.

In addition to the AP-42 data, we identified four other sources of test data for welding emission factors: two National Shipbuilding Research Program (NSRP) reports [2, 3]; ESAB Welding and Cutting Products (ESAB) testing involving E309 electrodes and funded by the National Steel and Shipbuilding Company (NASSCO) in September 2000 [4]; and some recent welding emission testing funded by California Air Resources Board (CARB) and done by the Department of Civil and Environmental Engineering, University of California, Davis [5].

The NSRP information was taken from two separate reports: (1) "Shipyard Welding Emission Factor Development" (September 1999) and (2) "Emission Factors for Flux Core Rod Used in Gas Shielded Processes" (December 2000). The NSRP-0574 and ESAB reports only involved stainless steel electrodes. A box of supporting test data and information related to NSRP 0574 [2] and NSRP 0587 [3] was sent to EPA on April 16, 2004, by the shipyard industry. The documentation for NSRP 0574 refers to one study for two welding technologies (SMAW and SAW) and several stainless steel electrodes. Dave Reeves of RTI International documented the results of his review of the test data and information in a memo to EPA dated April 21, 2004 (Attachment 1).

We then reviewed the testing data documented in the ESAB and CARB reports. The ESAB study [4] was provided by Ms. Dina Torgerson of NASSCO on May 3, 2004. The study involved fume analysis testing of three welding processes (SMAW, GMAW, and FCAW carbon dioxide [CO_2] shielding) for E309 stainless steel welding with E309 filler material. The data show a comparison of the fume generation rates and the analysis of the weld fume. In follow-up correspondence, it was determined that the analytical laboratory split each of the test samples and ran two analytical tests. Because the analytical results for the two tests done on the same sample were very close, the test lab used the arithmetic average of the two analytical results for each of the metals reported.

The final CARB/University of California-Davis test report provided by Chris Halm of CARB [5] was received in August 2004. The study provided data for hexavalent chrome. Unfortunately, the data for the other metals (total chromium, manganese, nickel, and lead) were not available. The final report can be downloaded from the CARB web site: http://www.arb.ca.gov.

5. Confidence Level for Risk Assessment

The screening analysis residual risk test report published in May 2003 is posted on the EPA shipbuilding Web site. It was conducted using available data and health-protective assumptions to fill data gaps. The resulting risk estimates exceeded the ample margin of safety criteria set by the Clean Air Act (CAA), triggering a more complete refined risk assessment. To develop this new assessment, we collected more specific usage and modeling data to run a more refined risk analysis. We also developed new welding emission factors based on a 95 percent upper confidence limit on the mean (95% UCL). These factors were derived after considering data that were available to EPA through October 2004, as we explained in Section 4 above.

Section 112(f)(1) requires EPA to address “any uncertainties in risk assessment methodology or other health assessment technique,” with a focus on uncertainty (degree of precision) in residual risk assessment. Several factors affect uncertainty in the risk assessment [6] and include

- Uncertainty in the structure of the models used to estimate risks (model uncertainty)

- Uncertainty in the input values used in the risk assessment models (parameter uncertainty).

Data (input value) uncertainty has to do with data quality or lack of knowledge of fundamental relationships [7]. This is different from data variability, which is an intrinsic property of the data being evaluated. The variability represents the degree of “heterogeneity” of an event or the population from which a sample was taken, and cannot be reduced by collecting more data.

With the shipbuilding industry’s cooperation, we have now acquired much more detailed information on the types of welding rods and apparatus used, and the specific locations of welding operations in each of the shipyards. We will therefore be able to model individual welding sources using more realistic inputs for this assessment. Furthermore, EPA has developed an improved dispersion/exposure model since the initial screening assessment was done, which we will use as the basis of the risk estimates.

6. Confidence Level Regarding the Emission Factors

Welding emission factors are important input parameters that can influence the outcome of a risk assessment. The 1995 AP-42 document provided subjective quality ratings (A, B, C, D, and E) for the emission factors, based on a number of criteria. For example, an emission factor was rated "D" when there was a lack of thorough documentation or an insufficient number of replications. However, these weighted average emission factors in AP-42 were not meant to reflect data precision or to be used for a refined risk analysis. Thus, we will not be using them for that purpose, especially now that we have developed emission factors to which we have assigned a confidence level. A major benefit of the evaluation of uncertainty that we attempted here is to improve the information necessary for management of risk. The final outcome or decision will depend on the uncertainty associated with the determined level of risk and specific control options and their economic impacts.

Data validation and evaluation is an important step in the risk assessment process and is a necessary step used to support decision-making. One question that often arises is whether the sample size is sufficient to produce meaningful statistical results. Sample size is important when there is great variability in a data set. Also, when the UCL exceeds the range of the values detected, the maximum value of a small data set may be a last resort option [8]. The larger the sample size, the more precisely it represents the population. Hence, for a given confidence level, the larger the sample size, the smaller the confidence interval, though the relationship does not change linearly.

We selected the 95% UCL of the unknown population arithmetic mean (mean) as our measure of precision, which is often used by EPA to support risk assessment applications and determine the attainment of cleanup standards.

To determine the 95% UCL of the unknown population mean, we computed several parametric UCLs, based on a normal, lognormal, and gamma distribution. In these tests, we are assuming that the sample is represented by the assumed distribution; hence that the mean, standard deviation, and other computed parameters of the distribution are valid. We also computed UCLs for several nonparametric methods. These include bootstrap procedures and Chebyshev Inequality. For the nonparametric methods, we did not have to assume a distribution. The parametric and nonparametric methods used and a brief explanation of the methods are shown in Attachment 2, and the values chosen as "recommended" are based on the criteria in Attachment 3, which have a theoretical foundation – based on the standard deviation of the log-transformed data [9]. For example, the information in Attachment 3 indicates that if the data are normally distributed, then the one-sided 95% UCL should be computed using Students' statistics. When the data set is moderately to highly skewed, the t-statistics will fail, especially when the data set is around 10 or fewer data points. However, if the sample size is large, the mean will be normally distributed, according to the Cental Limit Theorem. This is true even if the data sample is highly skewed, has outliers, or represents more than one population. For lognormally distributed data sets, use of the Chebyshev minimum-variance unbiased estimator (MVUE) for the mean and variance is recommended to obtain a UCL. This approach is preferred to the Land's Method when the underlying distribution is lognormal. Numerical illustrations of some of the methods discussed here are given in reference [9].

Attachment 4 provides a summary of UCL calculation methods. For our analysis, the following statistical procedure was used to evaluate the data distributions associated with the welding emission factor test data and information:

A. Test for normality, lognormality, and Gamma distribution of the data:
   – Graphical Q-Q plot and Histogram
   – Shapiro-Wilk test (sample size, n, < or = 50)
   – Lillieforth test (n < 50), a generalization of K-S test.

B. If the data set was determined not to have normal, lognormal, or gamma distribution, we selected nonparametric statistical methods:
   – Bootstrap-t
   – Bootstrap (percentile)
   – Bootstrap Hall's
   – Modified-t
   – Modified Chebyshev (Mean, SD).

7. Development of New EPA Welding Emission Factors

Attachment 5 contains a summary of the new welding emission factors for different types of electrodes (e.g., stainless steel, mild steel, and alloy steel), covering four welding processes:

- Shielded Metal Arc Welding (SMAW)
- Gas Metal Arc Welding (GMAW)
- Flux Core Arc Welding (FCAW)
- Submerged Arc Welding (SAW).

SAW is primarily a flat position welding process, and significant amounts of SAW with mild steel electrodes were reported by two shipyards. However, there are limited emission data for SAW except for a few comparisons with SMAW, such as " SAW has significantly lower fume generation rates than does SMAW." We documented the available information (Attachment 6) and recommended HAP metal emission factors for SAW equal to 10 percent of SMAW emission factors.

Alloy steel electrodes have higher manganese, chromium, or nickel contents and are generally used in small quantities. However, there were very limited test data or emission factors for any of the alloy steel electrodes. Therefore, we developed a methodology and default emission factors for all of the alloy steel electrodes using fume generation rates for the different welding processes and the percentage of metal in the welding fumes (Attachment 7).

8. Statistical Analysis of Welding Emission Test Data

This section describes the statistical analysis of the test data for stainless steel and mild steel electrodes and the resulting emission factors. A summary of all the test data is included as Attachment 8. (Please note that the information is compiled in Excel spreadsheets and is organized as follows: stainless steel - 8A; mild steel - 8B; and alloy steel - 8C). In this effort, we have grouped emission factors that both came from single test runs and were generated using laboratory test set-ups that represent variations of the "Laboratory Method for Measuring Fume Generation Rates and Total Fume Emissions of Welding and Allied Processes," AWS F1.2:1999) [10]. We compiled the single test run data for total chromium, hexavalent chromium, manganese, nickel, and lead from the documents identified in Section 4.

We determined the 95% UCL of the mean, in Attachment 8, using the methods discussed in Section 6. Although the use of single test runs instead of averages or weighted averages increased the data points for the statistical analysis, there were many instances where we had fewer than five data points for a process/electrode combination, or even no data. Therefore, we made several judgement calls for combining the single data points for all electrodes under a process. More data points helped to increase the data pool before we computed the 95 % UCL and expanded the applicability of the emission factor to other electrodes of similar composition.

A. Attachment 8A, Worksheet for Stainless Steel Data

1. Chromium. The data for SMAW/308 and SMAW/316 electrodes were combined (14 data points) before computing the 95% UCL. We determined the UCL for SMAW/E309 as a separate data set (7 data points), since electrode E309 can be used to weld both stainless steel and mild steel materials (substrates). We were aware that the stainless steel substrate can contribute chromium to the fumes, up to 10 percent (by mass). The level of chromium in stainless steel can exceed 20 percent of the rod mass, whereas it is less than 1 percent in mild steel.

The 95% UCL values for electrodes E308/E316 and E309 were reasonably close (~0.89 and ~0.81 g/kg, respectively). We ended up combining all of the data for electrodes E308, E309, and E316 and computing a new 95% UCL (~ 0.81 g/kg) using the 21 data points. The combined data followed a normal distribution, as was the case for the individual data sets. We therefore conclude that this emission factor can be used for all stainless steels that have the same range of chromium content. Because the welding operational factors (e.g., current, voltage, shielding type) used to generate the individual test data compiled here are generally not documented in the original references, we have no way of determining if the spread in the values of the emission factors for a process/electrode combination is due to variability in the process or the electrode properties, or simply analytical errors. We have no way of making that distinction with any level of confidence using the information at hand.

Concerning chromium for both GMAW and FCAW processes, we did not have enough data points to generate meaningful UCLs for these process/rod combinations. We combined the data, ending up with a data set for GMAW and another for FCAW. We also recommend the use of the new factor for those stainless steel electrodes that have levels of chromium similar to those in this study. We have included additional comments in the work sheet for stainless steel (see "Notes" portion of Attachment 8A).

We could not explain why the total chromium results for GMAW/309 NSRP are so much different than the emission factor data we collected for this process/electrode combination. A shielding gas was used, the test was conducted at the same time as the other tests in that NSRP report, and the air volume, test length, and mass of electrode used appear to be consistent with the other tests.

2. Nickel. In the case of nickel in stainless steels, the statistical analysis resulted in a 95% UCL value greater than the amount of material in the electrode. We generated a default UCL using three pieces of data: (1) the metal composition of the electrode, (2) the data curves from Appendix A in AP-42 to determine the average metal content of the welding fumes, and (3) the maximum fume (PM/TSP) formation rates from Table 4-15 in AP-42.

We used the highest fume formation rate from any of the electrodes that were reported by the shipyards in the project database. The same approach was used for all alloy steel rods where we did not have any test data or emission factors. We selected this approach instead of the using the metal content (percent by mass) of the electrode as the default 95 % UCL.

3. Lead. We recommended a default emission values for lead in stainless steel based on the lead value for mild steels, considering that lead is a trace contaminant in these electrodes. Hence, we are proposing to use 0.215 g/kg for both stainless steel and mild steel.

B. Attachment 8B, Worksheet for Mild Steel Data

1. Chromium. We had very little data for chromium. Mild steels have a total chromium content less than 0.05 percent, as compared to stainless steels (e.g., 304, 308, 309, 310, 316, and 347) which have total chromium contents ranging from 16 to 25 percent. We adjusted for data gaps and unusually high or low values. For example, we used the average chromium ranges for SMAW, GMAW, and FCAW [11] to generate factors for estimating chromium in mild steel, based on the percentage of the chromium in the welding electrode. The procedure is explained for SMAW in the “Notes” portion of Attachment 8B.

2. Nomenclature. Mild steel electrodes E-70T and E70S (11 percent by mass), E-71T (45 percent), E7018 (12 percent), E6011 (4 percent), E7024 (10 percent), and EM12K (6 percent) constitute a large portion of the mild steels used by the 13 shipyards in our database. Electrodes E70T-1 and E71T-1 both contain less than 0.05 percent (by mass) chromium and approximately 1.3 percent manganese, and 0.01 percent nickel. Other mild steels ER70S-2 and ER70S-3 have a manganese content of 0.9 to 1.4 percent, and ER70S-6 has a manganese content of 1.4 to 1.85 percent (while nickel and chromium are considered “residual elements” and shall not exceed 0.05 percent). The NSRP report provided test data for electrode E-770. However, we believe that the rod is TM-770 by Tri-Mark, equivalent to AWS E71T-1M, E71T-12MJ (ref. www.hobartbrothers.com). We are proposing separate emission factors for the

E70/E71 series and the series containing the letter “M,” until we can understand the reason the factors are several order of magnitude higher in the M series.

9. References

1. EPA’s Compilation of Air Pollutant Emission Factors: Development of Particulate and Hazardous Emission Factors for Electric Arc Welding (AP-42, Section 12.19), Revised Final Report, May 1994.

2. “Shipyard Welding Emission Factor Development,” National Shipbuilding Research Program (NSRP 0574), N1-98-2, September 1, 1999.

3. “Emission Factors for Flux Core Rod Used in Gas Shielded Processes,” National Shipbuilding Research Program (NSRP 0587), N1-98-1 Subtask 43, December 18, 2000.

4. “Welding Fume Analysis Study” by ESAB Welding Products & Cutting Products for National Steel and Shipbuilding Company (NASSCO),

5. “Improving Welding Toxic Metal Emission Estimates in California,” Department of Civil & Environmental Engineering, University of California, Davis for California Air Resources Board (CARB), Final Report, August 2004.

6. Residual Risk Report to Congress, US Environmetal Protection Agency, Office of Air Quality Planning And Standards, Research Triangle Park, EPA-453/R-99-001, May 1999.

7. Residual Risk Report to Congress, US Environmetal Protection Agency, Office of Air Quality Planning And Standards, Research Triangle Park, EPA-453/R-99-001, May 1999.

8. Calculating Upper Confidence Limits for Exposure Limits For Exposure Point Concentrations at Hazardous Waste Sites, Office of Emergency and Remedial Responses US Environmental Protection Agency, Washington, D.C., OSWER 9285.6-10, December 2002, p 20.

9. Calculating Upper Confidence Limits for Exposure Limits For Exposure Point Concentrations at Hazardous Waste Sites, Office of Emergency and Remedial Responses US Environmental Protection Agency, Washington, D.C., OSWER 9285.6-10, December 2002, p 20.

10. “Laboratory Method for Measuring Fume Generation Rates and Total Fume Emissions of Welding and Allied Processes, ” **AWS** F1.2:1999.

11. “Chromium in Stainless Steel Welding Fumes,” The Chromium File from the International Chromium Development Association, Issue No. 9, April 2002. (Available at http:// www.chromium-asoc.com/publications/crfile9apr02.htm)

10. List of Attachments

Attachment 1 -	Memo from D. Reeves, RTI International, to M. Serageldin, EPA, documenting results of technical review of test data related to NSRP 0574 and NSRP 0587. April 21, 2004.
Attachment 2 -	Parametric and Nonparametric Methods Evaluated (Excel table)
Attachment 3 -	UCL Method Flow Chart (shown as “Figure1")
Attachment 4 -	Summary of UCL Calculation Methods (shown as “Exhibit 14")
Attachment 5 -	Summary of New Welding Emission Factors (Excel table)
Attachment 6 -	Memo from D. Reeves, RTI International, to M. Serageldin, EPA, “Recommended Emission Factors for Submerged Arc Welding (SAW).” October 12, 2004.
Attachment 7 -	Memo from D. Reeves, RTI International, to M. Serageldin, EPA, “Recommended Default Welding Emission Factors for Alloy Steels.” November 18, 2004.
Attachment 8 -	Summary Excel spreadsheets with statistical analysis of welding test data and emission factors based on 95% UCL. 8A - Stainless Steel Electrode Data 8B - Mild Steel Electrode Data 8C - Alloy Steel Electrode Data

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

Figure 1: UCL Method Flow Chart

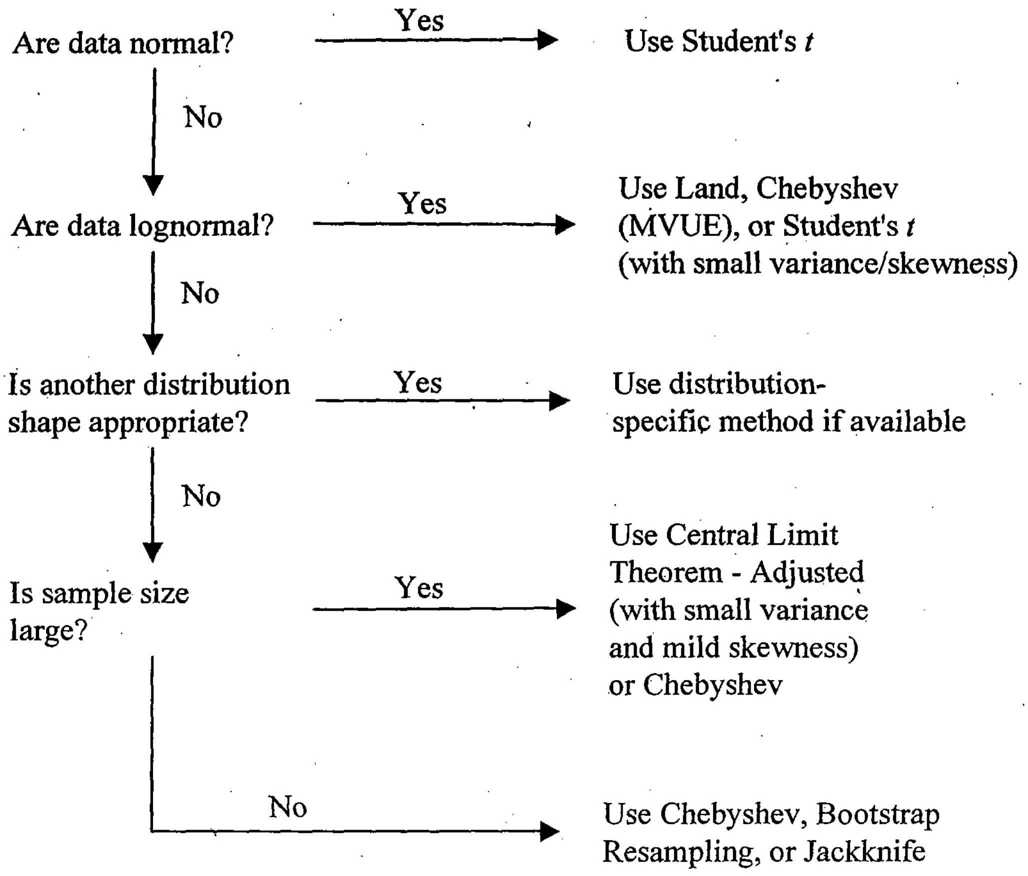

Exhibit 14
Summary of UCL Calculation Methods

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 new GMAW/SS factors; Ni: Use AP-42 TSP, comp. curve.
Use GMAW E70S (-3 to -6) data
Use GMAW E70S (-3 to -6) data
Use AP-42 TSP max. (3.9 g/kg), composition curves
Use GMAW E70S (-3 to -6) data
Use GMAW E70S (-3 to -6) data
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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
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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
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Use 10% of SMAW/7018/7028 factors.
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Use 10% of SMAW/7018/7028 factors.

Attachment 6

To:	Dr. Mohamed Serageldin Project File	From: Date:	Dave Reeves 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: Date:	Dave Reeves 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:
   $\%\ \text{Cr in fume} = -0.31 + [0.66 \times (\%\ \text{Cr in electrode})]$
   B - Eq. 9 calculates Mn fraction in fume as function of Mn content of electrode:
   $\%\ \text{Mn in fume} = -0.99 + [4.60 \times (\%\ \text{Mn in electrode})^{1/2}] + [0.57 \times (\%\ \text{Mn in electrode})]$
   C - Eq. 10 calculates Ni fraction in fume as function of Ni content of electrode:
   $\%\ \text{Ni in fume} = -0.78 + [1.59 \times (\%\ \text{Ni in electrode})^{1/2}] + [0.04 \times (\%\ \text{Ni in electrode})]$

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.

<u>Example:</u>

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				Comments
				Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	
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				Comments
				Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	
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; used default value for 95%UCL = maximim data reported for any mild steel or SS = 0.215 g/kg
			E309	0.007049	0.0089	6	0.008065	
			all data	0.008817	0.0319	19	**0.215**	
		GMAW	E316	ND	ND	0		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
			E309		0.0613	1	0.0613	
			all data		0.0613	1	**0.215**	
		FCAW	E316	ND	ND	0		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
			E309	0.0639	0.064	2	0.064	
			all data		0.064	2	**0.215**	

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				Comments
				Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	
1	**Total Chromium**	SMAW	E7018/28	0.0109	0.0117	2		Assigned default value based on SS value and rattio of total Cr in mild steel to SS:
			E11018	ND	ND	0		
			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 28-0ct-04 (Revisted) Data from file: EFwelding01Oct04.xls

No.	Metal in Fumes	Welding Process	Rod Type	Statistics				Comments
				Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	
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				Comments
				Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	
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				Comments
				Mean (g/kg)	Maximum (g/kg)	Sample Size	95% UCL (g/kg)	
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

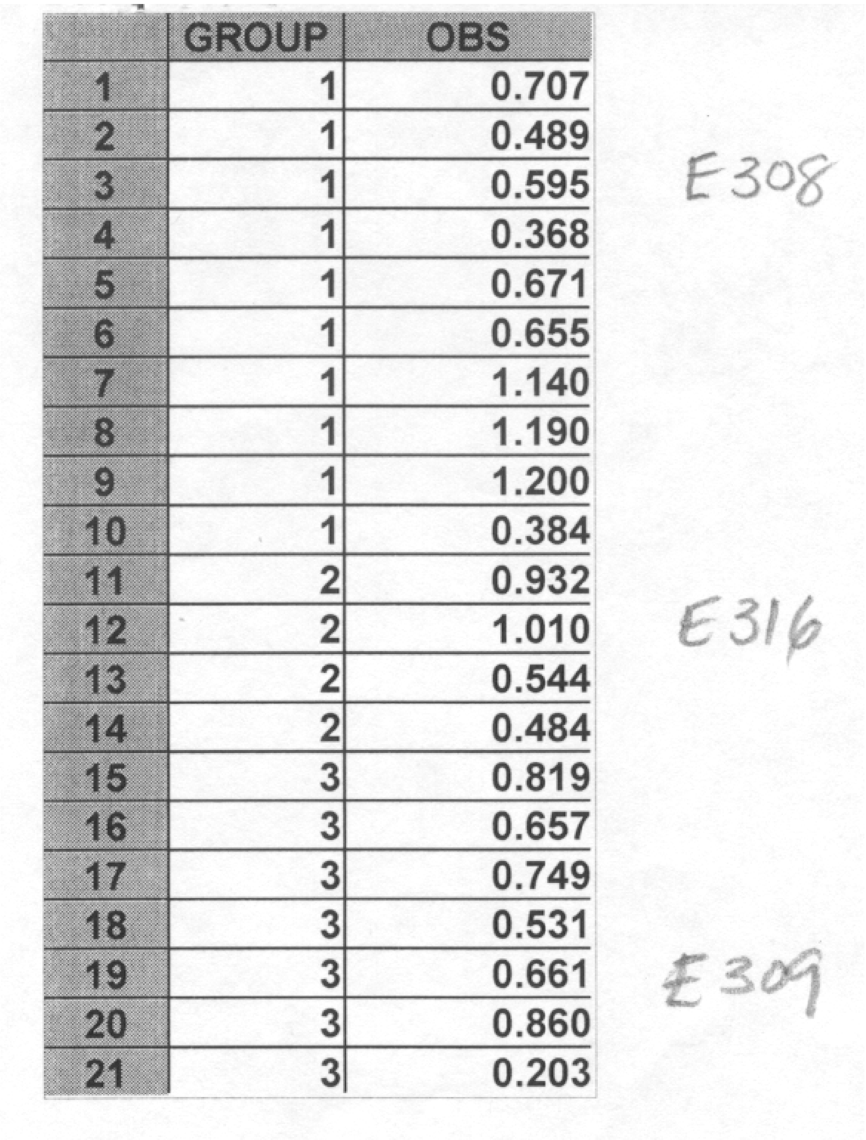
1. Only single data points were used for determining the 95% UCL.

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

otherwise a non parametric method was selected.

Addendum 1 – Welding Data

Cr ➜ SMAW/Stainless Steel



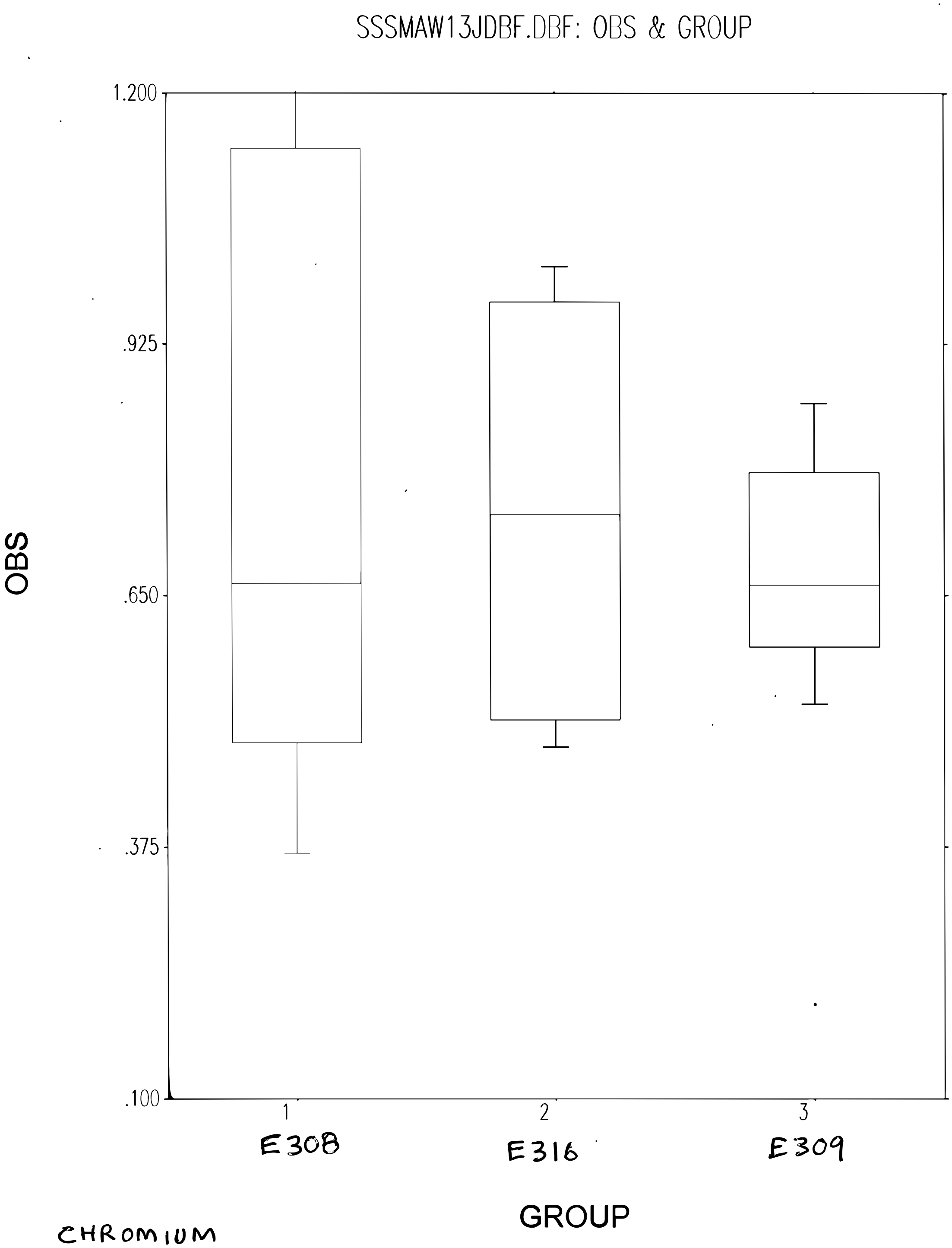
	GROUP	OBS
1	1	0.707
2	1	0.489
3	1	0.595
4	1	0.368
5	1	0.671
6	1	0.655
7	1	1.140
8	1	1.190
9	1	1.200
10	1	0.384
11	2	0.932
12	2	1.010
13	2	0.544
14	2	0.484
15	3	0.819
16	3	0.657
17	3	0.749
18	3	0.531
19	3	0.661
20	3	0.860
21	3	0.203

E308

E316

E309

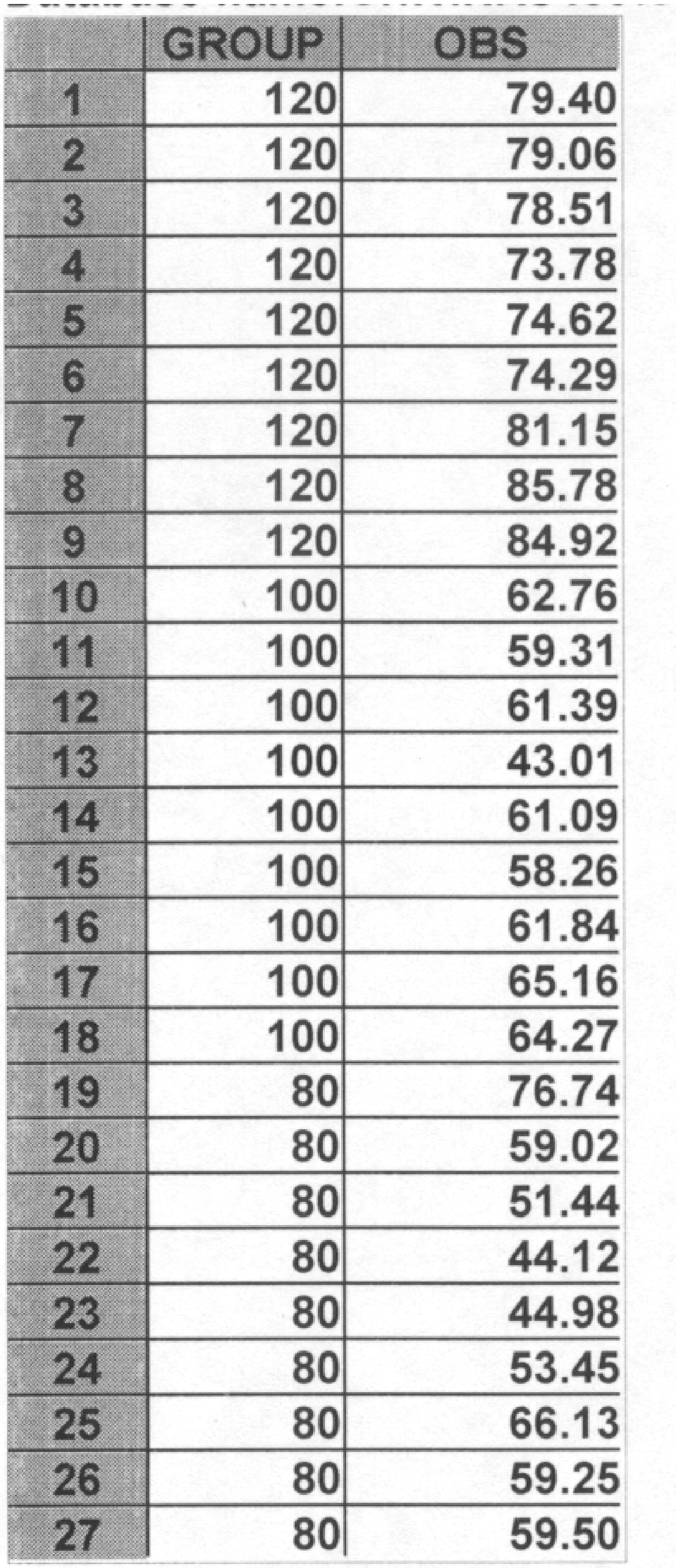
Addendum 1A – Welding Data



CHROMIUM
FROM
SMAW

Addendum 2 – Abrasive Blasting Data

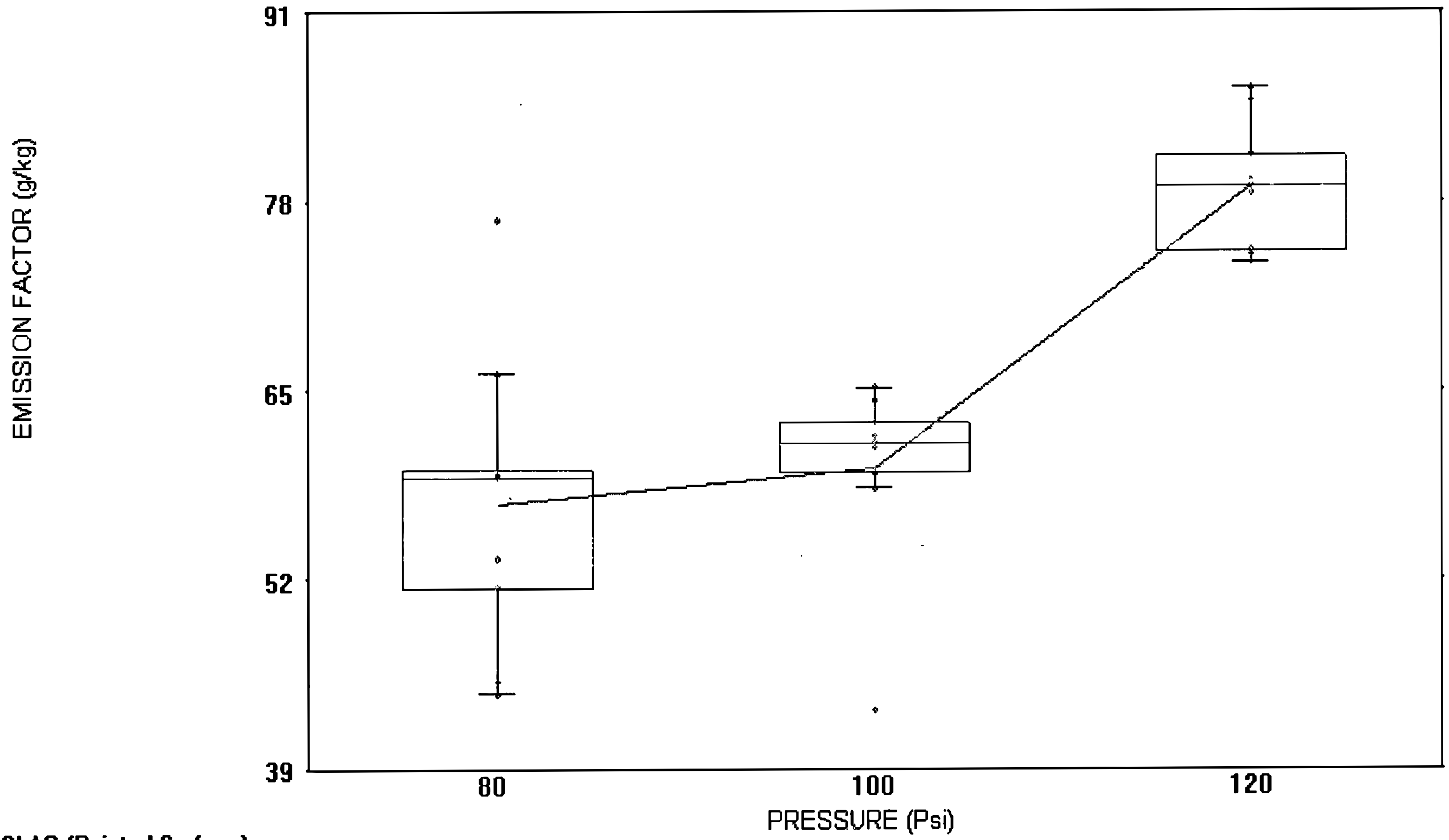
(Coal Slag Media – Painted Surface)



	GROUP	OBS
1	120	79.40
2	120	79.06
3	120	78.51
4	120	73.78
5	120	74.62
6	120	74.29
7	120	81.15
8	120	85.78
9	120	84.92
10	100	62.76
11	100	59.31
12	100	61.39
13	100	43.01
14	100	61.09
15	100	58.26
16	100	61.84
17	100	65.16
18	100	64.27
19	80	76.74
20	80	59.02
21	80	51.44
22	80	44.12
23	80	44.98
24	80	53.45
25	80	66.13
26	80	59.25
27	80	59.50

Addendum 2A

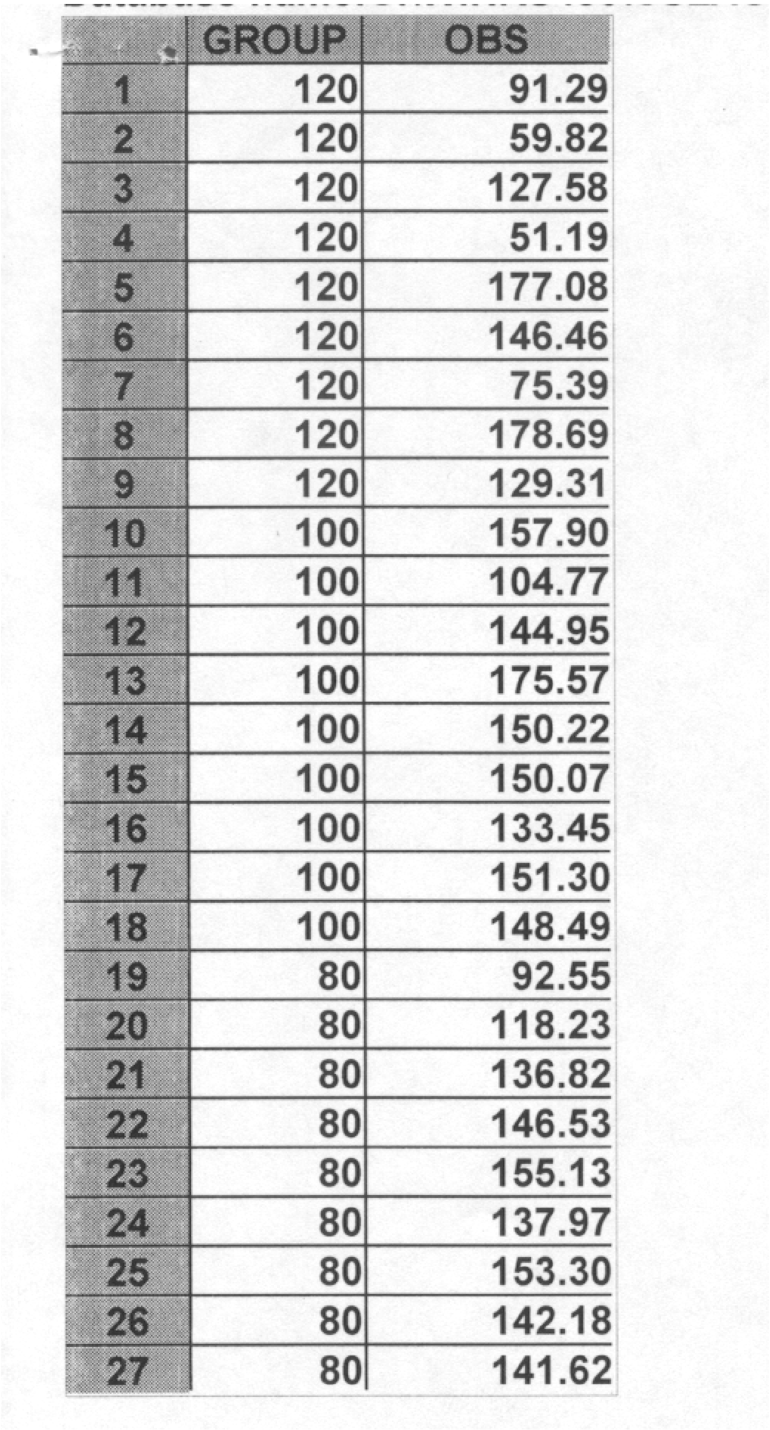
CSLAGALL.DBF: PRESSURE & EMISSION FACTOR



COAL SLAG (Painted Surface)

Addendum 3 – Abrasive Blasting Data

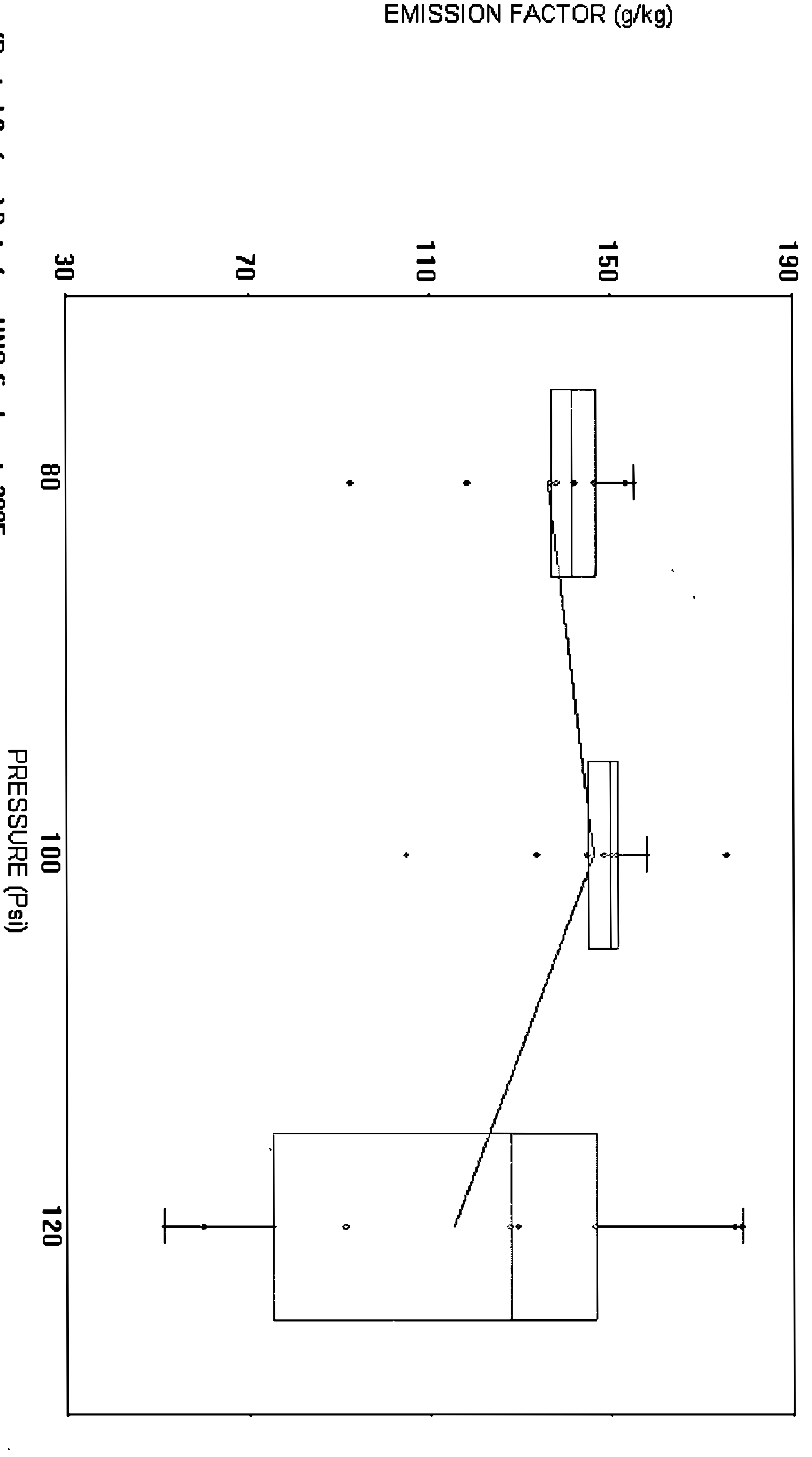
(Coal Slag Media – Rusted Surface)



	GROUP	OBS
1	120	91.29
2	120	59.82
3	120	127.58
4	120	51.19
5	120	177.08
6	120	146.46
7	120	75.39
8	120	178.69
9	120	129.31
10	100	157.90
11	100	104.77
12	100	144.95
13	100	175.57
14	100	150.22
15	100	150.07
16	100	133.45
17	100	151.30
18	100	148.49
19	80	92.55
20	80	118.23
21	80	136.82
22	80	146.53
23	80	155.13
24	80	137.97
25	80	153.30
26	80	142.18
27	80	141.62

Addendum 3A

CSLAG2AL.DBF: PRESSURE & EMISSION FACTOR



Coal Slag (Rusted Surface) Data from UNO final rept. 2005

Addendum 4

From AP-42 Reference 11: "Fumes from Shielded Metal Arc Welding Electrodes" by J.G. McLiwain and L.A. Neumeir. 1987.

electrodes, as a group, are 55 times more hazardous to use than the carbon steel E7018 electrodes. Included in the data are two standard deviation (2 SD) values calculated from the data listed. Although not strictly justifiable from the small number of samples used, this statistic should encompass most of the electrode brands not tested.

The data in figures 2 through 5 were tested to determine fits to curves of the form $f_f = a_o + a_1 f_e$ and $f_f = a_o + a_1 f_e^{1/2} + a_2 f_e$, where f_f and f_e are the elemental fractions in the fume and electrode, respectively. Although the second curve gave slightly better fits for each of the elements, negative values for the coefficient a_1 for Cr and Fe argued in favor of linear fits for these data. Figure 2 plots data for five of the electrode groups in which Cr was a contributor to the fume. The least-squares fit shown is

$$f_{Cr,\ fume} = -0.31 + 0.66\ f_{Cr,\ elec}, \qquad (5)$$

with deviations of about 24 pct. All fume fractions in equations 5 through 10 are in weight percent. More precise fits result from separately grouping the ECoCr-A or the stainless steel electrodes with Mn-Cr electrodes, giving for the ECoCr-A group

$$f_{Cr,\ fume} = -0.11 + 0.75\ f_{Cr,\ elec}, \qquad (6)$$

and for the stainless steel E308-16 and E310-16 electrodes combined

$$f_{Cr,\ fume} = -0.054 + 0.57\ f_{Cr,\ elec}. \qquad (7)$$

Shown also in the figure are mean values of the weld-metal specifications for Cr in these alloy groups. These values, representing the Cr level in the weld deposit, are the only Cr fractions generally available.

Levels of hexavalent Cr in the fumes did not follow a pattern with respect to total Cr content in the electrode. The valence of the Cr is sensitive to the flux composition, which is quite complex for these electrodes.

A linear fit to the Fe data (fig. 3) is given by

$$f_{Fe,\ fume} = 0.916 + 0.45\ f_{Fe,\ elec}. \qquad (8)$$

Again, scatter is significant at about 30 pct. The weld-metal specification values are shown also. The Mn and Ni data are described by the relations

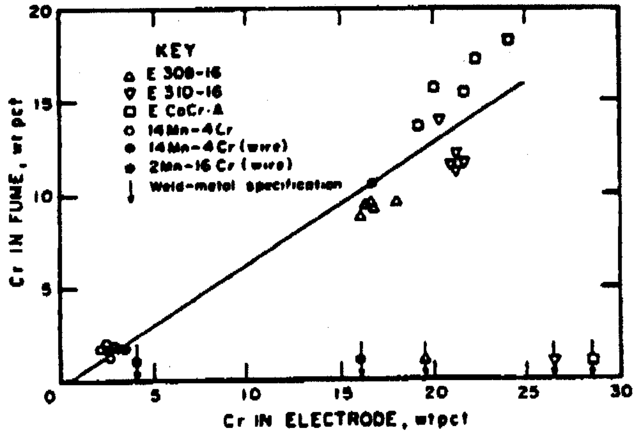


FIGURE 2.—Chromium fraction in fume as function of Cr content of electrode, including flux coating. Welding onto mild-steel plate.

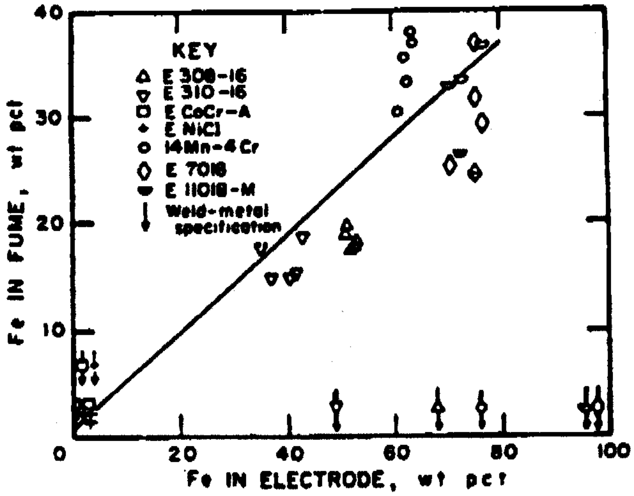


FIGURE 3.—Iron fraction in fume as function of Fe content of electrode, including flux coating. Welding onto mild-steel plate.

$$f_{Mn,fume} = -0.99 + 4.60\, f^{1/2}_{Mn,elec} + 0.57\, f_{Mn,elec}, \qquad (9)$$

and

$$f_{Ni,fume} = -0.78 + 1.59\, f^{1/2}_{Ni,elec} - 0.04\, f_{Ni,elec}, \qquad (10)$$

respectively. Figures 4 and 5 give the data and the weld-metal specification values. Mn comes the closest to matching these values in terms of the total electrode content. Its propensity to fume is substantially greater than that of the other metals shown, while Ni displays the least. The curves, combined in figure 6, show that these metals fume in ascending order as Ni, Fe, Cr, and Mn, roughly in proportion to their vapor pressures.

Because Co was not present in the other electrodes, the data for it were not plotted. The mean ratio of fume to electrode fractions for the five ECoCr-A electrodes is 0.54±0.06. If its fuming rate were linear with electrode content, Co would fall between Fe and Cr in fuming propensity. It does not follow in order of its vapor pressure, which is lower than that of Ni.

Partly because of the low fuming potential of Ni, the exposure index for the ENiCI electrodes was determined primarily by the Ba content of the fume, with secondary contributions from Sr and Ca. Although the fuming potentials for these elements, as determined by ratios of fume to electrode fractions, were

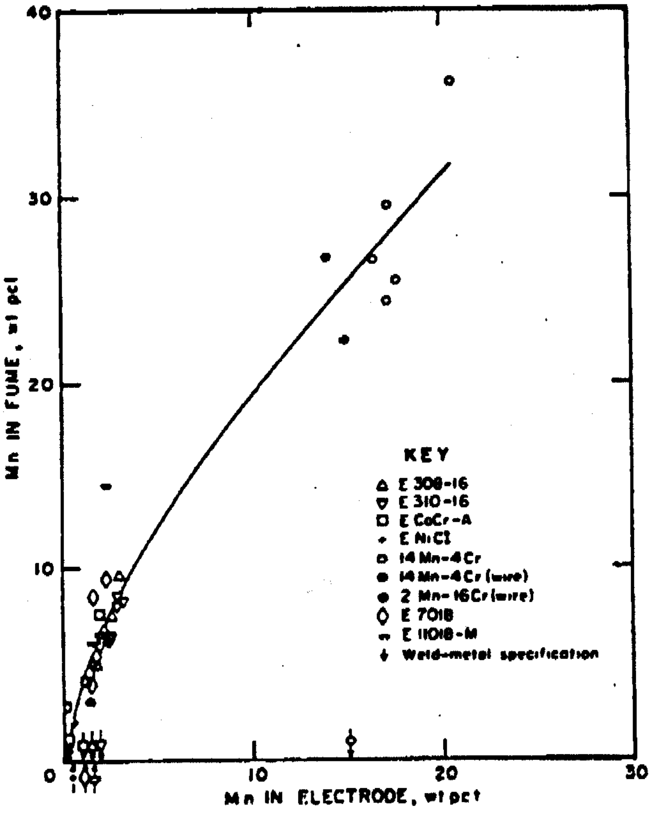


FIGURE 4.—Manganese fraction in fume as function of Mn content of electrode, including flux coating. Welding onto mild-steel plate.

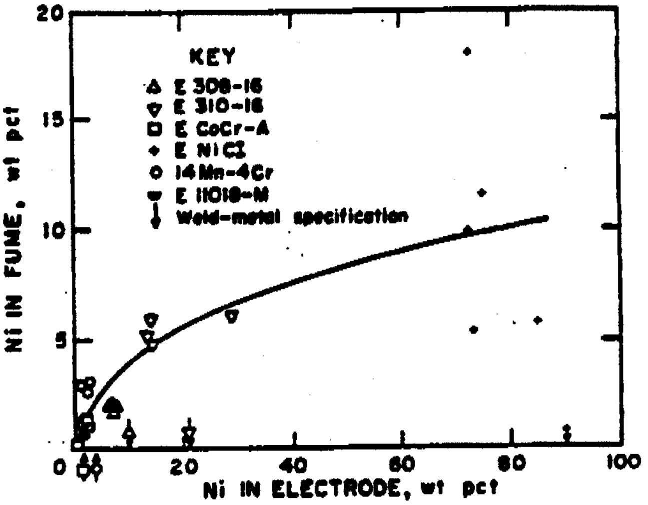


FIGURE 5.—Nickel fraction in fume as function of Ni content of electrode, including flux coating. Welding onto mild-steel plate.

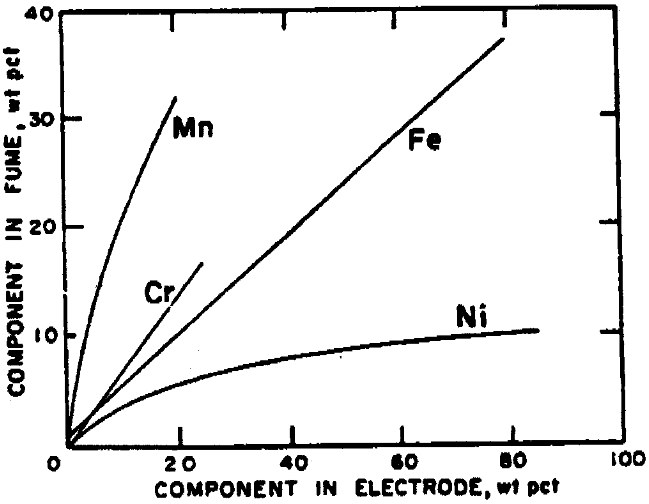


FIGURE 6.—Comparison of elemental components of fume to their respective contents in electrode.

Addendum 5

NSRP vs. UNO Study

NSRP Study Conditions

- Fan capacity: 700 cfm
- Room size: 15’ x 8’ x 20’
- Simulated equivalent wind velocity inside the shed: 0.0389 ft/sec; 0.026 miles/hr; 0.0119 m/sec
- PM reported: PM10, PM4, PM2.5, and PM1
- Research approach: Emissions captured using a bag; PM escaping the bag were unaccounted; Emissions were not actually measured but extrapolated based on several assumptions; Did not use the EPA source test.

UNO Study Conditions

- Average flow of 3000 cfm
- 12’x10’x8’
- 0.521ft/sec; 0.355 miles/hr; 0.159 m/sec
- Total particulate matter (TPM)
- Emissions were actually measured using EPA source testing procedure. All particles were accounted and the room was under negative pressure to prevent particle escape (visual examination) from the shed. Designed to address limitations of previous studies.

Addendum 5 (continued)

Criteria Used for UNO Exhaust System

- Ref: Design Procedures for Sizing Local Exhaust Ventilation (LEV) Systems; Air Pollution Engineering Manual by Air & Waste Management Association (AWMA) – Page 196
- Transport velocities recommended for <u>abrasive blasting</u>: 3500 – 4000 fpm (say, V)
- UNO duct size: 1 foot diameter (say, d)
- Exhaust gas flow rate required: $(\pi/4) \times (d^2) \times V$
- Recommended gas flow (average): 3000 cfm (~)
- UNO gas flow rate used (average): 3000 cfm (~)

Addendum 5 (continued)

Discussion on Some Critical Parameters

- Wind speed in case of outdoor operations: High wind speeds produce increased emissions

- Equivalent wind speed simulated inside UNO chamber: 0.355 miles/hour [(3000 cfm / (8’ x 12’)) x 0.01136) which corresponds to calm period

- Exhaust gas flow from a chamber: Similar to outdoor effect, gas flow and emissions are directly proportional

Addendum 5 (continued)

Environmentally-friendly Abrasives

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GCRMTC, NSRP SP-1 and NSRP SP-3 Meetings