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TITLE

INVESTIGATION OF FUMES GENRATED IN WELDING AND CUTTING OF NAVY MATERIALS

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#507207 #

Investigation of Fumes Generated in Welding and Cutting of Navy Materials

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ABSTRACT

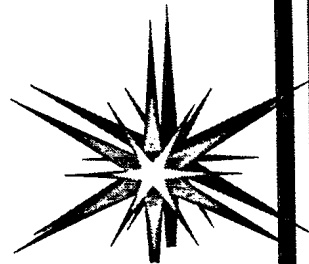
A Navy/Industry Task Group, coordinated by the Naval Sea Systems Command, is addressing the technical and economic impact of anticipated United States Occupational Safety and Health Administration (USOSHA) reductions in permissible worker exposure limits for hexavalent chromium (Cr(VI)). This change is expected to reduce the permissible exposure limit (PEL) from an existing ceiling level of 100 mg/m³ to between 0.5 mg/m³ and 5.0 mg/m³. As a part of this effort, the Naval Surface Warfare Center, Carderock Division, is investigating methods that can be adopted to reduce worker exposure to Cr(VI) and other hazardous components (Mn, Ni) of airborne emissions from welding and other related operations.

The first step of this process has been to establish baseline data for several of the Navy's materials. A standardized approach was taken to facilitate comparisons of materials, operations, and fume test methods. The operations investigated were shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), and oxyacetylene cutting. Plate materials included mild steel; DH-36, A387-Grade 22, HSLA-65, HSLA-80, HSLA-100, HY-80, and HY-100. SMAW electrodes included 7018, 11018, 12018, 8018-B2L, 9018-B3L, 309-15, and 309-16. GMAW electrodes included 70S, 100S, 120S, and Alloy 625. FCAW consumables included 71T, 101T, and 309LT. Shielding gases included Ar - 2% O₂, Ar - 5% CO₂, Ar - 25% CO₂, and 100% CO₂. The laboratory space used for all operations met the Task Group definition of an open space (ceiling height greater than 16 feet). All operations were performed for a testing period of 150 minutes. Welding was performed at a 60% duty cycle, while cutting was continuous. Appropriate filters were placed on the welder's collar, and additional filters were placed approximately ten feet from the operation to collect personal as well as area fume samples. No local exhaust system was imposed to extract fumes from the work site. USOSHA draft Method 215 was used to determine Cr(VI), and inductively coupled plasma was used to determine thirteen additional elements in the fume samples.

Correlations are made between materials, operations, and fume results. Additional comparisons are discussed concerning the effects of shielding gas, SMAW electrode coating formulation, product formulation/chemistry, and plate material used. Results indicate that, without engineering controls, use of welding products for all materials investigated can result in fumes with Cr(VI) above action levels. Oxyacetylene cutting also requires engineering controls to reduce worker exposure to hazardous fume constituents. Certain operations and materials will also produce unacceptable levels of nickel and manganese in fume.

The next phase of this work will investigate the effectiveness of several types of engineering controls on reducing these airborne emissions to acceptable levels.





3rd CF/CRAD Meeting

Halifax, Nova Scotia

Investigation of Fumes Generated in Welding and Cutting of Navy Materials

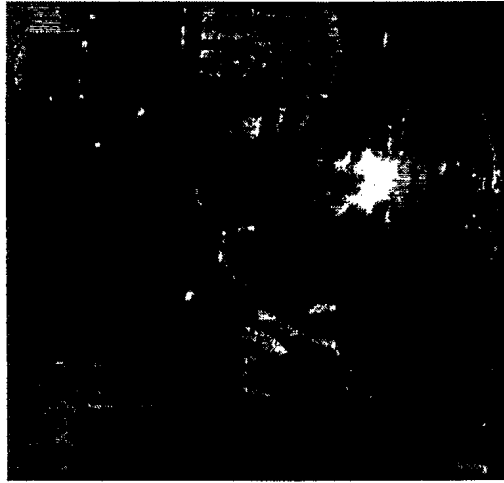
G.L. Franke, R.H. Juers, and R.T. Brenna

Naval Surface Warfare Center

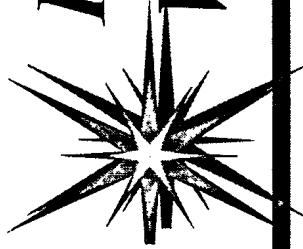
Carderock Division

West Bethesda, Maryland, USA

Cr(VI) Reduction in Navy Welding and Manufacturing Operations



NSWCDD 615 - 0497CRAD



Proposed Exposure Limits Validation Criteria

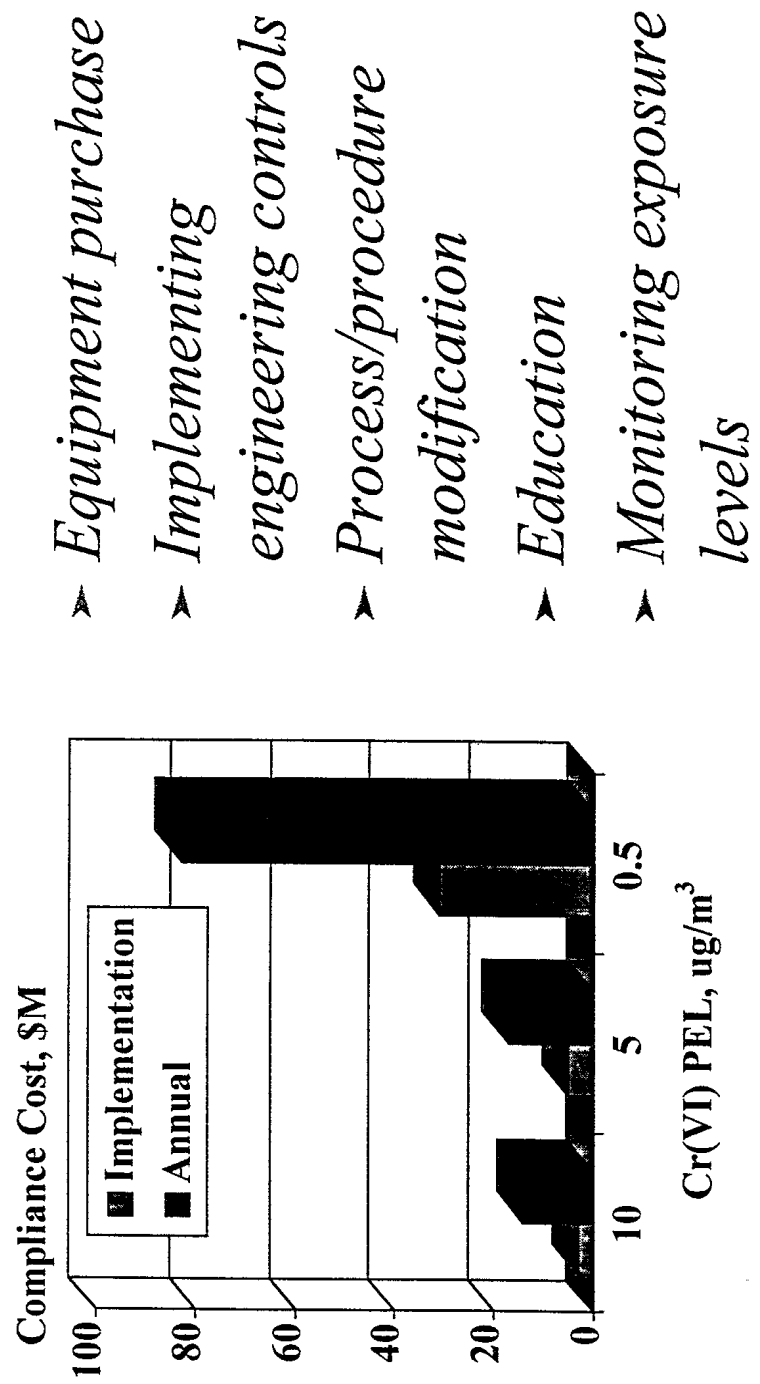
	<u>Current</u>	<u>Proposed</u>
➤ Cr(VI)	100	0.5
	(as chromates)	
➤ Mn	1000	200
➤ Ni	1000	50

All values in ug/m³

Manufacturing Operations Impact

- *Construction, repair, and fabrication of Navy facilities*
- *Metal cleaning of chromate-coated materials*
- *Electroplating*
- *Painting/application of chromate paints and coatings*
- *Welding, thermal spraying, thermal cutting, and gouging*

Economic Impact





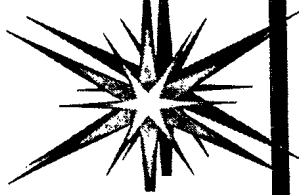
Potential Solutions

- ▶ *Engineering controls*
 - Commercially available, cost effective
- ▶ *Process modifications*
 - Can be developed, easy to implement
- ▶ *Materials modifications*
 - Major development and certification
- ▶ *Alternative practices (e.g., reduced work hours, training, monitoring)*
 - Expensive, cumbersome



Objective

- *Characterize airborne emissions of chromium, nickel, and manganese from welding and related operations in Navy fabrication and repair.*
- *Evaluate methods to minimize these emissions in order to comply with anticipated OSHA and EPA requirements.*



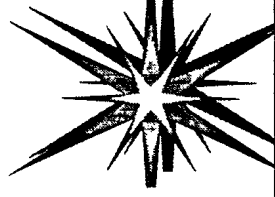
Baseline Fume Testing

> Operations, with duty cycle

• Oxy-Fuel Cutting (OFC)	100%
• Shielded Metal Arc Welding (SMAW)	66%
• Gas Metal Arc Welding (GMAW)	60%
• Flux Cored Arc Welding (FCAW)	60%

> Conditions

- Open space (high ceiling)
- 150 minute duration
- No engineering controls



Baseline Fume Testing

> Materials

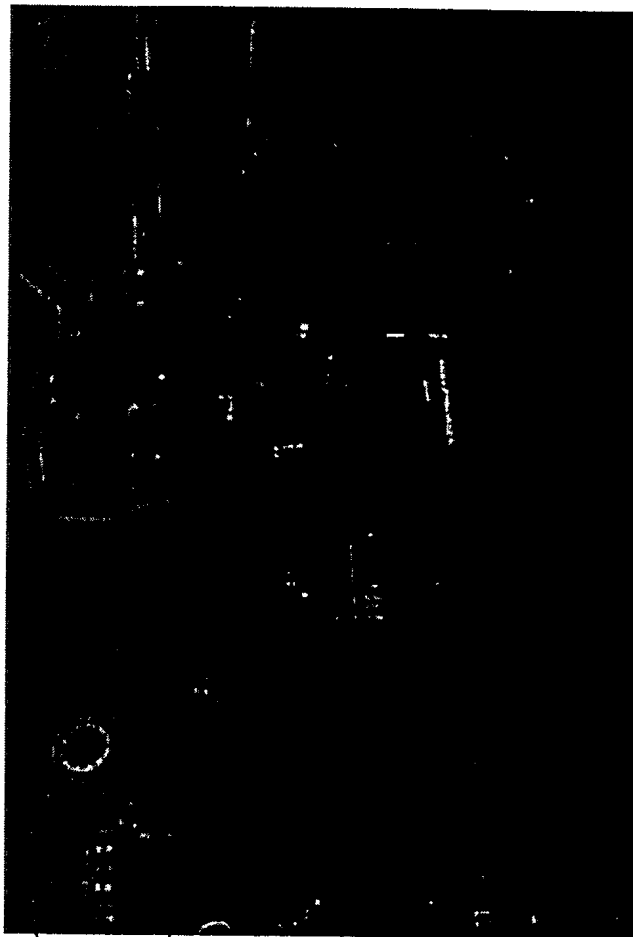
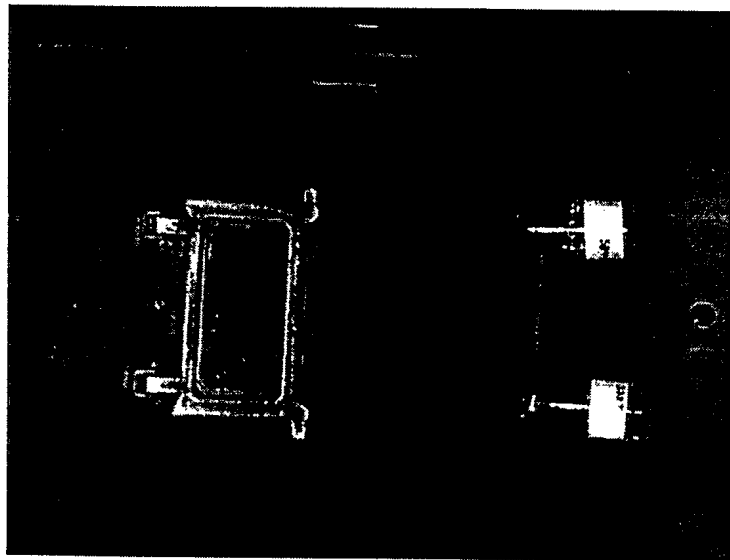
- **Plate - Mild steel, DH-36, ASTM A387-Gr.22, HSLA-65, HSLA-80, HSLA-100, HY-80, HY-100**
- **SMAW - 7018, 11018, 12018, 8018-B2L, 9018-B3L, 309-15, 309-16**
- **GMAW - 70S-6, 100S-1, 100S-2, 120S-1, 625**
- **FCAW - 71T-1, 101TM, 309LT-1**
- **Gases - Ar-2% O₂(M2), Ar-5% CO₂(C5), Ar-25% CO₂(C25), 100% CO₂**



Baseline Fume Analysis

- *Sampling*
 - *Stressors, test methods*
 - Cr(VI), Method 215
 - Total fume, ICP scan for 13 elements
 - *Locations*
 - Personal (operator's collar)
 - Area (10-15 feet from operation)
- *Calculate 8-hr time weighted average (TWA)*

Filter Placement



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Personal Results Summary - Current Requirements

Action level
Exceeds req't

% Cr	OFC	GMAW	SMAW	FCAW	Cr(VI) [100 ug/m3]
<0.50	0 - 2	0 - 0.4	0.3 - 0.7	0 - 0.4	
0.50 - 1.00	0.1 - 0.2	0.1 - 0.2	0.3 - 0.5	-----	
1.00 - 2.50	0.2 - 3	-----	3 - 8	-----	
>20	-----	5	2 - 16	?	
Mn [1000 ug/m3]					
<0.50	19 - 156	78 - 609	81 - 125	253 - 534	
0.50 - 1.00	8 - 29	59 - 75	100 - 159	-----	
1.00 - 2.50	3 - 17	-----	44 - 84	-----	
>20	-----	9	47 - 141	?	
Ni [1000 ug/m3]					
<0.50	1 - 81	2 - 17	1 - 6	1 - 16	
0.50 - 1.00	2 - 62	7 - 9	8 - 9	-----	
1.00 - 2.50	106 - 450	-----	1	-----	
>20	-----	540	8 - 62	?	

All fume values are 8-hr TWA in ug/m³

Personal Results Summary - Proposed Requirements

Action level
Exceeds req.

% Cr	OFC	GMAW	SMAW	FCAW
<0.50	0 - 2	0 - 0.4	0 - 0.7	0 - 0.4
0.50 - 1.00	0.1 - 0.2	0.1 - 0.2	0.3 - 0.5	-----
1.00 - 2.50	0.2 - 0.3	-----	0.8	-----
>20	-----	-----	12 - 167	?

Cr(VI)
[0.5 ug/m3]

% Cr	OFC	GMAW	SMAW	FCAW
<0.50	19 - 156	78 - 605	81 - 125	-----
0.50 - 1.00	8 - 29	59 - 75	100 - 159	-----
1.00 - 2.50	3 - 17	-----	44 - 84	-----
>20	-----	9	47 - 141	?

Mn
[200 ug/m3]

% Cr	OFC	GMAW	SMAW	FCAW
<0.50	-----	2 - 17	1 - 6	1 - 16
0.50 - 1.00	-----	7 - 9	8 - 9	-----
1.00 - 2.50	106 - 150	-----	1	-----
>20	-----	-----	-----	?

Ni
[50 ug/m3]

All fume values are 8-hr TWA in ug/m³

Area Results Summary - Proposed Requirements

Action level
Exceeds req.

% Cr	OFC	GMAW	SMAW	FCAW
<0.50	0 - 0.2	0 - 0.2	0.3 - 1	0 - 0.4
0.50 - 1.00	0.1 - 0.2	0.1 - 0.2	0.3	-----
1.00 - 2.50	0.1 - 0.2	-----	-----	-----
>20	-----	-----	15 - 28	?

Cr(VI)
[0.5 ug/m3]

Min
[200 ug/m3]

Ni
[50 ug/m3]

<0.50	2 - 122	72 - 550	78 - 181	121 - 301
0.50 - 1.00	5 - 40	62 - 75	78 - 128	-----
1.00 - 2.50	2 - 16	-----	25 - 112	-----
>20	-----	7	53 - 88	?

<0.50	1 - 81	1 - 13	1 - 5	1 - 16
0.50 - 1.00	3 - 38	6 - 8	3 - 5	-----
1.00 - 2.50	69 - 625	-----	1	-----
>20	-----	169	5 - 38	?

All fume values are 8-hr TWA in ug/m³

Personal Results Summary - Cr(VI) Requirements

Action level
Exceeds req

% Cr	OFC	GMAW	SMAW	FCAW	Cr(VI) [100 ug/m3]
<0.50	0 - 2	0 - 0.4	0.3 - 0.7	0 - 0.4	
0.50 - 1.00	0.1 - 0.2	0.1 - 0.2	0.3 - 0.5	-----	
1.00 - 2.50	0.2 - 3	-----	3 - 8	-----	
>20	-----	5		?	

% Cr	OFC	GMAW	SMAW	FCAW	Cr(VI) [5 ug/m3]
<0.50	0 - 2	0 - 0.4	0.3 - 0.7	0 - 0.4	
0.50 - 1.00	0.1 - 0.2	0.1 - 0.2	0.3 - 0.5	-----	
1.00 - 2.50	0.2 - 3	-----		-----	
>20	-----			?	

% Cr	OFC	GMAW	SMAW	FCAW	Cr(VI) [0.5 ug/m3]
<0.50		0 - 0.4		0 - 0.4	
0.50 - 1.00	0.1 - 0.2	0.1 - 0.2		-----	
1.00 - 2.50		-----		-----	
>20	-----		12-167	?	

All fume values are 8-hr TWA in ug/m³

Personal Results Summary - Mn

Action level

% Cr	OFC	GMAW	SMAW	FCAW
<0.50	19 - 156	78 - 609	81 - 125	253 - 534
0.50 - 1.00	8 - 29	59 - 75	100 - 159	-----
1.00 - 2.50	3 - 17	-----	44 - 84	-----
>20	-----	9	47 - 141	?

Mn
[1000 ug/m3]

Mn
[200 ug/m3]

All fume values are 8-hr TWA in ug/m³



Personal Results Summary - Ni

Action level
Exceeds Reg. II

% Cr	OFC	GMAW	SMAW	FCAW
<0.50	1 - 81	2 - 17	1 - 6	1 - 16
0.50 - 1.00	2 - 62	7 - 9	8 - 9	-----
1.00 - 2.50	106 - 450	-----	1	-----
>20	-----	540	8 - 62	?

Ni
[1000 ug/m3]

<0.50	1 - 81	2 - 17	1 - 6	1 - 16
0.50 - 1.00	2 - 62	7 - 9	8 - 9	-----
1.00 - 2.50	-----	-----	1	-----
>20	-----	-----	8 - 62	?

Ni
[100 ug/m3]

<0.50	-----	2 - 17	1 - 6	1 - 16
0.50 - 1.00	-----	7 - 9	8 - 9	-----
1.00 - 2.50	106 - 450	-----	1	-----
>20	-----	540	8 - 62	?

Ni
[50 ug/m3]

All fume values are 8-hr TWA in ug/m³

Results - OFC

Action level
Exceeds level

Material	% Cr	Cr(VI)	Mn	Ni
DH-36	<0.50	0.10	21	1
HSLA-65	<0.50	1.9	26	8
HSLA-80	0.50 - 1.00	0.10	29	2
HSLA-100	0.50 - 1.00	0.16	8	1
HY-100	1.00 - 2.50	0.20	3	11
		1.5	7	13
		2.8	13	239
		1.75	17	450

All fume values are 8-hr TWA in ug/m³



Results - SMAW

Action level
 Exceeds level

Material	% Cr	Cr(VI)	Mn	Ni
11018 (Mfr A)	<0.50	0.66	122	6
11018 (Mfr B)	<0.50	0.38	125	5
12018 (Mfr C)	0.50 - 1.00	0.47	159	9
12018 (Mfr D)	0.50 - 1.00	0.30	100	8

Material	% Cr	Cr(VI)	Mn	Ni
309-15 (Old)	>20		141	23
309-15 (New)	>20		106	18
309-16 (Old)	>20		116	6
309-16 (New)	>20		47	8

All fume values are 8-hr TWA in ug/m³



Results - GMAW

Material	Shielding	% Cr	Cr(VI)	Mn	Ni
100S-1	C5	<0.50	0.38	100	8
100S-1	M2	<0.50	0.29	106	12
100S-2	C5	<0.50	0.05		17
100S-2	C5	<0.50	0.05	609	16
120S-1	C5	0.50 - 1.00	0.14	75	9
120S-1	M2	0.50 - 1.00	0.17	59	7

Action level

Exceeds level

All fume values are 8-hr TWA in ug/m³



Results - Lower Strength Steels

Process	Material	Shielding	% Cr	Cr(VI)	Mn	Ni
SMAW	7018	---	<0.50	0.34	81	1
SMAW	7018	---	<0.50	0.50	109	1
GMAW	70S-6	C5	<0.50	0.05	122	2
FCAW	71T-1	CO2	<0.50	0.38		1
FCAW	71T-1	C25	<0.50	0.29		1

Action level

All fume values are 8-hr TWA in ug/m³



Conclusions

- *The potential exists, with the materials and operations investigated, to exceed the lower anticipated ceilings for Cr(VI), Mn, and Ni for both operators and personnel in the immediate area surrounding the operation.*
- *The PEL finally adopted by OSHA will dictate the extent of this problem, and, therefore, the cost of the solution.*



Conclusions (continued)

- *Of the identified solutions, application of engineering controls appears to be the most appropriate for successful reduction of airborne emissions.*
- *Variability observed in the results may be inherent to the operations and measurement techniques. A broader data base is required to resolve issues and establish the statistical significance of the data.*

