2.0

EMISSION FACTORS

The objective of this portion of the study was to identify and/or develop emission factors that could be used to estimate facility-specific and AQMD-wide estimates of chromium, lead, nickel and zinc emissions from metal welding, cutting and spraying process information provided by survey respondents. As will be discussed, no comprehensive, immediately usable set of emission factors was available. Furthermore, emissions testing for emission factor determination was outside the scope of the project. This section describes how emission factors were developed from the information at hand. Information sources are briefly described in Section 2.1. Methods for converting the available emission factors into a format useful for this inventory are discussed in Section 2.2. Finally, the working set of emission factors is presented in Section 2.3.

2.1 INFORMATION SOURCES

The information available for each of the emission source categories (i.e., welding, cutting, and metal spraying) differed markedly in quantity and quality. The information sources that were available for each type of metal process are outlined below.

2.1.1 Welding

More information was available for welding than for any of the other categories. The U.S. Environmental Protection Agency (USEPA) has published emission factors for welding in Section 12.19 of *AP-42, Compilation of Air Pollutant Emission Factors* (USEPA, 1995). The EPA also published a background document, *Development of Particulate and Hazardous Emission Factors for Electric Arc Welding – Revised Final Report* (MRI, 1994). This background document contains an extensive discussion of welding processes and an analysis of the documents used to develop welding emission factors.

Appendix B defines and describes the major welding processes encountered in the AQMD. These processes may be divided into three major groups:

- Resistance welding,
- Arc welding, and
- Oxyfuel welding.

Arc welding is further divided into non-consumable and consumable electrode arc welding. Non-consumable electrode arc welding consists of gas tungsten arc welding (GTAW) and plasma arc welding (PAW). Consumable electrode arc welding includes shielded metal arc welding (SMAW), Gas metal arc welding (GMAW), flux cored arc welding (FCAW), submerged arc welding (SAW), electrogas welding (EGW), Electroslag welding (ESW), and others. The background document for *AP-42* Section 12.19 states, "Only electric arc welding generates pollutants in quantities of major concern.[1] Resistance welding using certain materials also may

[1] As will be seen in Section 5, this is not true in the case of the emission inventory developed through this project.

generate hazardous pollutants. Due to the lower temperatures of the other welding processes, fewer fumes are released."

According to the *AP-42* background document, arc welding is the most commonly used process. The document reports that sales of consumable electrodes in 1991 were[2]:

- SMAW – 45 percent
- GMAW – 34 percent
- FCAW – 17 percent
- SAW – 4 percent

The background document also includes information of the usage at a British shipyard, a manufacturer of pressure vessels, and a California shipyard. Although usage of the different welding processes varied, SMAW was the most widely used process at the British shipyard and the pressure vessel manufacturer. The California shipyard used FCAW more than the other processes.

AP-42 contains chromium, hexavalent chromium, cobalt, manganese, and lead emission factors for SMAW, GMAW, FCAW, and SAW. Cobalt is not listed under the South Coast Air Quality Management District's (AQMD's) Rule 1401, and was therefore not considered further. Emission factors are published for specific electrodes used in each process. Actual emissions depend not only on the process and the electrode type, but also on the base metal material, voltage, current, arc length, shielding gas, travel speed, and welding electrode angle. The *AP-42* emission factors do not identify the relative importance of these additional variables.

PES investigated additional sources of information. The purposes of this investigation were (1) to extend the *AP-42* emission factors to cover additional processes and two other toxic metals (cadmium and zinc), (2) to simplify the *AP-42* emission factors so that they could be related to the base metal welded rather than to the electrode used, and (3) to update the *AP-42* emission factors (if possible) using newer information. The following additional references were obtained and reviewed:

Additional Reference W-1 (Gerstle et al., 1993)

Richard Gerstle, Sandra B. Hance, and George N. Csordas of the IT Corporation in Cincinnati, Ohio presented "Emission Factors for Arc Welding" at the 86th Annual Meeting of the Air and Waste Management Association (AWMA) at Denver, Colorado in June 1993. The study was conducted for the USEPA to determine the emissions of aluminum, copper, chromium, cobalt, nickel, manganese, vanadium, barium, and zinc and the amounts of these metals in slag. The industry and the Office of Toxic Substances needed these estimates for use in SARA, Title III, Section 313 reporting. Aluminum, cobalt, vanadium, and barium are not included in the AQMD's Rule 1401. (Vanadium pentoxide is included in Rule 1401). Estimates were developed for specific electrodes commonly used by industry.

[2] These percentages differ significantly from those determined by the present survey; see Section 5.2.2.

Additional Reference W-2 (Jacobs et al., 1995)

Bruce W. Jacobs and Barry D. Adams of General Physics Corporation in Columbia, Maryland and Amy Lafontaine Dean of the Directorate of Safety, Health and Environment, Aberdeen Proving Ground, Maryland presented "Emissions Characterization for Complex Welding, Cutting, Soldering and Brazing Operations" at the 88th Annual Meeting of the AWMA at San Antonio, Texas in June 1995. In this study, emissions were estimated for a Metal Working Training Center at Aberdeen Proving Ground. These emissions estimates were used in a permit application for the State of Maryland. Estimates were made for oxyacetylene welding, arc welding (i.e., for SMAW, GMAW, and GTAW), oxyacetylene cutting, air carbon arc cutting, brazing, and iron and torch soldering. The authors did not conduct any testing. All emission estimates were based on published data from the American Welding Society, the USEPA, the U.S. Army, and Airco Welding Products.

Additional Reference W-3 (Stern et al., 1978)

The AQMD provided a report of a study by the Danish Welding Institute on the generation of fumes by various welding processes. The USEPA had not reviewed this document when the *AP-42* emission factors were developed. The report's terminology for electrodes differs from that used in *AP-42*; the electrodes tested may be European and not easy to relate to those commonly used in the United States. This document contains data on fume chemistry but does not have fume generation rates. Therefore, the data cannot be used to develop emission factors. However, the document does discuss some of the factors that affect fume chemistry.

Additional Reference W-4 (Quimby and Ulrich, 1999)

B. J. Quimby and G. D. Ulrich of the Department of Chemical Engineering at the University of New Hampshire used a new fume chamber design to develop fume generation data for steady- and pulsed-current welding of mild steels using 92 percent argon/8 percent carbon dioxide shielding gas. The data presented in graphs demonstrates changes in the fume generation rate (in g/min) based on variation in voltage and wire feed speed. No data on toxic air contaminants were included.

Additional Reference W-5 (Paulson and Brenna, 1998)

Kathleen M. Paulson, P.E., of the Naval Facilities Engineering Service Center, Port Hueneme, CA and Reynold Brenna of the Naval Surface Warfare Center, Carderock Division, Bethesda, MD presented "Characterization of Welding Emissions at Naval Shipbuilding Support Activities" at the 91st Annual Meeting of the AWMA in San Diego in June 1998. This paper reports on measurements taken for comparison with proposed Occupational Safety and Health Administration permissible exposure levels. As such the data in this study are not directly related to emission factors.

2.1.2 Metal Cutting

Appendix B defines and describes the major metal cutting processes encountered in the AQMD. *AP-42* does not include any emission factors for metal cutting. The *AP-42* background document does identify and describe briefly various cutting processes. These include oxyfuel cutting and arc cutting. Arc cutting comprises plasma arc cutting (PAC), air carbon arc cutting

(CAC-A), shielded metal arc cutting (SMAC), gas metal arc cutting (GMAC), gas tungsten arc cutting (GTAC), oxygen arc cutting (AOC), and carbon arc cutting (CAC).

A limited amount of information on emissions from metal cutting was found. These references are described below.

Reference C-1 (Western Environmental Services, 1989)

The AQMD provided a report by Western Environmental Services of Redondo Beach, California on a source test of plasma arc cutting on stainless steel at a facility in Orange County. One test run was conducted. Particulate samples collected by EPA Method 5 were analyzed by ion chromatography for total and hexavalent chromium and for cadmium. The metal cut contained 15 to 18 percent chromium by weight. Emissions of cadmium were below the detection limit of 0.00005 lb/hr (0.0004 g/min). Total and hexavalent chromium emissions were 0.041 lb/hr (0.31 g/min) and 0.00027 lb/hr (0.0020 g/min), respectively.

Reference C-2 (Jacobs et al., 1995)

As discussed above, Bruce W. Jacobs and Barry D. Adams of General Physics Corporation and Amy Lafontaine Dean of the Directorate of Safety, Health and Environment at Aberdeen Proving Ground provided emission factors for oxyfuel cutting and CAC-A in a paper presented at the 88th Annual Meeting of the AWMA.

Reference C-3 (Kura et al., 1999)

B. Kura of the University of New Orleans, A. S. Wisbith and R. Stone of the Puget Sound Naval Shipyard, and T. Judy of the Naval Surface Warfare Center, Carderock Division, presented a paper, "Metal Cutting Operations: Emission Factors for Particulates, Metals and Metal Ions," at an emission inventory conference sponsored by the USEPA and the AWMA. These researchers took samples of fumes generated from oxyfuel and plasma arc cutting of various types of metal plates taken from submarines. The emission factors derived from these tests were much higher than those reported in the first two references. However, because the sampling techniques used were not isokinetic these emission factors were not used.

2.1.3 Metal Spraying

The evaluation of emission factors for toxic metals from spraying operations was based upon the results of 18 source tests at six facilities in the South Coast Air AQMD and in San Diego County.[3] Table 2-1 summarizes the nature of the tests. Note that the most recent test in this group was performed in 1991.

[3] The contractor conducted a brief literature review through the Internet and found no useful information.

2.2 DEVELOPMENT OF WORKING EMISSION FACTORS

2.2.1 Welding

Enough information was available to develop working emission factors for up to four pollutants (total chromium, nickel, lead and zinc) for six welding processes (GMAW, SMAW, FCAW, GTAW, PAW and OXY). No credible, supportable information on cadmium emissions from welding was found. Total chromium was used because relatively little information on hexavalent chromium was available.[4]

As will be discussed in Section 3.2, survey participants were asked to report their consumption of electrode materials (e.g. rod and/or wire), the annual hours spent in welding, and the types of metals welded. To be useful, the emission factors had to be in terms of some reported process variable. The *AP-42* welding emission factors are in form of mass pollutant emitted per mass of electrode consumed. Emission factors from other sources are in the form of mass pollutant emitted per unit of time welding. Both types of process variable (mass electrode and time spent welding) were reported by most of the survey respondents. However, many welding emission factors (including those in *AP-42*) are organized by very specific electrode type (e.g. "E310-15"), without regard to the type of metal welded. The questionnaire in the present study did *not* ask for the specific electrode type. During follow-up questioning, survey respondents either could not identify the electrode types that they used, or reported using a type not listed in *AP-42* or any other emissions literature.

Table 2-2 summarizes the methods used to develop the working emission factors. No data were available to justify modifying the *AP-42* emission factors for SMAW, GMAW, and FCAW. However, it was necessary to relate the electrode types in *AP-42* to the types of metals welded. This was done by reviewing the extensive process information in *Welding: Principles and Applications* (Jeffus, 1999). Additional information on electrode-base metal correlations was found through searches of the Internet and discussions with welding electrode suppliers. Table 2-3 summarizes the correspondences that were identified.

Although Additional Reference W-1 (Gerstle et al., 1993) provides emission factors for chromium and nickel for certain electrodes other than those in AP-42, it does not identify the type of welding or the metal substrate. However, by reviewing the aforementioned electrode-base metal correspondences, it was possible to deduce that many of Reference W-1's emission factors apply to welding with SMAW, GMAW and FCAW on steel or stainless steel. These emission factors were therefore included in the selection process. In addition, Gerstle et al. were the only researchers to provide SMAW, GMAW and FCAW emission factors for zinc. These were used for calculating zinc emissions from welding with SMAW, GMAW and FCAW on steel or stainless steel. The calculation of the zinc emission factors is shown in Table 2-4.

For GTAW and oxyacetylene welding (OXY), emission factors from Additional Reference W-2 (Jacobs et al., 1995) were used. These are shown in Table 2-5.

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[4] See Section 2.3.

Table 2-2

METHODS USED TO SELECT WORKING EMISSION FACTORS FOR WELDING

Process	Pollutants	Primary EF Sources	Data Processing	Selection	Final Units
GMAW	Cr, Ni, Pb	*AP-42*; Gerstle et al., 1993	Grouped electrodes by base metal	Highest EF for each base metal	10^{-1} lb/10^{3} lb electrode
	Zn	Gerstle et al., 1993	Deduced base metal type; converted units		
SMAW	Cr, Ni, Pb	*AP-42*; Gerstle et al., 1993	Grouped electrodes by base metal	Highest EF for each base metal	10^{-1} lb/10^{3} lb electrode
	Zn	Gerstle et al., 1993	Deduced base metal type; converted units		
FCAW	Cr, Ni, Pb	*AP-42*; Gerstle et al., 1993	Grouped electrodes by base metal	Highest EF for each base metal	10^{-1} lb/10^{3} lb electrode
	Zn	Gerstle et al., 1993	Deduced base metal type; converted units		
GTAW	Cr, Ni, Zn	Jacobs et al., 1995	Multiplied fume generation rate by toxic metal fractions	Highest EF when more than one available	g/min
PAW	Cr, Ni, Zn	Jacobs et al., 1995	Assumed same as GTAW	Highest EF when more than one available	g/min
OXY	Cr, Ni, Zn	Jacobs et al., 1995	Multiplied fume generation rate by toxic metal fractions	Used all available emission factors	g/min

Table 2-3

MAPPING OF ELECTRODES TO WELDING TYPE AND BASE METAL

Welding Method	Type of Metal Welded	Electrodes Used
GMAW	Mild Steel	E70S
	Stainless Steel	E308, ER316
	Aluminum	ER1260, ER5154
	Other	ERNiCrMo, ERNiCu
SMAW	Mild Steel	E6010, E6011, E6012, E6013, E7018, E7024, E7028, E8018
	Stainless Steel	E308, ER316
	High-Temperature Stainless Steel	E310
	Aluminum	E410
	Other	Eni-Cl, EniCrMo, Eni-Cu-2, ECoCr
FCAW	Mild Steel	E70T, E71T
	Stainless Steel	E308, ER316
	Aluminum	E410
	Other	No data

Table 2-4

CALCULATION OF EMISSION FACTORS FOR ZINC FROM WELDING

Electrode Type	Fume Generation Rate[a] (lb/100 lb)	Zinc as Percent of Total Fume[a]	Emission Factor[b] (10^{-1} lb/10^3 lb Electrode Consumed)
E70S-3	0.86	0.094	8.1E-02
E70S-6	0.79	0.078	6.2E-02
E308LSi	0.54	0.042	2.3E-02
E70T-1	0.87	0.065	5.7E-02
E71T-1	1.20	0.086	1.0E-01
E6010(A)	2.27	0.022	5.0E-02
E6010(B)	2.05	0.036	7.4E-02
E6011	3.84	0.016	6.1E-02
E6013	1.36	12	1.6E+01
E308-16	0.64	0.087	5.6E-02
E7018	1.57	0.12	1.9E-01

[a]Data from Gerstle et al., 1993.

[b]Calculated for this project.

Table 2-5

EMISSION FACTOR DATA FOR GTAW AND OXYACETYLENE WELDING

Process	Material Welded/Electrode Type	Fume Generation Rate (g/min)	Fume Composition (Percent by Weight)		
			Chromium	Nickel	Zinc
GTAW	Stainless Steel/SS Welding Rod	0.0025	20	10	
	Aluminum/Aluminum Welding Rod	0.0065			0.1
	Titanium/Titanium Filler Wire	0.0065		0.8	
	Inconel/Inconel Filler Wire	0.0065	21	55	
	Cobalt/Cobalt Filler Wire	0.0065	20	10	
	Mg/Mg Filler	0.0065			2
Oxyacetylene	Carbon Steel/Mild Steel Welding Rod	0.38			
	4130 Steel/4130 Filler Wire	0.38	0.95		

Source: Jacobs et al., 1995.

2.2.2 Metal Cutting

For plasma arc cutting (PAC) on stainless steel, the emission factors developed through the source test described in Reference C-1 (Western Environmental Services, 1989) were used.[5] Table 2-6 shows the metal cutting emission factor information obtained from Reference C-2 (Jacobs et al., 1995). For air carbon arc cutting (CAC-A), the maximum emission factor for each toxic metal, irrespective of the type of metal cut, was selected. For all cutting methods except PAC and CAC-A, the Reference C-2 emission factors for acetylene were used.

Table 2-6

EMISSION FACTOR DATA FOR AIR CARBON ARC AND OXYACETYLENE CUTTING

Process	Material Cut	Fume Generation Rate (g/min)	Fume Composition (Percent by Weight)		
			Chromium	Nickel	Zinc
CAC-A	6061 Aluminum	0.38	0.2		0.25
	Copper Clad Rods	0.38			
	1040 Carbon Steel	0.38			
Oxyacetylene	Steel Plate	0.38	0.02	0.05	0.36

Source: Jacobs et al., 1995.

2.2.3 Metal Spraying

Each of the source tests listed in Table 2-1 was reviewed to determine whether proper sampling and analytical procedures were followed and information necessary for emission factor calculation was reported. An emission factor for chromium or nickel was defined as follows:

$$EF_i = E_i/S_I \qquad [2\text{-}1]$$

where E_i is the mass emitted per unit time (e.g. pounds per hour) of the pollutant and S_i is the *mass of the element of interest* that is sprayed per unit time. To calculate the latter quantity, reported composition data (manufacturer's specifications and/or laboratory analyses made specifically for the source test) were examined to determine the pollutant's weight fraction of the powder sprayed. For example, suppose that 8 lb/hr of a material containing 70 percent dichromium trioxide (Cr_2O_3) is sprayed. The atomic weights of chromium and oxygen are 51.996 and 15.994, respectively. Therefore the fraction of chromium in the sprayed material is:

$$\text{Fraction Cr} = (0.70)\,[(2)(51.996)]/[(2)(51.996) + (3)(15.994)]$$

$$= 0.479$$

The value of S_i in this case would then be (8)(0.479) = 3.8 lb/hr.

[5] See Section 2.1.2.

Chromium

Table 2-7 summarizes the source test data and the emission factor calculations for chromium. Each test run was considered a "case." Emission factors for both total chromium and hexavalent chromium [Cr(VI)] were calculated. Note that in most, if not all, cases the chromium in the *spray material* is not hexavalent. In all the tests examined for this project, however, hexavalent chromium was present in the emissions. Therefore, some of the chromium in the material was most likely converted to hexavalent form by the spray process. This was confirmed in a laboratory test in which Cr(VI) comprised 30 percent of the fumes generated in plasma metal sprayer in which only Cr (III) was sprayed (Sawatari and Serita, 1986). In the tests examined, the fraction of total chromium represented by Cr(VI) ranges from about 0.1 to 49 percent. These tests were generally conducted before improvements in laboratory methodologies allowed reliable discrimination between total and hexavalent chromium. Therefore, the hexavalent chromium data in these tests are questionable. For the emission factor calculations, the S_i term refers to "chromium" in the sprayed material, whatever its oxidation state, and whatever the oxidation state of the pollutant emitted.

Table 2-8 summarizes descriptive statistics for the chromium emission factors.[6] Other statistical analyses were performed on these values, to determine whether they were correlated with type of emission control, amount of metal in the sprayed material, and type of material sprayed. The only statistically significant result found (at the 95-percent confidence level) was that use of a cyclone, cartridge dust collector and HEPA filter system (Case 1) resulted in a lower emission factor for both total and hexavalent chromium.

Insufficient information was available to relate emission factors to other process variables, such as type of spray nozzle, argon and hydrogen gas pressure, spraying distance, and arc current and potential. Values for these parameters were available only for a few of the sources tested.

That the median chromium emission factors are lower than their respective means indicates that the distribution is skewed toward lower values. To be conservative, it was decided to use the mean value for total chromium, 0.051 lb/lb sprayed. Given the aforementioned uncertainty in the chrome speciation data, it was decided *not* to recommend an emission factor for hexavalent chromium.

[6] Case 1, in which a HEPA filter system was used, was not included in the calculations. See text.

Table 2-8

DESCRIPTIVE STATISTICS FOR CHROMIUM EMISSION FACTORS FOR METAL SPRAYING

Pollutant	Emission Factor (lb per lb element sprayed)[a]						
	Minimum	Maximum	Median	Mean	Standard Deviation	95% Conf. Interval Low	95% Conf. Interval High
Total Chromium	0.00090	0.23	0.042	0.051	0.0620	0.017	0.085
Hexavalent Chromium	0.000063	0.0144	0.0012	0.0033	0.0048	0.0008	0.0057

[a]Does not include the case with a HEPA filter system.

<u>Nickel</u>

Table 2-9 shows the source test data and the emission factor calculations for nickel. All but one of the calculated emission factors are between 0.042 and 0.25 lb/lb. The single exception was Case 6, in which the sample was collected upstream of a wet scrubber (Case 7). This case is problematic, in that it appears that over 90 percent of the nickel in the spray powder fails to reach the surface onto which it is sprayed. This is unreasonable. The source test report for Cases 6 and 7 was reviewed thoroughly and no supporting documentation for the nickel content of the powder was found. It was decided therefore to remove Cases 6 and 7 from the statistical analysis of the nickel spraying data.

The mean nickel emission factor for the two cases with no emission controls (Cases 1 and 2) was 0.15 lb/lb. For the remaining three cases, in which a water wall spray booth was used, the mean nickel emission factor was 0.055 lb/lb. These values were used to calculate nickel emissions, where applicable, from the survey response data.

2.3 SUMMARY OF EMISSION FACTORS USED IN THE INVENTORY

Tables 2-10 through 2-12 present the emission factors selected for welding, cutting and metal spraying emission inventories, respectively.

Table 2-10

WELDING EMISSION FACTORS USED IN THE INVENTORY

Welding Technique	Type of Metal Welded	Emission Factor (10^{-1} lb/10^{3} lb Electrode Consumed			
		Nickel	Chromium	Zinc	Lead
GMAW	Mild Steel	0.01	0.01	0.081	NA
	Stainless Steel	2.26	5.28	0.056	NA
	Aluminum	NA[a]	0.1	NA	NA
	Other	12.5	3.53	NA	NA
SMAW	Mild Steel	0.51	0.17	16.3	1.62
	Stainless Steel	0.55	5.22	0.056	NA
	High Temperature Stainless Steel	1.96	25.3	NA	0.24
	Aluminum	0.14	NA	NA	NA
	Other	8.9	4.2	NA	NA
FCAW	Mild Steel	0.05	0.04	0.1	NA
	Stainless Steel	0.93	9.7	0.056	NA
	Aluminum	0.14	NA	NA	NA
	Other	1.12	9.69	NA	NA

Welding Technique	Type of Metal Welded	Emission Factor (g/min)			
		Nickel	Chromium	Zinc	Lead
GTAW & PAW	Mild Steel	0.00025	0.0005	NA	NA
	Stainless Steel	0.00025	0.0005	NA	NA
	Aluminum	NA	NA	0.0000065	NA
	Other	0.003575	0.001365	0.00013	NA
Oxyacetylene	Mild Steel	NA	NA	NA	NA
	Stainless Steel	NA	0.00361	NA	NA
	Aluminum	NA	NA	NA	NA
	Other	NA	NA	NA	NA

[a]NA = No emission factor available.

Table 2-11

CUTTING EMISSION FACTORS USED IN THE INVENTORY

Cutting Method	Metal Cut	Emission Factors (g/min)		
		Nickel	Chromium	Zinc
CAC	All	1.9E-04	7.6E-05	1.4E-03
CAC-A	All	1.9E-04	7.6E-04	9.5E-04
GMAC	All	1.9E-04	7.6E-05	1.4E-03
Laser	All	1.9E-04	7.6E-05	1.4E-03
OAC	All	1.9E-04	7.6E-05	1.4E-03
OXY	All	1.9E-04	7.6E-05	1.4E-03
PAC	Stainless Steel		3.1E-01	
	All Others	1.9E-04	7.6E-05	1.4E-03

Table 2-12

METAL SPRAYING EMISSION FACTORS USED IN THE INVENTORY

Controls	Lb Metal per lb Element Sprayed	
	Total Chromium[a]	Nickel
Uncontrolled	5.1E-02	1.5E-01
Spray Booth		5.5E-02
HEPA Filter	1.0E-05	

[a]Uncontrolled and spray booth emission factors are essentially the same; one wet scrubber included in the data set.

2.4 DISCUSSION

No emissions were estimated for resistance welding and submerged arc welding (SAW). The background document for *AP-42* indicated that no air toxics emissions would expected from resistance welding. Emission factors for SAW are between two and three orders of magnitude lower than those for SMAW, GMAW, and FCAW (MRI, 1994).

Data on the partitioning of chromium emissions among oxidation states were to scarce to permit development of an emission factor specific to hexavalent chromium. Analysis of the *AP-42* emission factors found that a 95-percent confidence interval for the percentage of total emissions represented by Cr(VI) is 9 to 84 percent.

There are no emission factors for cadmium in Table 2-10 and few factors for lead. Although the emission rate of a particular metal species depends upon many factors other than the content of that species in the electrodes consumed or the metal welded, one would reasonably expect that there would be no emissions in the absence of the species. Several material safety data sheets (MSDSs) for the electrodes considered were reviewed to determine cadmium and/or lead was. A summary of these MSDSs is given in Table 2-13. As can be seen from this table, no cadmium and lead were present.[7]

Table 2-13

TOXIC METAL CONTENT OF SELECTED ELECTRODES (WIRES AND RODS) AS REPORTED ON MATERIAL SAFETY DATA SHEETS

	Weight Percentage				
Electrode	Chromium	Nickel	Zinc	Cadmium	Lead
E110	<3	<4	NR	NR	NR
E11018	<5	<5	NR	NR	NR
E308	18 - 22	9 - 12	NR	NR	NR
E310	25 - 29	20 - 23	NR	NR	NR
E316	18 - 20	11 - 14	NR	NR	NR
E410	10 - 25	0 - 30	NR	NR	NR
E6010	NR[a]	NR	NR	NR	NR
E6011	NR	NR	NR	NR	NR
E6012	NR	NR	NR	NR	NR
E6013	NR	NR	NR	NR	NR
E7018	<9	<5	NR	NR	NR
E7024	NR	NR	NR	NR	NR
E7028	NR	NR	NR	NR	NR
E70S	NR	NR	NR	NR	NR
E70T	NR	NR	NR	NR	NR
E71T	NR	NR	NR	NR	NR
E8018	<5	<5	NR	NR	NR
E9018	<5	<5	NR	NR	NR
E9018	<9	<5	NR	NR	NR
ER316	10 - 32	0 - 37	NR	NR	NR

[a]NR = MSDS does not report this element in the electrode's composition.

The emission factor for total chromium from plasma arc cutting on stainless steel is four orders of magnitude higher than those for other metals. This factor is based upon a single source test, and is therefore of questionable validity.

[7] Nevertheless, *AP-42* has lead emission factors for two of these electrodes.