Emission Factor Documentation for AP-42
Section 12.20

Electroplating

Final Report

For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group

EPA Contract 68-D2-0159
Work Assignment No. III-01

MRI Project No. 4603-01

July 1996

Emission Factor Documentation for AP-42
Section 12.20

Electroplating

Final Report

For U. S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Emission Factor and Inventory Group
Research Triangle Park, NC 27711

Attn: Mr. Ron Myers (MD-14)

EPA Contract 68-D2-0159
Work Assignment No. III-01

MRI Project No. 4603-01

July 1996

NOTICE

The information in this document has been funded wholly or in part by the United States Environmental Protection Agency under Contract No. 68-D2-0159 to Midwest Research Institute. It has been reviewed by the Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, and has been approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U. S. Environmental Protection Agency (EPA), under Contract No. 68-D2-0159, Work Assignment No. III-01. Mr. Ron Myers was the requester of the work.

Approved for:

MIDWEST RESEARCH INSTITUTE

Roy Neulicht
Program Manager
Environmental Engineering Department

Jeff Shular
Director, Environmental Engineering
Department

July 1996

CONTENTS

Page

LIST OF FIGURES viii
LIST OF TABLES ix

1. INTRODUCTION 1-1
2. INDUSTRY DESCRIPTION 2-1
   2.1 INDUSTRY CHARACTERIZATION 2-1
   2.2 PROCESS DESCRIPTION 2-1
      2.2.1 Chromium Electroplating 2-2
      2.2.2 Other Types of Electroplating 2-10
3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES 3-1
   3.1 LITERATURE SEARCH AND SCREENING 3-1
   3.2 DATA QUALITY RATING SYSTEM 3-1
   3.3 EMISSION FACTOR QUALITY RATING SYSTEM 3-3
   3.4 EMISSION TEST METHODS FOR CHROMIUM ELECTROPLATING AND CHROMIC ACID ANODIZING 3-3
   3.5 FACTORS AFFECTING CHROMIUM EMISSIONS FROM ELECTROPLATING AND ANODIZING 3-5
   3.6 EMISSION FACTOR UNITS FOR ELECTROPLATING AND CHROMIC ACID ANODIZING 3-8
      3.6.1 Electroplating Emission Factor Units 3-8
      3.6.2 Chromic Acid Anodizing Emission Factor Units 3-8
4. AP-42 SECTION DEVELOPMENT 4-1
   4.1 REVIEW OF SPECIFIC DATA SETS 4-1
      4.1.1 Reference 1 4-1
      4.1.2 Reference 2 4-1
      4.1.3 Reference 3 4-2
      4.1.4 Reference 4 4-3
      4.1.5 Reference 5 4-4
      4.1.6 Reference 6 4-4
      4.1.7 Reference 7 4-6
      4.1.8 Reference 8 4-7
      4.1.9 Reference 9 4-7
      4.1.10 Reference 10 4-8
      4.1.11 Reference 11 4-9
      4.1.12 Reference 12 4-10
      4.1.13 Reference 13 4-11
      4.1.14 Reference 14 4-12
      4.1.15 Reference 15 4-13
      4.1.16 Reference 16 4-13
      4.1.17 Reference 17 4-15
      4.1.18 Reference 18 4-15
      4.1.19 Reference 19 4-16
      4.1.20 Reference 20 4-17
      4.1.21 Reference 21 4-18

TABLE OF CONTENTS (continued)

Page

4.1.22 Reference 22 4-19
4.1.23 Reference 23 4-19
4.1.24 Reference 24 4-19
4.1.25 Reference 25 4-20
4.1.26 Reference 26 4-20
4.1.27 Reference 27 4-21
4.1.28 Reference 28 4-21
4.1.29 Reference 29 4-21
4.1.30 Reference 30 4-22
4.1.31 Reference 31 4-22
4.1.32 Reference 33 4-23
4.1.33 Reference 58 4-23
4.1.34 Reference 59 4-24
4.1.35 Reference 62 4-24
4.1.36 Reference 63 4-25
4.1.37 Reference 66 4-25
4.1.38 Reference 67 4-25
4.1.39 Reference 71 4-26
4.1.40 Reference 74 4-27
4.1.41 Reference 75 4-27
4.1.42 Reference 77 4-27
4.1.43 Reference 78 4-28
4.1.44 Reference 81 4-28
4.1.45 Reference 83 4-29
4.1.46 Reference 84 4-29
4.1.47 Reference 85 4-29
4.1.48 Reference 86 4-30
4.1.49 Reference 88 4-30
4.1.50 Reference 89 4-31
4.1.51 Reference 90 4-31
4.1.52 Reference 93 4-31
4.1.53 Reference 94 4-32
4.1.54 Reference 95 4-32
4.1.55 Reference 98 4-33
4.2 DEVELOPMENT OF CANDIDATE EMISSION FACTORS 4-34
4.2.1 General Procedures 4-34
4.2.2 Hard Chromium Electroplating 4-35
4.2.3 Decorative Chromium Electroplating 4-36
4.2.4 Chromic Acid Anodizing 4-37
4.2.5 Total PM Emissions From Chromium Electroplating and Chromic Acid Anodizing 4-38
4.2.6 Electroplating of Other (Nonchromium) Metals 4-39
4.2.7 Statistical Analysis of Emission Factor Data 4-39

TABLE OF CONTENTS (continued)

Page

4.3 ESTIMATES OF EMISSIONS FROM OTHER TYPES OF ELECTROPLATING . . . 4-39
4.3.1 Uncontrolled Emissions From Nonchromium Electroplating 4-39
4.3.2 Controlled Emissions From Nonchromium Electroplating 4-40
4.3.3 Emissions From Air Sparging and Electroless Plating 4-41
4.3.4 Example Calculations 4-42

5. PROPOSED AP-42 SECTION 12.20 5-1

LIST OF FIGURES

Figure		Page
2-1	Flow diagram for a typical hard chromium plating process	2-13
2-2	Flow diagram for decorative chromium plating on a metal substrate	2-14
2-3	Flow diagram for a typical chromic acid anodizing process	2-15

LIST OF TABLES

Table		Page
4-1.	REFERENCES NOT USED FOR EMISSION FACTOR DEVELOPMENT	4-44
4-2.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 1	4-46
4-3.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 2	4-47
4-4.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 3	4-48
4-5.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 4	4-49
4-6.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 5	4-50
4-7.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 6	4-51
4-8.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 7	4-52
4-9.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 8	4-54
4-10.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 9	4-55
4-11.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 10	4-56
4-12.	AVERAGE OPERATING PARAMETERS MONITORED DURING EACH EMISSIONS TEST RUN	4-57
4-13.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 11	4-58
4-14.	DIMENSIONS AND OPERATING PARAMETERS FOR THE SEVEN HARD CHROMIUM PLATING TANKS FOR REFERENCE 12	4-59
4-15.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 12	4-60
4-16.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 13	4-61
4-17.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 14	4-62
4-18.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 15	4-63
4-19.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 16	4-64
4-20.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 17	4-65
4-21.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 19	4-66
4-22.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 20	4-67
4-23.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR	

LIST OF TABLES (continued)

Table		Page
	REFERENCE 21	4-68
4-24.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 22	4-69
4-25.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 23	4-70
4-26.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 24	4-71
4-27.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 25	4-72
4-28.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 26	4-74
4-29.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 27	4-76
4-30.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 28	4-78
4-31.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 29	4-80
4-32.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 30	4-81
4-33.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 31	4-83
4-34.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 33	4-84
4-35.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 58	4-85
4-36.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 59	4-86
4-37.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 62	4-87
4-38.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 63	4-88
4-39.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 66	4-90
4-40.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 67	4-91
4-41.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 71	4-94
4-42.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 74	4-95
4-43.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 75	4-96
4-44.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 77	4-97
4-45.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR	

LIST OF TABLES (continued)

Table Page

REFERENCE 78 4-98

LIST OF TABLES (continued)

Table		Page
4-46.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 81	4-99
4-47.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 83	4-100
4-48.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 84	4-101
4-49.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 85	4-102
4-50.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 86	4-103
4-51.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 88	4-104
4-52.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 89	4-105
4-53.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 90	4-106
4-54.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 93	4-107
4-55.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 94	4-108
4-56.	SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 95	4-109
4-57.	SUMMARY OF TEST DATA FOR ELECTROPLATING	4-110
4-58.	SUMMARY OF CANDIDATE EMISSION FACTORS FOR CHROMIUM ELECTROPLATING	4-117
4-59.	SUMMARY OF CANDIDATE EMISSION FACTORS FOR ELECTROPLATING--OTHER METALS	4-118
4-60.	SUMMARY OF CANDIDATE EMISSION FACTORS FOR ELECTROPLATING--OTHER METALS	4-119

EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 12.20
Electroplating

1. INTRODUCTION

The document *Compilation of Air Pollutant Emission Factors* (AP-42) has been published by the U. S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State and local air pollution control programs, and industry.

An emission factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors usually are expressed as the weight of pollutant divided by the unit weight, volume, distance, or duration of the activity that emits the pollutant. The emission factors presented in AP-42 may be appropriate to use in a number of situations, such as making source-specific emission estimates for areawide inventories for dispersion modeling, developing control strategies, screening sources for compliance purposes, establishing operating permit fees, and making permit applicability determinations. The purpose of this report is to provide background information from test reports and other information to support AP-42 Section 12.20, Electroplating.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the electroplating industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from electroplating. Section 3 is a review of emission data collection and laboratory analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details how the new AP-42 section was developed. It includes the review of specific data sets and a description of how candidate emission factors were developed. Section 5 presents the AP-42 Section 12.20, Electroplating.

2. INDUSTRY DESCRIPTION

This section provides a brief overview of electroplating, including industry characteristics and general process descriptions. However, emphasis is placed on chromium electroplating and chromic acid anodizing because the majority emissions data and other information available were for this area of the electroplating industry. Process descriptions, sources of emissions, and available control technology are described for chromium electroplating and chromic acid anodizing.

2.1 INDUSTRY CHARACTERIZATION[1-2]

Electroplating, which falls under Standard Industrial Classification (SIC) 3471, is performed in job shops, where a customer's work is plated, and in captive or in-house shops. In 1992, there were approximately 7,500 plating facilities in the United States, which was a decrease from the 12,000 reported facilities in 1980. The reduction occurred primarily in the number of smaller job shops and was related to difficulties in meeting the waste regulations imposed on plating effluents. The six-digit Source Classification Code (SCC) for electroplating is 3-09-010.

For chromium electroplating and chromic acid anodizing, operations range in size from small shops, with one or two tanks that are operated only a few hours per week, to large shops with several tanks that are operated 24 hours per day, 7 days per week. Many plating and anodizing operations are captive shops that perform chromium electroplating or chromic acid anodizing as one operation within or for a manufacturing facility, while others are job shops that provide custom plating or anodizing services for many different clients. Captive and job shops may perform hard or decorative chromium plating, chromic acid anodizing, or any combination of these three operations.

The estimated number of chromium electroplating shops nationwide is 1,540 hard chromium plating facilities and 2,800 decorative chromium plating facilities. The estimated number of chromic acid anodizing shops nationwide is 680. Electroplating and anodizing shops typically are located in or near industrial centers in areas of high population density. States with large numbers of chromium electroplaters include California, Illinois, Massachusetts, Michigan, New York, Ohio, and Pennsylvania.

2.2 PROCESS DESCRIPTION[2-3]

Electroplating is the process of applying a metallic coating to an article by passing an electric current through an electrolyte in contact with the article, thereby forming a surface having properties or dimensions different from those of the article. Essentially any electrically conductive surface can be electroplated. Special techniques, such as coating with metallic-loaded paints or silver-reduced spray, can be used to make nonconductive surfaces, such as plastic, electrically conductive. The metals and alloy substrates electroplated on a commercial scale are cadmium, chromium, cobalt, copper, gold, indium, iron, lead, nickel, platinum group metals, silver, tin, zinc, brass, bronze, many gold alloys, lead-tin, nickel-iron, nickel-cobalt, nickel-phosphorus, tin-nickel, tin-zinc, zinc-nickel, zinc-cobalt, and zinc-iron. Electroplated materials are generally used for a specific property or function, although there may be some overlap, e.g., a material may be electroplated for decorative use as well as corrosion resistance. Table 2-1 shows the various uses for electroplating and the metals employed.

The essential components of an electroplating process are an electrode to be plated (the cathode or substrate), a second electrode to complete the circuit (the anode), an electrolyte containing the metal ions to

be deposited, and a direct current power source. The electrodes are immersed in the electrolyte with the anode connected to the positive leg of the power supply and the cathode to the negative leg. As the current is increased from zero, a point is reached where metal plating begins to occur on the cathode. The plating tank is either made of or lined with totally inert materials to protect the tank. Anodes can be either soluble or insoluble, with most electroplating baths using one or the other type. The majority of power supplies are solid-state silicon rectifiers, which may have a variety of modifications, such as stepless controls, constant current, and constant voltage. Plate thickness is dependent on the cathode efficiency of a particular plating solution, the current density, and the amount of plating time. The following section describes the process, emissions, and emission control technology associated with the chromium electroplating industry. Following the description of chromium plating, brief descriptions of other types of electroplating are presented.

2.2.1 Chromium Electroplating

Chromium plating and anodizing operations include hard chromium electroplating of metals, decorative chromium electroplating of metals, decorative chromium electroplating of plastics, chromic acid anodizing, and trivalent chromium plating. Each of these categories of the chromium electroplating industry is described below.

2.2.1.1 Hard Chromium Electroplating of Metals. In hard plating, a relatively thick layer of chromium is deposited directly on the base metal (usually steel) to provide a surface with wear resistance, a low coefficient of friction, hardness, and corrosion resistance, or to build up surfaces that have been eroded by use. Hard plating is used for items such as hydraulic cylinders and rods, industrial rolls, zinc die castings, plastic molds, engine components, and marine hardware.

A flow diagram for a typical hard chromium plating process is presented in Figure 2-1. The process consists of the following steps:

1. Pretreatment (polishing, grinding, degreasing);
2. Alkaline cleaning and acid dipping (optional);
3. Chromic acid anodic treatment (optional); and
4. Chromium electroplating.

The part being plated is rinsed after each step in the process to prevent carry-over of solution that may contaminate the baths used in successive process steps. Either hot or cold water may be used in rinse tanks, but hot water is more efficient than cold water for removing contaminants. Softened, distilled, or deionized water may be required for final rinses.

Pretreatment steps include polishing, grinding, and/or degreasing the metal part to prepare the surface for plating. Polishing and grinding are performed to smooth the surface of the part. Degreasing is performed either by dipping the part in organic solvents or by vapor degreasing the part using organic solvents. Vapor degreasing is typically used when the surface loading of oil or grease is excessive. The two organic solvents most commonly used in dipping solutions or for vapor degreasing are trichloroethylene and perchloroethylene. In vapor degreasing, the solvent is boiled in a tank and the vapor condenses on the part and removes the oil and grease from its surface. Vapor degreasers must be fitted with a local ventilation system designed to pick up solvent vapors escaping from the tanks without pulling vapor from the machine itself.

Alkaline cleaning is sometimes used to dislodge surface soil and prevent it from settling back onto the metal. These cleaning solutions are typically made of compounds such as sodium carbonate, sodium phosphate, and sodium hydroxide and usually contain a surfactant. Alkaline cleaning techniques include soaking and cathodic and anodic cleaning. In soaking, the metal is placed in an alkaline bath that is agitated mildly. In cathodic cleaning, the metal is placed in an alkaline bath and direct current is applied. The part acts as the cathode; therefore, when current is applied, hydrogen gas evolves, enhancing the detergent action of the solution. Two disadvantages of cathodic cleaning are that impurities in the cleaning solution may be deposited on the metal and hydrogen may embrittle the metal. In anodic cleaning, the part is placed in an alkaline bath and reverse current is applied. The part then acts as the anode so that when the current is applied, oxygen gas is evolved. One disadvantage of anodic cleaning is that oxides may form on the surface of the metal. Also, anodic cleaning is less efficient than cathodic cleaning because oxygen gas is liberated at one-half the rate that hydrogen gas is liberated during cathodic cleaning. During alkaline cleaning, an alkaline mist can be released at a fairly high rate because of the hydrogen and oxygen gases entrapping the solution and releasing it as the bubbles burst at the surface; therefore, adequate ventilation should be provided.

Acid dips may be used to remove any tarnish or oxide films formed in the alkaline cleaning step and to neutralize the alkaline film. Acid dip solutions typically contain from 10 to 30 percent by volume hydrochloric or sulfuric acid in water. Because of the release of hydrogen and oxygen gases, an acid mist is generated from the dip tanks at varying rates and, as with alkaline cleaning, proper ventilation should be provided.

A chromic acid anodic treatment step is sometimes included. This treatment cleans the metal surface, with the evolution of oxygen gas scouring the metal. The chromic acid also activates the surface, which enhances the adhesion of chromium in the electroplating step. A typical bath contains chromic acid in a concentration that ranges from 120 to 240 grams per liter (g/L) (16 to 32 ounces per gallon [oz/gal]) at temperatures ranging from 49° to 66°C (120° to 150°F). Satisfactory cleaning and activation of the surface are usually obtained at 6 volts (V) and a current density ranging from 1,550 to 4,650 amperes per square meter (A/m^2) (140 to 430 amperes per square foot [A/ft^2]) for 1 to 3 minutes. Anodic treatment is typically accomplished by applying reverse current in the hard chromium plating tank. The anodic treatment also adds a protective oxide layer to the metal so that the chromium can be plated without applying an undercoating of nickel.

The final step of the process is the chromium electroplating operation. Chromium electroplating requires constant control of the plating bath temperature, current density, plating time, and bath composition.

Tanks used for hard chromium electroplating usually are constructed of steel and lined with a polyvinyl chloride sheet or plastisol. The anodes, which are insoluble, are made of a lead alloy that contains either tin or antimony. The substrate is suspended from a plating rack that is connected to the cathode bar of the rectifier. The plating rack may be loaded in the tank manually, by a hoist, or by an automatically controlled hoist system.

The plating tanks typically are equipped with some type of heat exchanger. Mechanical agitators or compressed air supplied through pipes on the tank bottom provide uniformity of bath temperature and composition. Hexavalent chromium plating baths are the most widely used baths to deposit chromium on metal. Hexavalent chromium baths are composed of chromic acid, sulfuric acid, and water. The chromic acid is the source of the hexavalent chromium that reacts and deposits on the metal and is emitted to the

atmosphere. The sulfuric acid in the bath catalyzes the chromium deposition reactions. Typical operating parameters are given in Table 2-2.

The evolution of hydrogen gas from chemical reactions at the cathode consumes 80 to 90 percent of the power supplied to the plating bath, leaving the remaining 10 to 20 percent for the deposition reaction. When the hydrogen gas evolves, it entrains chromic acid and causes misting at the surface of the plating bath.

2.2.1.2 Decorative Chromium Electroplating of Metals. In decorative plating, the base material (e.g., brass, steel, aluminum, or plastic) generally is plated with layers of copper and nickel followed by a relatively thin layer of chromium to provide a bright surface with wear and tarnish resistance. Decorative plating is used for items such as automotive trim, metal furniture, bicycles, hand tools, and plumbing fixtures. The purpose of decorative chromium plating is to achieve a combination of the following surface properties:

1. Blue-white color;
2. High reflectivity;
3. Tarnish resistance;
4. Corrosion resistance;
5. Wear resistance; and
6. Scratch resistance.

The decorative chromium plating process consists of a series of plating operations. Figure 2-2 presents a process flow diagram for the decorative chromium plating of metals (i.e., brass, steel, and aluminum). The process consists of the following steps:

1. Pretreatment (polishing, grinding, degreasing);
2. Alkaline cleaning;
3. Acid dipping;
4. Strike plating of copper;
5. Electroplating of copper;
6. Electroplating of nickel; and
7. Electroplating of chromium.

As with hard chromium plating, the part being plated is rinsed after each step in the process to prevent carry-over of solution that may contaminate the baths used in successive process steps. Either hot or cold water may be used in the rinse tanks, but hot water is more efficient than cold water for removing contaminants. Softened, distilled, or deionized water may be required for final rinses.

Decorative electroplating baths operate on the same principle as that described of the hard chromium plating process: the metal substrate is immersed in a plating solution, and direct current is passed from the anode through the plating solution causing the desired metal (copper, nickel, chromium) to deposit out of the solution onto the metal substrate (cathode).

Pretreatment steps include polishing, grinding, and/or degreasing the part to prepare for plating. Polishing and grinding are performed to smooth the surface of the part. Alkaline cleaning may be used to dislodge surface soil and prevent it from settling back onto the metal. Acid dipping is sometimes used to remove tarnish or oxide films formed in the alkaline cleaning step. Acid dips are also typically used

following strike plating of copper. These steps are described in more detail in Section 2.2.2.1 for hard chromium plating.

The first step following pretreatment is a copper strike, which consists of applying a thin layer of copper to enhance the conductive properties of the base metal and to protect the part from attack by the acidic copper sulfate baths. The plating bath is typically a copper cyanide solution. The plating time (0.5 to 2.0 minutes [min]) is limited to that necessary for completely covering the entire surface of the part with a thin layer approximately 2.5 micrometers (µm) (0.1 mil) thick. Strike plating of copper typically is followed by an acid dip.

The part is then usually electroplated with an undercoat of copper to improve the corrosion resistance and to cover scratch marks and other defects. Copper deposits in the recesses of the part more readily than nickel or chromium, and this enhances the corrosion resistance of the part. The baths used for copper electroplating are either alkaline (cyanides or pyrophosphates) or acid copper solutions. Copper cyanide solution is used most often; however, use of an acid copper bath is growing, due mainly to the low chemical cost and simplified effluent treatment. The acid copper bath requires a copper strike plate for steel substrates before electroplating because the copper cannot be applied directly to steel; however, copper cyanide baths can be directly applied to the steel substrate. Copper cyanide baths are composed of copper cyanide, potassium or sodium cyanide, potassium or sodium hydroxide, potassium or sodium carbonate, and a Rochelle salt. Acid copper baths are usually composed of copper sulfate, sulfuric acid, chloride, and thiourea. Another commonly used acid plating formulation contains copper fluoborate (instead of copper sulfate) as the active component. Copper may be deposited as a matte finish, or brightening agents may be added to the bath to produce a semibright or bright surface.

When a cyanide bath is used for strike copper plating or copper electroplating, both cyanide and alkaline mist are released from the bath. The potential for release of significant concentrations of these materials into the workroom atmosphere is great enough to warrant the use of local exhaust ventilation. Acid copper plating solutions are capable of releasing the copper salt and sulfuric acid mist into the atmosphere, but because of the generally high electrode efficiencies, acid mist generation is minimal. However, when high current densities or agitation is used, mist generation can increase and local exhaust ventilation must be provided.

Nickel plating improves the corrosion resistance and strength of the metal substrate and activates the surface of the metal for chromium plating. The nickel is plated on the surface of the part in two layers. The first layer is semibright (sulfur-free) nickel, and the second layer is bright (sulfur-containing) nickel. Pits that form in the outer (bright) layer cannot continue through the inner (semibright) layer because of the difference in the electromagnetic properties of the two layers. Both the bright and semibright nickel plating steps uses a Watts plating bath. Nickel plating baths typically operate at 45° to 65°C (110° to 150°F) with current densities ranging from 270 to 1,075 A/m^2 (25 to 100 A/ft^2).

Generally, gassing from the nickel plating solutions containing sulfate and/or chloride baths is low because the baths are operated at moderate temperatures and low to moderate current densities and have high cathode efficiencies (95 to 98 percent). The need for local exhaust ventilation under such conditions may be minimal.

The final step in the decorative chromium plating process is the plating of chromium itself. Typical operating parameters for this step are presented in Table 2-3.

Decorative chromium plating requires shorter plating times and operates at lower current densities than does hard chromium plating to achieve the desired properties of the chromium plate. Some decorative chromium plating operations use fluoride catalysts instead of sulfuric acid because fluoride catalysts, such as fluosilicate or fluoborate, have been found to produce higher bath efficiencies.

2.2.1.3 Decorative Chromium Electroplating of Plastics. Most plastics that are electroplated with chromium are formed from the polymer composed of acrylonitrile, butadiene, and styrene (ABS). The process for chromium electroplating of ABS plastics consists of the following steps:

1. Chromic acid/sulfuric acid etch;
2. Dilute hydrochloric acid dip;
3. Colloidal palladium activation;
4. Dilute hydrochloric acid dip;
5. Electroless nickel plating or copper plating; and
6. Chromium electroplating cycle.

After each process step, the plastic is rinsed with water to prevent carry-over of solution from one bath to another. The chromic acid/sulfuric acid etch solution (see Table 2-4) renders the ABS surface hydrophilic and modifies the surface to provide adhesion for the metal coating. The dilute hydrochloric acid dips are used to clean the surface and remove palladium metal from the plating rack, which is insulated with a coating of polyvinyl chloride. The colloidal palladium activation solution deposits a thin layer of metallic palladium over the plastic surface. The metallic palladium induces the deposition of copper or nickel which will not deposit directly onto plastic. The electroless nickel and copper plate are applied to impart electrical conductivity to the part; otherwise, the insulating surface of the plastic could not be electroplated with chromium. The electroless nickel plating or copper electroplating baths develop a film on the plastic about 1.0 μm (3.9×10^{-5} inch [in.]) thick. The plating time for electroless nickel plating and electroless copper plating ranges from 10 to 15 minutes and 15 to 30 minutes, respectively, at temperatures ranging from 25° to 35°C (77° to 95°F). The components of the plating baths include the metal salt (nickel or copper), a reducing agent, a complexing agent, a stabilizer, and a pH buffer system. The electroplating of plastics follows the same cycle as that described for decorative chromium electroplating.

2.2.1.4 Chromic Acid Anodizing. Chromic acid anodizing is used primarily on aircraft parts and architectural structures that are subject to high stress and corrosion. Chromic acid anodizing is used to provide an oxide layer on aluminum that imparts the following properties:

1. Corrosion protection;
2. Electrical insulation;
3. Ease of coloring; and
4. Improved dielectric strength.

Figure 2-3 presents a flow diagram for a typical chromic acid anodizing process.

There are four primary differences between the equipment used for chromium electroplating and that used for chromic acid anodizing: (a) chromic acid anodizing requires the rectifier to be fitted with a rheostat or other control mechanism to permit starting at about 5 V, (b) the tank is the cathode in the electrical circuit, (c) the aluminum substrate acts as the anode, and (d) sidewall shields typically are used

instead of a liner in the tank to minimize short circuits and to decrease the effective cathode area. Types of shield materials used are herculite glass, wire safety glass, neoprene, and vinyl chloride polymers.

The following pretreatment steps typically are used to clean the aluminum before anodizing:

1. Alkaline soak;
2. Desmut;
3. Etching; and
4. Vapor degreasing.

The pretreatment steps used for a particular aluminum substrate depend upon the amount of smut and the composition of the aluminum. The aluminum substrate is rinsed between pretreatment steps to remove cleaners.

The alkaline soak is the primary preparatory step in cleaning the aluminum; its purpose is to dislodge soil from the aluminum surface. The solutions for alkaline cleaning are typically made of compounds such as sodium carbonate, sodium phosphate, and sodium hydroxide and usually contain a small amount of silicate to prevent metal attack. The alkaline soak consists of immersing the metal in the alkaline solution that is mildly agitated with air.

The purpose of desmutting is to remove soil or grease films that cleaners and etchants leave behind. Desmutting baths typically consist of a cold nitric acid solution mixed with water at a concentration ranging from 5 to 50 percent acid by volume. The nitric acid bath also is used either as a bleaching treatment to remove dyes from faulty coatings or as part of the technique of producing multicolor coatings. Other desmutting treatments use combinations of chromic, phosphoric, and sulfuric acids depending upon the amount of smut to be removed or the aluminum composition.

When a dull finish is desired, the aluminum is etched before anodizing. Etching baths consist of a dilute solution of soda ash, caustic soda, or nitric acid. The degree of etching desired and the composition of the aluminum being treated determine the concentration of the etch solution, temperature of the bath, and duration of the etch.

The vapor degreasing step removes any residual oil or grease on the surface of the aluminum prior to the anodizing operation.

Typical operating parameters for chromic acid anodizing baths are presented in Table 2-5. The voltage is applied step-wise (5 V per minute) from 0 to 40 V and maintained at 40 V for the remainder of the anodizing time. A low starting voltage (i.e., 5 V) minimizes current surge that may cause "burning" at contact points between the rack and the aluminum part. The process is effective over a wide range of voltages, temperatures, and anodizing times. All other factors being equal, high voltages tend to produce bright transparent films, and lower voltages tend to produce opaque films. Raising the bath temperature increases current density to produce thicker films in a given time period. Temperatures up to 49°C (120°F) typically are used to produce films that are to be colored by dyeing. The amount of current varies depending on the size of the aluminum parts; however, the current density typically ranges from 1,550 to 7,750 A/m^2 (144 to 720 A/ft^2).

The postanodizing steps include sealing and air drying. Sealing causes hydration of the aluminum oxide and fills the pores in the aluminum surface. As a result, the elasticity of the oxide film increases, but

the hardness and wear resistance decrease. Sealing is performed by immersing aluminum in a water bath at 88° to 99°C (190° to 210°F) for a minimum of 15 minutes. Chromic acid or other chromates may be added to the solution to help improve corrosion resistance. The aluminum is allowed to air dry after it is sealed.

2.2.1.5 Trivalent Chromium Plating. Trivalent chromium electroplating baths have been developed primarily to replace decorative hexavalent chromium plating baths. Development of a trivalent bath has proven to be difficult because trivalent chromium solvates in water to form complex stable ions that do not readily release chromium. The trivalent chromium baths that have been developed are proprietary baths.

There are two types of trivalent chromium processes on the market: single-cell and double-cell. The major differences in the two processes are that (1) the double-cell process solution contains minimal-to-no chlorides whereas the single-cell process solution contains a high concentration of chlorides; and (2) the double-cell process utilizes lead anodes that are placed in anode boxes that contain a dilute sulfuric acid solution and are lined with a permeable membrane whereas the single-cell process utilizes carbon or graphite anodes that are placed in direct contact with the plating solution.

The advantages of the trivalent chromium processes over the hexavalent chromium process are (1) fewer environmental concerns due to the lower toxicity of trivalent chromium, (2) higher productivity, and (3) lower operating costs. In the trivalent chromium process, hexavalent chromium is a plating bath contaminant. Therefore, the bath does not contain any appreciable amount of hexavalent chromium. The total chromium concentration of trivalent chromium solutions is approximately one-fifth that of hexavalent chromium solutions. As a result of the chemistry of the trivalent chromium electrolyte, misting does not occur during plating as it does during hexavalent chromium plating. Use of trivalent chromium also reduces waste disposal problems and costs. Waste treatment of hexavalent chromium is a two-stage process. The hexavalent chromium is first reduced to the trivalent chromium ion; then it can be precipitated as chromium hydroxide. Trivalent chromium plating solution wastewaters are already in the reduced trivalent state and require only the chromium hydroxide precipitation step.

Productivity is increased when trivalent chromium processes are used because less stripping and replating of parts are required, more parts can be placed on a rack, and more racks can be placed on a workbar.

The cost of operating a trivalent chromium process is less than that of a hexavalent chromium process because of the lower wastewater treatment costs, a reduction in rejects, and high productivity.

The disadvantages of the trivalent chromium process are that the process is more sensitive to contamination than the hexavalent chromium process, and the trivalent chromium process cannot plate the full range of plate thicknesses that the hexavalent chromium process can. Because it is sensitive to contamination, the trivalent chromium process requires more thorough rinsing and tighter laboratory control than does the hexavalent chromium process. Trivalent chromium baths can plate thicknesses ranging up to 0.13 to 25 μm (0.005 to 1.0 mils) and, therefore, cannot be used for most hard chromium plating applications. The hexavalent chromium process can plate thicknesses up to 762 μm (30 mils).

The plating efficiency of a trivalent chromium bath, approximately 20 to 25 percent, is slightly higher than that of a hexavalent chromium plating bath. The color, hardness, and corrosion resistance of trivalent chromium deposits are comparable to those of hexavalent chromium deposits. However, the

composition of a trivalent chromium deposit differs significantly from that of a hexavalent chromium deposit. Table 2-6 presents the composition of trivalent and hexavalent chromium deposits.

2.2.1.6 Emissions From Chromium Electroplating. Plating operations generate mists due to the evolution of hydrogen and oxygen gas. The gases are formed in the process tanks on the surface of the submerged part or on anodes or cathodes. As these gas bubbles rise to the surface, they escape into the air and may carry considerable liquid with them in the form of a fine mist. The rate of gassing is a function of the chemical or electrochemical activity in the tank and increases with the amount of work in the tank, the strength and temperature of the solution, and the current densities in the plating tanks.

Emissions are also generated from surface preparation steps (alkaline cleaning, acid dipping, and vapor degreasing). These emissions are in the form of alkaline and acid mists and solvent vapors. The extent of acid misting from the plating processes (copper, nickel, and chromium) depends mainly on the efficiency of the plating bath. Both copper and nickel plating baths have high cathode efficiencies so that the generation of mist is minimal. However, the cathode efficiency of chromium plating baths is very low (10 to 20 percent), and a substantial quantity of chromic acid mist is generated.

Emissions of chromic acid mist from the electrodeposition of chromium from chromic acid plating baths occur because of the inefficiency of the hexavalent chromium plating process. Only about 10 to 20 percent of the current applied actually is used to deposit chromium on the item plated; the remaining 80 to 90 percent of the current applied is consumed by the evolution of hydrogen gas at the cathode with the resultant liberation of gas bubbles. Additional bubbles are formed at the anode due to the evolution of oxygen. As the bubbles burst at the surface of the plating solution, a fine mist of chromic acid droplets is formed.

2.2.1.7 Emission Control Technology for Chromium Electroplating. The principal techniques used to control emissions of chromic acid mist from decorative and hard chromium plating and chromic acid anodizing operations include add-on control devices and chemical fume suppressants. The control devices most frequently used are mist eliminators and wet scrubbers that are operated at relatively low pressure drops. Because of the corrosive properties of chromic acid, control devices typically are made of polyvinyl chloride (PVC) or fiberglass.

Chemical fume suppressants are added to decorative chromium plating and chromic acid anodizing baths to reduce chromic acid mist. Although chemical agents alone are effective control techniques, many plants use them in conjunction with an add-on control device.

Chevron-blade and mesh-pad mist eliminators are the types of mist eliminators most frequently used to control chromic acid mist. The most important mechanism by which mist eliminators remove chromic acid droplets from gas streams is the inertial impaction of droplets onto a stationary set of blades or a mesh pad. Mist eliminators typically are operated as dry units that are periodically washed down with water to clean the impaction media.

The wet scrubbers typically used to control emissions of chromic acid mist from chromium plating and chromic acid anodizing operations are single and double packed-bed scrubbers. Other scrubber types used less frequently include fan-separator packed-bed and centrifugal-flow scrubbers. Scrubbers remove chromic acid droplets from the gas stream by humidifying the gas stream to increase the mass of the droplet particles, which are then removed by impingement on a packed bed. Once-through water or recirculated water typically is used as the scrubbing liquid because chromic acid is highly soluble in water.

Chemical fume suppressants are surface-active compounds that are added directly to chromium plating and chromic acid anodizing baths to reduce or control misting. Fume suppressants are classified as temporary or as permanent. Temporary fume suppressants are depleted mainly by the decomposition of the fume suppressant and dragout of the plating solution, and permanent fume suppressant are depleted mainly by dragout of the plating solution. Fume suppressants, which are manufactured in liquid, powder, or tablet form, include wetting agents that reduce misting by lowering the surface tension of the plating or anodizing bath, foam blankets that entrap chromic acid mist at the surface of the plating solution, or combinations of both a wetting agent and foam blanket. Polypropylene balls, which float on the surface of the plating baths, also are used as a fume suppressant in chromium plating tanks.

Table 2-7 presents control efficiency for general types of chromium electroplating emission control technologies based on data from EPA-sponsored emission tests.

For decorative chromium plating operations, the performance efficiency of both chemical fume suppressants tested (a foam blanket and a combination of a foam blanket and wetting agent) is greater than 99 percent. This performance efficiency is achievable as long as vendor recommendations on the makeup and use of the fume suppressants are followed rigorously.

2.2.2 Other Types of Electroplating[4-18]

The following paragraphs provide a brief overview of electroplating of metals other than chromium. The metals addressed include brass, cadmium, copper, gold, indium, iron, nickel, palladium, platinum, rhodium, ruthenium, silver, tin, lead, and zinc.

2.2.2.1 Brass. Brass, which is an alloy of copper and zinc, is the most widely used alloy electroplate. Brass plating primarily is used for decorative applications, but it is also used for engineering applications such as for plating steel wire cord for steel-belted radial tires. Although all of the alloys of copper and zinc can be plated, the brass alloy most often used includes 70 to 80 percent copper, with the balance zinc. Table 2-8 lists the important constituents of the solution and operating parameters for plating this alloy.

2.2.2.2 Cadmium. Cadmium plating generally is performed in alkaline cyanide baths that are prepared by dissolving cadmium oxide in a sodium cyanide solution. However, because of the hazards associated with cyanide use, noncyanide cadmium plating solutions are being used more widely. The primary noncyanide plating solutions are neutral sulfate, acid fluoborate, and acid sulfate. Table 2-9 lists the main constituents and operating parameters for both cyanide and noncyanide cadmium plating solutions.

2.2.2.3 Copper. Copper cyanide plating is widely used in many plating operations as a strike. However, its use for thick deposits is decreasing. For copper cyanide plating, cuprous cyanide must be complexed with either potassium or sodium to form soluble copper compounds in aqueous solutions. Table 2-10 summarizes the operating parameters for both potassium and sodium cyanide plating baths.

Other types of baths used in copper plating include copper pyrophosphate and copper sulfate baths. Copper pyrophosphate plating, which is used for plating on plastics and printed circuits, requires more control and maintenance of the plating baths than copper cyanide plating does. However, copper pyrophosphate solutions are relatively nontoxic. Table 2-11 summarizes the operating parameters for a typical copper pyrophosphate plating operation.

Copper sulfate baths, which are more economical to prepare and operate than copper pyrophosphate baths, are used for plating printed circuits, electronics, rotogravure, and plastics, and for electroforming and decorative uses. In this type of bath copper and sulfate and sulfuric acid form the ionized species in solution. Table 2-12 summarizes the operating parameters for a typical copper sulfate plating operation.

2.2.2.4 Gold. Gold and gold alloy plating are used in a wide variety of applications. Gold plating solutions can be classified in five general groups: alkaline gold cyanide, for gold and gold alloy plating; neutral cyanide gold, for high purity gold plating; acid gold cyanide, for bright hard gold and gold alloy plating; noncyanide (generally sulfite), for gold and gold plating; and miscellaneous. Tables 2-13 to 2-15 summarize the operating parameters for alkaline gold cyanide, neutral gold cyanide, and acid gold cyanide plating operations, respectively.

2.2.2.5 Indium. In general, indium is electroplated using three types of plating baths: cyanide, sulfamate, and fluoborate. Tables 2-16 to 2-18 summarize the operating parameters for indium cyanide, indium sulfamate, and indium fluoborate plating operations, respectively. Indium is the only trivalent metal that can be electrodeposited readily from a cyanide solution. Cyanide baths are used in applications that require very high throwing power and adhesion. Indium sulfamate baths are very stable, relatively easy to control, and are characterized by a high cathode efficiency that remains relatively high (90 percent).

2.2.2.6 Iron. Iron is electroplated using chloride, sulfate, sulfamate, or fluoborate plating baths. However, because of its poor metallurgical properties, iron plating is used rarely and is not discussed further in this report.

2.2.2.7 Nickel. Nickel plating is used for decorative, engineering, and electroforming purposes. Table 2-19 summarizes the operating parameters for several types of baths used in both engineering and decorative nickel plating. Decorative nickel plating differs from other types of nickel plating in that the solutions contains organic agents, such as benzene disulfonic acids, benzene trisulfonic acid, naphthalene trisulfonic acid, benzene sulfonamide, formaldehyde, coumarin, ethylene cyanohydrin, and butynediol. Nickel plating for engineering applications uses solutions that deposit pure nickel. Table 2-20 summarizes the operating parameters for nickel electroforming.

2.2.2.8 Palladium and Palladium-Nickel. Palladium plating solutions are categorized as ammoniacal, chelated, or acid. Table 2-21 summarizes the operating parameters of two types of ammoniacal plating baths, and Table 2-22 summarizes the parameters for acid plating baths.

Palladium alloys readily with other metals, the most important of which is nickel. Table 2-23 summarizes the operating parameters for a palladium-nickel plating.

2.2.2.9 Platinum. Solutions used for platinum plating are similar to those used for palladium plating. Table 2-24 summarizes the operating parameters for three types of platinum plating baths.

2.2.2.10 Rhodium. Rhodium plating traditionally has been used as decorative plating in jewelry and silverware. However, the use of rhodium plating for electronics and other industrial applications has been increasing in recent years. Table 2-25 summarizes the operating parameters for three types of decorative rhodium plating solutions and Table 2-26 summarizes the operating for electronic/industrial rhodium plating solutions.

2.2.2.11 Ruthenium. Electroplated ruthenium is a very good electrical conductor and produces a very hard deposit. Table 2-27 summarizes the operating parameters of a general purpose ruthenium plating bath.

2.2.2.12 Silver. Silver plating traditionally has been performed using a cyanide-based plating solution. Although some noncyanide solutions have been developed, due to various shortcomings, cyanide solutions still are commonly used. Table 2-28 summarizes the operating parameters of the traditional cyanide-based silver plating bath.

2.2.2.13 Tin-Lead, Lead, and Tin. Fluoborate and fluoboric acid can be used to plate all percentages of tin and lead. Alloys of tin and lead are most commonly used for plating in the proportions of 60 percent tin and 40 percent lead. Table 2-29 summarizes the operating parameters for a typical 60/40 tin lead plating bath. Table 2-30 summarizes the parameters for lead fluoborate, which is the accepted electrolyte for lead plating.

Tin plating generally is performed using one of three types of plating solutions (stannous fluoborate, stannous sulfate, or sodium or potassium stannate), or by the halogen tin process. The operating parameters for the stannous fluoborate, stannous sulfate, and sodium/potassium stannate baths are summarized in Tables 2-31 to 2-33.

2.2.2.14 Tin-Nickel. Tin-nickel alloy plating is used in light engineering and electronic applications and is used as an alternative to decorative chromium plating. The operating parameters for tin-nickel plating solutions, which generally are fluoride- or pyrophosphate-base, are summarized in Tables 2-34 and 2-35.

2.2.2.15 Zinc. The most widely used zinc plating solutions are categorized as acid chloride, alkaline noncyanide, and cyanide. Table 2-36 summarizes the operating parameters for these three types of plating baths. The most widely used zinc alloys for electroplating are zinc-nickel, zinc-cobalt, and zinc-iron. The operating parameters for the baths used in these operations are summarized in Tables 2-37 to 2-39.

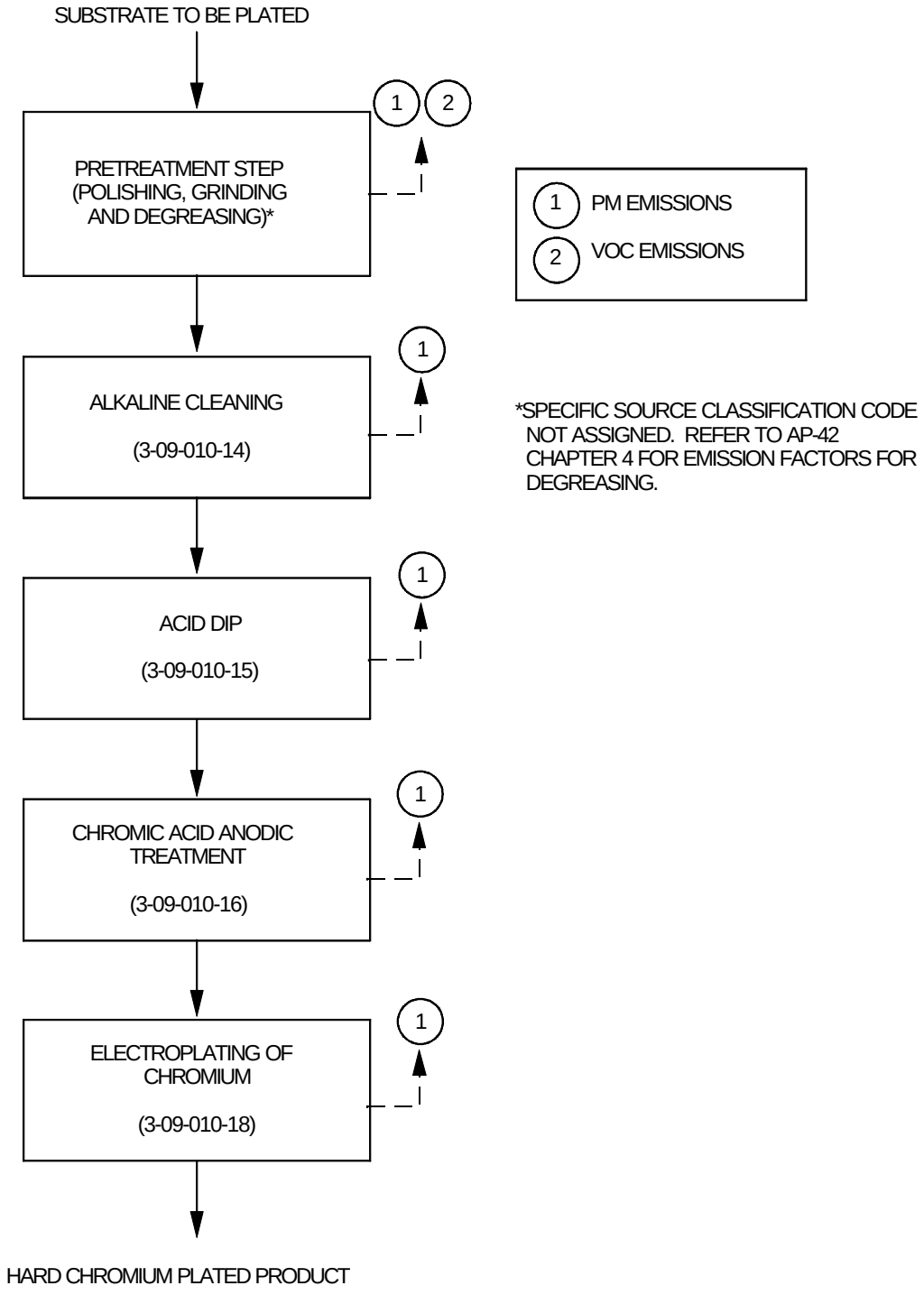

Figure 2-1. Flow diagram for a typical hard chromium plating process.[3]
(Source Classification Codes in parentheses)

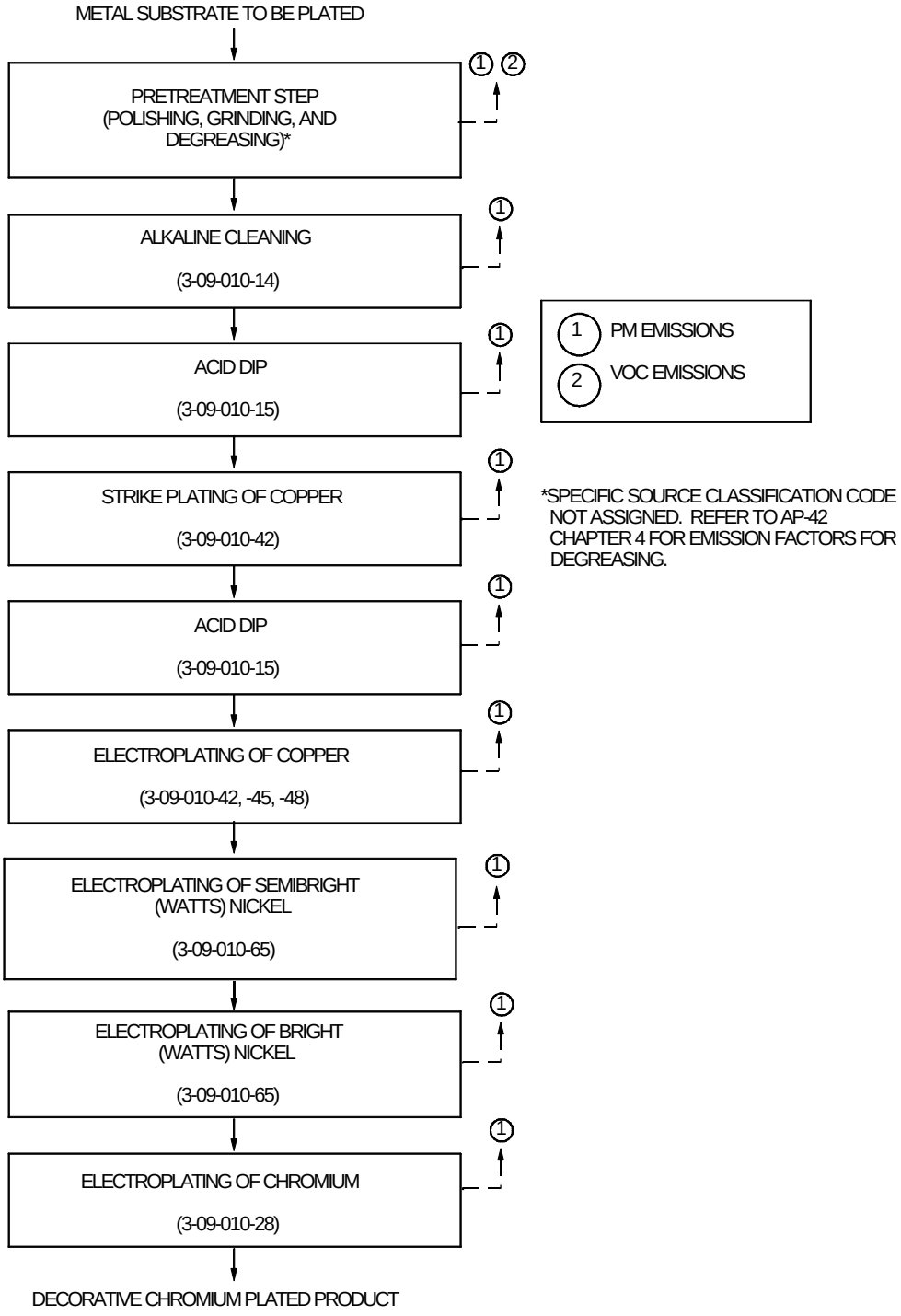

Figure 2-2. Flow diagram for decorative chromium plating on a metal substrate.[3] (Source Classification Codes in parentheses).

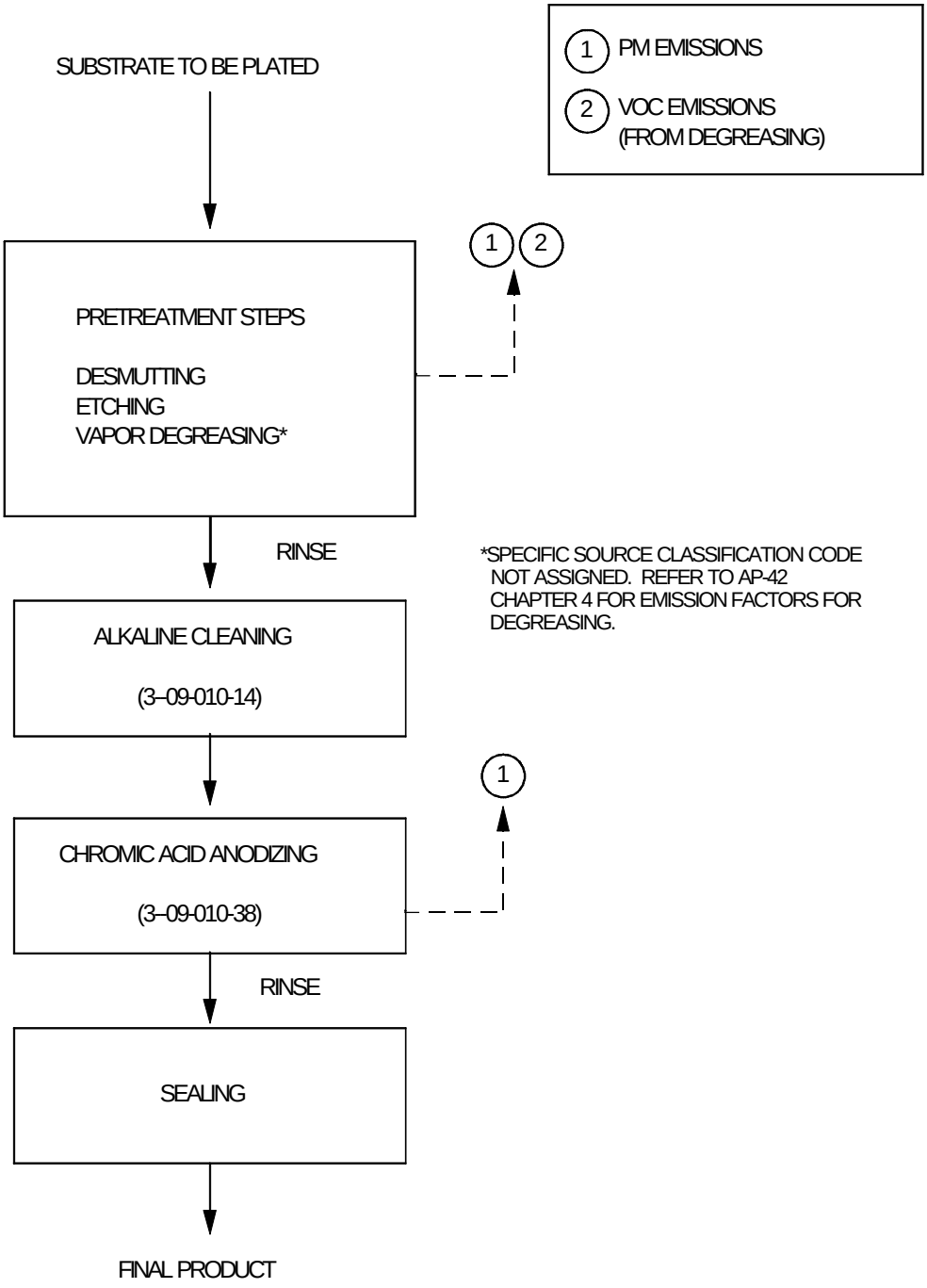

Figure 2-3. Flow diagram for a typical chromic acid anodizing process.[3] (Source Classification Codes in parentheses).

TABLE 2-1. ELECTROPLATING APPLICATIONS AND PRINCIPAL METALS USED[a]

Property/function	Principal plating metals
Decorative	Chromium, copper, nickel, brass, bronze, gold, silver, platinum-group, zinc
Corrosion resistance	Nickel, chromium, electroless nickel, zinc, cadmium, copper and copper alloys
Wear, lubricity, hardness	Chromium, electroless nickel, bronze, nickel, cadmium, metal composites
Bearings	Copper and bronze, silver and silver alloys, lead-tin
Joining, soldering, brazing, electrical contact resistance, conductivity	Nickel, electroless nickel, electroless copper, copper, cadmium, gold, silver, lead-tin, tin, cobalt
Barrier coatings, antidiffusion, heat-treat, stop-off	Nickel, cobalt, iron, copper, bronze, tin-nickel
Electromagnetic shielding	Copper, electroless copper, nickel, or electroless nickel, zinc
Paint/lacquer base, rubber bonding	Zinc, tin, chromium, brass
Manufacturing: electroforming	Copper, nickel
Manufacturing: electronic circuitry	Electroless copper, copper, electroless nickel, nickel
Dimensional buildup, salvage of worn parts	Chromium nickel, electroless nickel, iron

[a]Reference 1.

TABLE 2-2. TYPICAL OPERATING PARAMETERS FOR HARD CHROMIUM ELECTROPLATING[a]

Parameter	Range of values
Plating thickness, μm (mil)	1.3-762 (0.05-30)
Plating time, min[b]	20-2,160
Chromic acid concentration, g/L (oz/gal)[c]	225-375 (30-50)
Sulfuric acid concentration, g/L (oz/gal)	2.25-3.75 (0.3-0.5)
Temperature of solution, °C (°F)	49-66 (120-150)
Voltage, volts	d
Current, A	e
Current density, A/m^2 (A/ft^2)[f]	1,600-6,500 (150-600)
Cathode efficiency, %	10-20

[a]Reference 2.
[b]min = minutes.
[c]g/L = grams per liter, oz/gal = ounces per gallon.
[d]Depends on the distance between the anodes and the items being plated.
[e]Depends on the amount of surface area plated.
[f]A/m^2 = amperes per square meter (square foot) of surface area plated.

TABLE 2-3. TYPICAL OPERATING PARAMETERS FOR DECORATIVE CHROMIUM PLATING

Parameter	Range of values
Plating thickness, μm (mil)	0.003-2.5 (0.001-0.1)
Plating time, min	0.5-5
Chromic acid concentration, g/L (oz/gal)	225-375 (30-50)
Sulfuric acid concentration, g/L (oz/gal)	2.25-3.75 (0.3-0.5)
Temperature of solution, °C (°F)	38-46 (100-115)
Voltage, volts	b
Current, A	c
Current density, A/m^2 (A/ft^2)[d]	540-2,400 (50-220)
Cathode efficiency, %	10-20

[a]Reference 2.
[b]Depends on the distance between the anodes and the items being plated.
[c]Depends on the amount of surface area being plated.
[d]Amperes per square meter (square foot) of surface area plated.

TABLE 2-4. TYPICAL OPERATING PARAMETERS FOR CHROMIC ACID/SULFURIC ACID ETCH SOLUTION[a]

Parameter	Values
Concentrated sulfuric acid, g/L (oz/gal)	172 (23)
Chromic acid, g/L (oz/gal)	430 (57)
Temperature, °C (°F)	60-65 (140-149)
Immersion time, min	3-10

[a]Reference 2.

TABLE 2-5. TYPICAL OPERATING PARAMETERS FOR CHROMIC ACID ANODIZING

Parameter	Range of values
Chromic acid concentration, g/L (oz/gal)	50-100 (6.67-13.3)
Temperature, °C (°F)	32-35 (90-95)
Plating time, min	30-60
pH	0.5-0.85
Current density, A/m^2 (A/ft^2)[b]	1,550-7,750 (144-720)
Voltage (step-wise), volts	30-40
Film thickness, μm (mil)	0.5-1.27 (0.02-0.05)

[a]Reference 2.
[b]Amperes per square meter (square foot) of surface area plated.

TABLE 2-6. HEXAVALENT AND TRIVALENT CHROMIUM DEPOSIT COMPOSITIONS[a]

Type of chromium deposit	Carbon, weight percent	Oxygen, weight percent	Chromium, weight percent
Hexavalent	0.0	0.4	99+
Trivalent	2.9	1.6	95+

[a]Reference 2.

TABLE 2-7. PERFORMANCE LEVELS OF CHROMIUM ELECTROPLATING EMISSION CONTROL TECHNOLOGIES[a]

Control device	Hexavalent chromium mass emission, kg/hr x 10^{-3}		Range of control device efficiencies, percent	Hexavalent chromium emission concentration, mg/dscm x 10^{-3}	
	Inlet	Outlet		Inlet	Outlet
Chevron-blade mist eliminators					
[b]	26	3.3	83.1-91.0	2,030	310
[c]	15	1.3	86.9-95.1	1,760	150
[d]	76	1.2	98.0-98.7	7,960	120
Mesh-pad mist eliminators					
[e]	31	0.4	98.4-99.0	3,070	40
[f]	83	0.23	99.2-99.9	11,400	33
[f]	24	0.27	98.7-99.0	4,410	43
Packed-bed scrubbers					
[g]	90	0.52	99.1-99.6	5,510	30
[h]	46	1.5	94.9-98.1	1,670	52
[j]	23	1.2	94.3-95.1	715	39
[k]	22	0.71	96.3-97.2	668	23
[m]	24	0.65	97.2-97.3	723	21
Polypropylene balls					
[n]	22	5.4	68.0-81.9	3,980	960
Fume suppressant					
[p]	3.6	0.02	99.3-99.6	921	4.7
[q]	3.6	0.01	99.7-99.9	921	2.2

[a]Reference 3.
[b]Chevron-blade mist eliminator with a single set of sinusoidal wave-type blades.
[c]Chevron-blade mist eliminator with a single set of overlapping-type blades.
[d]Chevron-blade mist eliminator with a double set of overlapping-type blades.
[e]Mist eliminator containing a double set of overlapping-type chevron blades followed by two mesh pads in series. Moisture extractor preceded mist eliminator. Tests were conducted at the inlet to the moisture extractor and at the outlet of the mist eliminator.
[f]Double mesh-pad mist eliminator.
[g]Single packed-bed, horizontal-flow wet scrubber.
[h]Double packed-bed, horizontal-flow wet scrubber.
[j]Single packed-bed, horizontal flow wet scrubber. No overhead washdown of the scrubber packing.
[k]Single packed-bed, horizontal flow wet scrubber. Periodic overhead washdown of the scrubber packing.
[m]Single packed-bed, horizontal flow wet scrubber. Continuous overhead washdown of the scrubber packing.
[n]Tests were conducted at the mist eliminator inlet with and without polypropylene balls. Polypropylene balls 3.8 cm in diameter with two to three layers of coverage.
[p]Foam blanket.
[q]Wetting agent in combination with a foam blanket.

TABLE 2-8. SUMMARY OF OPERATING PARAMETERS FOR BRASS PLATING BATHS[a]

Parameter	Value
Copper cyanide, g/L (oz/gal)	32 (4.2)
Zinc cyanide, g/L (oz/gal)	10 (1.3)
Sodium cyanide, g/L (oz/gal)	50 (6.5)
Sodium carbonate (soda ash), g/L (oz/gal)	7.5 (1)
Sodium bicarbonate, g/L (oz/gal)	10 (1.5)
Ammonia, ml/L (quart/100 gal)	2.5-5 (1-2)
pH	10.0-10.2
Temperature of operation, °C (°F)	25-35 (75-95)

[a]Reference 4.

TABLE 2-9. SUMMARY OF OPERATING PARAMETERS FOR CADMIUM PLATING BATHS[a]

Bath component, g/L (oz/gal)	Alkaline cyanide	Neutral sulfate	Acid fluoborate	Acid sulfate
Ammonium chloride	--	11.2-22.5 (1.5-3.0)	--	--
Ammonium fluoborate	--	--	59.9 (8.0)	--
Ammonium sulfate	--	74.9-112.4 (10.0-15.0)	--	--
Boric acid	--	--	27.0 (3.6)	--
Cadmium	20.2 (2.7)	3.7-11.2 (0.5-1.5)	94.4 (12.6)	--
Cadmium fluoborate	--	--	241.2 (32.2)	--
Cadmium oxide	22.5 (3.0)	--	--	7.5-11.2 (1.0-1.5)
Sodium carbonate	30.0-59.9 (4.0-8.0)	--	--	--
Sodium cyanide	101.1 (13.5)	--	--	--
Sodium hydroxide	14.2 (1.9)	--	--	--
Sulfuric acid	--	--	--	33.7-37.5 (4.5-5.0)
Operating parameter				
Current density, A/m^2 (A/ft^2)	54-970 (5-90)	22-160 (2-15)	320-650 (30-60)	110-650 (10-60)
Temperature, °C (°F)	15.6-37.8 (60-100)	15.6-37.8 (60-100)	21.1-37.8 (70-100)	15.6-32.2 (60-90)

[a]Reference 5.

TABLE 2-10. SUMMARY OF OPERATING PARAMETERS FOR COPPER POTASSIUM AND SODIUM CYANIDE PLATING BATHS[a]

Parameter	Value	
	Potassium	Sodium
Copper cyanide, g/L (oz/gal)	30 (4.0)	30.0 (4.0)
Total potassium cyanide, g/L (oz/gal)	58.5 (7.8)	--
Total sodium cyanide, g/L (oz/gal)	--	48.0 (6.4)
Potassium hydroxide, g/L (oz/gal)	3.75-7.5 (0.5-1.0)	--
Sodium hydroxide, g/L (oz/gal)	--	
Potassium carbonate, g/L (oz/gal)	15.0 (2.0)	
Sodium carbonate, g/L (oz/gal)		15.0 (2.0)
Rochelle salt, g/L (oz/gal)	30.0 (4.0)	30.0 (4.0)
Free potassium cyanide by analysis, g/L (oz/gal)	11.25-15.0 (1.5-2.0)	
Free sodium cyanide by analysis, g/L (oz/gal)	--	11.25-15.0 (1.5-2.0)
Temperature, °C (°F)	24-66 (75-140)	
Current density, A/m^2 (A/ft^2)	54-430 (5-40)	
Time, min	0.5-2 or until fully covered	
Cathode efficiency, %	30-60	
Recommended agitation	None or mechanical	

[a]Reference 6.

TABLE 2-11. SUMMARY OF OPERATING PARAMETERS FOR COPPER PYROPHOSPHATE PLATING BATHS[a]

Parameter	Value
Copper pyrophosphate ($Cu_2P_2O_7 \cdot 3H_2O$), g/L (oz/gal)	52.5-84.0 (7.0-11.2)
Potassium pyrophosphate ($K_4P_2O_7$), g/L (oz/gal)	201.1-349.1 (26.8-46.5)
Potassium nitrate, g/L (oz/gal)	3.0-6.0 (0.4-0.8)
Concentrated ammonium hydroxide, ml/L (oz/gal)	3.75-11.0 (0.5-1.5)
pH	8.0-8.7
Temperature, °C (°F)	43-60 (110-140)
Current density, A/m^2 (A/ft^2)	110-860 (10.0-80.0)
Agitation	Mechanical and air
Filtration	Continuous

[a]Reference 6.

TABLE 2-12. SUMMARY OF OPERATING PARAMETERS FOR COPPER SULFATE PLATING BATHS[a]

Parameter	Value
General formation:	
Copper sulfate, g/L (oz/gal)	195-248 (26-33)
Sulfuric acid, g/L (oz/gal)	30-75 (4-10)
Chloride, ppm	50-120
Current density, A/m^2 (A/ft^2)	215-1,080 (20-100)
Semibright plating (Clifton-Phillips):	
Copper sulfate, g/L (oz/gal)	248 (33)
Sulfuric acid, g/L (oz/gal)	11 (1.5)
Chloride, ppm	50-120
Thiourea, g/L (oz/gal)	0.00075 (0.0001)
Wetting agent, g/L (oz/gal)	0.2 (0.027)
Bright plating (Beaver):	
Copper sulfate, g/L (oz/gal)	210 (28)
Sulfuric acid, g/L (oz/gal)	60 (8)
Chloride, ppm	50-120
Thiourea, g/L (oz/gal)	0.1 (0.0013)
Dextrin, g/L (oz/gal)	0.01 (0.0013)
Bright plating (Clifton-Phillips):	
Copper sulfate, g/L (oz/gal)	199 (26.5)
Sulfuric acid, g/L (oz/gal)	30 (4)
Chloride, ppm	50-120
Thiourea, g/L (oz/gal)	0.0375 (0.005)
Molasses, g/L (oz/gal)	0.75 (0.1)

[a]Reference 6.

TABLE 2-13. SUMMARY OF OPERATING PARAMETERS FOR ALKALINE GOLD CYANIDE PLATING BATHS[a]

Parameter	Value	
	Mat	Bright
Gold as potassium gold cyanide, g/L (oz/gal)	8-20 (1.1-2.7)	8-20 (1.1-2.7)
Silver as potassium silver cyanide, g/L (oz/gal)	--	0.3-0.6 (.04-.08)
Dipotassium phosphate, g/L (oz/gal)	22-45 (2.9-6)	--
Potassium cyanide, g/L (oz/gal)	15-30 (2-4)	60-100 (8-13.4)
pH	12	12
Temperature, °C (°F)	48.9-71.1 (120-160)	15.6-26.7 (60-80)
Anodes	Stainless steel	Stainless steel
Anode/cathode	1:1	1:1 to 5:1
Agitation	Moderate-vigorous	None to moderate
Current density (Rack), A/m^2 (A/ft^2)	32-54 (3-5)	32-86 (3-8)
Current density (Barrel), A/m^2 (A/ft^2)	11-22 (1-2)	11-22 (1-2)
Cathode efficiency, %	90-95	90-100
Time to plate 0.0001 in., min.	8 at 54 A/m^2 (8 at 5 A/ft^2)	7 at 64 A/m^2 (7 at 6 A/ft^2)
Replenishment	1 oz gold/4½ amp-hrs	1 oz gold/4½ amp-hrs

[a]Reference 7.

TABLE 2-14. SUMMARY OF OPERATING PARAMETERS FOR NEUTRAL GOLD CYANIDE PLATING BATHS[a]

Parameter	Value	
	Rack or barrel	High speed continuous
Gold as potassium gold cyanide, g/L (oz/gal)	8-20 (1.1-2.7)	15-30 (2-4)
Monopotassium phosphate, g/L (oz/gal) or	80 (10.7)	--
Potassium citrate, g/L (oz/gal)	70 (9.3)	90 (12)
pH	6.0-8.0	4.5-5.5
Temperature, °C (°F)	71.1 (160)	48.9-71.1 (120-160)
Agitation	Desired	Violent
Anodes	Platinum clad columbium	Platinum clad columbium
Current density, A/m^2 (A/ft^2)	11-32 (1-3)	1,080-4,300 (100-400)
Cathode efficiency, %	90	95-98
Time to plate 0.0001 in., min.	12	0.17-0.33
Replenishment	1 oz gold/4½ amp-hrs	1 oz gold/4½ amp-hrs

[a]Reference 7.

TABLE 2-15. SUMMARY OF OPERATING PARAMETERS FOR ACID GOLD CYANIDE PLATING BATHS[a]

Parameter	Value		
	Barrel	Rack or barrel	High speed/continuous
	Mat Bath No. 1	Bright Bath No. 2	
Gold as potassium gold cyanide, g/L (oz/gal)	8 (1.1)	8 (1.1)	8-16 (1.1-2.1)
Citric acid, g/L (oz/gal)	60 (8)	60 (8)	90 (12)
Cobalt as cobalt metal, g/L (oz/gal) or	--	0.2-0.5 (.03-.07)	0.75 (0.1)
Nickel as nickel metal, g/L (oz/gal)			
pH	3.8-5.0	3.8-4.5	3.8-4.3
Temperature, °C (°F)	49-60 (120-140)	21-32 (70-90)	21-49 (70-120)
Anodes	Platinum clad	Platinum clad or stainless steel	Platinum clad
Agitation	Desirable	Desirable	Violent
Current density, A/m^2 (A/ft^2)	11-54 (1-5)	54-220 (5-20)	1,080-4,300 (100-400)
Cathode efficiency, %		30-40	30-40
Time to plate 0.0001 in., min.		10 at 108 A/m^2 (10 at 10 A/ft^2)	0.25 at 4,300 A/m^2 (0.25 at 400 A/ft^2)
Replenishment		1 oz/gold/12 amp-hrs	1 oz gold/12 amp-hrs

[a]Reference 7.

TABLE 2-16. SUMMARY OF OPERATING PARAMETERS FOR INDIUM CYANIDE PLATING BATHS[a]

Parameter	Value
Indium as metal, g/L (oz/gal)	33 (4)
Dextrose, g/L (oz/gal)	33 (4)
Total cyanide (KCN), g/L (oz/gal)	96 (12.8)
Potassium hydroxide (KOH), g/L (oz/gal)	64 (8.5)
Temperature (static)	Room temperature
Cathode efficiency, %	50-75
Anodes	Plain steel
Throwing power	Excellent
Quality of plate	Excellent
Ease of solution analysis	Difficult
Critical temperature (working)	None, with or without agitation
Wettability	Easy
Tendency to pit	None
Control of solution	Cyanide and metal by additions
Use	General
Current density, A/m^2 (A/ft^2)	162-216 (15-20)
pH	High pH

[a]Reference 8.

TABLE 2-17. SUMMARY OF OPERATING PARAMETERS FOR INDIUM SULFAMATE PLATING BATHS[a]

Parameter	Value
Indium sulfamate, g/L (oz/gal)	105 (14)
Sodium sulfamate, g/L (oz/gal)	150 (20)
Sulfamic acid, g/L (oz/gal)	26.4 (3.5)
Sodium chloride, g/L (oz/gal)	45.84 (6)
Dextrose, g/L (oz/gal)	8.0 (1)
Triethanolamine, g/L (oz/gal)	2.29 (0.3)
pH	1-3.5 (1.5-2.0 preferred)
Temperature (static)	Room temperature
Cathode efficiency, %	90
Anode efficiency, %	Indium, 100
Throwing power	Excellent
Quality of plate	Excellent
Ease of solution analysis	Easy
Critical temperature (working)	None, with or without agitation
Wettability	Fairly easy
Tendency to pit	None
Control of solution	Metal and pH
Use of solution	General
Current density, A/m^2 (A/ft^2)	Optimum 108-216 (10-20). If metal is increased, current density can be increased up to 1,080 (100)

[a]Reference 8.

TABLE 2-18. SUMMARY OF OPERATING PARAMETERS FOR INDIUM FLUOBORATE PLATING BATHS[a]

Parameter	Value
Indium fluoborate, g/L (oz/gal)	236 (31.5)
Boric acid, g/L (oz/gal)	22-30 (2.9-4.0)
Ammonium fluoroborate, g/L (oz/gal)	40-50 (5.3-6.7)
pH (colorimetric)	1.0
Temperature (static) °C (°F)	21-32 (70-90)
Cathode efficiency, %	40-75
Anode efficiency, %	Indium, 100
Throwing power	Good
Quality of plate	Good
Ease of solution analysis	Easy
Critical temperature (working), °C (°F)	21-32 (70-90) with or without agitation
Wettability	Difficult
Tendency to pit	None
Control of solution	Metal and pH
Use	General
Current density, A/m^2 (A/ft^2)	540-1,080 (50-100)

[a]Reference 8.

TABLE 2-19. SUMMARY OF OPERATING PARAMETERS FOR NICKEL PLATING BATHS[a]

Parameter	Value								
Constituents	All chloride	Chloride sulfate	All fluoborate	All sulfate	All sulfamate	Chloride sulfamate	Hard sulfamate	Watts	Hard watts
Typical electrolyte compositions, g/L (oz/gal)									
Total nickel	75 (10)	86.4 (11.5)	75 (10)	70 (9.3)	84 (11.2)	84 (11.2)	45 (6)	78 (10.4)	60 (8)
Nickel chloride	300 (40)	158 (21)				22.5 (3)	7.5 (1)	60 (8)	45 (6)
Nickel sulfate		188 (25)		330 (44)				300 (40)	262 (35)
Nickel sulfamate					450 (60)	428 (57)	248 (33)		
Nickel fluoborate			300 (40)						
Boric acid	30 (4)	37.5 (5)	30 (4)	30 (4)	37.5 (5)	37.5 (5)	30 (4)	30 (4)	30 (4)
Anti pitter	x	x	x		x	x	x		x
Addition agent							Optional stress reducer		Optional stress reducer
Operating conditions									
Temperature, °C (°F)	55 (130)	55 (130)	55 (130)	55 (130)	60 (140)	60 (140)	55 (130)	55 (130)	50 (122)
pH	2.0	3.0	2.7	1.5	4.0	4.0	5.0	3.0	5.0
Current density, A/m^2 (A/ft^2)	540 (50)	540 (50)	320 (30)	400 (40)	540 (50)	540 (50)	600 (60)	540 (50)	540 (50)
Cathode efficiency, %	93 - 97%								

[a]Reference 10.

TABLE 2-20. SUMMARY OF OPERATING PARAMETERS FOR NICKEL ELECTROFORMING BATHS[a]

Parameter	Value	
	Watts nickel	Nickel sulfamate
Electrolyte composition, g/L (oz/gal)	$NiSO_4 \cdot 6H_2O$ — 225-300 (30-40) $NiCl_2 \cdot 6H_2O$ — 37.5-52.5 (5-7) H_3BO_3 — 30-45 (4-6)	$Ni(SO_3,NH_2)$ — 315-450 (42-60) H_2BO_2 — 30-45 (4-6) $NiCl_2 \cdot 6H_2O$ — 0-22.5 (0-3)
Operating conditions		
Temperature, °C (°F)	44-66 (115-150)	32-60 (90-140)
Agitation	Air or mechanical	Air or mechanical
Cathode current density, A/m^2 (A/ft^2)	270-1,075 (25-100)	50-3,225 (5-300)
Anodes	Soluble nickel	Soluble nickel
pH	3.0-4.2	3.5-4.5

[a]Reference 10.

TABLE 2-21. SUMMARY OF OPERATING PARAMETERS FOR PALLADIUM AMMONIACAL PLATING BATHS[a]

Parameter	Value
P-salt/sulfamate:	
Palladium as $Pd(NH_3)_2(NO_2)_2$, g/L (oz/gal)	10-15 (1.3-2)
Ammonium sulfamate, g/L (oz/gal)	100 (13.4)
Ammonium hydroxide to pH	7.5-8.5
Temperature, °C (°F)	25-33 (77-91)
Current density, A/m^2 (A/ft^2)	1-20 (0.093-1.86)
Anodes	Platinized
Palladosamine chloride:	
Palladium as $Pd(NH_3)_4Cl_2$, g/L (oz/gal)	10-15 (1.3-2)
Ammonium chloride, g/L (oz/gal)	60-90 (8-12)
Ammonium hydroxide to pH	8.0-9.5
Temperature, °C (°F)	25-50 (77-122)
Current density, A/m^2 (A/ft^2)	1-25 (0.093-2.32)
Anodes	Platinized

[a]Reference 11.

TABLE 2-22. SUMMARY OF OPERATING PARAMETERS FOR PALLADIUM ACID PLATING BATHS[a]

Parameter	Value
P-salt/sulfamate:	
Palladium as $PdCl_2$, g/L (oz/gal)	50 (6.7)
Ammonium chloride, g/L (oz/gal)	30 (4)
Hydrochloric acid	to pH 0.1-0.5
Temperature, °C (°F)	40-50 (104-122)
Current density, A/m^2 (A/ft^2)	1-10 (0.093-0.93)
Anodes	Pure palladium
Cathode efficiency, %	97-100

[a]Reference 11.

TABLE 2-23. SUMMARY OF OPERATING PARAMETERS FOR PALLADIUM-NICKEL PLATING BATHS[a]

Parameter	Value
Palladium as Pd $(NH_3)_2(NO_2)_2$ (palladium metal 3 g/L), g/L (oz/gal)	6 (0.8)
Nickel sulfamate concentrate (nickel metal 3 g/L), g/L (oz/gal)	20 (2.7)
Ammonium sulfamate, g/L (oz/gal)	90 (12)
Ammonium hydroxide to pH	8-9
Temperature, °C (°F)	20-40 (68-104)
Anodes	Platinized

[a]Reference 11.

TABLE 2-24. SUMMARY OF OPERATING PARAMETERS FOR PLATINUM PLATING BATHS[a]

Parameter	Value
Dinitroplatinite sulfate--sulfuric acid:	
Platinum as $H_2Pt(NO_2)_2SO_4$, g/L (oz/gal)	5.0 (0.68)
Sulfuric acid to pH	2.0
Temperature, °C (°F)	40 (104)
Current density, A/m^2 (A/ft^2)	1-10 (0.093-0.93)
Anodes	Platinum
Chloroplatinic acid:	
Platinum as H_2PtCl_6, g/L (oz/gal)	20 (2.7)
Hydrochloric acid, g/L (oz/gal)	300 (40)
Temperature, °C (°F)	65 (149)
Current density, A/m^2 (A/ft^2)	1-20 (0.093-1.86)
Anodes	Platinum
Chloroplatinic acid--Ammoniacal:	
Platinum as H_2PtCl_6, g/L (oz/gal)	10 (1.3)
Ammonium phosphate, g/L (oz/gal)	60 (8)
Ammonium hydroxide to pH	7.5-9
Temperature, °C (°F)	65-75 (149-167)
Current density, A/m^2 (A/ft^2)	1-10 (0.093-0.93)
Anodes	Platinized

[a]Reference 12.

TABLE 2-25. SUMMARY OF OPERATING PARAMETERS FOR DECORATIVE RHODIUM PLATING BATHS[a]

Parameter	Value
Phosphate rhodium bath:	
Rhodium as phosphate concentrate, g/L (oz/gal)	2.0 (0.27)
Phosphoric acid (85% CP grade), ml/L (oz/gal)	40-80 (5.3-11)
Anodes	Platinum/platinum clad
Temperature, °C (°F)	40-50 (104-122)
Agitation	None-moderate
Current density, A/m^2 (A/ft^2)	20-100 (1.86-9.3)
Sulfate rhodium bath:	
Rhodium as sulfate concentrate, g/L (oz/gal)	1.3-2.0 (0.17-0.27)
Sulfuric acid (95% CP grade), ml/L (oz/gal)	25-80 (3-11)
Anodes	Platinum/platinum clad
Temperature, °C (°F)	40-50 (104-122)
AgitationCurrent density, A/m^2 (A/ft^2)	None-moderate 20-100 (1.86-9.3)
Phosphate-sulfate rhodium bath:	
Rhodium as phosphate concentrate, g/L (oz/gal)	2 (0.3)
Sulfuric acid (95% CP grade), ml/L (oz/gal)	25-80 (3-11)
Anodes	Platinum/platinum clad
Temperature, °C (°F)	40-50 (104-122)
Agitation	None-moderate
Current density, A/m^2 (A/ft^2)	20-100 (1.86-9.3)

[a]Reference 13.

TABLE 2-26. SUMMARY OF OPERATING PARAMETERS FOR ELECTRONIC/ INDUSTRIAL RHODIUM PLATING BATHS[a]

Parameter	Value
Rhodium metal as sulfate concentrate, g/L (oz/gal)	5.0 (0.67)
Sulfuric acid (95% CP grade), ml/L (oz/gal)	25-50 (3-7)
Anodes	Platinum/platinum clad
Temperature, °C (°F)	45-50 (113-122)
Current density, A/m^2 (A/ft^2)	10-30 (0.93-2.79)
Cathode efficiency, %	70-90 with agitation 50-60 without agitation

[a]Reference 13.

TABLE 2-27. SUMMARY OF OPERATING PARAMETERS FOR RUTHENIUM PLATING BATHS[a]

Parameter	Value
Ruthenium (as sulfamate or nitrosyl sulfamate), g/L (oz/gal)	5.3 (0.71)
Sulfamic acid, g/L (oz/gal)	8.0 (1.1)
Anodes	Platinum
pH	1-2
Temperature, °C (°F)	27-60 (80-140) sulfamate 21-88 (70-190) nitrosyl sulfamate
Current density, A/m^2 (A/ft^2)	108-320 (10-30)
Cathode efficiency, %	20
Time to plate 0.0001 in., min	30-40 at 215 A/m^2 (30-40 at 20 A/ft^2)

[a]Reference 14.

TABLE 2-28. SUMMARY OF OPERATING PARAMETERS FOR SILVER CYANIDE PLATING BATHS[a]

Parameter	Value
Silver, as $KAg(CN)_2$, g/L (oz/gal)	5-40 (0.67-5.3)
Potassium cyanide (free), g/L (oz/gal)	12-120 (1.6-16)
Potassium carbonate (min.), g/L (oz/gal)	15 (2)
Temperature, °C (°F)	20-30 (70-85)
Current density, A/m^2 (A/ft^2)	11-430 (1-40)

[a]Reference 15.

TABLE 2-29. SUMMARY OF OPERATING PARAMETERS FOR 60/40 TIN-LEAD PLATING BATHS[a]

Parameter	Value			
	Optimum		Range	
	oz/gal	g/L	oz/gal	g/L
Stannous tin	7.5	56.3	7-8	52.5-60
Lead	3.5	26.3	3-4	22.5-30
Fluoboric acid	13.3	99.8	13-20	98-150
Boric acid	3.5	26.3	3-5	22.5-37.5
Liquid peptone or Peptone	2.6 0.7	19.5 5.3	2-3 0.6-0.9	15-22.5 4.5-7
Current density, A/m^2 (A/ft^2)	320 (30)		270-380 (25-35)	
Anode to cathode ratio	2:1			
Anodes	60/40 tin lead bagged with Dynel or polypropylene			
Temperature, °C (°F)	20 (70)		15.5-27 (60-80)	
Agitation	Mild cathode rod			
Filtration	Continuous is recommended to maintain a clear solution.			

[a]Reference 16.

TABLE 2-30. SUMMARY OF OPERATING PARAMETERS FOR LEAD FLUOBORATE PLATING BATHS[a]

Parameter	Value			
	Optimum		Range	
	oz/gal	g/L	oz/gal	g/L
Lead fluoborate	50	375	45-55	337-412
Lead	29	218	26-32	195-239
Fluoboric acid	3	22.5	2-4	15-30
Boric acid	4	30	3-5	22.5-37.5
Liquid peptone or Peptone	2.6 0.7	19.5 5.3	2-3 0.6-0.9	15-22.5 4.5-7
pH	Less than 1			
Current density, A/m^2 (A/ft^2)	215-750 (20-70)			
Anode to cathode ratio	1:1			
Anodes	Pure lead			
Temperature, °C (°F)	20-38 (70-100)			
Agitation	Mechanical			
Filtration	Will ensure smooth deposits. If solution is maintained under a constantly operated filter pump, it will assure the best agitation and filtration.			

[a]Reference 16.

TABLE 2-31. SUMMARY OF OPERATING PARAMETERS FOR STANNOUS FLUOBORATE PLATING BATHS[a]

Parameter	Value			
	Optimum		Range	
	oz/gal	g/L	oz/gal	g/L
Stannous fluoborate	12.5	94	10-15	75-113
Tin	5	37	4-6	30-45
Fluoboric acid	30	225	25-35	188-263
Boric acid	4	30	3-5	22.5-37.5
Addition agent	As recommended by manufacturer			
Anodes	Pure tin, bagged with Dynel or polypropylene			
Anode current density, A/m^2 (A/ft^2)	215-270 (20-25)			
Filtration	Constant filtration using a nonsilicated fiber aid is desirable, although not necessary; such treatment keeps the solution clean and affords agitation.			
Temperature, °C (°F)	32-49 (90-120)			
Agitation	Mild, mechanical			
Cathode current density, A/m^2 (A/ft^2)	10.8-860 (1-80)			
Cathode efficiency, %	>95			

[a]Reference 16.

TABLE 2-32. SUMMARY OF OPERATING PARAMETERS FOR STANNOUS SULFATE PLATING BATHS[a]

Parameter	Value			
	Optimum		Range	
	oz/gal	g/L	oz/gal	g/L
Stannous sulfate	4	30	2-6	15-45
Stannous tin	2	15	1-3	7.5-22.5
Sulfuric acid	23	172	18-28	135-210
Addition agent	As recommended by manufacturer			
Anodes	Pure tin			
Anode current density, A/m^2 (A/ft^2)	215 (20)		Up to 270 (25)	
Cathode current density, A/m^2 (A/ft^2)	215 (20)		10.8-24.7 (1-25)	
Cathode efficiency, %	>95		>95	
Voltage	0.4		0.4-0.8	
Temperature, °C (°F)	20 (70)		13-29 (55-85)	
Agitation	Mechanical, cathode rod			
Filtration	Constant filtration using a nonsilicated filter aid is desirable, although not necessary; such treatment keeps the solution clean and affords agitation.			

[a]Reference 16.

TABLE 2-33. SUMMARY OF OPERATING PARAMETERS FOR SODIUM/ POTASSIUM STANNATE PLATING BATHS[a]

Parameter	Value			
	Rack		Barrel	
	oz/gal	g/L	oz/gal	g/L
Sodium stannate bath				
Sodium stannate	12	90	24	180
Tin metal	5.3	40	10.6	80
Free sodium hydroxide	1.6	12	3	22.5
Cathode current density, A/m^2 (A/ft^2)	162-216 (15-20)		54-162 (5-15)	
Anode current density, A/m^2 (A/ft^2)	270 (25)		162-270 (15-25)	
Voltage	3-4		3-4	
Temperature, °C (°F)	77-82 (170-180)		74-79 (165-175)	
Potassium stannate bath				
Potassium stannate	13.3	100	26.6	200
Tin metal	5.3	40	10.6	80
Free potassium hydroxide	2	15	3	22.5
Cathode current density, A/m^2 (A/ft^2)	320-1,080 (30-100)		10.7-1,080 (1-100)	
Anode current density, A/m^2 (A/ft^2)	320-430 (30-40)		108-320 (10-30)	
Voltage	4-8		4-14	
Temperature, °C (°F)	66-82 (150-180)		66-82 (150-180)	

[a]Reference 16.

TABLE 2-34. SUMMARY OF OPERATING PARAMETERS FOR TIN-NICKEL FLUORIDE PLATING BATHS[a]

Parameter	Value
Solution composition:	
Stannous chloride anhydrous ($SnCl_2$), g/L (oz/gal)	49 (6.5)
Nickel chloride ($NiCl_2 6H_2O$), g/L (oz/gal)	300 (40)
Ammonium bifluoride (NH_4HF_2), g/L (oz/gal)	56 (7.5)
Control limits:	
Stannous tin, g/L (oz/gal)	26-38 (3.5-5.0)
Nickel, g/L (oz/gal)	60-83 (8.0-11.0)
Total fluoride, g/L (oz/gal)	34-45 (4.5-6.0)
pH	2-2.5
Operating conditions:	
Temperature, °C (°F)	65 (150)
Voltage, V	2-4
Cathode current density, A/m^2 (A/ft^2)	270 (25)

[a]Reference 16.

TABLE 2-35. SUMMARY OF OPERATING PARAMETERS FOR TIN-NICKEL PYROPHOSPHATE PLATING BATHS[a]

Parameter	Value
Stannous chloride ($SnCl_2 2H_2O$), g/L (oz/gal)	28.2 (3.8)
Nickel chloride ($NiCl_2 6H_2O$), g/L (oz/gal)	31.3 (4.2)
Potassium pyrophosphate ($K_4P_2O_7 3H_2O$), g/L (oz/gal)	192.2 (25.8)
Glycine, g/L (oz/gal)	20.0 (2.7)
Temperature, °C (°F)	50 (122)
pH	7.5-8.5
Current density, A/m^2 (A/ft^2)	52-150 (4.8-14)

[a]Reference 16.

TABLE 2-36. SUMMARY OF OPERATING PARAMETERS FOR ZINC PLATING BATHS[a]

Parameter	Value							
	Zinc metal[b]	Sodium hydroxide[c]	Sodium cyanide	Ammonium chloride[d]	Potassium chloride[d]	Boric acid[e]	pH	Temperature °C (°F)
	g/L (oz/gal)							
Acid chloride zinc								
All ammonium chloride	14.9-30 (2.0-4.0)			120-150 (16.0-20.0)			5.0-6.0	
Low ammonium potassium chloride	14.9-30 (2.0-4.0)			30-45 (4.0-6.0)	120-150 (16.0-20.0)		5.0-6.0	15.5-54 (60-130)
Nonammonium or all-potassium chloride	22.5-37.5 (3.0-5.0)				187-225 (25.0-30.0)	22.5-37.5 (3.0-5.0)	5.0-5.5	
Alkaline noncyanide zinc:								
Low chemistry	6-9 (0.8-1.2)	75-105 (10.0-14.0)						15.5-43 (60-110)
High chemistry	13.5-22.5 (1.8-3.0)	120-150 (16.0-20.0)						
Cyanide zinc:								
Low cyanide	7.5-11 (1.0-1.5)	75-90 (10.0-12.0)	11-19 (1.5-2.5)					
Mid cyanide	13.5-19 (1.8-2.5)	75-90 (10.0-12.0)	26-45 (3.5-6.0)					15.5-38 (60-100)
High cyanide	26-34 (3.5-4.5)	75-90 (10.0-12.0)	82-105 (11.0-14.0)					

[a]Reference 17.
[b]Zinc metal source: Acid chloride zinc--zinc chloride.
Alkaline noncyanide zinc--zinc oxide (preferably nonleaded).
Cyanide zinc--zinc oxide or zinc cyanide.
[c]Sodium hydroxide source: mercury cell grade or rayon grade.
[d]Ammonium and potassium chloride source: untreated is preferred.
[e]Boric acid source: granular preferred as powdered form creates a dusting problem.

TABLE 2-37. SUMMARY OF OPERATING PARAMETERS FOR ZINC-NICKEL PLATING BATHS[a]

Parameter	Value	
	Rack	Barrel
Acid zinc-nickel bath:		
Zinc chloride, g/L (oz/gal)	130 (17)	120 (16)
Nickel chloride, g/L (oz/gal)	130 (17)	110 (15)
Potassium chloride, g/L (oz/gal)	230 (31)	--
pH	5.0-6.0	5.0-6.0
Temperature, °C (°F)	24-30 (75-86)	35-40 (95-104)
Cathode current density, A/m^2 (A/ft^2)	10-40 (0.9-3.7)	5-30 (0.46-2.8)
Anodes	Zinc and nickel separately. In some cases, separate rectifiers and bussing are required.	
Alkaline zinc-nickel bath		
Zinc metal, g/L (oz/gal)		8.0 (1.1)
Nickel metal, g/L (oz/gal)		1.6 (0.21)
Sodium hydroxide, g/L (oz/gal)		130 (17)
Ratio zinc/nickel, g/L (oz/gal)		5.0
Temperature, °C (°F)		23-26 (73-79)
Cathode current density, A/m^2 (A/ft^2)		20-100 (1.85-9.3)
Anode current density, A/m^2 (A/ft^2)		50-70 (4.6-6.5)
Anodes		Pure zinc

[a]Reference 18.

TABLE 2-38. SUMMARY OF OPERATING PARAMETERS FOR ZINC-COBALT PLATING BATHS[a]

Parameter	Value	
	Rack	Barrel
Acid zinc-cobalt bath:		
Zinc metal, g/L (oz/gal)	30 (4)	30 (4)
Potassium chloride, g/L (oz/gal)	180 (24)	225 (30)
Ammonium chloride, g/L (oz/gal)	45 (6)	--
Cobalt (as metal), g/L (oz/gal)	1.9-3.8 (0.25-0.5)	1.9-3.8 (0.25-0.51)
Boric acid, g/L (oz/gal)	15-25 (2-3.3)	15-25 (2-3.3)
pH	5.0-6.0	5.0-6.0
Temperature, °C (°F)	21-38 (70-100)	21-38 (70-100)
Cathode current density, A/m^2 (A/ft^2)	1-50 (0.09-4.6)	10-500 (0.93-46)
Anodes	Pure zinc	Pure zinc
Alkaline zinc-cobalt bath:		
Zinc metal, g/L (oz/gal)		6-9 (0.80-1.2)
Caustic soda, g/L (oz/gal)		75-105 (10-14)
Cobalt metal, g/L (oz/gal)		30-50 (0.004-0.007)
Temperature, °C (°F)		21-32 (70-90)
Cathode current density, A/m^2 (A/ft^2)		20-40 (1.9-3.7)
Anodes		Steel

[a]Reference 18.

TABLE 2-39. SUMMARY OF OPERATING PARAMETERS FOR ZINC-IRON PLATING BATHS[a]

Parameter	Value
Acid zinc-iron bath:	
Ferric sulfate, g/L (oz/gal)	200-300 (27-40)
Zinc sulfate, g/L (oz/gal)	200-300 (27-40)
Sodium sulfate, g/L (oz/gal)	30 (4)
Sodium acetate, g/L (oz/gal)	20 (2.7)
Alkaline zinc-iron bath:	
Zinc metal, g/L (oz/gal)	20-25 (2.7-3.3)
Iron metal, g/L (oz/gal)	0.25-0.50 (0.033-0.067)
Caustic soda, g/L (oz/gal)	120-140 (16-19)
Temperature, °C (°F)	18-23 (64-73)
Cathode current density, A/m^2 (A/ft^2)	15-30 (1.4-2.8)
Anodes	Steel

[a]Reference 18.

REFERENCES FOR SECTION 2

1. J. Horner, "Electroplating," *Kirk-Othmer Encyclopedia of Chemical Technology, 4th Ed., Volume No. 9*, John Wiley and Sons, Inc., New York, NY, 1994.

2. *Locating and Estimating Air Emissions from Sources of Chromium (Supplement)*. U. S. Environmental Protection Agency, Research Triangle Park, NC. EPA Publication No. 450/2-89-002. August 1989.

3. *Chromium Emissions From Chromium Electroplating and Chromic Acid Anodizing Operations--Background Information for Proposed Standards*, EPA 453/R-93-030a, U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1993.

4. H. Strow, "Brass Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91,* Number 1A, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

5. H. Morrow, "Cadmium Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

6. A. Sato and R. Barauskas, "Copper Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

7. A. Weisberg, "Gold Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

8. J. Slattery, "Indium Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

9. R. Williams, "Iron Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

10. G. DiBari, "Nickel Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

11. R. Morrissey,"Palladium and Palladium-Nickel Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

12. R. Morrissey, "Platinum Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

13. A. Weisberg, "Rhodium Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

14. A. Weisberg, "Ruthenium Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

15. A. Blair, "Silver Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

16. S. Hirsch, "Tin-Lead, Lead and Tin Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

17. V. Kansupada, C. Biddulph, and M. Marzano, "Zinc Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

18. E. Budman, "Zinc Alloy Plating," *Metal Finishing Guidebook and Directory Issue '93, Volume 91, Number 1A*, Elsevier Science Publishing Company, Inc., New York, NY, January 1993.

3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The AP-42 Background Files located in the Emission Factors and Inventory Group (EFIG) were reviewed for information on the industry, processes, and emissions. The majority of information was obtained from the Emission Standards Division (ESD) project files on electroplating, the Locating and Estimating Air Emissions from Sources of Chromium document, and the national emission standards for hazardous air pollutants (NESHAP) for chromium electroplating. Additional emission test reports were obtained from the Source Test Information Retrieval System (STIRS) data base. The American Electroplaters and Surface Finishers Society and the National Association of Metal Finishers also were contacted for information on the industry.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study should contain test results based on more than one test run. If results from only one run are presented, the emission factors must be down rated.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 DATA QUALITY RATING SYSTEM

As part of the analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were excluded from consideration:

1. Test series averages reported in units that cannot be converted to the selected reporting units;

2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front half with EPA Method 5 front and back half);

3. Test series of controlled emissions for which the control device is not specified;

4. Test series in which the source process is not clearly identified and described; and

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EFIG for preparing AP-42 sections. The data were rated as follows:

A--Multiple tests that were performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in EPA reference test methods, although these methods were used as a guide for the methodology actually used.

B--Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C--Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D--Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM[1]

The quality of the emission factors developed from analysis of the test data was rated using the following general criteria:

A—Excellent: Developed from A- and B-rated source test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B—Above average: Developed only from A- or B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A-, B- and/or C-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. In addition, the source category is specific enough so that variability within the source category population may be minimized.

D—Below average: The emission factor was developed only from A-, B-, and/or C-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E—Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are footnoted.

The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Section 4.

3.4 EMISSION TEST METHODS FOR CHROMIUM ELECTROPLATING AND CHROMIC ACID ANODIZING[2]

Significant quantities of chromium are emitted from hard chromium plating, decorative chromium plating, and chromic acid anodizing operations. The various test methods used to quantify the amount of chromium emitted from these sources are all primarily a modification of Method 5. The EPA standard reference methods for chromium are Methods 306 and 306A, Determination of Chromium Emissions from Decorative and Hard Chromium Electroplating and Anodizing Operations (40 CFR 63, Appendix A).

Method 306 was developed in support of the NESHAP for chromium plating and anodizing operations. During the development of Method 306, the test method was referred to as a modified Method 5 as well as a modified Method 13B in the EPA test reports. The initial modifications to the Method 5 sampling train were the use of 0.1 normal (N) sodium hydroxide or 0.1 N sodium bicarbonate instead of water as the impinger solution and the elimination of the filter. The impinger solution was changed in order to stabilize the hexavalent chromium content of the sample collected. The sampling protocol also requires that 0.1 N sodium hydroxide or sodium bicarbonate, depending upon whichever

solution was used as the impinger solution, be used as the sample recovery solution instead of acetone. The purpose of eliminating the filter was to improve the accuracy of the test results. The presence of the filter increased the difficulty of sample recovery; chromium could also be trapped in the filter frit and not be recovered. An additional modification was made to the sampling train after it was determined that the use of the stainless steel nozzle and probe assembly could potentially react with the hexavalent chromium collected resulting in the reduction of hexavalent chromium to trivalent chromium. Therefore, the final modification to the sampling train consisted of requiring a glass nozzle and glass-lined probe.

The analytical methods for measuring the chromium content of the samples collected also evolved over the course of the standards development project. In the early phases of the project, the samples were analyzed for the total chromium content using inductively coupled argon plasmography (ICAP) or graphite furnace atomic absorption spectroscopy (GFAAS). Graphite furnace atomic absorption spectroscopy has a lower detection limit than ICAP and should be used on emission samples collected at the outlet of control systems. The detection limits for ICAP and GFAAS are 7 micrograms per liter (μg/L) and 1 μg/L. The minimum quantification limit for these methods is 5 times the detection limit of the method. At present, the ICAP method is only recommended for measuring uncontrolled chromium emissions from a source.

As with total chromium emission measurements, two methods were used for determining the hexavalent chromium content of the sample. Hexavalent chromium emissions were determined using either the diphenylcarbazide colorimetric method or ion chromatography with a post column reactor (ICPCR). The diphenylcarbazide colorimetric method has a detection limit of 10 μg/L; therefore, the lowest quantifiable limit for this method is 50 μg/L. Following the recent promulgation of stringent State standards, improved control systems were developed for chromium plating and anodizing operations. As a result of the improved emission control, the diphenylcarbazide colorimetric method was replaced with the ICPCR method for determining the hexavalent chromium content of the collected samples. The detection limit of the ICPCR method is 0.5 μg/L and the quantifiable limit is 2.5 μg/L. To quantify hexavalent chromium emissions from electroplating tanks with the improved emission controls using the colorimetric method would have required much longer sampling times. By using ICPCR as the analytical method, the sample time and sample volume did not need to be increased dramatically in order to ensure the sample collected was quantifiable.

The final Method 306 sampling and analytical procedures consist of sampling using a modified Method 5 sampling train. The Method 5 sampling train is modified by using sodium hydroxide or sodium bicarbonate as the impinger solution, eliminating the filter, and using a glass probe and nozzle assembly rather than a stainless steel assembly. The preferred analytical methods are ICPCR for determining the hexavalent chromium content and GFAAS for determining the total chromium content.

A second test method, Method 306A, was developed by EPA's Emissions, Monitoring, and Analysis Division as a low-cost alternative to Method 306. Correctly applied, the precision and bias of the sample results obtained using Method 306A are comparable to those obtained using Method 306. Under Method 306A, the sample is extracted from the emission source at a constant sampling rate determined by a critical orifice and collected in a probe and impingers. The sampling time at the sampling traverse points is varied according to the stack gas velocity at each point to obtain a proportional sample rather than an isokinetic sample obtained using Method 306. The components of the sampling train are available commercially, but some fabrication and assembly are required. The probe nozzle is made from 1/4 in. inner diameter glass or rigid plastic tubing about 8 in. long with a short 90 degree bend at one end to form the nozzle. The nozzle is then attached to flexible tubing of sufficient length to collect a sample from the stack. The plastic tubing (e.g., polyethylene, polypropylene, or polyvinylchloride) should have an inner

diameter of 1/4 in. to 3/8 in. The plastic tubing is also used to connect the other train components. Three one-quart "Mason" glass canning jars with vacuum seal lids are used as the impingers. The first jar is used for collecting the absorbing solution, the second jar is empty and is used to collected any absorbing solution carried over from the first impinger, and the third jar contains the drying agent. As with Method 306, 0.1 N sodium hydroxide or sodium bicarbonate is used as the impinger solution and for sample recovery. The other components required for sampling are a manometer, critical orifice, vacuum pump, and dry gas meter. Alternatively, Method 306 equipment can be used and the sampling rate of the meter box set at the delta H specified for the calibrated orifice; the train is then operated as specified by Method 306A. The analytical methods used for determining the total and hexavalent chromium content of the sample are the same as those used for Method 306. Additional details on Method 306A are provided in 40 CFR 63, Appendix A.

A third test method used to measure emissions from chromium electroplating and anodizing operations is California Air Resources Board (CARB) Method 425. The CARB Method 425 sample train is almost identical to the Method 306 train except that the filter is used between the third and fourth impingers. The catch on these filters is usually negligible. Therefore, the sampling train is basically equivalent to the Method 306 train. However, the analytical method specified by CARB Method 425 is the diphenylcarbazide colorimetric method for determining the hexavalent chromium content of the sample collected. If the sample size collected is sufficient to ensure that the chromium content in the sample is above the quantification limit of the diphenylcarbazide colorimetric method, the results from CARB Method 425 should be acceptable. Alternatively, if the collected samples are analyzed using either GFAAS for total chromium or ICPCR for hexavalent chromium, CARB Method 425 results should be acceptable.

The acceptability of other test methods should be determined based on a comparison of the sampling and analytical techniques to those used under Method 306. Results from tests that do not meet the minimum quantification limits of the analytical method cannot be accepted as valid emission test measurements.

3.5 FACTORS AFFECTING CHROMIUM EMISSIONS FROM ELECTROPLATING AND ANODIZING[2]

The data for emission tests on chromium electroplating tanks show a large degree of variability from test to test. Numerous factors cause the variability in the emission data. These factors include:

1. Current density applied;
2. Surface area of the part plated;
3. Plate thickness;
4. Plating time;
5. Type of parts plated;
6. Orientation of the parts within the tank;
7. Chromic acid concentration; and
8. Surface tension of the plating bath.

The first four of these factors are all interrelated and determined by using the electrochemical equivalent of chromium, which is:

$$\frac{(\text{Current, amperes})\ (\text{Plating time, hr})}{(\text{Thickness, mil})\ (\text{Surface area of part, ft}^2)} = 51.8$$

The electrochemical equivalent is derived from Faraday's law. The equation above is based on a cathode efficiency of 100 percent and means that 51.8 A-hr are required to deposit 25 µm (1 mil) of chromium per square foot of part surface area. Table 3-1

TABLE 3-1. ELECTROCHEMICAL EQUIVALENTS OF PLATING METALS[a]

Metal	Atomic weight	Specific gravity	Valence No.	Electrochemical equivalent, A-hr/mil-ft^2
Cadmium	112.4	8.64	2	9.73
Chromium	52.01	7.1	6 3	51.8 25.9
Copper	63.57	8.92	2 1	17.7 8.84
Gold	197.2	19.3	3 2 1	18.6 12.4 6.2
Indium	114.76	7.31	3	12.1
Iron	55.84	7.9	2	17.9
Lead	207.2	11.3	2	6.9
Nickel	58.69	8.9	2	19.0
Palladium	106.7	12	4 3 2	28.6 21.4 14.2
Platinum	195.23	21.4	4	27.6 13.85
Rhodium	102.9	12.5	4 3 2	30.8 23.1 15.37
Silver	107.87	10.5	1	6.16
Tin	118.7	7.3	4 2	15.6 7.82
Zinc	65.37	7.1	2	13.7

[a]Reference 3.

lists the electrochemical equivalent for several plating metals. As discussed previously, the cathode efficiency for actual chromium plating baths is only 10 to 20 percent. The surface area of the part and the minimum plate thickness generally are known. The other variables can be estimated by modifying the equation to account for the actual cathode efficiency. In the majority of cases, facilities increase the plating time to account for the lower cathode efficiency. It is a common practice to set the current based on a current density of 3,100 A/m^2 (2 $A/in.^2$) for hard chromium plating and approximately 1,500 A/m^2 (1 $A/in.^2$) for decorative chromium plating. The low cathode efficiency means that 80 to 90 percent of the current supplied to the bath goes to form hydrogen gas, which entraps the chromium solution. The amount of misting then becomes directly proportional to the amount of current supplied over a given time period.

The type of part plated affects emissions because of its shape. For example, if two similar parts (parts with the same surface area) are plated to equal minimum thicknesses, but one part has a smooth surface and the other part has many recessed areas, the part with the recessed areas will require more current than the part with the smooth surface. The poor throwing power of chromium plating baths results in thicker deposits in the high current density range and thinner deposits in the low current density range. The current densities vary across the surface of recessed parts because of the varying distances from the anode. The orientation of the part within the tank also affects the amount of emissions. For example, if the same part is plated in a shallow horizontal tank, more chromium will be emitted than if the part is plated in a deep vertical tank. In a shallow tank, the hydrogen gas is evolved closer to the surface of the solution and the agitation effect is much greater than with the hydrogen gas generated in a deeper tank. The chromic acid concentration affects emissions generation because the higher the concentration of the solution that is entrapped in the hydrogen gas bubbles, the more chromium will be emitted when the bubbles burst to form the mist. The surface tension of the plating solution is another factor that affects the emissions. Common hexavalent chromium plating baths have a surface tension of 70 dynes/cm (4.8×10^{-3} lb/ft). However, surfactants can be added to the plating bath to reduce the surface tension below 40 dynes/cm (2.7×10^{-3} lb/ft). At the lower surface tension, the hydrogen gas bubbles will not burst at the surface of the solution and the misting is substantially reduced.

There are two other factors that do not affect the quantity of emissions generated but that do affect the measurement of those emissions. These factors are the ventilation rate and the sample location in the duct. The ventilation rate must be adequate to capture the chromium mist; if the mist is not captured, then it cannot be measured accurately. In addition, the required ventilation rate is determined based on the surface area of the tank. Therefore, two tanks with the same capacities but different surface areas will be vented at different rates. If the two tanks are plating identical parts, the tank with the higher ventilation rate will have a lower concentration of chromium than the tank with a lower ventilation rate. The sample location will also affect the quantity of emissions measured because chromic acid mist will impinge on the duct walls and will lower the amount of chromium measured. For example, if a plating tank was tested with sample locations directly following the

hood and 15 m (50 ft) downstream of the hood, the emissions measured at the hood would be higher than those measured 15 m (50 ft) downstream.

3.6 EMISSION FACTOR UNITS FOR ELECTROPLATING AND CHROMIC ACID ANODIZING[2]

3.6.1 Electroplating Emission Factor Units

As part of the development of the chromium electroplating NESHAP, an analysis of emission test data was conducted to evaluate the relationship between chromium emissions from hard chromium plating operations and key process operating parameters. Although small positive correlations were observed between total hexavalent chromium emissions and both energy input in ampere-hours and tank surface area, no statistically significant relationships were found. Based on engineering judgment, total energy input (ampere-hours) was selected as the best measure of process rate for uncontrolled emissions from electroplating operations for the following reasons: (1) emission generating mechanisms are related directly to energy input, and (2) energy input can be measured accurately. Emission data were normalized for different process rates and expressed in units of milligrams of chromium per ampere-hour (mg/A-hr) (grains per ampere-hour [gr/hr]). Subsequent analyses of the test data indicated that the variability in process emission rates between plants was much greater than the variability in process emission rates for different test runs at the same plant. These results suggest that operating differences between plants have a greater impact on emissions than does normal process measurement variability.

For controlled emissions from electroplating operations, each of the add-on control devices used in the industry generally achieves a narrow range of outlet concentrations of chromium, regardless of the level of energy input. For this reason, total energy input may not be an appropriate basis for establishing factors for controlled emissions for this industry. Therefore, the factors for controlled emissions from chromium electroplating tanks are presented in the draft AP-42 section both as concentrations in units of milligrams per dry standard cubic meter (mg/dscm) (grains per dry standard cubic foot [gr/dscf]) and in units of total energy input. Emission rates for controlled emissions should be estimated using the concentration factors and typical exhaust flow rates for the particular type of exhaust system in question. The factors for controlled emissions based on total energy input should only be used in the absence of site-specific information.

The AP-42 section on electroplating presents all electroplating emission factors in the units described above. For the electroplating of metals other than chromium, the concentration-based emission factors should be used whenever possible for the reasons given in the previous paragraphs.

3.6.2 Chromic Acid Anodizing Emission Factor Units

The factors that affect the hexavalent chromium emission rate from chromic acid anodizing tanks are the type and surface area of parts anodized, surface area of the anodizing tank, orientation of parts within the anodizing tank, plating bath temperature, chromic acid concentration, and surface tension of the anodizing solution. These factors affect emissions in the same manner as they affect emissions from plating baths (see Section 3.5). However, a key difference between chromium plating and anodizing is the effect of the current applied on emission generation. In plating, the current does not vary over the plating time, and therefore, the chromium mist is generated at a constant rate. In anodizing, the current varies because the oxide layer that is built up on the anodized part is resistant to current flow; the current peaks at the beginning of the anodizing cycle and decreases as the thickness of the oxide layer (or resistance) builds up. Therefore, the amount of hydrogen gassing or chromium misting decreases over the anodizing time as

the current decreases. Because of the current fluctuations in anodizing, the average current supplied to the anodizing tank is difficult to determine, which in turn makes it difficult to develop an emission factor based on energy input.

The other predominant factors that affect emissions from chromic acid anodizing operations are the type and surface area of parts anodized, the surface area of the anodizing tank, and the chromic acid concentration. The chromic acid concentration is fairly constant for all anodizing baths and does not account for variations in the process load. The surface area of the parts is probably the best measure of emissions; however, the surface area may or may not be known and is difficult to quantify for most shapes. Therefore, tank surface area was selected as the best measure of emissions for the following reasons: (1) energy input for anodizing operations cannot be accurately measured, and (2) tank surface area is a constraint on the workload, which is related to emission-generating mechanisms. The emission factors for chromic acid anodizing are presented in units of grams per hour per square meter (g/hr-m^2) and grains per hour per square foot (gr/hr-f^2).

REFERENCE FOR SECTION 3

1. *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*, EPA-454/B-93-050, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1993.

2. *Chromium Emissions From Chromium Electroplating and Chromic Acid Anodizing Operations--Background Information for Proposed Standards*, EPA-453/R-93-030a, U. S. Environmental Protection Agency, Research Triangle Park, NC, July 1993.

3. A. Graham, *Electroplating Engineering Handbook*, Third Edition, Van Nostrand Reinhold Company, New York, NY, 1971.

4. AP-42 SECTION DEVELOPMENT

This section describes how the AP-42 section on electroplating was developed. First, descriptions of data sets that were reviewed for this report are presented, followed by a discussion of how candidate emission factors were developed from the electroplating data and a statistical analysis of the data used to develop candidate emission factors. Finally, a methodology is presented for estimating emission factors for the electroplating of metals other than chromium.

4.1 REVIEW OF SPECIFIC DATA SETS

The literature search yielded a total of 97 reports that contained data on emissions from electroplating. Emission factors were developed from 54 of those documents. A review of the usable references is provided in the following paragraphs. Table 4-1 summarizes the reasons why the other documents could not be used to develop emission factors.

4.1.1 Reference 1. This report documents an emission test conducted at a medium-size job shop that performs hard chromium electroplating of textile, hydraulic, woodworking, and laundry machine parts. The hard chromium plating facility consisted of six tanks; however, emissions testing was conducted only on the chevron-blade mist eliminator controlling chromium emissions from Tank 6, which has a capacity of 9,800 L (2,590 gal). Based on size, chromic acid concentration, and operating parameters such as current, voltage, and plating time, Tank 6 is typical of hard chromium plating tanks in the electroplating industry. The plating solution used in Tank 6 was a conventional chromic acid solution containing chromic acid in a concentration of 255 g/L (34 oz/gal) of plating solution. Sulfuric acid in a concentration of about 2.55 g/L (0.34 oz/gal) of solution was added as a catalyst. About 5,500 kg (12,000 lb) of chromic acid were consumed by the plant per year.

Emissions were captured by an exhaust system and then vented to a chevron-blade mist eliminator with a single set of sinusoidal-wave-type blades. The mist eliminator was periodically washed with water, which drained into the plating tank. Emissions were quantified using Method 13B. The samples were analyzed for total chromium by neutron activation analysis (NAA) and for hexavalent chromium by the diphenylcarbazide colorimetric method. Four test runs were conducted at the inlet and outlet of the mist eliminator to characterize uncontrolled chromium emissions from Tank 6 and the performance of the mist eliminator. Particle size distribution also was measured at the inlet and outlet using cascade impactors. However, because the train used a buttonhook nozzle, the data are not valid. The process was operating normally during the tests.

The parameters and results of the emission tests are shown in Table 4-2. These emission data are rated A.

4.1.2 Reference 2

This report documents the results of an emission test conducted at a plant that manufactures and refurbishes industrial rolls for the packing and textile industries. The plant operated six hard chromium plating tanks. Hard chromium plate is applied to the industrial rolls as the final, finishing stage to provide a wear-resistant surface and protection from corrosion.

The facility tested consisted of two hard chromium plating tanks that were controlled by a chevron-blade mist eliminator with a single set of blades. Emissions tests were performed at the inlet and outlet of the mist eliminator. The first tank had a capacity of about 1,780 L (470 gal) of plating solution and the second tank had a capacity of about 2,350 L (620 gal) of plating solution. The chromium acid concentration of the plating baths was 210 g/L (28 oz/gal) of solution. The normal operating temperature of the plating baths ranges from 43° to 54°C (110° to 130°F). Both tanks were equipped with a circulating water cooling system.

Tank 1 contained two work stations, each of which was equipped with a 3,000-A rectifier. Tank 2 was equipped with one 5,000-A rectifier. Typically, one industrial roll could be plated at a time in each tank. The operating voltage and current for each roll typically ranged from 10 to 15 V and 1,200 to 1,600 A. About 13 µm (0.5 mil) of chromium plate was applied to each roll.

Both tanks were equipped with double-sided lateral exhaust hoods. Exhaust gases from both tanks were ducted together and vented to a horizontal-flow chevron-blade mist eliminator. The mist eliminator contained a single set of overlapping-type blades and was located on the roof of the plating shop. The overlapping-type blade design changed the direction of the gas flow four times, causing chromic acid droplets to impinge on the blades by inertial force. A moisture extractor was installed in the stack to control chromium emissions that may be drawn through the mist eliminator. The mist eliminator and moisture extractor were equipped with a spray washdown system. The mist eliminator and moisture extractor were washed down one or two times per day depending on the amount of plating solution makeup needed. Industrial rolls used in the textile and packaging industries were chromium plated during testing. Typically, the time required to plate one roll in each work station ranged from 45 to 60 minutes.

Emissions were quantified using Method 13B. The samples were analyzed for total chromium by ICAP and for hexavalent chromium by the diphenylcarbazide colorimetric method. Three test runs were conducted at the inlet and outlet of the mist eliminator to characterize uncontrolled emissions and the performance of the mist eliminator. Particle size distribution also was measured at the inlet and outlet using a cascade impactor, and the distributions of PM and total chromium were determined for each impactor stage. The distributions reported did not include the nozzle rinse because it was suspected that chromium particles of all sizes were adhering to the exposed surfaces of the nozzle and impactor cone, thereby causing the rinse fraction to be biased high. However, it was believed that this phenomenon did not significantly affect the particle size distribution across the impactor stages. The inlet and outlet testing was conducted simultaneously. Although the bath temperatures were higher than normal, the higher temperatures did not adversely affect the plating process. The parameters and results of the emission tests are shown in Table 4-3. Emission factors were developed for uncontrolled and controlled emissions of total chromium and hexavalent chromium based on the Method 13B data. The particle size data also was used to develop an emission factor for filterable PM-10. The Method 13B data are rated A. The particle size data are rated C because the net mass collected on some of the impactors during some of the runs was negative, and it is unknown how the particle size distribution was affected by the adherence of chromium to the sampling train. The filterable PM-10 are not rated because it is unknown what portion of the chromium particles in the exhaust stream adhered to the nozzle and impactor cone.

4.1.3 Reference 3

This report documents the results of an emission test conducted at a small job shop that performed hard chromium electroplating of industrial rolls. Emissions tests were performed on the inlet and outlet of a chevron-blade mist eliminator controlling chromium emissions from one hard chromium plating tank.

The tank held about 15,100 L (3,980 gal) of plating solution. The plating bath used was a conventional hard chromium plating solution with a chromic acid concentration of 210 gal/L (28 oz/gal) of solution and a sulfuric acid catalyst concentration of 1.3 g/L (0.18 oz/gal) of solution. The tank was equipped with a transformer/rectifier rated at 12 V and 12,000 A. The operating temperature of the plating bath ranged from 43° to 60°C (110° to 140°F).

Removable panels were placed over the top of the tank during plating to enclose the surface of the plating solution to maximize capture efficiency. The mist eliminator contained two sets of overlapping-type blades. A moisture extractor was installed in the stack downstream of the mist eliminator. The moisture extractor consisted of a stationary set of blades that forced acid mist or droplets entrained in the exhaust gas to impinge against the sides of the extractor wall. Samples were collected upstream of the moisture extractor.

Emissions were quantified using Method 13B. The samples were analyzed for total chromium by ICAP and for hexavalent chromium by the diphenylcarbazide colorimetric method. Three test runs were conducted at the inlet and outlet of the mist eliminator. Particle size distribution also was measured at the inlet and outlet using cascade impactors. However, because the train used a buttonhook nozzle, the data are not valid. The parameter and results of the emission tests are shown in Table 4-4. The emission data are rated A.

4.1.4 Reference 4

This report documents an emission test conducted at a job shop specializing in precision finishing and refinishing of industrial rolls. Operations performed at this facility included hard chromium plating, sulfamate nickel plating, machining, grinding, and mirror finishing. The plant plates rolls that are used primarily in the paper manufacturing, roofing, laminating, and coating industries.

Seven hard chromium plating tanks were at this facility. Tests were conducted across the mist eliminator unit used to control emissions from Tank 6, which was used to plate small industrial rolls, aircraft engine pistons, and rotary pumps. The tank held approximately 9,270 L (2,450 gal) of plating solution. The plating solution contained chromic acid in a bath concentration of 250 g/L (33 oz/gal). Sulfuric acid was used as a catalyst at a bath concentration of 2.5 g/L (0.33 oz/gal). The current and voltage applied to Tank 6 were 8,000 A and 12 V.

Tank 6 was typical of other hard chromium plating tanks used in the electroplating industry, based on operating parameters such as current, voltage, plating time, temperature, and chromic acid concentration. Although the composition of the plating solution remained constant, the operating voltage and current varied with each roll that was plated.

The capture and control system on Tank 6 consisted of a double-sided lateral hood ducted to a moisture extractor followed by a mist eliminator unit containing two sets of overlapping-type blades and two mesh pads. The blade section consisted of two sets of overlapping-type blades. Catchments were located along the overlapping edges of the blades and acted as collection troughs, providing a central location for droplet collection and facilitating gravitational drainage of the droplets into a collection sump. Two sets of spray nozzles (three nozzles per set) were located in front of each set of blades and were activated periodically to wash down the blades. The washdown water was drained to a holding tank and recirculated to the plating tank to replace plating solution evaporation losses. The mesh pad section consisted of two mesh pads in series. Each pad consisted of eight layers of mesh.

The moisture extractor was located in the ductwork near the ceiling of the plating shop. Because moisture extractors are designed for the removal of large droplets that also would be collected in the first stage of the mist eliminator unit, the overall performance measured during testing was considered to be representative of the average performance of the mist eliminator unit alone.

Mass emission tests were conducted at the following locations to characterize the performance of the control devices independently and in series: (1) the inlet of the moisture extractor, (2) between the moisture extractor and mist eliminator unit, and (3) the outlet of the mist eliminator unit. The process was operating normally during emissions testing.

Method 13B was used to quantify emissions. The samples were analyzed for hexavalent chromium by the diphenylcarbazide colorimetric method. Three test runs were performed. Run No. 1 was interrupted for 14 minutes because of a power loss to the meter boxes. However, no other process interruptions occurred during the test runs. The parameters and results of the emission tests are shown in Table 4-5. These emission data are rated A.

4.1.5 Reference 5

This report documents an emission test conducted at a small job shop specializing in precision finishing of hydraulic cylinders. The plant operated one hard chromium plating tank. The plating tank held approximately 4,810 L (1,270 gal) of plating solution. The plating solution contained chromic acid in a concentration of about 210 g/L (28 oz/gal) of solution. Sulfuric acid was used as a catalyst at a bath concentration of 2.1 g/L (0.28 oz/gal) of solution. The temperature of the plating solution was maintained at about 54°C (130°F). The tank was divided into two plating cells with each plating cell equipped with a rectifier. The typical current and voltage applied to each cell ranged from 2,500 to 3,000 A and from 4.5 to 6.0 V, respectively.

The capture and control system on the plating tank consisted of a single-sided lateral hood ducted to a mesh-pad mist eliminator. The mist eliminator consisted of two mesh pads. The unit was equipped with two spray nozzles that were activated periodically to wash down the pads. One spray nozzle was located at the inlet of the unit prior to the primary mesh pad, and the other spray nozzle was located at the outlet of the unit behind the secondary mesh pad. At the end of each day, the ventilation system was shut off, and the spray nozzles were activated to wash down the mesh pads. In addition, the unit had a removable cover that allowed the mesh pads to be removed and cleaned by immersion in the plating bath. Immersion cleaning was performed once a month.

Emissions were quantified using Method 13B. The samples were analyzed for hexavalent chromium by the diphenylcarbazide colorimetric method. Mass emissions tests were conducted simultaneously at the inlet and outlet of the mist eliminator unit to characterize the performance of the control device in controlling chromic acid mist. The process was operating normally during testing. Five test runs were performed. The parameters and results of these emission tests are shown in Table 4-6. These emission data have a rating of A.

4.1.6 Reference 6

This report documents the results of emission tests conducted at a job shop that plates industrial rolls, hydraulic components, dies, and molds.

The hard chromium plating line at this facility consisted of an alkaline strip tank to clean the parts prior to plating, two alkaline rinse tanks, an alkaline scrub tank, and the hard chromium plating tank followed by a spray rinse tank and three countercurrent rinse tanks.

Emission testing was conducted on the mesh-pad mist eliminator controlling chromium emissions from the hard chromium plating tank. This tank had a capacity of 5,720 L (1,510 gal) of plating solution. The plating solution contained chromic acid in a bath concentration of about 210 g/L (28 oz/gal) of solution. Sulfuric acid was used as a catalyst at a bath concentration of 2.1 g/L (0.28 oz/gal) of solution. The temperature of the solution was maintained between 54° and 60°C (130° and 140°F). The plating tank was equipped with an air agitation system to maintain uniform bath temperature and chromic acid concentration. The maximum current and voltage of the rectifier was 8,000 A and 9 V, respectively.

The capture and control system on the plating tank consisted of a single-sided lateral hood ducted to a mesh-pad mist eliminator. Removal of chromic acid mist was accomplished by direct interception or impaction of the chromic acid mist on the mesh pads. The collected droplets then coalesced along the fibers and drained down the pads into the drain pipe located at the bottom of the unit.

The mist eliminator unit was equipped with two spray nozzles to clean the pads. One spray nozzle was located at the inlet of the unit prior to the first mesh pad, and the other spray nozzle was located behind the second mesh pad. At the end of each day, the ventilation system was shut off and the spray nozzles were activated for approximately 30 seconds to wash down the mesh pads. The washdown water was drained to the plating tank. In addition, the unit was designed so that the mesh pads could be easily removed and cleaned by immersion in the plating bath. The immersion cleaning was performed once a month.

Emissions were quantified using Method 13B. The samples were analyzed for hexavalent chromium by the diphenylcarbazide colorimetric method. Five test runs were conducted at the inlet and outlet of the mesh-pad mist eliminator. During this source test program, the plating tank was operated with and without polypropylene balls covering the surface of the plating solution. The first three test runs were done without any polypropylene balls on the plating tank surface to determine the effectiveness of the mesh-pad mist eliminator. The two subsequent test runs were conducted while polypropylene balls covered the surface of the plating solution to determine their effectiveness in controlling chromic acid mist. There was no observed dispersion of polypropylene balls away from the cathode area during plating because of the relatively thick coverage supplied by the balls. In typical industrial applications, coverage is not usually as complete as that tested. Table 4-7 shows the parameters and results of these emission tests. These emission data are rated A for runs 1-3 and B for runs 4-5.

One or two hydraulic cylinders were plated during each test run. During plating, no visible misting was observed escaping the plating tank's ventilation system. During test run Nos. 4 and 5, visible misting was observed above the polypropylene balls; however, the mist was captured by the ventilation system.

The fan speed was increased after test run No. 1, on the recommendation of the control system vendor. The vendor felt that increasing the airflow was necessary to operate closer to the design condition.

A slightly larger sampling nozzle was used during test run Nos. 4 and 5, which resulted in a larger sample volume collected. The larger nozzle was used to ensure adequate sample collection for the test runs where polypropylene balls were in the tank. Run No. 4 was interrupted for approximately 4 minutes when the scaffolding supporting the sampling train at the inlet fell, pulling the probe from the test port. However, no other process interruptions occurred during the test runs.

4.1.7 Reference 7

This report documents emission tests conducted at a job shop that performs hard chromium plating of industrial machine parts, industrial rolls, and steel tubing. The facility consisted of three plating tanks. During the source test, only the tanks designated as the 23-ft and 10-ft tanks were operated. These tanks had a capacities of 6,850 L (1,810 gal) and 2,990 L (790 gal), respectively. The plating solution used in the tanks was a conventional hard chromium plating solution with a chromic acid concentration of 250 g/L (32 oz/gal) of solution and a sulfuric acid concentration of 2.52 g/L (0.32 oz/gal) of solution.

The 23-ft tank contained up to four work stations. Three of the work stations were charged with the 1,000-A rectifiers, and one work station was charged with the 6,000-A rectifier. The 10-ft tank contained up to five work stations, each of which is charged with a separate 1,000-A rectifier. During this source test program, the 23-ft and 10-ft tanks were divided into two and five work stations, respectively.

All three tanks were equipped with double-sided draft hoods that were installed along the length of each tank. The three tanks were ducted together and vented to a fume scrubber located outside the building. The scrubber was a horizontal-flow single packed-bed unit that was equipped with a self-contained recirculation system. Behind the packed bed was a chevron-blade mist elimination section.

About four times per day, 95 L (25 gal) of clean water were automatically added over the packed bed when the sensor indicated that water was needed to replace evaporation losses. The scrubber water was drained to the plating tanks approximately once per day to replace plating solution evaporation losses. The scrubber was then recharged with clean water.

The target level scrubber water chromic acid concentrations selected for testing were 0, 30, 60, and 120 g/L (0, 4, 8, and 16 oz/gal) of solution. The four target level concentrations were selected to represent the range of concentrations that could potentially occur under normal operating conditions. The target level of 120 g/L (16 oz/gal) was selected to represent worst-case conditions. Emissions were quantified using Method 13B. The samples were analyzed for total chromium by ICAP and for hexavalent chromium by the diphenylcarbazide colorimetric method. Three test runs were conducted at the inlet and outlet of the scrubber for each of the four target level concentrations. The parameters and results of these tests are shown in Table 4-8. The scrubber operated normally throughout the test runs. The emission data are rated A and B. Test run No. 4 at the inlet was not included in average emission factor calculations because it was suspected that the nozzle may have contacted the dust wall during testing. Test run No. 3 at the outlet was not included in average emission factor calculations because heavy rain entered the stack during testing and may have biased the results. Subsequently, the emission data associated with these test runs are rated B. Only the tests conducted for the first condition (i.e., negligible chromic acid concentration in the scrubber water) represent normal operating conditions, and the data for the other tests were not considered in the development of candidate emission factors.

4.1.8 Reference 8

This report documents emission tests conducted at an original equipment manufacturer of steel heddles for textile looms. The plating facility was operated both on a captive and a job shop basis. Reeds and combs for textile looms and miscellaneous parts from outside customers underwent hard chromium plating.

The chromium plating facility consisted of four tanks. Based on size; operating parameters such as current, voltage, and plating time; and chromic acid concentrations, all four tanks were typical of other hard chromium plating tanks used in the electroplating industry. During this source test, Tanks 1, 2, and 4 were operated. These tanks had capacities of 2,650 L (700 gal), 1,290 L (340 gal), and 1,210 L (320 gal), respectively. The plating solution used in the tanks was a conventional hard chromium plating solution with a chromic acid concentration of 250 g/L (33 oz/gal) of solution and a sulfuric acid catalyst concentration of 2.5 g/L (0.33 oz/gal) of solution. The chromic acid consumption for the plant was 1,500 kg (3,300 lb) per year.

Tanks 1 and 4 were equipped with push-pull emission capture systems, and Tank 2 was equipped with a single-sided draft hood. Emissions from all three tanks were ducted to a scrubber system that was located on the roof of the plating shop. The scrubber was a horizontal-flow double packed-bed unit. Six nozzles located in front of each packed bed sprayed water continuously countercurrent to the flow of the gas stream. Chromic acid mist that impinged on the packing material was washed to the bottom of the scrubber. The packed beds were filled with polypropylene, spherical-type mass packing. The scrubber also contained a chevron-blade mist elimination section located downstream of the second packed bed. The scrubber water flowed by gravity from the scrubber to a recirculation tank located inside the plating shop. Clean water was used to replace evaporation losses from the system. The ductwork was washed down once per month with water that subsequently drained into the plating tanks.

Emissions were quantified using Method 13B. The samples were analyzed for total chromium by ICAP and for hexavalent chromium by the diphenylcarbazide colorimetric method. Three test runs were conducted at the inlet and outlet of the scrubber to characterize the uncontrolled emissions from the three hard chromium plating tanks and the performance of the scrubber. Particle size distribution also was measured at the inlet and outlet using cascade impactors. However, because the train used a buttonhook nozzle, the data are not valid. The parameters and results of these tests are shown in Table 4-9. The process was operating normally during the tests. Test run Nos. 2 and 3 were interrupted for 30 and 45 minutes, respectively, during shift changes. These interruptions did not affect emissions. The emission data are rated A.

4.1.9 Reference 9

The report documents emission tests conducted at a job shop that specializes in hard chromium electroplating of crankshafts. The plating shop consisted of five hard chromium plating tanks. The plating tank (No. 1) tested during this source test program held approximately 10,400 L (2,750 gal) of plating solution. The plating tank was equipped with a single rectifier rated at 15 V and 8,000 A. The tank contained a conventional hard chromium plating solution consisting of a chromic acid concentration 240 g/L (32 oz/gal) of solution and a sulfuric acid concentration 2.4 g/L (0.32 oz/gal) of solution. The plating solution was maintained at 54°C (130°F).

The plating tank tested was typical of other hard chromium plating tanks used in the electroplating industry with regard to size; operating parameters such as current, voltage, and plating time; and chromic acid concentration of the plating bath. The capture and control system on the plating tank consisted of a double-sided draft hood that was vented to a horizontal-flow single packed-bed scrubber. Within the scrubber system, the velocity of the gas stream was reduced to approximately 130 m/min (440 ft/min), and the gas stream was humidified by a spray of water. Water was sprayed countercurrent to the flow of the gas stream through 10 spray nozzles. The saturated gas stream then passed through a packed bed of polypropylene, spherical-type mass packing. The packed bed was wetted continuously with scrubbing water supplied by the series of spray nozzles in front of the bed. Entrained mist and water droplets impinged on the packing and drained into the sump. Behind the packed bed was a two-stage mist elimination section that removed entrained water droplets. The mist eliminator was not washed down.

Emissions were quantified using Method 13B. The samples were analyzed for hexavalent chromium by the diphenylcarbazide colorimetric method. Emission test runs were conducted at the inlet and outlet of the scrubber at each of the following conditions:

1. Three test runs were conducted while the scrubber recirculation system was in operation and the required makeup water was supplied by a hose through one of the scrubber's inspection doors;

2. Three test runs were conducted while the scrubber recirculation system was in operation and the required makeup water was supplied through a pipe that extended out about 10 to 13 cm (4 to 5 in.) over the top of the packed bed; and

3. Two test runs were conducted at the inlet and outlet of the scrubber with the scrubber recirculation system operation and a continuous flow of fresh water supplied through the overhead weir at a rate of 7.6 L/min (2.0 gal/min).

Test run No. 1 was interrupted for approximately 3 hours because of an electrical problem in the plating line, which resulted from a current overload. Test run No. 2 was interrupted for 8 minutes because of a problem with maintaining the isokinetic sampling rate at the outlet test location. Emission tests parameters and results are shown in Table 4-10. The emission data for the 3-run tests are rated A, and the emission data for the 2-run tests are rated B.

4.1.10 Reference 10

This report documents the results of emission source tests conducted at a medium size job shop that performs hard chromium plating of industrial rolls, hydraulic cylinders, and miscellaneous small parts. There were six hard chromium plating tanks at this facility, although during the source tests, only Tanks 1, 2, and 7 were tested. Tanks 1 and 2 had a capacity of 9,250 L (2,450 gal) and Tank 7 had a capacity of 11,810 L (3,120 gal). All three plating tanks were divided into two cells, and each cell was equipped with a rectifier to control the current flow. Current ratings (per cell) of the rectifiers were 5,000 A, 3,000 A, and 10,000 A for Tanks 1, 2, and 7, respectively. The plating solution in each tank consisted of chromic acid at a concentration of 250 g/L (33 oz/gal) of solution. The temperature of the plating solution was

maintained at approximately 60°C (140°F). In addition, each of the tanks was equipped with an air agitation system to aid in maintaining uniform bath concentration and temperature.

Each tank was equipped with a double-sided hood for ventilation. Moisture extractors were located in the hood uptakes to remove the coarser mist droplets from the exhaust stream, thereby reducing the inlet loading to the composite mesh-pad mist eliminator. Tanks 1 and 2 were ducted together to form one inlet leg to the mist eliminator, while Tank 7 was ducted separately to form another inlet leg to the mist eliminator. The two inlet legs joined just prior to the inlet plenum of the mist eliminator.

The mist eliminator was located on the roof of the plating shop and consisted of a set of chevron-blade baffles followed by a series of three mesh pads. The first pad removed the majority of the chromic acid mist particles. The second pad (the composite mesh pad) served to enlarge the size of the particles that penetrated the first pad, and these particles then impinged on the back side of the second pad and coalesced into larger droplets. The third pad, which is identical the first pad, removed any reentrained droplets carried over from the second pad. A series of spray nozzles located in front of each mesh pad washed down the pad to remove the built up chromium.

Emissions were quantified using Method 13B. The samples were analyzed for total chromium by ICAP and for hexavalent chromium by ICPCR. Three test runs were conducted at each of the two inlet locations (A and B) and at the outlet (stack, C) of the mist eliminator. Testing at the three locations was performed simultaneously. Each test run was 4 to 6 hours in duration. Hydraulic cylinders were plated during each test run.

The parameters and results of emission tests are shown in Table 4-11. The emission data are rated A.

4.1.11 Reference 11

This report documents the results of emission source tests conducted on a facility that performs hard chromium electroplating of shock absorbers of various sizes. The plating operation of the facility uses a chemical fume suppressant to inhibit misting. Therefore, testing was performed with and without the fume suppressant in the plating bath.

The plant had one chromium electroplating tank in the plating line that held approximately 11,400 L (3,000 gal) of plating solution. The plating solution in the tank contained chromic acid in a concentration of 240 g/L (32 oz/gal) of solution. The normal operating bath temperature was 54°C (130°F). The plating tank was equipped with heating and cooling systems and was air agitated to maintain a uniform plating bath temperature and composition. The tank was serviced by an 11,000 A, 12 V rectifier and was operated at a current ranging from 3,300 A to 10,000 A, depending on the length of the shock adsorber rods.

The chromium emissions from the plating tank were exhausted to a composite mesh-pad mist eliminator system consisting of two sets of double-sided chevron blades followed by a series of three mesh pads. The first pad in the series of pads was a coarse mesh that removed the majority of the chromic acid mist particles. The second pad (the composite mesh pad) served to enlarge the size of the particles that penetrated the first pad. These larger particles then impinged on the back side of the second pad. The third pad, which was identical to the first pad, removed any reentrained droplets carried over from the second pad.

The control system was operated dry but is equipped with a spray system to wash the individual pads when the pressure drop across the system increases. During the emissions testing, a chemical fume suppressant was used during half of the emissions test runs. The foam was designed to inhibit chromic acid misting from the plating bath by trapping the mist in the foam layer. The wetting agent inhibited misting by lowering the surface tension of the plating bath, allowing the gases to escape at the surface with less of a bursting effect.

Emissions were quantified using Method 13B. The samples were analyzed for total chromium by ICAP. Six test runs were conducted at the inlet and outlet of the mesh-pad mist eliminator system to characterize the overall performance. Each test run was approximately 2 hours in duration. Test Runs 1, 3, and 4 were performed when no fume suppressant was used, and test Runs 2, 5, and 6 were performed when the combination foam blanket and wetting agent was used in the bath. Table 4-12 presents the average operating parameters (voltage, current, and temperature of the plating solution) monitored during each test run.

The pressure drop across the composite mesh-pad mist eliminator system did not increase during any of the test runs; therefore, no washing of the pads was necessary. Table 4-13 presents the parameters and results of emission tests for total chromium. The removal efficiency of the composite mesh-pad mist eliminator control system in the absence of a fume suppressant averaged 98.7 percent. The average total current applied to the electroplating tank during outlet testing averaged 13,600 A·hr. These emission data are rated A.

The removal efficiency of the composite mesh-pad mist eliminator system when a fume suppressant was used averaged 97.5 percent. The average total current applied to the tank during outlet testing was 18,100 A·hr. These emission data also are rated A.

4.1.12 Reference 12

This report documents the results of emission source tests conducted at a large job shop that performs hard chromium electroplating of hydraulic cylinders, shock absorbers, offshore equipment, and accumulators. The performance of the emission control system, a packed-bed scrubber/mesh-pad mist eliminator system that incorporates the use of a composite mesh pad, was determined by testing at the inlet and outlet of the system.

The facility operated seven hard chromium electroplating tanks. Table 4-14 presents the descriptions and maximum operating parameters for each of these tanks. Four of the tanks tested were cylindrical with diameters of 0.91 to 1.2 m (3 to 4 ft) and depths of 6.1 to 15.2 m (20 to 50 ft). The other two tanks were relatively large with capacities of 11,360 L (3,000 gal). The plating solution in each tank consisted of chromic acid at a concentration of 240 g/L (32 oz/gal) of solution, and sulfuric acid, a catalyst, at a concentration of 2.4 g/L (0.32 oz/gal), of solution. The normal operating bath temperature range was 49° to 54°C (120° to 130°F). All tanks were equipped with heating and cooling systems and were air agitated to maintain uniform plating bath temperature and composition. Tanks 1 and 2 were divided into two cells with one rectifier used to control the current flow in each cell. Tanks 3 through 5 were each controlled by one rectifier, and Tanks 6 and 7 were each controlled by two rectifiers.

Tanks 1 and 2 were equipped with double-sided hoods and Tanks 3 through 7 were equipped with circular hoods. The chromium emissions from the plating tanks were exhausted to the packed-bed scrubber/composite mesh-pad mist eliminator system located on a mezzanine beside the plating tanks.

The scrubber at this facility has a packed bed followed by the composite mesh-pad mist eliminator section located directly behind the scrubber. Because of the extended depth of the packed bed, the scrubber is also equipped with an overhead spray system in which spray nozzles are used to ensure sufficient wetting of the bed packing media.

Behind the packed bed, a mist elimination section removed entrained water droplets. The first stage of this section allowed large droplets to settle by gravity to the bottom of the scrubber. The next stage consisted of a composite mesh pad followed by a backup mesh pad. Small particles that escaped the packed bed coalesced into large droplets as they passed through the inner layers of the pad. The enlarged particles were then removed in the back section of the composite pad or in the backup mesh pad. The design of the mesh-pad section specified continuous irrigation of the composite mesh pad. The backup pad was designed to be washed down on an as-needed basis.

Three mass emission test runs were conducted simultaneously at the inlet and outlet of the packed-bed scrubber/mesh-pad mist eliminator system to characterize the overall performance of the control system. Six of the seven chromium electroplating tanks ducted to the control system were in operation, and the process was operating normally during the tests. During emissions testing, dummy rods were plated in each of the tanks.

Emissions were quantified using Method 13B. The samples were analyzed for total chromium by ICAP and for hexavalent chromium by ICPCR. Measurements to determine emissions concentrations at the inlet to the scrubber system were made at two locations. Measurements taken at Inlet A represent emissions vented from Tanks 1 and 2, while Inlet B readings measured emissions vented from the remaining four tanks. The data for both inlets were combined to yield the total uncontrolled emissions.

Performance data for the control system are summarized in Table 4-15. The factors (in units of mg/A-hr) for uncontrolled emissions developed from the data were an order of magnitude higher than the factors developed from other tests on hard chromium electroplating facilities. The higher factors most likely result from the large size and unusual configuration of tanks at the site. Although the data are rated A, the factors may not be representative of emissions at other facilities. Therefore, the factors developed from the data in this reference for uncontrolled emissions were not used in the determination of candidate emission factors for the industry.

4.1.13 Reference 13

This report documents measurements of emissions from a hard chromium electroplating facility in 1987. The test was conducted to evaluate a screening method as an inexpensive alternative to Method 13B.

The source tested collected emissions from four hard chromium electroplating tanks. The tanks are operated at maximum current levels of 8,000 to 20,000 A, chromic acid concentration of 250 g/L (33 oz/gal) of solution, and tank temperatures from 52° to 55°C (126° to 131°F). Emissions from the tanks are combined and ducted to a packed bed scrubber with two outlets. The outlet ducts are combined at the inlet to a mist eliminator. Testing was conducted at the scrubber inlet, both scrubber outlets, and the mist eliminator outlet. Emissions were measured using Method 13B and the screening method, which used Teflon filters from personal samplers and Teflon tubing. Both the filter and the tubing were placed in the gas stream with the tubing and filter openings facing the gas stream flow. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method. Six runs were performed at each location.

Emission factors were developed for uncontrolled total chromium and hexavalent chromium emissions; the data for the scrubber and mist eliminator outlets were not used for emission factors because the scrubber was operating at a pressure drop and gas velocity well below design and the mist eliminator rinse system had not yet been installed. The emission data are rated A. The test method was sound, no problems were reported, and six runs were conducted. Table 4-16 summarizes the results of the emission test.

4.1.14 Reference 14

This report documents the results of emission source tests conducted at a medium-size job shop that performs hard chromium plating for industrial rolls, hydraulic cylinders, and miscellaneous parts. The facility has eight hard chromium plating tanks.

Emission tests were performed only on Tank No. 8, which had a capacity of 3,900 L (1,030 gal). The plating solution consisted of chromic acid at a concentration of 240 g/L (32 oz/gal) of solution and sulfuric acid, a plating bath catalyst, at a concentration of 2.4 g/L (0.32 oz/gal) of solution. The plating bath temperature was 54°C (130°F). The plating tank, which was typically operated with a foam blanket and polypropylene balls covering the surface of the plating solution, was equipped with two rectifiers rated at 6,000 and 2,000 amperes, respectively. However, only the 6,000-ampere rectifier was in use on the tank during the tests. Uniform bath temperature and composition within the tank was maintained by an air-agitated heat and cooling system.

The plating tank tested was equipped with double-sided draft hoods to capture the chromic and mist generated during plating. These hoods were ducted to a single packed-bed scrubber. As the gas stream flowed through the packed bed, the chromic acid droplets impinged on the packing material and drained to the bottom of the unit. A chevron-blade mist eliminator followed the packed-bed section, which removed any reentrained water carried over from the packed bed. Recirculated water was drained from the scrubber approximately once per day and was used in the plating tank as makeup for plating solution evaporation losses.

Three tests were conducted using a modification of EPA Method 13B to measure chromium concentration at the inlet and outlet of the scrubber under two conditions: without a foam blanket or polypropylene balls in the plating tank and with a foam blanket and polypropylene balls in the plating tanks. The samples were analyzed for total chromium by GFAAS. All six tests runs were approximately 2 hours in duration. Test run No. 6 was interrupted for approximately 5 minutes due to the rectifier tripping off. No other process interruptions occurred during sampling. During each test run, the same five dummy parts were plated in the plating tank.

The parameters and results of the emission tests are shown in Table 4-17. The data in this reference are rated A.

4.1.15 Reference 15

This report documents emission tests conducted at a large captive shop that performs decorative chromium electroplating of automobile bumpers. The plating facility consisted of five decorative chromium plating lines, but only three lines (Nos. 2, 4, and 5) were being operated at the time of the tests. Each plating line consisted of about 20 tanks containing various cleaning and plating solutions. The chromium plating segment of each line consisted of a plating tank and several rinse tanks.

The chromium plating tank on Line No. 4 was tested to characterize uncontrolled emissions. Based on size, operating parameters (such as current, voltage, and plating time), and chromic acid concentration, the tank was typical of other large decorative chromium plating tanks used in the electroplating industry. The chromium plating tank held approximately 61,700 L (16,160 gal) of plating solution, which contained chromic acid in a bath concentration ranging from 247 to 374 g/L (33 to 50 oz/gal) of solution. Sulfuric acid was used as a catalyst in a chromic acid-to-sulfuric acid ratio of 180:1.

Typically, two or three cells were operated at a time. Two separate transformer/rectifiers charged the electrodes in each cell. During activation, each rectifier was set at 5 to 6 V and 2,500 to 3,000 A. After activation, the actual plating phase of the cycle began. During plating, each rectifier was set at 16 to 17 V and 8,500 to 10,000 A.

The chromium plating tank on Line No. 4 was equipped with single-sided draft hoods on each end and double-sided draft hoods between each cell. The hoods on the tank were connected to a common duct that led to an extensive evaporator/scrubber system. Emissions were quantified using Method 13B. The samples were analyzed for total chromium by ICAP and for hexavalent chromium by the diphenylcarbazide colorimetric method. Three test runs were conducted at the inlet of the evaporator/scrubber to characterize the uncontrolled emissions from the decorative chromium plating tank.

Test run No. 1 was interrupted for 13 minutes for electrical repairs on the plating line. Test Run No. 2 was interrupted three times for 51, 3, and 11 minutes. The 3-minute interruption was caused by delays at the racking station where bumpers are mounted on the racks. The other two interruptions occurred when the process was stopped for repair. Test run No. 3 was interrupted three times for 3, 5, and 165 minutes. The interruptions were a result of malfunctions with the overhead conveyor. The parameters and results of the emission tests are shown in Table 4-18. These emission data are rated A.

4.1.16 Reference 16

This report documents emission tests conducted at a small job shop that performs decorative chromium electroplating of automotive trim. The plating facility consist of two decorative chromium plating lines: the main plating line and a rework plating line.

The chromium plating tank in the main plating line was tested to evaluate the performance of fume suppressants in reducing chromic acid mist. The main plating line consisted of a series of tanks used for cleaning and plating the parts. Parts were plated with layers of copper and nickel before they were chromium plated. The chromium plating segment of the line consisted of a chromium predip, a plating tank, a chromium saver tank, and three bisulfite rinse tanks. The plating line was serviced by an automatically controlled overhead conveyor that transferred racks of parts to each tank in a programmed sequence.

The chromium plating tank held approximately 3,940 L (1,040 gal) of plating solution, which contained chromic acid in a bath concentration of 280 g/L (37 oz/gal) of solution. The plating solution contained both fluoride and sulfuric acid catalysts. The temperature of the plating bath was maintained between 43° an 47°C (110° and 116°F).

The tank was equipped with three rectifiers. For the first 15 seconds of plating, the parts were activated. During activation, the rectifier connected to Cell No. 1 was operated at 0 to 5 V and 0 to 200 A.

After activation, the racks were automatically moved toward the center of the plating tank. During plating, the rectifier connected to Cell Nos. 2 through 5 was set at 5.2 V and 3,000 A. The rectifier connected to Cell No. 6 was set at 3.0 V and minimal to no current.

The chromium plating tank was equipped with a single-sided draft hood. The exhaust gases captured by the hood were ducted to a vertical-flow, single packed-bed scrubber. Two other tanks, the alkaline soak tank in the main plating line and the chromium plating tank in the rework plating line, were also vented to the scrubber through a common duct. The hood on the alkaline soak tank was blocked off during testing to increase the airflow rate through the hood on the chromium plating tank.

During the source test, the chromium plating tank was operated under three different conditions:

1. Without a fume suppressant;
2. With a foam blanket; and
3. With a "combination" fume suppressant consisting of a foam blanket and a wetting agent.

The foam blanket reduced chromic acid mist by entrapping the mist in the foam layer. The "combination" fume suppressant formed a layer of foam over the surface of the plating solution and lowered the surface tension of the plating solution. Because the surface tension of the bath was lower, the gases escaped with less of a "bursting" effect at the surface, and thus, less mist was formed. The foam layer captured any mist that was formed. The fume suppressants were selected for use during the source test because they are representative of the types and brands of fume suppressants widely used in the decorative chromium electroplating industry.

Emissions were quantified using Method 13B. The samples were analyzed for hexavalent chromium by the diphenylcarbazide colorimetric method. Nine test runs were conducted to characterize uncontrolled emissions from a decorative chromium plating tank and to evaluate the performance of fume suppressants in controlling chromic acid mist. Three test runs were performed under each of the following conditions:

1. No chemical fume suppressant in the plating bath (uncontrolled);
2. A foam blanket maintained in the plating bath; and
3. A "combination" fume suppressant maintained in the plating bath.

The test port was located in the main duct prior to the entrance of the duct from the rework plating tank. The process was maintained within normal operating limits during each test run. All test runs were completed without a process interruption except test run No. 2, which was interrupted for 4 minutes because of downtime in the process line. Table 4-19 shows the parameters and results of the emission tests. The emission data are rated A.

4.1.17 Reference 17

This report documents the results of emission source tests conducted at a captive job shop that performs trivalent chromium electroplating of metal shafts used for golf clubs. The facility consisted of one decorative chromium plating line. The tank for this plating line had a 20,400 L (5,400 gal) capacity, and contained trivalent chromium in a concentration ranging from 21 to 24 g/L (2.8 to 3.2 oz/gal) of water. The plating tank was equipped with one rectifier with a maximum verification capacity of 12 volts and 14,000 amperes. The rectifier was set to operate at 5,500 amperes and 8 volts at the maximum plating

capacity of 168 shafts. The temperature of the plating solution was maintained at approximately 36°C (97°F).

The chromic plating tank was equipped with a push-pull ventilation system. The tank was vented to a scrubber system. The trivalent chromium plating solution contained wetting agents, which lowered the bath surface tension and thus enhanced the ability of the bath to provide a more uniform plate thickness over the entire surface area of the part. The lower surface tension also minimized the potential of emissions from the bath by reducing the tendency of the gas bubbles generated at the electrodes to burst at the surface of the solution to form a fine mist. The use of the wetting agents resulted in no visible emissions for the tank during the emission tests.

Emissions were quantified using Method 13B. The samples were analyzed for total chromium by ICAP and for hexavalent chromium by ICPCR. Three test runs were conducted at the inlet of the scrubber system to characterize the uncontrolled emissions from the trivalent chromium plating tank. No process interruptions occurred during sampling.

The parameters and results of the emission tests are shown in Table 4-20. Although no problems were reported, the hexavalent chromium concentrations were much higher than could reasonably be expected for the trivalent process. Therefore, the data are suspect and are not rated.

4.1.18 Reference 18

This report documents emission tests conducted at a small job shop engaged primarily in chromic acid anodizing of aircraft and miscellaneous parts. The one chromic acid anodizing tank at this facility had a capacity of approximately 1,893 L (500 gal) of anodizing solution. The chromic acid anodizing process consisted of the following steps: alkaline cleaning, cold water rinse, nitric acid dip, cold water rinse, anodizing, and nickel acetate sealing and/or hot water sealing. The aluminum parts were frequently dyed after sealing. The anodizing line was equipped with an automatic hoist to transfer parts into and out of process tanks.

The anodizing solution contained chromic acid in a concentration of approximately 60 to 75 g/L (8 to 10 oz/gal) of water. The operating temperatures ranged from 35° to 38°C (95° to 100°F). The tank was equipped with a 4,000-A rectifier. The voltage was applied stepwise until a level of 40 V was reached, which was applied for the remainder of the anodizing time.

The anodizing tank was equipped with a double-sided draft hood to capture the chromic acid mist. The ventilation hood was ducted to a wet scrubber located adjacent to the anodizing tank. The scrubber was a fume exhaust and separating unit developed primarily for the electroplating and chemical industries. The scrubbing action was achieved by a combination of water adsorption and centrifugal separation. The scrubber water was not recycled and the scrubber was continuously sprayed with fresh water.

Testing was conducted on the scrubber to estimate the amount of uncontrolled emissions from the process. A mass balance was performed on the scrubber to obtain an estimate for the amount of uncontrolled chromium emissions. The testing consisted of obtaining composite samples representative of the scrubber influent, scrubber effluent, and anodizing solution for each of four 1-hour anodizing cycles. The composite samples obtained during the tests were analyzed for both hexavalent and total chromium.

The results of the sample analyses were used to perform a chromium mass balance around the scrubber to estimate uncontrolled chromium emissions. The analytical results show that all of the chromium in the outlet scrubber water was in the hexavalent state.

The following equation was used to solve for the uncontrolled chromium mass emission rate:

$$M = \frac{[(Q_w)\ (C_w)]}{E} \qquad (1)$$

where:

M = uncontrolled chromium mass emission rate, kg/hr (lb/hr);
Q_w = outlet water flow rate of scrubber, L/hr (gal/hr);
C_w = chromium concentration of outlet water stream, kg/L (lb/gal); and
E = efficiency of the scrubber, 90 percent.

The uncontrolled chromium emission rate was calculated using engineering analysis. Previous source tests at chromium electroplating facilities showed that the efficiency of packed-bed scrubbers ranged from 93 to 99 percent. However, the conservative estimate of 90 percent efficiency was used in these analyses because it was expected that the fume scrubber was less efficient than a packed-bed scrubber. The uncontrolled chromium emission rate ranged from 1.5×10^{-4} kg/hr (3.3×10^{-4} lb/hr) to 2.5×10^{-3} kg/hr (5.5×10^{-3} lb/hr). The variation in the estimated uncontrolled emission rates is directly related to the total surface area and configuration of the parts anodized during each test run. The same type of aircraft parts was anodized during runs Nos. 2 and 3. The types of parts anodized during both run Nos. 1 and 4 were similar and consisted of racks of small aircraft and electronic parts.

The average uncontrolled chromium emission rate for all runs was 1.2×10^{-3} kg/hr (2.6×10^{-3} lb/hr). Even though the data showed a wide range of uncontrolled emission rates due to the different workloads during each run, it is reasonable to average the estimated emissions because workload variations are common in the industry. Emission factors could not be determined for this reference because it contains only grab samples and is not a complete test report.

4.1.19 Reference 19

This report documents the results of emission tests conducted at a facility performing chromic acid anodizing operations. The report does not designate job-shop size or objects plated. The facility contained one 1,500-L (400-gal) chromic acid anodizing tank with two 20-volt rectifiers. The anodizing solution concentration and operating temperatures were not reported.

The chromic acid anodizing tank was equipped with a mesh pad eliminator. Three test runs were performed and emission were measured at the inlet and outlet of the first run and at the outlet only during the second and third runs. During the first run, floating polypropylene balls were used to control chromium emissions. During the second and third runs, polypropylene balls and an antimist additive were used for emission reduction.

The test method used was a revised California Air Resources Board (CARB) Method 425 to determine chromium emissions. The CARB Method 425 sampling train is basically an EPA Method 5 train with the following exceptions: (1) sodium hydroxide solution (0.1 Normal) is placed in the first and second impingers instead of water, (2) a teflon coated filter (not heated) is placed between the third and

fourth impingers, and (3) the transition between the sampling probe and the first impinger is either flexible teflon tubing or glass cyclone and filter by-passes. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method.

The parameters and results of the emission tests are shown in Table 4-21. Emission factors could not be determined because the tank dimensions were not specified in the report.

4.1.20 Reference 20

This report documents the results of emission tests conducted at a facility performing chromic acid anodizing, hard chromium plating, and other plating operations. The report does not designate job-shop size or the type of objects plated. Emission tests were performed on the chromic acid anodizing, hard chromium electroplating, copper cyanide plating, and cadmium cyanide plating exhaust lines. The chromic acid anodizing process consisted of a 29,150-L (7,700-gal) tank with an anodizing solution concentration of 75 to 90 g/L (10 to 12 oz/gal) of water. The hard chrome plating line consisted of one 3,030-L (800-gal) tank and four 2,700 L (715-gal) tanks. The plating solution in these tanks contained chromic acid in a concentration of 224 to 247 g/L (30 to 33 oz/gal) of water. The operating temperature was 32°C (90°F) for the chromic acid anodizing line and 60°C (140°F) for the hard chromic plating line.

The copper plating line included a 680-L (180-gal) tank with 30 to 60 g/L (4 to 8 oz/gal) of copper cyanide and 15 to 60 g/L (2 to 8 oz/gal) of sodium cyanide; two 1,140-L (300-gal) tanks containing chromic acid solutions also were exhausted to the same control device. The cadmium plating line included one 850-L (224-gal) and one 4,160-L (1,100-gal) tanks, each with 22 g/L (3 oz/gal) of cadmium oxide and 130 g/L (17 oz/gal) of cadmium cyanide.

Emissions from each plating line were controlled with a mesh-pad mist eliminator. An antimist additive was added to some runs of the hard chromic tanks. Two simultaneous tests were performed after the control device for the chromic acid anodizing tank. Four tests were performed before and after the control device for the hard chromic tanks. An antimisting agent was added to half of the tests for the hard chromic tanks. The test method used was a revised CARB Method 425 (See Reference 19 discussion.) The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method.

Emissions of cyanide from the copper plating operation were measured using CARB Method 426; emissions of cadmium and cyanide from the cadmium plating operations were measured using CARB Methods 426 and 424, respectively. Three runs were conducted at the outlet of the control device for each plating line.

The parameters and results of the emission tests are summarized in Table 4-22. The emission data for the chromic acid anodizing operation are rated D because only one of the two runs was above the quantitation limit for total chromium. The uncontrolled emission data for the hard chromium plating operation are rated C because only two runs were conducted and both runs were anisokinetic. The controlled emission data for the hard chromium plating operation are rated B. No problems were reported but only two runs were conducted. Emissions from the cadmium and copper plating lines also are rated C because of the lack of complete documentation and because the exhaust streams included emissions from other processes.

4.1.21 Reference 21

This report documents measurements of emissions from an electroplating facility and a cleaning facility at a naval base in 1980. The tests were performed for informational purposes. The electroplating facility includes separate lines for magnesium treatment; alodine treatment; hard chromium electroplating; zincate acid copper, tin plating, and acid dip; nickel, copper, and silver plating; cadmium cyanide plating; and automatic cadmium plating machines. Each line included from 7 to 55 cleaning, surface treating, and electroplating tanks. Emissions from each line in the electroplating operation are ducted to an unspecified type of scrubber. It is assumed that the scrubbers were packed-bed type because that is the type most commonly found in the industry.

The cadmium plating line included two cadmium plating tanks. One tank had a volume of 8,720 L (2,304 gal) and the volume of the other tank was not specified. Both tanks contained 22 to 30 g/L (3 to 4 oz/gal) of cadmium oxide.

Emissions were measured using a modified Method 8 sampling train, and three runs were conducted. The primary modifications consisted of replacement of the contents of impinger with 0.1 normal potassium hydroxide and the addition of an impinger containing 100 g of activated carbon between the third and fourth impinger in the train. The analytical method was not specified in the report.

Emissions of several inorganic pollutants were quantified, including chromium, copper, cyanide, ammonia, nickel, silver, and tin. Emission factors were developed only for the cadmium plating line, which included a total of 23 tanks. Emission factors could not be developed for the other electroplating sources for the following reasons: chromium emissions from the hard chromium plating operation were below detection limit; the process data for the test on the automatic cadmium plating machine emissions were incomplete (one run only); and for the other plating operations, the exhaust streams included a combination of plating tanks and other sources that are not likely to be representative of other facilities.

For the cadmium plating operation, emission factors were developed for chromium, cadmium, cyanide, and ammonia. The emission data are rated C because the analytical method was not identified, the process description was incomplete, the process data were unclear. Based on the presence of significant quantities of chromium in the samples, it is also apparent that the exhaust stream included emissions from tanks other than the cadmium plating tanks. Table 4-23 summarizes the results of the emission test.

4.1.22 Reference 22

This report documents measurements of emissions from an electroplating facility at a naval base in 1990. The purpose of the test was not specified in the report. The sources tested included one chromium electroplating line. However, the report provides no information on the type of chromium electroplating. Emissions from each section are ducted to an unspecified type of scrubber. It is assumed that the scrubber type was packed-bed type because that is the type most commonly used in the industry.

Emissions were measured using CARB Method 425, and two runs were conducted at both the inlet and outlet of the control device. Because of the configuration of the exhaust duct, only one traverse was conducted. In addition, only one of two inlets was sampled and the total inlet emissions were estimated by doubling the flow rate for the inlet duct that was sampled. The samples were analyzed for total chromium by GFAAS.

Emission factors were developed for controlled and uncontrolled emissions of total chromium. The emission data are rated D because information on the process and control device was inadequate, sampling was conducted along one traverse only, and only one inlet duct was sampled. Furthermore, the emission rates at the inlet and outlet of the control device were almost identical. Table 4-24 summarizes the results of the emission test.

4.1.23 Reference 23

This report documents measurements of emissions from an electroplating facility at a naval base in 1990. The purpose of the test was not specified in the report. The sources tested included one chromic acid anodizing line and two hard chromium electroplating lines. Emissions from each of the electroplating lines are ducted to an unspecified type of scrubber. It is assumed that the scrubber type was packed bed because that is the type most commonly used in the industry.

Emissions were measured using CARB Method 425, and two runs were conducted at both the inlet and outlet of the control device. Because of the configuration of the exhaust duct, only one traverse was conducted. In addition, only one of two inlets was sampled and the total inlet emissions were estimated by doubling the flow rate for the inlet duct that was sampled. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method.

Emission factors were developed for controlled and uncontrolled emissions of hexavalent and total chromium from each of the electroplating lines. Due to the lack of information on the process and control device, the fact that sampling was conducted along one traverse only, and only one of two inlet ducts were sampled, the emission data are rated D. Table 4-25 summarizes the results of the emission tests.

4.1.24 Reference 24

This report documents measurements of emissions from the same electroplating lines that were the subject of Reference 23. The purpose of the test was to determine the performance of recently upgraded control equipment. The sources tested included one chromic acid anodizing line and two hard chromium electroplating lines. Emissions from each of the electroplating lines are ducted to a combination of an unspecified type of wet scrubber and a fiber-bed mist eliminator. It is assumed that the scrubber type was packed bed because that is the type most commonly used in the industry.

Emissions were measured using CARB Method 425, and three runs were conducted at the outlet of the control devices. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method. However, hexavalent chromium was not detected during any of the test runs, and total chromium was detected during only one of the runs on each of the hard chromium plating lines. Emission factors were calculated by assuming one-half the detection limit for the runs for which total chromium was not detected in the sample.

Emission factors were developed for controlled total chromium emission from both hard chromium plating lines. However, because only one of three runs was above detection limit, the data were not rated. Table 4-26 summarizes the results of the emission tests.

4.1.25 Reference 25

This report documents measurements of emissions from a hard chromium electroplating facility in 1989. The test was conducted to evaluate the performance of fume suppressants and polyethylene balls in reducing chromium emissions from hard chrome plating.

Emissions were measured using CARB Method 425. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method. Two runs each were performed at three different load conditions (at applied amperages of approximately 800, 1,600, and 2,400) for both uncontrolled emissions and controlled emissions. The chromic acid concentration ranged from 261 to 269 g/L (35 to 36 oz/gal) of solution, and tank temperatures ranged from 53.3° to 56.1°C (128° to 133°F).

Emission factors were developed for uncontrolled and controlled total chromium and hexavalent chromium emissions based on the averages for all six test runs. The emission data are rated A. The test method was sound, no problems were reported, and six runs were conducted. Table 4-27 summarizes the results of the emission tests.

4.1.26 Reference 26

This report documents the results of an emission test at the same facility and under the same conditions as the test documented in Reference 25. However, in this case, a different fume suppressant was used to control emissions from the plating operations.

The chromic acid concentration was approximately 246 g/L (33 oz/gal) of solution, and tank temperatures ranged from 54.4° to 56.7°C (130° to 134°F). Emissions were measured using CARB Method 425. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method. Two runs each were performed at three different load conditions (at applied amperages of approximately 800, 1,600, and 2,400) for both controlled emissions and uncontrolled emissions. The data for the uncontrolled test runs were quantifiable. For the controlled runs, all six runs were above the quantitation limit for total chromium, and five of the six runs were above the quantitation limit for hexavalent chromium.

Emission factors were developed for uncontrolled and controlled total chromium and hexavalent chromium emissions based on the averages for all quantifiable test runs. The emission data are rated A. The test method was sound, no problems were reported, and the data for five to six runs were quantifiable. Table 4-28 summarizes the results of the emission tests.

4.1.27 Reference 27

This report documents measurements of emissions from a decorative chromium electroplating facility in 1990. The test was conducted to evaluate the performance of fume suppressants in reducing chromium emissions from decorative chrome plating.

The chromic acid concentration was approximately 172 g/L (23 oz/gal) of solution, and tank temperature was approximately 37.8°C (100°F). Emissions were measured using CARB Method 425. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method. Two runs each were performed at three different load conditions

(at applied amperages of approximately 800, 1,300, and 2,300) for both uncontrolled emissions and controlled emissions. The data for the uncontrolled test runs were quantifiable. For the controlled runs, four of the six runs were above the quantitation limit for total chromium, but the hexavalent chromium data was not quantifiable.

Emission factors were developed for uncontrolled total chromium and hexavalent chromium emissions, and for controlled total chromium emissions based on the averages for all quantifiable test runs. The emission data are rated A. The test method was sound, no problems were reported, and the data for four to six runs were quantifiable. Table 4-29 summarizes the results of the emission tests.

4.1.28 Reference 28

This report documents the results of an emission test at the same facility and under the same conditions as the test documented in Reference 27. However, in this case, a different fume suppressant was used to control emissions from the plating operations.

The chromic acid concentration was approximately 172 g/L (23 oz/gal) of solution, and tank temperature was approximately 37.8°C (100°F). Emissions were measured using CARB Method 425. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method. Two runs each were performed at three different load conditions (at applied amperages of approximately 800, 1,300, and 2,300) for both uncontrolled emissions and controlled emissions. The data for the uncontrolled test runs were quantifiable. For the controlled runs, five of the six runs were above the quantitation limit for total chromium, but the hexavalent chromium data was not quantifiable.

Emission factors were developed for uncontrolled total chromium and hexavalent chromium emissions, and for controlled total chromium emissions based on the averages for all quantifiable test runs. The emission data are rated A. The test method was sound, no problems were reported, and the data for five to six runs were quantifiable. Table 4-30 summarizes the results of the emission tests.

4.1.29 Reference 29

This report documents measurements of emissions from a hard chromium electroplating facility in 1990. The test was conducted to gather information on the usefulness of the Constant Sampling Rate Method for measuring emissions from chromium electroplating sources and to evaluate the performance of a mesh-pad mist eliminator in reducing chromium emissions from hard chrome plating.

Emissions were measured using the Constant Sampling Rate Method with hexavalent chromium analysis by diphenylcarbazide colorimetry. Three runs were performed at both the inlet and outlet of the control device. The chromic acid concentration during the test was approximately 234 g/L (31.3 oz/gal) of solution, and tank temperature was 55.6°C (132°F).

Emission factors were developed for uncontrolled hexavalent chromium emissions from the plating tank; the mass of hexavalent chromium collected at the outlet of the control device was below the quantitation limit for all three runs. The test method was sound and no problems were reported. However, the results from the first run are inconsistent with the other two runs. In addition, the emission factors for the second and third runs are much higher than expected and are much higher than factors developed from similar sources. Therefore, the data are rated D. Table 4-31 summarizes the results of the emission test.

4.1.30 Reference 30

This report documents measurements of emissions from a chromic acid anodizing facility in 1990. The test was conducted to evaluate the performance of fume suppressants and polyethylene balls in reducing chromium emissions from chromic acid anodizing.

Emissions were measured using CARB Method 425. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method. Two runs each were performed at three different load conditions (at applied amperages of approximately 100, 200, and 400) for both uncontrolled emissions and controlled emissions. The chromic acid concentration was approximately 52 g/L (7 oz/gal) of solution, and tank temperature was approximately 34.4°C (94°F).

Emission factors were developed for uncontrolled and controlled total chromium and hexavalent chromium emissions based on the averages for all six test runs. The emission data are rated A. The test method was sound, no problems were reported, and six runs were conducted. Table 4-32 summarizes the results of the emission tests.

4.1.31 Reference 31

This report documents measurements of emissions from an electroplating facility and a cleaning facility at a naval base in 1985. The tests were performed for informational purposes. Emissions from two electroplating lines were measured: a hard chromium electroplating line and a line that included a combination of zinc, brass, and cadmium plating. Emissions from each electroplating operation are ducted to mesh-pad mist eliminator.

The hard chromium plating tank was operated at a temperature of 60°C (140°F), and the chromic acid concentration was 210 g/L (28.1 oz/gal) of solution. Emissions of total chromium were measured using a modified Method 8 sampling train, and three runs were conducted. The primary modification consisted of replacement of the contents of the first impinger with 0.1 normal potassium hydroxide. The analytical method was not specified in the report. Particle size data was also collected at the inlet of the control device. Cascade impactors were used, and two runs were conducted. The data was analyzed to determine the size distribution of the chromium particles in the gas stream.

Emission factors were developed only for the hard chromium plating operation. Emission factors were not developed for the other electroplating line because the emissions measurements from the combination of plating tanks (zinc, brass, and cadmium) would not be applicable to other facilities.

Emission factors were developed for total chromium emissions from the hard chromium plating operation. The emission data are rated B because the report lacked adequate documentation to warrant a higher rating. Table 4-33 summarizes the results of the emission test.

4.1.32 Reference 33

This report documents measurements of emissions from a hard chromium electroplating line that included three tanks at a naval base in 1986. The tests were performed for informational purposes. Emissions from the electroplating operation were ducted to a mesh-pad mist eliminator.

The hard chrome tanks were operated at a temperature of 54.4°C (130°F) and a chromic acid concentration of 246 g/L (33 oz/gal) of solution. Emissions were measured using a modified Method 5 sampling train, and three runs were conducted at the inlet and outlet of the control device. In addition to filterable PM, total chromium emissions were quantified by analyzing the Method 5 samples by GFAAS.

Emission factors were developed for filterable PM and total chromium. The filterable PM data are not rated due to the problems associated with sampling filterable PM from electroplating tanks. Regarding the total chromium data, although no problems were reported, both the controlled and uncontrolled data are much higher than would be expected from this type of source, and the control efficiency for total chromium (77 percent) is much lower than would be expected for a mesh-pad mist eliminator. Therefore, the data are rated D. Table 4-34 summarizes the results of the emission test.

4.1.33 Reference 58

This report documents measurements of filterable PM, total chromium, and hexavalent chromium from a decorative chromium electroplating operation. The test was conducted in 1985 as part of an EPA-sponsored screening study of emissions from chromium electroplating.

The plating line tested included one plating tank that was operating with a chromic acid concentration in the range of 220 to 370 g/L (30 to 50 oz/gal) of solution. The normal operating temperature of the tank was between 46° and 63°C (115° and 145°F). Emissions from the plating operation were controlled with a packed-bed scrubber. Emissions were measured at both the inlet and outlet of the scrubber.

Filterable PM emissions were measured using Method 5. The Method 5 samples also were analyzed for total chromium using NAA and for hexavalent chromium using diphenylcarbazide colorimetry. In addition, an "impinger train" was run concurrent with the Method 5 train at the scrubber inlet. However, the report does not describe the configuration of the impinger train. Three runs were conducted at both the inlet and outlet of the scrubber.

Emission factors were developed for uncontrolled and controlled emissions. However, all of the data are unrated. The filterable PM data are unrated due to the problems associated with using the Method 5 train on this type of source. The chromium data are unrated because the factors for total and hexavalent chromium are higher for the scrubber outlet than for the inlet. Table 4-35 summarizes the results of the emission test.

4.1.34 Reference 59

This report documents measurements of filterable PM, total chromium, and hexavalent chromium from a hard chromium electroplating operation. The test was conducted in 1985 as part of an EPA-sponsored screening study of emissions from chromium electroplating.

The plating line tested included seven plating tanks that were operated with a chromic acid concentration of 250 g/L (33 oz/gal) of solution. Emissions from the plating operation were controlled with a fume suppressant and a packed-bed scrubber. Emissions were measured at both the inlet and outlet of the scrubber.

Filterable PM emissions were measured using Method 5. The Method 5 samples also were analyzed for total chromium using NAA and for hexavalent chromium using diphenylcarbazide colorimetry. Three runs were conducted at both the inlet and outlet of the scrubber. However, only one traverse of the sampling train was performed at the inlet. In addition, an error was suspected in the calculation of stack area and flowrates.

Emission factors were developed for uncontrolled and controlled emissions. However, because of the suspected calculation error, the data are not rated. Table 4-36 summarizes the results of the emission test.

4.1.35 Reference 62

This report documents measurements of total and hexavalent chromium from a chromic acid anodizing operation. The test was conducted in 1990 to evaluate the effectiveness of an antimisting agent for controlling chromium emissions.

The anodizing operation tested included one 800-gal tank that was operated with a chromic acid concentration of 51 to 59.6 g/L (7 to 8 oz/gal) of solution and at a temperature of 39.4°C (103°F). Total and hexavalent chromium emissions were measured using CARB Method 425, and two runs were conducted for uncontrolled and controlled emissions. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method.

Emission factors were developed for uncontrolled total and hexavalent chromium, and for controlled total chromium emissions; the mass of hexavalent chromium collected for the controlled runs was below the quantitation limit. The emission data are rated B. The test method was sound, and no problems were reported, but the test documentation was inadequate to warrant a higher rating. Table 4-37 summarizes the results of the emission test.

4.1.36 Reference 63

This report documents measurements of total and hexavalent chromium from a chromic acid anodizing operation. The test was conducted in 1989 to evaluate the effectiveness of various methods for controlling chromium emissions.

No information was provided on the operating parameters of the two anodizing tanks tested. Emissions were sampled for the following five controls: (1) none, (2) foam blanket, (3) foam blanket and polypropylene balls, (4) foam blanket and antimisting agent, and (5) polypropylene balls alone.

Total and hexavalent chromium emissions were measured using South Coast Air Quality Management District (SCAQMD) Method 205, and either two or three runs were conducted for each control method. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by the diphenylcarbazide colorimetric method. Emission factors for total chromium were developed for each control method. Factors could not be developed for controlled hexavalent chromium emissions because the mass collected during all runs was below the quantitation limit. The data for uncontrolled total chromium emissions from one of the tanks are rated B; the test documentation was inadequate to warrant a higher rating. The data for the combination foam blanket/antimisting agent-controlled emissions were not rated because the results of only one run could be quantified; the remaining total chromium data are rated C because only two runs were conducted. Table 4-38 summarizes the results of the emission tests.

4.1.37 Reference 66

This report documents measurements of total and hexavalent chromium from a chromic acid anodizing tank. The test was conducted in 1989 to demonstrate compliance with State regulations.

No information was provided on the operating parameters of the two anodizing tanks tested. Emissions from the tank are ducted to two packed-bed scrubbers. The scrubber outlets were sampled for two runs each under conditions of low and high gas flow rates and two load conditions. Total and hexavalent chromium emissions were measured using SCAQMD Method 205.1. Emission factors could not be calculated because tank dimensions were not specified in the report. Table 4-39 summarizes the results of the emission tests.

4.1.38 Reference 67

This report documents the results of testing performed on the inlets and outlets of two scrubbers that exhausted several electroplating tanks. The testing was conducted in response to California's Air Bill 2588 "Hot Spots" Program.

The first scrubber exhausts emissions from six nickel electroplating tanks and one copper electroplating tank. The scrubber also controls emissions from three other tanks; one tank contains a lead solution used in an unspecified nonelectroplating process, and the two other tanks contain 21 g/L (2.8 oz/gal) of chromic acid. The tanks containing the chromic acid solution also are used for an unspecified nonelectroplating process. The second scrubber exhausts two cadmium electroplating tanks and two tanks used for an unspecified nonelectroplating zinc process. The cadmium plating tanks contained 24.3 g/L (3.25 oz/gal) of cadmium oxide, and the zinc process tanks contained 28.8 g/L (3.85 oz/gal) of zinc oxide. The complete details of the plating lines are not provided because the facility considers the information to be confidential. However, the report states that the purpose of the scrubber that served the cadmium plating line was to control cyanide emissions, and the cadmium oxide concentration in the bath was consistent with the cadmium cyanide plating process. Therefore, it is assumed that the cadmium plating line used the cadmium cyanide plating process. Furthermore, the report states that the scrubber that served the copper plating line controlled acid emissions. In the absence of other information, it is assumed that the copper plating line used the copper sulfate process, which includes sulfuric acid in the plating solution. The report does not specify the scrubber design.

The exhaust streams were sampled for emissions of copper, lead, nickel, cadmium, zinc, and chromium. Emissions of total and hexavalent chromium were quantified using CARB Method 425 with total chromium analysis by GFAAS and hexavalent chromium analysis by diphenylcarbazide colorimetry; emissions of the other metals were determined using EPA Method 0012, multi-metals sampling train. Emissions of cadmium and nickel also were sampled using CARB Methods 424 and 433, respectively. For the electroplating tanks, process rates are provided in units of A-hr.

Emission factors were determined for emissions of copper (scrubber outlet), nickel (scrubber inlet and outlet), and cadmium (scrubber inlet and outlet). Emission factors were not determined for the chromium, lead, and zinc process tanks because the purpose of the tanks was not explained in the report. In addition, the hexavalent chromium concentration was below detection limit in all test runs. For the copper plating process, copper emissions were below detection limit for two of the three runs conducted on the inlet to the scrubber.

For a number of tests on the copper, nickel, and cadmium processes, the energy input and emission factors varied dramatically from run to run; for this reason and because the report did not include complete documentation of the test, the test data for those pollutants were assigned a rating of C. The other data sets for these processes were rated B. The emission data for the chromium, lead, and zinc processes were not rated because a process description was not provided for those sources. Table 4-40 summarizes the results of these tests.

4.1.39 Reference 71

This report documents measurements of emissions from a high purity chromium metal production process. The purpose of the test, which was conducted in 1991, apparently was to demonstrate emissions from the process prior to permitting a new facility. The report does not provide details on the process or the control device. However, additional information was provided by the facility (Reference 99).

The high purity chromium metal production process is similar to hard chromium electroplating. However, in the high purity chromium metal process, the cathode is plated to a thickness of 3 to 4 millimeters over a period of 7 days. The high purity chromium metal then is stripped off the cathode and used in the electronics industry.

Emissions from the process are controlled with a mesh pad mist eliminator followed by a packed bed scrubber. The test was conducted at the inlet of the scrubber. Emissions were measured using Method 13B. The samples were analyzed for total chromium by GFAAS and for hexavalent chromium by ICPCR. Three 64-minute test runs were conducted. Table 4-41 summarizes the results of this test.

The emission data are rated B. The test methods were sound and no problems were reported, but the report does not fully describe the process and control device.

4.1.40 Reference 74

This document consists of a summary and field data sheets for tests conducted on an electroplating line. The line includes one 1 m by 4 m (3 ft by 12 ft) plating tank and one 2 m by 2 m (6 ft by 6 ft) plating tanks. The type of chromium plating process is not identified, but based on the information provided it appears to have been a hard chromium plating line. The test was conducted to determine compliance with State regulations.

Emissions from the plating are controlled with an unspecified type of scrubber. However, only uncontrolled hexavalent chromium emissions were sampled. Three test runs were conducted using two test methods simultaneously. One method is identified as "ST-35" but no description of the method is provided. The second method used was CARB Method 425. The analytical methods were not specified, but it is assumed that total chromium was analyzed by GFAAS and hexavalent chromium was analyzed by diphenylcarbazide colorimetry. In all cases, the sample was collected continuously through all three test runs, resulting in a single quantification of mass collected. The amount of material caught per run was estimated by proportioning the volume of liquid collected during each run. In addition, average rather than run-by-run volumetric flow rates and process rates were reported.

The emission data are rated C; complete run-by-run data and a process description were not reported, and only a 3-run composite sample was collected rather than three separate samples. Table 4-42 summarizes the results of this test.

4.1.41 Reference 75

This report documents the results of a test conducted on a chromic acid anodizing operation in 1993. The purpose of the test is not stated in the report.

The tank measured 1 m by 7 m by 2 m (3 ft wide by 22 ft long by 6 ft deep). Emissions from the anodizing tank are controlled with a wet scrubber. The scrubber solution is maintained at a pH of 3.5 and contains 20 ppm of a chlorine oxygen scavenger for reducing hexavalent chromium to trivalent chromium. Emissions were sampled at both the inlet and outlet to the scrubber using CARB Method 425; total chromium was analyzed by ICP and hexavalent chromium was analyzed by IC. Three test runs were conducted. Emission factors were determined for total and hexavalent chromium.

The inlet emission data and the outlet total chromium data rated A; the test methods were sound, and no problems were reported. The outlet hexavalent chromium data are rated B because the results of one run were below the quantification limit for the analytical method. Table 4-43 summarizes the results of this test.

4.1.42 Reference 77

This report presents the results of emission tests conducted on one chromic acid anodizing line and two hard chromium electroplating lines. The tests were conducted in 1989; the purpose of the tests was not stated.

The chromic acid anodizing tank dimensions were not specified, so emission factors could not be developed from the test data on that source. Emissions from each electroplating line were controlled with a wet scrubber; details on the scrubbers were not provided in the report. Both uncontrolled and controlled emissions were measured using Method 13B with hexavalent chromium analysis by diphenylcarbazide colorimetry. Two test runs were conducted on each plating line.

The emission data for the first electroplating line are rated B. The test method was sound, and no problems were reported, but only two test runs were conducted. The data rating for the second line are rated C because a comparison of the inlet and outlet data reveals a relatively poor control efficiency (37 percent), indicating a malfunctioning scrubber. Table 4-44 summarizes the results of this test.

4.1.43 Reference 78

This report documents the results of a test conducted in 1990 on a process that is identified as magnesium anodizing. The purpose of the test is not stated in the report.

The process, which also referred to as the modified acid fluoride anodizing process, is used to anodize magnesium parts in the presence of an acidic chromate and fluoride solution. In this respect, the process is a kind of chromic acid anodizing operation. The anodizing tank solution consisted of 67 to 105 g/L (9 to 14 oz/gal) of phosphoric acid, 82 to 112 g/L (11 to 15 oz/gal) of sodium dichromate, and 300 to 450 g/L (40 to 60 oz/gal) of ammonium difluoride. The dimensions of the anodizing tank were not specified. However, the tank capacity is reported as 5,450 gallons. Assuming a tank length of twice its width, and a tank depth equal to its width, the surface area of the tank can be estimated as 9.5 m^2 (102 ft^2). Emissions from the anodizing tank are controlled with a wet scrubber.

Emissions were sampled at both the inlet and outlet to the scrubber using CARB Method 425 with total chromium analysis by GFAAS and hexavalent chromium analysis by diphenylcarbazide colorimetry. Three test runs were conducted. Emission factors were determined for total and hexavalent chromium.

The total chromium emission data are rated C; the test methods were sound, and no problems were reported, but to determine the emission factor, the tank dimensions had to be estimated. The hexavalent chromium emission data are not rated because the results of all runs were below the quantification limit for the analytical method. Table 4-45 summarizes the results of this test.

4.1.44 Reference 81

This report presents the results of an emission test conducted on a hard chromium electroplating line. The test was conducted in 1993 to demonstrate compliance with State standards.

The electroplating line tested included three plating tanks. Emissions from the plating line were controlled with a wet scrubber. Details on the scrubber were not provided in the report, but it is assumed that the device was a packed bed scrubber. Both uncontrolled and controlled emissions were measured using CARB Method 425 with total chromium analysis by ICP and hexavalent chromium analysis by IC. Three test runs were conducted.

The emission data are rated B. The test method was sound, and no problems were reported, but the type of scrubber was not fully described. Table 4-46 summarizes the results of this test.

4.1.45 Reference 83

This report presents the results of an emission test conducted on two chromic acid anodizing lines (C2 and Helo blade) at a Naval base. The tests were conducted in 1991. The purpose of the test was not stated in the report.

The dimensions of the C2 chromic acid anodizing tank were 1.5 m wide by 4.4 m long by 2.2 m deep (5 ft by 14.5 ft by 7 ft). The dimensions of the Helo Blade anodizing tank were 0.61 m wide by 4.8 m long by 0.86 m deep (2 ft by 15.7 ft by 2.83 ft). Emissions from each tank are controlled with packed bed scrubber. In addition, a fume suppressant also was used to control emissions. CARB Method 425 was used to quantify emissions with total chromium analysis by GFAAS and hexavalent chromium analysis by IC. Three test runs were conducted on the C2 anodizing line. Production problems caused sampling interruptions during the test on the Helo Blade line, so four runs were conducted. The results generally were much higher for the test on the second line, and the report concludes that the Helo Blade scrubber was not operating properly.

The emission data for the test on the C2 anodizing line are rated B. The test method was sound, and no problems were reported, but the report was not fully documented. The data for the Helo Blade line test are rated D because of the suspected problem with the scrubber. Table 4-47 summarizes the results of these tests.

4.1.46 Reference 84

This report presents the results of an emission test conducted on the Helo Blade chromic acid anodizing line described in Reference 83. The test was conducted in 1992. The purpose of the test was to determine the effectiveness of a recently overhauled scrubber in controlling chromium emissions from the process.

The dimensions of the chromic acid anodizing tank were 0.61 m wide by 4.8 m long by 0.86 m deep (2 ft by 15.7 ft by 2.83 ft). Emissions from the tank are controlled with packed-bed scrubber equipped with a mesh-pad mist eliminator. CARB Method 425 was used to quantify emissions with total chromium analysis by ICP and hexavalent chromium analysis by IC. Three test runs were conducted, but the results of the third run were below the quantification limit.

The emission data are rated B. The test method was sound, and no problems were reported, but only two test runs were quantifiable. Table 4-48 summarizes the results of this test.

4.1.47 Reference 85

This report presents the results of emission tests conducted on one chromic acid anodizing line and two hard chromium electroplating lines. The tests were conducted in 1992 to demonstrate compliance with local regulations.

Emissions from the chromic acid anodizing operation were below detection limit on both test runs; those data could not be used to develop emission factors. Emissions from each electroplating line were controlled with a wet scrubber and a fiber bed filter. CARB Method 425 was used to measure emissions of total chromium with total chromium analysis by GFAAS and hexavalent chromium analysis by diphenylcarbazide colorimetry. Two test runs were conducted on each plating line. The results from all test runs were above the detection limit, but below the quantitation limit.

The emission data for the two electroplating lines are rated C. The test method was sound, and no problems were reported, but only two test runs were conducted, and emissions were just below the quantitation limit for the analytical method. Table 4-49 summarizes the results of these tests.

4.1.48 Reference 86

This report presents the results of emission tests conducted on the same two chromic acid anodizing lines that were the subject of the tests documented in References 83 (C2 and Helo Blade) and 84 (Helo Blade line only). The tests were conducted in 1991. The purpose of the test was not stated in the report.

The dimensions of the C2 chromic acid anodizing tank were 1.5 m wide by 4.4 m long by 2.2 m deep (5 ft by 14.5 ft by 7 ft). The dimensions of the Helo Blade anodizing tank were 0.61 m wide by 4.8 m long by 0.86 m deep (2 ft by 15.7 ft by 2.83 ft). Emissions from each tank are controlled with packed bed scrubber. CARB Method 425 was used to quantify emissions with total chromium analysis by GFAAS and hexavalent chromium analysis by IC. Three test runs were conducted on the C2 anodizing line. The first test run during the test on the Helo Blade line was aborted due to production problems, but an additional three runs were conducted. In addition, the scrubber on the Helo Blade line failed during the final test run.

The emission data for the test on the C2 anodizing line are rated B. The test method was sound, and no problems were reported, but the report was not fully documented. The data for the Helo Blade line test are rated C because of the problem with the scrubber. Table 4-50 summarizes the results of these tests.

4.1.49 Reference 88

This report presents the results of an emission test conducted on a hard chromium electroplating line. The test was conducted in 1991 to demonstrate compliance with local emission standards.

The electroplating line tested included one plating tank. Emissions from the plating line were controlled with two wet scrubbers in parallel. Details on the scrubbers were not provided in the report, but it is assumed that the devices were a packed bed scrubber. In addition, polypropylene chips also were placed in the tank to reduce emissions from the process. During the test, one scrubber was closed down so that all emissions would be directed to the other scrubber. Emissions were quantified at the outlet of that scrubber using CARB Method 425 with total chromium analysis by GFAAS and hexavalent chromium analysis by diphenylcarbazide colorimetry. Three test runs were conducted.

The total chromium emission data are rated B. The test method was sound, and no problems were reported, but the type of scrubber was not fully described. The hexavalent chromium emission data are not rated because the results of all runs were below the quantification limit of the analytical method. Table 4-51 summarizes the results of this test.

4.1.50 Reference 89

This report presents the results of an emission test conducted on the same hard chromium plating line that was the subject of the test documented in Reference 88. This test also was conducted in 1991, 5 months before the test documented in Reference 88.

The electroplating line tested included one plating tank. Emissions from the plating line were controlled with two wet scrubbers in parallel. Details on the scrubbers were not provided in the report, but it is assumed that the devices were a packed bed scrubber. In addition, polypropylene chips also were placed in the tank to reduce emissions from the process. Emissions were quantified at the outlet of one of the scrubbers using CARB Method 425 with total chromium analysis by GFAAS and hexavalent chromium analysis by the diphenylcarbazide colorimetry. Three test runs were conducted. Emission factors by assuming that the total emission rate was twice the emission rate measured from one stack.

The total chromium emission data are rated C because only one of the two parallel stacks was tested. The hexavalent chromium data are not rated because the results of all three test runs were below the quantification limit for the method. Table 4-52 summarizes the results of this test.

4.1.51 Reference 90

This report presents the results of an emission test conducted on a unspecified chromium electroplating line. The test was conducted in 1990; the purpose of the test was not stated in the report.

The electroplating line tested included one plating tank. Based on the results, it appears that the line was used for hard chromium electroplating. Emissions from the plating line were controlled with a wet

scrubber followed by a moisture extractor. Details on the scrubber were not provided in the report, but the information provided in the report indicates that the device was a packed bed scrubber. In addition, polypropylene balls were placed in the tank, and two-thirds of the tank was covered with a plastic sheet to reduce emissions from the process.

Emissions were quantified at the inlet and outlet of the scrubber using EPA Method 13B with hexavalent chromium analysis by diphenylcarbazide colorimetry. Two test runs were conducted. The results of the second run on the scrubber outlet was approximately half the quantification limit for the analytical method.

The inlet emission data are rated B. The test method was sound, and no problems were reported, but the type of scrubber was not fully described. The outlet emission data are rated C because, in addition to the above, one of the two runs was below the quantification limit. Table 4-53 summarizes the results of these tests.

4.1.52 Reference 93

This report presents the results of an emission test conducted on a unspecified chromium electroplating line. The test was conducted in 1992; the purpose of the test was not stated in the report.

The electroplating line tested included one plating tank. Based on the results, it appears that the line was used for hard chromium electroplating. Emissions from the plating line were controlled with a wet scrubber. Details on the scrubber were not provided in the report, it is assumed that the device was a packed bed scrubber. In addition, fume suppressant was used to reduce emissions from the process.

Emissions were quantified at the inlet and outlet of the scrubber using CARB Method 13B with total chromium analysis by GFAAS and hexavalent chromium analysis by diphenylcarbazide colorimetry. The samples also were analyzed for total chromium. Three test runs were conducted. Hexavalent chromium emissions were below the quantification limit for the analytical method on all three test runs.

The total chromium emission data are rated B. The test method was sound, and no problems were reported, but the type of scrubber was not fully described. The hexavalent chromium emission data are not rated. Table 4-54 summarizes the results of this test.

4.1.53 Reference 94

This report presents the results of an emission test conducted on a chromic acid anodizing line. The purpose of the test, which was conducted in 1991, was not stated in the report.

The chromic acid anodizing line includes two 9.8 m long by 1.7 m wide by 2.4 m deep (32 ft by 5.5 ft by 8 ft) tanks manifolded together and exhausted to a common stack. Emissions from the anodizing line were controlled with a packed bed scrubber followed by two high efficiency particulate air (HEPA) filters. CARB Method 425 was used to measure emissions of total chromium with total chromium analysis by ICP/MS and hexavalent chromium analysis by IC. Three test runs were conducted on the inlet and outlet of the control device. The outlet total chromium concentrations were below the detection limit on two of the three test runs.

The inlet data and outlet hexavalent chromium emission data are rated B. The test method was sound, and no problems were reported, but the report was not fully documented. The total chromium outlet emission data are rated D because the results of only one run were above the detection limit. Table 4-55 summarizes the results of this test.

4.1.54 Reference 95

This report presents the results of an emission test conducted on a chromic acid anodizing line at the same facility that was the subject to the test documented in Reference 94. The purpose of the test, which was conducted in 1991, was not stated in the report.

The chromic acid anodizing line included a single anodizing tank. The dimensions of the tank were not reported. However, it was assumed that the tank had the same dimensions as the tanks that were the subject of the Reference 94 test. The dimensions of those tanks were 9.8 m long by 1.7 m wide by 2.4 m deep (32 ft by 5.5 ft by 8 ft). Emissions from the anodizing line were controlled with a four-stage scrubber. Method 13B was used to measure emissions of total and hexavalent chromium. Total chromium concentrations were determined by CP/MS and hexavalent chromium analysis by diphenylcarbazide colorimetry. Three test runs were conducted on the inlet and outlet of the control device. The outlet concentrations of all samples were below the detection limit or quantification on all test runs.

The inlet emission data are rated C. The test method was sound, and no problems were reported, the tank dimensions were estimated based on information in Reference 94. The outlet emission data are not rated. Table 4-56 summarizes the results of this test.

4.1.55 Reference 98

This reference is a technical paper that describes two methods for estimating chromium emissions from electroless chromium conversion coating (ECCC) process tanks. The first method uses emission factors for hard and decorative chromium electroplating to estimate emissions from air sparged (aerated) or agitated ECCC process tanks. The method is based on the assumption that emissions per unit surface area of chromium electroplating tanks is comparable to emissions from sparged ECCC process tanks. However, the emission mechanisms are entirely different for the two processes. In electroplating, electrical energy applied to the solution creates hydrogen gas bubbles, which burst at the tank surface, resulting in emissions in the form of a mist. In the ECCC process, emissions result from tank aeration or from the mechanical agitation of the solution, and no rationale is provided for why the emissions from the two processes are comparable.

The second method is based on a theoretical model, which estimates the mass of liquid entrained due to the bursting of a bubble at the surface of the liquid. Emissions can be estimated as a function of several parameters, including the bubble radius, gas (i.e., air) density, and the density and surface tension of the liquid, in the following equation:

$$Y = k_1 R_b^2 \left[\frac{(1 - 2a + 9a^2)^{0.5} + (a - 1)}{(1 + 3a) - (1 - 2a + 9a^2)^{0.5}} \right]^{0.5} \qquad (2)$$

where:

$$a = \frac{R_b^{\ 2}}{k_2},\ k_1 = \frac{1.15\ \pi\sigma}{c_s^{\ 2}},\ k_2 = \frac{6\ \sigma}{(\rho_1 - \rho_g)\ g}$$

and

Y = emission factor, grams per bubble;
R_b = radius of bubble, cm;
c_s = speed of sound, 3.3×10^4 cm/s;
ρ_1 = density of liquid, g/cm^3;
ρ_g = density of gas, g/cm^3;
g = acceleration due to gravity, 980 cm/sec^2; and
σ = surface tension at liquid air interface, dyne/cm.

If the air sparging rate and the average bubble radius are known, the model can be used to estimate the emission rate per unit of tank area. For air-sparged process tanks, this method appears to be a useful means of estimating emissions provided the values of all parameters are known or can be estimated.

4.2 DEVELOPMENT OF CANDIDATE EMISSION FACTORS

Table 4-57 summarizes the emission data used to develop emission factors for electroplating. The candidate emission factors for chromium electroplating are presented in Table 4-58, and Table 4-59 presents the candidate emission factors for the plating of metals other than chromium. The following paragraphs describe how the data presented in Table 4-57 were used to develop candidate emission factors for the draft AP-42 section on electroplating and presents statistical information on some of the candidate emission factors. Appendix A summarizes the calculations performed to arrive at the candidate emission factors.

4.2.1 General Procedures

The data sets were screened and evaluated, and the candidate emission factors generally were rated according to the criteria presented in Sections 3.2 and 3.3 of this report. To summarize, if an adequate number of A- and B-rated data sets were available for a specific combination of source and pollutant, the remaining data sets were discarded. If the number of A- and B-rated data sets were few, then B-rated data sets were included in the determination of candidate emission factors. Otherwise, C- and D-rated data were used only if no higher rated data were available.

Most of the candidate emission factors were determined as the mean of the factors determined by averaging the run-by-run data for each data set considered. However, if the data sets under consideration included more than one set of test data for a particular source, the factors for each test on that particular source were first averaged, and that value was used in the calculation of the mean of the factors for all sources.

For several of the emission tests in which both total chromium and hexavalent chromium emission rates were quantified, the hexavalent chromium emission rates were found to be higher than the total chromium emission rates. These discrepancies can be attributed primarily to differences in analytical methods. To resolve this issue, only the analyte quantified using the analytical method with the lower

detection limit was considered. Therefore, for those tests in which both total and hexavalent chromium were quantified and the colorimetric method was used to quantify hexavalent chromium, the total chromium data were considered. For those tests in which both total and hexavalent chromium were quantified and ICPCR was used to quantify hexavalent chromium, the hexavalent chromium data were considered. For the tests in which either total or hexavalent chromium, but not both, were quantified, the data were considered regardless of the analytical method used.

For the sake of consistency with the Clean Air Act (CAA), the factors for chromium emissions are identified in the draft AP-42 section as chromium compounds, as included in the list of hazardous air pollutants in Section 112 (b) of the CAA.

As discussed in Section 3.6 of this report, factors for uncontrolled emissions from electroplating are presented on the basis of total energy input in units of mg/A-hr and gr/A-hr. Factors for controlled emissions from electroplating are presented in those same units and as concentrations in units of mg/dscm and gr/dscf. It is strongly recommended that the concentration factors are used, because those factors are more representative of the emission control that can be achieved using the control devices indicated. The factors for controlled emissions based on total energy input should only be used in the absence of data on the type of ventilation system used.

As also discussed in Section 3.6, factors for chromic acid anodizing emissions (uncontrolled and controlled) are presented on the basis of tank surface area in units of g/hr-m^2 and gr/hr-ft^2.

4.2.2 Hard Chromium Electroplating

For uncontrolled chromium compound emissions from hard chromium electroplating, a total of 26 data sets were available. Fifteen of the data sets were rated A, and five data sets were rated B. Although the data set from Reference 12 was rated A, it was not considered due to the atypical nature of the source and its relatively high magnitude; that factor (74 mg/A-hr [1.1 gr/A-hr]) is more than three standard deviations higher than the mean of the sample population. Additional information on this source is provided in Section 4.1.12. The factors for the remaining 19 A- and B-rated data sets ranged from 1.7 to 18 mg/A-hr (0.025 to 0.28 gr/A-hr) and averaged 7.8 mg/A-hr (0.12 gr/A-hr). This factor is assigned a rating of B because it is based on a relatively large number of A- and B-rated data sets.

For chromium compound emissions controlled with a moisture extractor, a total of three A-rated data sets were available. The factors from these sets ranged from 0.16 to 0.43 mg/dscm (6.9×10^{-5} to 0.00019 gr/dscf) and averaged 0.31 mg/dscm (0.00014 gr/dscf). This candidate factor is rated D because it is based on a relatively small number of data sets.

For chromium compound emissions controlled with a polypropylene balls, two B-rated data sets were available. The chromium concentration for the second data set (Reference 90) was nearly an order of magnitude higher than the concentration for the first data set (Reference 6). In fact, the Reference 90 concentration results were even higher than the average concentration for uncontrolled hard chromium electroplating. For this reason, the Reference 90 data were not used; only the Reference 6 data were used. The factor developed from the Reference 6 data (0.96 mg/dscm [0.00042 gr/dscf]) is rated D because it is based on a single B-rated data set.

For chromium compound emissions controlled with a fume suppressant, one A-rated data set (0.37 mg/dscm [0.00016 gr/dscf]) and one C-rated data set (0.034 mg/dscm [1.5×10^{-5} gr/dscf]) were

available. The C-rated data set was discarded. The factor developed from the A-rated data is rated D because it is based on a single A-rated data set.

For chromium compound emissions controlled with a combination of fume suppressant and polypropylene balls, three A-rated data sets were available. The factors from these sets ranged from 0.037 to 0.11 mg/dscm (1.6×10^{-5} to 4.6×10^{-5} gr/dscf) and averaged 0.069 mg/dscm (3.0×10^{-5} gr/dscf). This candidate factor is rated D because it is based on a relatively small number of data sets.

For chromium compound emissions controlled with a packed-bed scrubber, five A-rated, two B-rated, two D-rated, and two unrated data sets were available. In addition, three data sets (two B-rated and one C-rated) were available for emissions controlled with an unspecified type of wet scrubber. Because the data from these tests are consistent with the packed-bed scrubber-controlled data, the wet scrubbers in question were assumed to be packed bed scrubbers. The C-rated, D-rated, and unrated data sets were discarded. Three of the useable data sets were for the same source (Reference 9). The average factor for those three sets was first determined and used as a single data point in determining the mean of the factors for all sources considered. The factors developed from the A- and B-rated data sets ranged from 0.0066 to 0.10 mg/dscm (2.9×10^{-6} to 4.5×10^{-5} gr/dscf) and averaged 0.047 mg/dscm (1.9×10^{-5} gr/dscf). The candidate emission factor is rated C because it is based on nine A- and B-rated data sets.

For chromium compound emissions controlled with a combination of a packed-bed scrubber and either a fume suppressant or polypropylene balls or both, one A-rated data set, two B-rated data sets, and two C-rated data sets were available. The C-rated data sets were inconsistent with the other data sets and were discarded. The factors developed from the remaining three data sets ranged from 0.0037 to 0.0086 mg/dscm (1.6×10^{-6} to 3.7×10^{-6} gr/dscf) and averaged 0.0059 mg/dscm (2.6×10^{-6} gr/dscf). This factor is rated D because it is on a small number of A- and B-rated data sets.

For chromium compound emissions controlled with a chevron blade mist eliminator, three A-rated data sets were available. The factors from these sets ranged from 0.12 to 0.35 mg/dscm (5.2×10^{-5} to 0.00015 gr/dscf) and averaged 0.20 mg/dscm (8.8×10^{-5} gr/dscf). This candidate factor is rated D because it is based on a relatively small number of data sets.

For chromium compound emissions controlled with a mesh-pad mist eliminator, three A-rated, four B-rated, and one D-rated data sets were available. The D-rated data set was discarded. Two of the A-rated data sets were for the same source (Reference 6), and two of the B-rated data sets were for the same source (Reference 20). The average factor for each of those pairs of data sets was first determined and used as single data points in determining the mean of the factors for all sources considered. In addition to a mesh-pad mist eliminator, one other control technology (polypropylene balls, fume suppressant, or moisture extractor) was used during three of the tests. However, those controls are not expected to enhance the control efficiency of the system controlled with a mesh-pad mist eliminator alone. Therefore, those data sets were considered to represent mesh-pad mist eliminator control. The factors developed from the A- and B-rated data sets ranged from 0.0047 to 0.043 mg/dscm (2.1×10^{-6} to 1.9×10^{-5} gr/dscf) and averaged 0.028 mg/dscm (1.2×10^{-5} gr/dscf). The candidate emission factor is rated D because it is based on data from a relatively small number (5) of sources. The data from Reference 71 were not included in this determination because of differences in the process and because the concentration-based emission factor based on the Reference 71 data was more than twice the factor for any other data set.

For chromium compound emissions controlled with a combination of packed-bed scrubber with a mesh-pad mist eliminator, two C-rated data sets were available. The factors from these data sets were 7.8×10^{-5} and 6.9×10^{-5} mg/dscm (3.4×10^{-8} and 3.0×10^{-8} gr/dscf). The average factor (7.3×10^{-5} mg/dscm [3.2×10^{-8} gr/dscf]) is rated E because it is based on C-rated data.

For chromium compound emissions controlled with a composite mesh-pad mist eliminator, four A-rated data sets were available. Two of the data sets were for the same source (Reference 11). The average factor for those two sets was first determined and used a single data point in determining the mean of the factors for all sources considered. The factors from these sets ranged from 0.0060 to 0.011 mg/dscm (2.6×10^{-6} to 5.0×10^{-6} gr/dscf) and averaged 0.0087 mg/dscm (3.8×10^{-5} gr/dscf). This candidate factor is rated D because it is based on a relatively small number of data sets.

4.2.3 Decorative Chromium Electroplating

For uncontrolled chromium compound emissions from decorative chromium electroplating, four A-rated data sets were available. The factors from these sets ranged from 0.41 to 1.4 mg/dscm (0.00018 to 0.00063 gr/dscf) and averaged 0.81 mg/dscm (0.00036 gr/dscf). This candidate factor is rated D because it is based on a relatively small number of data sets.

For chromium compound emissions from decorative plating controlled with a fume suppressant, four A-rated and three unrated data sets were available. The unrated tests were discarded. Two of the A-rated data sets were for the same source (Reference 16). The average factor for those two sets was first determined and used as a single data point in determining the mean of the factors for all sources considered. The factors from these sets ranged from 0.0021 to 0.0046 mg/dscm (9.3×10^{-7} to 2.0×10^{-6} gr/dscf) and averaged 0.0027 mg/dscm (1.2×10^{-6} gr/dscf). This candidate factor is rated D because it is based on a relatively small number of data sets.

4.2.4 Chromic Acid Anodizing

For uncontrolled chromium compound emissions from chromic acid anodizing, two A-rated, three B-rated, and one C-rated data sets were available. The C-rated data set was consistent with the others and was retained. The factors from these sets ranged from 0.64 to 3.4 g/hr-m^2 (0.92 to 4.8 gr/hr-ft^2) and averaged 1.4 g/hr-m^2 (2.0 gr/hr-ft^2). This candidate factor is rated D because it is based on a relatively small number of data sets.

For chromium compound emissions controlled with polypropylene balls, one B-rated data set was available. The factor developed from the data (1.2 g/hr-m^2 [1.7 gr/hr-ft^2]) is rated D because it is based on a single B-rated data set.

For chromium compound emissions controlled with a fume suppressant, four data sets were available (one A-rated, one B-rated, one C-rated, and one unrated). The unrated data set was discarded. However, due to the relatively small number of data sets, the C-rated data set was included with the A- and B-rated data. The factors from these sets ranged from 0.026 to 0.057 g/hr-m^2 (0.037 to 0.082 gr/hr-ft^2) and averaged 0.044 g/hr-m^2 (0.064 gr/hr-ft^2). This candidate factor is rated D because it is based on a relatively small number of data sets.

For chromium compound emissions controlled with a fume suppressant and polypropylene balls, two data sets were available (one A-rated and one C-rated). However, due to the relatively small number

of data sets, the C-rated data set was included with the A-rated data. The factors from these sets were 0.018 g/hr-m^2 (0.026 gr/hr-ft^2) for the A-rated data set and 0.016 g/hr-m^2 (0.023 gr/hr-ft^2) for the C-rated data set. The average of these two sets is 0.017 g/hr-m^2 (0.025 gr/hr-ft^2). This candidate factor is rated D because it is based on a relatively small number of data sets.

For chromium compound emissions controlled with a packed bed scrubber or an unspecified wet scrubber, two B-rated and one C-rated data sets were available. Due to the small number of data sets, the C-rated set was retained. The emission factors developed from the data ranged from 0.0019 to 0.013 g/hr-m^2 (0.0027 to 0.018 gr/hr-ft^2) and averaged 0.0062 g/hr-m^2 (0.0086 gr/hr-ft^2). The candidate emission factor is rated D because it is based on a small number of B- and C-rated tests.

For chromium compound emissions controlled with a combination of fume suppressant and packed bed scrubber, one B-rated and one D-rated data sets were available. The D-rated data set was discarded. The emission factor developed from the B-rated data is 0.00052 g/hr-m^2 (0.00075 gr/hr-ft^2) and is rated D because it is based on a one B-rated test.

For chromium compound emissions controlled with a mesh-pad mist eliminator, one D-rated data set was available. The factor developed from the data (0.0035 g/hr-m^2 [0.0051 gr/hr-ft^2]) is rated E because it is based on D-rated data.

For chromium compound emissions controlled with a combination of packed bed scrubber and mesh pad mist eliminator, one B-rated data set was available. The emission factor developed from the data is 0.00038 g/hr-m^2 (0.00054 gr/hr-ft^2) and is rated D because it is based on a one B-rated test.

For chromium compound emissions controlled with a combination of moisture extractor, wet scrubber, and HEPA filter, one B-rated and one unrated data sets were available. The unrated data set was discarded. The emission factor developed from the B-rated data is 0.00033 g/hr-m^2 (0.00048 gr/hr-ft^2) and is rated D because it is based on a one B-rated test.

4.2.5 Total PM Emissions From Chromium Electroplating and Chromic Acid Anodizing

Although three of the emission test reports reviewed contained data on filterable PM emissions, none of that data could be rated and considered for candidate emission factor development. Emissions from chromium electroplating and chromic acid anodizing operations consist of chromic acid mist. Because the concentration of sulfuric acid in chromium plating solutions generally is about 1 percent of the chromic acid concentrations, emissions of sulfuric acid can be considered negligible. Furthermore, chromium electroplating solutions are free of contaminants. Factors for total PM emissions can be estimated using the ratio of the molecular weight of chromium in chromic acid to the molecular weight of chromic acid as follows:

Chemical formula for chromic acid: $H_2Cr_2O_7$
Molecular weight of chromium in chromic acid = 2(52) = 104
Molecular weight of chromic acid = 2(1) + 2(52) + 7(16) = 218
Molecular weight ratio of $H_2Cr_2O_7$ to Cr_2 = 218/104 = 2.1

Therefore, the emission factor for total PM from chromium electroplating can be estimated as:

$$EF_{PM} = 2.1 \times EF_{Cr} \quad (3)$$

where:

EF_{PM} = is the factor for total PM emissions; and

EF_{Cr} = is the factor for chromium emissions.

Furthermore, because emissions consist of a mist, all of the PM emitted can be considered to be PM-10. Because these PM factors are based on estimates rather than actual measurements, the factors are assigned one quality rating lower than the corresponding factor for chromium compound emissions. For example, for hard chromium electroplating emissions controlled with a moisture extractor, the chromium compound factor is 0.31 mg/dscm and is rated D. For total PM (or PM-10) emissions from hard chromium electroplating controlled with a moisture extractor, the factor is (0.31)(2.1) = 0.65 mg/dscm and is rated E.

4.2.6 Electroplating of Other (Nonchromium) Metals

Three of the references reviewed for this study included data that could be used to develop factors for emissions from the plating of metals other than chromium. Table 4-59 summarizes the emission factors for the plating of these other metals. Included in the table are emission factors for copper, cadmium, and nickel electroplating.

The test reports used to develop the factors presented in Table 4-58 generally were not fully documented, and many of the tests were performed on exhaust streams that included a combination of processes, such as plating, cleaning, and etching. In addition, several of the data sets showed wide variations in emissions from run to run, and only one or two B- or C-rated data sets were available for a particular process. For these reasons, the candidate emission factors developed for the nonchromium electroplating sources are all assigned a rating of E.

The emission factors for the other plating processes are presented in the same units as the factors for chromium electroplating (i.e., in units of energy applied and as concentrations). When possible, the concentration-based emission factors should be used to estimate controlled emissions; the factors in units of energy applied should only be used when the information is inadequate to estimate exhaust flow rates.

4.2.7 Statistical Analysis of Emission Factor Data

Statistical analyses were performed on the candidate emission factor data sets that included the results of at least five emission tests. The results of the analyses are presented in Table 4-60. For each of these data sets, the following statistics were determined: minimum value, maximum value, mean value, standard deviation, variance, standard error, and the 95th percent confidence interval for the mean. In performing the analyses, the average emission factor for each test was treated as a separate data point. In addition, for controlled emissions, the analyses were performed on the concentration-based emission factors only.

4.3 ESTIMATES OF EMISSIONS FROM OTHER TYPES OF ELECTROPLATING

4.3.1 Uncontrolled Emissions From Nonchromium Electroplating

Due to the scarcity of emission test data, only a few factors could be developed for emissions from the electroplating of metals other than chromium. However, the following paragraphs describe a

methodology for estimating emission factors for metals from other types of electroplating based on the factors for chromium electroplating and other parameters related to electroplating emissions.

As discussed in Section 3.5, emissions from electroplating are a function of several operating parameters. These parameters include the electrochemical equivalent, cathode efficiency, bath concentration, and current density. The electrochemical equivalent for a particular metal is based on Faraday's Law and takes into account the atomic weight and valence state of the plating metal and relates the applied current, plating time, plate thickness, and surface area of the substrate to a constant. Cathode efficiency represents the portion of the total applied energy that is consumed by the electrochemical plating reactions. The remaining energy is consumed in side reactions such as the dissociation of water into hydrogen and oxygen. As gaseous hydrogen and oxygen evolve, they entrap plating solution. At the surface of the plating solution, these gas bubbles burst, forming a fine mist. Therefore, the bath concentration of a particular metal compound is important in determining the emission potential. Higher bath concentrations result in a higher emission potential than do lower bath concentrations.

The current density relates the amount of energy applied to the surface area of substrate; by varying the current density, the plating time can be increased or decreased. As plating time increases, the amount of gas that evolves in the plating bath increases.

Assuming that the relationship between the value of these parameters for chromium and the values for other metals is linear, and that the type and orientation of the substrate plated and the bath surface tensions are comparable, the following relationship can be developed:

$$EF_m = k_1 \text{ x } EF_{Cr} \text{ x } (EE_m/EE_{Cr}) \text{ x } (e_{Cr}/e_m) \text{ x } (C_m/C_{Cr}) \text{ x } (D_m/D_{Cr}) \qquad (4)$$

where:

k_1 = dimensionless contstant;
EF_m = emission factor for emissions of metal m, gr/dscf;
EF_{Cr} = emission factor for chromium emissions, gr/dscf;
EE_m = electrochemical equivalent of metal m, A-hr/mil-ft^2;
EE_{Cr} = electrochemical equivalent of chromium, A-hr/mil-ft^2;
e_m = cathode efficiency for metal m, percent;
e_{Cr} = cathode efficiency for metal chromium, percent;
C_m = bath concentration of metal m, oz/gal;
C_{Cr} = bath concentration of chromium, oz/gal;
D_m = current density for plating metal m, A/ft^2; and
D_{Cr} = current density for chromium electroplating, A/ft^2.

The constant k_1 can be estimated using the concentration data for uncontrolled cadmium emissions ($8.4 \text{ x } 10^{-6}$ gr/dscf) included in Reference 67 and the hard chromium electroplating data as follows:

$$EF_{Cd} = k_1 \times EF_{Cr} \text{ x } (EE_{Cd}/EE_{Cr}) \text{ x } (e_{Cr}/e_{Cd}) \text{ x } (C_{Cd}/C_{Cr}) \text{ x } (D_{Cd}/D_{Cr})$$
$$8.4 \text{ x } 10^{-6} = k_1 \text{ x } (0.0014) \text{ x } (9.7/51.8) \text{ x } (10/50) \text{ x } (2.85/33) \text{ x } (46/260)$$
$$k_1 = 10.5$$

By substituting for k_1 and typical values of the chromium electroplating parameters, Equation 4 can be reduced to the following:

$$EF_m = 3.3 \times 10^{-7} \times (EE_m/e_m) \times C_m \times D_m \quad (5)$$

This equation can be used to estimate emissions from uncontrolled electroplating operations.

4.3.2 Controlled Emissions From Nonchromium Electroplating

As discussed in Section 3.6, the controls used to reduce emissions from electroplating act as constant outlet devices; regardless of inlet concentrations, outlet concentrations fall within a relatively narrow range of values. Therefore, several of the parameters included in the above equation may not affect controlled emissions. For this reason, it is suggested controlled emissions can be estimated using only the ratios of the bath concentrations as follows:

$$EF_m = k_2 \times EF_{Cr} \times (C_m/C_{Cr}) \quad (6)$$

The constant k_2 can be estimated using the concentration data for packed-bed scrubber-controlled cadmium emissions (1.7×10^{-6} gr/dscf) from References 21 and 67 and the hard chromium electroplating data as follows:

$$1.7 \times 10^{-6} = k_2 \times 2.1 \times 10^{-5} \times (2.85/33)$$

$$k_2 = 0.94$$

By substituting for k_2 and typical values of chromium bath concentrations, Equation 6 can be reduced to the following:

$$EF_m = 0.028 \times EF_{Cr} \times C_m \quad (7)$$

4.3.3 Emissions From Air Sparging and Electroless Plating

Equations 5 and 6 estimate emissions from the formation of gas as a result of the electrical energy applied to the plating tank; the equations do not account for additional emissions that result from air sparging or mechanical agitation of the tank solution. To estimate uncontrolled emissions due to air sparging, Equation 2, as presented in Section 4.1.55, can be used. Equation 2 also can be used to estimate emissions from electroless plating tanks or other process in which emissions are due primarily to the bursting of bubbles at the liquid surface of a tank. The English units equivalent to Equation 2 is as follows:

$$E_1 = k_1 R_b^2 \left[\frac{(1 - 2a + 9a^2)^{0.5} + (a - 1)}{(1 + 3a) - (1 - 2a + 9a^2)^{0.5}} \right]^{0.5} \quad (8)$$

$$a = \frac{6.45\ R_b^2}{k_2},\ k_1 = \frac{56.7\ \sigma}{c_s^2},\ k_2 = \frac{1.79 \times 10^5\ \sigma}{(\rho_1 - \rho_g)\ g}$$

where:

E_1 = emission factor, gr/bubble;
R_b = average bubble radius, in.;

σ = surface tension of bath, pounds force per foot (lb_f/ft);
c_s = speed of sound, ft/sec;
ρ_1 = density of liquid, lb/ft^3;
ρ_g = density of gas (air), lb/ft^3; and
g = acceleration due to gravity, ft/sec^2.

Substituting for constants c_s (34,000 cm/sec [1,140 ft/sec]), π (3.1416), g (9.81 m/sec^2 [32.2 ft/sec^2]), and assuming values for ρ_l (0.999 g/cm^3 [62.4 lb/ft^3]) and ρ_g (0.00122 g/cm^3 [0.0763 lb/ft^3]), Equation 8 can be reduced to following equation:

$$E_2 = \frac{1.9\ \sigma}{R_b} \left[\frac{(1 - 2a + 9a^2)^{0.5} + (a - 1)}{(1 + 3a) - (1 - 2a + 9a^2)^{0.5}} \right]^{0.5} \qquad (9)$$

where:

$$a = \frac{0.072\ R_b^2}{\sigma}$$

E_2 = emission factor in gr/ft^3 of aeration air; and
the other variables are as defined previously.

It should be noted that these equations (2, 5 and 7) have not been validated using multiple emission tests and should be used cautiously. Furthermore, the emission factors that are calculated in units of concentration may not be applicable to plating lines in which there are multiple tanks that introduce varying amounts of dilution air to a common control device. Finally, Equations 5 and 7 do take into account emissions reductions for tanks containing fume suppressants. If a fume suppressant is used, the corresponding emissions reduction should be incorporated into the emissions estimate.

4.3.4 Example Calculations

Example 1. Uncontrolled zinc emissions from zinc plating bath

Assume: Electrochemical equivalent (EE_{Zn}) = 13.7 A-hr/mil-ft^2;
Cathode efficiency (e_{Zn}) = 50 percent;
Bath concentration (C_{Zn}) = 4.0 oz/gal; and
Current density (D_{Zn}) = 2.0 A/ft^2.

Substituting into Equation 5:

$$EF_{Zn} = (3.3 \times 10^{-7}) \times (13.7/50) \times 4.0 \times 2.0 = 7.2 \times 10^{-7} \text{ gr/dscf}$$

Example 2. Packed-bed scrubber-controlled zinc emissions from zinc plating bath

Assume: Chromium electroplating emission factor (EF_{Cr}) = 2.1 x 10^{-5} gr/dscf; and
Bath concentration (C_{Zn}) = 4.0 oz/gal.

Substituting into Equation 7:

$$EF_{Zn} = 0.028 \times (2.1 \times 10^{-5}) \times 4.0 = 2.4 \times 10^{-6} \text{ gr/dscf}$$

Example 3. Emissions from air sparging of electroless plating operation

Assume: Surface tension of bath solution (σ) = 0.0051 lb_f/ft; and
Average bubble radius (R_b) = 0.10 in.

Substituting into Equation 9:

$$a = \frac{(0.072)(0.10)^2}{0.0051} = 0.14$$

$$E_2 = \frac{1.9\ (0.0051)}{0.10)} \left[\frac{(1 - 2(0.14) + 9(0.14)^2)^{0.5} + (0.14 - 1)}{(1 + 3(0.14) - (1 - 2(0.14) + 9(0.14)^2)^{0.5}} \right]^{0.5}$$

$$= 0.042\ gr/ft^3 \text{ of sparging air}$$

TABLE 4-1. REFERENCES NOT USED FOR EMISSION FACTOR DEVELOPMENT

No.	Reason for rejection
32	Process description not provided, type of chromium plating not identified, and process data not reported.
34	Process description, process rates not provided.
35	Process description, process rates not provided.
36	Later correspondence indicated unexplained calculational error, which could not be confirmed.
37	Ventilation system not operating normally during test.
38	Data not valid due to deviations in test method.
39	Anisokinetic sampling, velocity data not reported.
40	Process description not provided, control device not identified, only one run conducted.
41	Impinger damaged during testing.
42	Inadequate process data, only one run conducted.
43	Anisokinetic sampling and sample catch below detection limit.
44	Impinger damaged during testing, only one run conducted.
45	Inadequate number of sampling points.
46	Process rates not reported.
47	Anisokinetic sampling, inadequate process data.
48	Not tested under typical operating conditions, inadequate number of sampling points.
49	Inadequate information about process, operation.
50	Process rates not reported.
51	Inadequate number of sampling points.
52	Anisokinetic sampling, inadequate process data.
53	Anisokinetic sampling, discrepancies in data.
54	Process rates not reported.
55	Insufficient documentation, process rates not reported.
56	Insufficient documentation, process rates not reported.
57	Insufficient documentation, process rates not reported.
60	Inadequate number of sampling points and traverses.
61	Inadequate number of sampling points and traverses.
64	Inadequate documentation.
65	Inadequate documentation, only one run conducted.
68	Test of emissions from nickel plating solution evaporator; process rates not provided.
69	Test of emissions from electropolishing and passivation line; emissions below detection limit on all runs and process rates not provided.
70	No process description and inadequate documentation to check results and process rates unclear.
72	Electroless chromium plating process; emissions below detection limit.
73	No description of process or control device; emissions below detection limit.

TABLE 4-1. (continued)

No.	Reason for rejection
76	No process, control device, or test method description provided; indications of unspecified errors in report.
79	No description of process, control device, or test method.
80	No description of process, control device, or test method.
82	Duplicate of Reference 24.
87	Test conducted on emissions from several types of plating tanks; details on process not provided; only one run conducted.
91	Emission source unclear; no process description or process data provided.
92	Test method not identified; process description not provided; Cr^{+6} below quantification limit for apparent analytical method (colorimetric).
96	All results below detection limit.
97	No process description, process data, or information on control device.
98	Does not include emission data.
99	Reference consists of a telephone contact report that provides additional information on the Reference 71 emission test.

TABLE 4-2. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 1

TABLE 4-2. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 1.

Tank type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	13B	120	99.6	7,890	0.00075	0.0508	11,800	3.9	0.060	
		total Cr	2		120	99.8	7,510	0.00119	0.0767	10,400	6.7	0.10	
		total Cr	3		120	101.0	7,600	0.00074	0.0480	15,900	2.7	0.042	
		total Cr	4		120	99.8	7,340	0.00128	0.0807	10,600	6.9	0.11	
		Average						0.00099			5.1	0.078	A
		Cr+6	1	13B	120	99.6	7,890	0.00066	0.0448	11,800	3.4	0.053	
		Cr+6	2		120	99.8	7,510	0.00107	0.0688	10,400	6.0	0.093	
		Cr+6	3		120	101.0	7,600	0.00068	0.0440	15,900	2.5	0.039	
		Cr+6	4		120	99.8	7,340	0.00113	0.0712	10,600	6.1	0.094	
		Average						0.00088			4.5	0.070	A
	CBME	total Cr	1	13B	128	97.9	6,410	9.70E-005	0.0053	13,200	0.39	0.0060	
		total Cr	2		128	99.3	6,480	0.00019	0.0106	11,000	0.93	0.014	
		total Cr	3		128	98.5	6,350	8.20E-005	0.0045	16,900	0.26	0.0039	
		total Cr	4		128	100.0	6,330	0.00025	0.0134	11,200	1.2	0.018	
		Average						0.00015			0.68	0.011	A
		Cr+6	1	13B	128	97.9	6,410	7.40E-005	0.0041	13,200	0.30	0.0046	
		Cr+6	2		128	99.3	6,480	0.00017	0.0092	11,000	0.80	0.012	
		Cr+6	3		128	98.5	6,350	7.60E-005	0.0041	16,900	0.24	0.0036	
		Cr+6	4		128	100.0	6,330	0.00022	0.0120	11,200	1.0	0.016	
		Average						0.00013			0.59	0.0092	A

(a) CBME = chevron blade mist eliminator.

TABLE 4-3. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 2

TABLE 4-3. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 2.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin. %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1		180	102.0	5,040	0.00063	0.027	15,000	2.5	0.038	
		total Cr	2	13B	180	94.4	5,030	0.00041	0.018	14,100	1.7	0.026	
		total Cr	3		180	100.0	5,100	0.00018	0.0080	14,100	0.77	0.012	
		Average						0.00041			1.7	0.025	A
		Cr+6	1		180	102.0	5,040	0.00079	0.034	15,000	3.1	0.048	
		Cr+6	2	13B	180	94.4	5,030	0.00076	0.033	14,100	3.1	0.049	
		Cr+6	3		180	100.0	5,100	0.00076	0.033	14,100	3.2	0.050	
		Average						0.00077			3.2	0.049	A
	CBME	total Cr	1		180	103.0	5,030	4.00E-005	0.0017	15,100	0.16	0.0024	
		total Cr	2	13B	180	101	5,090	6.30E-005	0.0028	14,200	0.26	0.0041	
		total Cr	3		180	103.0	5,280	5.20E-005	0.0024	14,100	0.23	0.0035	
		Average						5.17E-005			0.22	0.0033	A
		Cr+6	1		180	103.0	5,030	3.90E-005	0.0017	15,100	0.15	0.0023	
		Cr+6	2	13B	180	101	5,090	9.80E-005	0.0043	14,200	0.41	0.0063	
		Cr+6	3		180	103.0	5,280	5.90E-005	0.0027	14,100	0.26	0.0040	
		Average						6.53E-005			0.27	0.0042	A
	none			Isokin. %	Vol., DSCF	Flow, DSCFM	Mass, mg	Concen., gr/DSCF	Emis. rate, lb/hr	Proc. rate, A-hr			
		filt. PM-10	1	101.8	96.0	5,011				15,100			
		filt. PM-10	2	108.2	115.4	5,127				14,200			
		filt. PM-10	3	105.1	126.9	5,079				14,100			
		Average			112.8	5,072	0.00616	0.00084	0.037	14,467	2.2	0.033	NR
	CBME	filt. PM-10	1	106.8	95.6	5,019				15,100			
		filt. PM-10	2	105.9	114.9	5,215				14,200			
		filt. PM-10	3	106.6	132.6	5,230				14,100			
		Average			114.3	5,155	0.00138	0.00019	0.0082	14,467	0.49	0.0076	NR

Particle size data

Uncontrolled			CBME-controlled		
Diameter, um	Cumulative percent less than terable PM	tal chromium	Diameter, um	Cumulative percent less than filterable PM	total chromium
<0.5	0	0	<0.49	0	0
0.5	9.12	6.9	0.49	18.5	20.38
2.4	48.31	67.66	2.35	94.71	97.5
8.0	59.27	82.63	7.9	100	99.15

(a) CBME = chevron blade mist eliminator.

TABLE 4-4. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 3

TABLE 4-4. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 3.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	13B	180	98.3	5,520	0.0044	0.21	25,800	11	0.17	
		total Cr	2		120	97.8	5,860	0.0030	0.15	18,800	7.1	0.11	
		total Cr	3		120	98.3	5,620	0.0030	0.15	14,200	9.3	0.14	
		Average						0.0034			9.1	0.14	A
		Cr+6	1	13B	180	98.3	5,520	0.0044	0.21	25,800	11	0.17	
		Cr+6	2		120	97.8	5,860	0.0030	0.15	18,800	7.2	0.11	
		Cr+6	3		120	98.3	5,620	0.0030	0.14	14,200	9.2	0.14	
		Average						0.0035			9.2	0.14	A
	CBME	total Cr	1	13B	178	98.8	5,730	6.10E-005	0.0030	25,500	0.16	0.0024	
		total Cr	2		120	100	5,730	6.40E-005	0.0031	19,400	0.15	0.0023	
		total Cr	3		120	93.4	5,720	4.90E-005	0.0024	14,800	0.15	0.0023	
		Average						5.80E-005			0.15	0.0023	A
		Cr+6	1	13B	178	98.8	5,730	5.70E-005	0.0028	25,500	0.15	0.0023	
		Cr+6	2		120	100	5,730	6.10E-005	0.0030	19,400	0.14	0.0022	
		Cr+6	3		120	93.4	5,720	4.50E-005	0.0022	14,800	0.13	0.0021	
		Average						5.43E-005			0.14	0.0022	A

(a) CBME = chevron blade mist elminator.

TABLE 4-5. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 4

TABLE 4-5. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 4.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	Cr+6	1	13B	192	96.2	6,250	0.0012	0.066	15,400	6.2	0.096	
		Cr+6	2		120	98.3	5,870	0.0015	0.073	10,400	6.4	0.098	
		Cr+6	3		120	96.2	6,010	0.0013	0.069	10,400	6.0	0.093	
		Average						0.0013			6.2	0.096	A
	MX	Cr+6	1	13B	188	101.9	5,910	0.00015	0.0077	15,400	0.71	0.011	
		Cr+6	2		117	98.6	6,210	0.00023	0.012	10,400	1.0	0.016	
		Cr+6	3		117	99.2	5,920	0.00019	0.0095	10,400	0.81	0.012	
		Average						0.00019			0.85	0.013	A
	MX/MPME	Cr+6	1	13B	192	96.7	6,280	1.00E-005	0.00070	15,400	0.066	0.0010	
		Cr+6	2		120	97.1	6,050	2.00E-005	0.0010	10,400	0.087	0.0013	
		Cr+6	3		120	94.4	6,230	2.00E-005	0.0011	10,400	0.096	0.0015	
		Average						1.67E-005			0.083	0.0013	A

(a) MX = moisture extractor, MPME = mesh pad mist eliminator.

TABLE 4-6. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 5

TABLE 4-6. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 5.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	Cr+6	1	13B	192	98.3	4,160	0.0032	0.11	21,100	7.8	0.12	
		Cr+6	2		120	98.9	4,430	0.0046	0.17	10,000	16	0.24	
		Cr+6	3		120	99.2	4,190	0.0053	0.19	10,400	16	0.25	
		Cr+6	4		120	99.9	4,340	0.0061	0.23	9,600	21	0.33	
		Cr+6	5		120	100.1	4,240	0.0058	0.21	9,700	20	0.31	
		Average						0.0050			16	0.25	A
	MPME	Cr+6	1	13B	192	97.6	4,140	2.60E-005	0.00091	21,100	0.063	0.0010	
		Cr+6	2		120	99.6	4,180	1.40E-005	0.00050	10,000	0.045	0.00070	
		Cr+6	3		120	99.8	4,150	1.50E-005	0.00053	10,400	0.046	0.00071	
		Cr+6	4		120	100.1	4,220	1.20E-005	0.00044	9,600	0.042	0.00064	
		Cr+6	5		120	100.6	4,170	5.00E-006	0.00016	9,700	0.015	0.00023	
		Average						1.44E-005			0.042	0.00065	A

(a) MPME = mesh pad mist eliminator.

TABLE 4-7. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 6

TABLE 4-7. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 6.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	Cr+6	1	13B	192	98.2	3,080	0.0017	0.045	9,600	6.9	0.11	
		Cr+6	2		120	94.7	3,300	0.0018	0.050	6,000	7.5	0.12	
		Cr+6	3		120	93.4	3,250	0.0023	0.064	10,800	5.4	0.083	
		Average						0.0019			6.6	0.10	A
	MPME	Cr+6	1	13B	192	95.5	3,460	1.90E-005	5.70E-004	9,600	0.086	0.0013	
		Cr+6	2		120	98.5	3,710	1.50E-005	4.90E-004	6,000	0.074	0.0011	
		Cr+6	3		120	98.1	3,640	2.20E-005	7.00E-004	10,800	0.059	0.00091	
		Average						1.87E-005			0.073	0.0011	A
	PB	Cr+6	4	13B	192	97.4	3,320	0.00051	0.015	9,600	2.2	0.034	
		Cr+6	5		120	97.9	3,270	0.00032	0.0090	6,000	1.4	0.021	
		Average						0.00042			1.8	0.028	B
	MPME/	Cr+6	4	13B	192	107.0	3,680	1.40E-005	0.00044	9,600	0.067	0.0010	
	PB	Cr+6	5		120	108.0	3,680	1.20E-005	0.00039	6,000	0.059	0.00091	
		Average						1.30E-005			0.063	0.0010	B

(a) MPME = mesh-pad mist eliminator; PPB = polypropylene balls.

TABLE 4-8. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 7

TABLE 4-8. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 7.

Tank Type(a)	Type of control(b)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin. %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	Cr+6	1	13B	120	98.7	9,710	0.0020	0.16	12,200	12	0.19	
target level 1		Cr+6	2		120	99.0	9,740	0.0031	0.26	13,200	18	0.27	
		Cr+6	3		120	99.5	9,820	0.0031	0.26	13,000	18	0.28	
		Average						0.0027			16	0.25	A
Hard chrome	none	Cr+6	4	13B	120	100.0	9,430			8,510			
target level 2		Cr+6	5		120	97.7	9,390	0.0024	0.19	9,400	19	0.29	
		Cr+6	6		120	97.7	9,450	0.0028	0.23	8,440	24	0.38	
		Average						0.0026			22	0.33	B
Hard chrome	none	Cr+6	7	13B	120	98.0	9,560	0.0021	0.18	6,470	25	0.38	
target level 3		Cr+6	8		120	98.3	9,700	0.0020	0.17	6,440	24	0.36	
		Cr+6	9		120	98.1	9,640	0.0019	0.16	5,470	26	0.40	
		Average						0.0020			25	0.38	A
Hard chrome	none	Cr+6	10	13B	120	97.2	9,720	0.0027	0.22	6,340	32	0.49	
target level 4		Cr+6	11		120	97.1	9,570	0.0024	0.20	6,230	29	0.44	
		Cr+6	12		120	97.0	9,490	0.0020	0.16	6,660	22	0.34	
		Average						0.0024			28	0.43	A
Hard chrome	PBS	Cr+6	1	13B	120	101.0	10,300	1.00E-005	0.00084	12,200	0.062	0.0010	
target level 1		Cr+6	2		120	104.0	10,500	1.20E-005	0.0011	13,200	0.074	0.0011	
		Cr+6	3		120	103.0	10,300			13,100			
		Average						1.10E-005			0.068	0.0011	B
Hard chrome	PBS	Cr+6	4	13B	120	102.0	10,100	1.00E-005	0.00088	8,610	0.093	0.0014	
target level 2		Cr+6	5		120	103.0	10,300	1.20E-005	0.0011	9,570	0.10	0.0016	
		Cr+6	6		120	103.0	10,000	1.10E-005	0.0010	8,490	0.10	0.0016	
		Average						1.10E-005			0.099	0.0015	A
Hard chrome	PBS	Cr+6	7	13B	120	100.0	10,100	1.30E-005	0.0011	6,490	0.16	0.0025	
target level 3		Cr+6	8		120	101.0	10,200	1.70E-005	0.0015	6,370	0.21	0.0033	
		Cr+6	9		120	102.0	10,100	1.50E-005	0.0013	5,480	0.21	0.0032	
		Average						1.50E-005			0.19	0.0030	A
Hard chrome	PBS	Cr+6	10	13B	120	101.0	10,100	1.40E-005	0.0012	6,300	0.17	0.0027	
target level 4		Cr+6	11		120	101.0	10,100	1.40E-005	0.0012	6,280	0.17	0.0027	
		Cr+6	12		120	101.0	10,100	1.70E-005	0.0015	6,680	0.20	0.0031	
		Average						1.50E-005			0.18	0.0028	A

TABLE 4-8. (Continued)

Tank Type(a)	Type of control	Pollutant	Run No.	Test	Samp. time, min	Isokinetic, %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	13B	120	98.7	9,710	0.0023	0.19	12,200	14	0.22	
target level 1		total Cr	2		120	99.0	9,740	0.0035	0.29	13,200	20	0.31	
		total Cr	3		120	99.5	9,820	0.0035	0.30	13,000	21	0.32	
		Average						0.0031			18	0.28	A
Hard chrome	none	total Cr	4	13B	120	100.0	9,430			8,510			
target level 2		total Cr	5		120	97.7	9,390	0.0026	0.21	9,400	20	0.31	
		total Cr	6		120	97.7	9,450	0.0031	0.25	8,440	27	0.41	
		Average						0.0028			24	0.36	B
Hard chrome	none	total Cr	7	13B	120	98.0	9,560	0.0025	0.20	6,470	28	0.43	
target level 3		total Cr	8		120	98.3	9,700	0.0022	0.18	6,440	26	0.40	
		total Cr	9		120	98.1	9,640	0.0021	0.17	5,470	29	0.44	
		Average						0.0022			28	0.42	A
Hard chrome	none	total Cr	10	13B	120	97.2	9,720	0.0029	0.24	6,340	34	0.53	
target level 4		total Cr	11		120	97.1	9,570	0.0027	0.22	6,230	32	0.49	
		total Cr	12		120	97.0	9,490	0.0022	0.18	6,660	25	0.38	
		Average						0.0026			30	0.47	A
Hard chrome	PBS	total Cr	1	13B	120	101.0	10,300	1.6E-005	0.0014	12,200	0.11	0.0016	
target level 1		total Cr	2		120	104.0	10,500	1.6E-005	0.0014	13,200	0.10	0.0015	
		total Cr	3		120	103.0	10,300			13,100			
		Average						1.60E-005			0.10	0.0016	B
Hard chrome	PBS	total Cr	4	13B	120	102.0	10,100	1.7E-005	0.0015	8,610	0.16	0.0024	
target level 2		total Cr	5		120	103.0	10,300	2.1E-005	0.0018	9,570	0.17	0.0027	
		total Cr	6		120	103.0	10,000	2.0E-005	0.0017	8,490	0.18	0.0028	
		Average						1.93E-005			0.17	0.0026	A
Hard chrome	PBS	total Cr	7	13B	120	100.0	10,100	1.5E-005	0.0013	6,490	0.18	0.0028	
target level 3		total Cr	8		120	101.0	10,200	1.9E-005	0.0017	6,370	0.24	0.0037	
		total Cr	9		120	102.0	10,100	1.7E-005	0.0015	5,480	0.25	0.0038	
		Average						1.70E-005			0.22	0.0034	A
Hard chrome	PBS	total Cr	10	13B	120	101.0	10,100	1.8E-005	0.0016	6,300	0.23	0.0035	
target level 4		total Cr	11		120	101.0	10,100	1.9E-005	0.0017	6,280	0.24	0.0037	
		total Cr	12		120	101.0	10,100	2.3E-005	0.0020	6,680	0.27	0.0042	
		Average						2.00E-005			0.25	0.0038	A

(a) Target levels 1, 2, 3, and 4 correspond to scrubber water chromic acid concentrations of 0, 30, 60, and 120 grams/liter, respectively.
(b) PBS = packed bed scrubber.

TABLE 4-9. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 8

TABLE 4-9. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 8.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	13B	180	96.6	16,300	0.0011	0.16	11,400	19	0.29	
		total Cr	2		180	94.3	16,500	0.00049	0.069	6,270	15	0.23	
		total Cr	3		180	94.5	16,400	0.00048	0.067	8,710	10	0.16	
		Average						0.00069			15	0.23	A
		Cr+6	1	13B	180	96.6	16,300	0.0012	0.16	11,400	20	0.30	
		Cr+6	2		180	94.3	16,500	0.00052	0.074	6,270	16	0.25	
		Cr+6	3		180	94.5	16,400	0.00049	0.069	8,710	11	0.17	
		Average						0.00073			15	0.24	A
	DPBS	total Cr	1	13B	120	97.7	16,800	2.20E-005	0.0031	11,400	0.25	0.0039	
		total Cr	2		120	97.3	17,300	2.10E-005	0.0032	6,230	0.46	0.0071	
		total Cr	3		120	97.4	17,300	2.50E-005	0.0036	8,610	0.38	0.0059	
		Average						2.27E-005			0.36	0.0056	A
		Cr+6	1	13B	120	97.7	16,800	2.20E-005	0.0032	11,400	0.25	0.0039	
		Cr+6	2		120	97.3	17,300	0.00023	0.0033	6,230	0.48	0.0075	
		Cr+6	3		120	97.4	17,300	2.40E-005	0.0035	8,610	0.37	0.0058	
		Average						9.20E-005			0.37	0.0057	A

(a) DPBS = double packed bed scrubber.

TABLE 4-10. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 9

TABLE 4-10. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 9.

Tank Type(a)	Type of control(b)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	Cr+6	1	13B	120	109.0	19,200	c					
condition 1		Cr+6	2		120	108.0	18,900	0.00028	0.046	6,000	6.9	0.11	
		Cr+6	3		120	107.0	19,000	0.00034	0.056	4,600	11	0.17	
		Average						0.00031			9.0	0.14	B
Hard chrome	none	Cr+6	4	13B	120	105.0	19,300	0.00037	0.061	7,200	7.7	0.12	
condition 2		Cr+6	5		120	104.0	19,200	0.00025	0.041	7,200	5.2	0.080	
		Cr+6	6		120	105.0	18,900	0.00025	0.041	7,400	5.0	0.078	
		Average						0.00029			6.0	0.092	A
Hard chrome	none	Cr+6	7	13B	192	105.0	19,300	0.00033	0.055	10,000	7.9	0.12	
condition 3		Cr+6	8		120	105.0	19,100	0.00030	0.049	5,600	8.0	0.12	
		Average						0.00032			8.0	0.12	B
Hard chrome	PBS	Cr+6	1	13B	120	104.0	17,700	1.60E-005	0.0025	5,400	0.42	0.0064	
condition 1		Cr+6	2		120	102.0	17,900	1.70E-005	0.0026	6,000	0.39	0.0061	
		Cr+6	3		120	102.0	17,800	1.80E-005	0.0027	4,600	0.54	0.0083	
		Average						1.70E-005			0.45	0.0070	A
Hard chrome	PBS	Cr+6	4	13B	120	102.0	1,800	1.10E-005	0.0017	7,100	0.22	0.0034	
condition 2		Cr+6	5		120	102.0	17,600	9.00E-006	0.0014	7,200	0.18	0.0028	
		Cr+6	6		120	103.0	17,600	1.00E-005	0.0015	7,400	0.19	0.0029	
		Average						1.00E-005			0.20	0.0030	A
Hard chrome	PBS	Cr+6	7	13B	192	98.0	17,800	1.00E-005	0.0015	10,000	0.22	0.0034	
condition 3		Cr+6	8		120	97.0	17,900	9.00E-006	0.0014	5,600	0.22	0.0034	
		Average						9.50E-006			0.22	0.0034	B

(a) See description of Reference 9 for parameters of conditions 1, 2, and 3.
(b) Packed bed scrubber.
(c) Sample contamination suspected, results not included.

TABLE 4-11. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 10

TABLE 4-11. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 10.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	MX	total Cr	1	13B	360	0.00014	0.011	67,000	0.43	0.0066	
		total Cr	2		240	0.00013	0.010	42,000	0.42	0.0065	
		total Cr	3		240	0.00020	0.017	38,000	0.79	0.0122	
		Average				0.00015			0.55	0.0084	A
		Cr+6	1	13B	360	0.00013	0.010	67,000	0.41	0.0064	
		Cr+6	2		240	0.00012	0.009	42,000	0.40	0.0062	
		Cr+6	3		240	0.00019	0.016	38,000	0.76	0.0117	
		Average				0.00015			0.52	0.0081	A
	MX	total Cr	1	13B	360	6.56E-005	0.0031	42,000	0.20	0.0031	
		total Cr	2		240	6.12E-005	0.0029	28,700	0.18	0.0028	
		total Cr	3		240	6.56E-005	0.0026	32,800	0.15	0.0023	
		Average				6.41E-005			0.18	0.0027	A
		Cr+6	1	13B	360	6.56E-005	0.003	42,000	0.20	0.0031	
		Cr+6	2		240	6.56E-005	0.002	28,700	0.15	0.0024	
		Cr+6	3		240	7.43E-005	0.003	32,800	0.17	0.0026	
		Average				6.85E-005			0.17	0.0027	A
	CMP	total Cr	1	13B	360	5.68E-006	0.00071	109,000	0.018	0.00027	
		total Cr	2		240	4.81E-006	0.00055	70,700	0.014	0.00022	
		total Cr	3		240	3.93E-006	0.00051	70,800	0.013	0.00020	
		Average				4.81E-006			0.016	0.00025	A
		Cr+6	1	13B	360	6.12E-006	0.00075	109,000	0.019	0.00029	
		Cr+6	2		240	3.93E-006	0.00049	70,700	0.012	0.00019	
		Cr+6	3		240	3.50E-006	0.00044	70,800	0.011	0.00017	
		Average				4.52E-006			0.014	0.00022	A

(a) MX = moisture extractor, CMP = composite mesh pad.

TABLE 4-12. AVERAGE OPERATING PARAMETERS MONITORED DURING EACH EMISSIONS TEST RUN

Run No.	Operating voltage, V	Operating current, A	Temperature of plating solution, °C (°F)
1	6.4	6,800	141
2	6.4	6,800	141
3	6.4	6,800	141
4	6.3	6,800	140
5	7.2	10,110	144
6	7.2	10,200	143

TABLE 4-13. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 11

TABLE 4-13. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 11.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	13B	120	0.00042	0.092	13,600	6.1	0.095	
		total Cr	2		120	0.00046	0.10	13,600	6.9	0.11	
		total Cr	3		120	0.00036	0.079	13,600	5.3	0.081	
		Average				0.00042			6.1	0.094	A
	CMP	total Cr	1	13B	120	3.93E-006	0.00095	13,600	0.063	0.00098	
		total Cr	2		120	5.24E-006	0.0012	13,600	0.083	0.0013	
		total Cr	3		120	5.68E-006	0.0013	13,600	0.090	0.0014	
		Average				4.95E-006			0.079	0.0012	A
	FS	total Cr	1	13B	120	7.43E-005	0.016	13,600	1.1	0.017	
		total Cr	2		120	0.00026	0.058	20,200	2.6	0.040	
		total Cr	3		120	0.00016	0.036	20,400	1.6	0.025	
		Average				0.00016			1.8	0.027	A
	FS/CMP	total Cr	1	13B	120	2.19E-006	0.00053	13,600	0.035	0.00054	
		total Cr	2		120	3.06E-006	0.00073	20,200	0.033	0.00050	
		total Cr	3		120	5.24E-006	0.0013	20,400	0.056	0.00086	
		Average				3.50E-006			0.041	0.00064	A

(a) FS = fume suppressant, CMP = composite mesh pad.

TABLE 4-14. DIMENSIONS AND OPERATING PARAMETERS FOR THE SEVEN HARD CHROMIUM PLATING TANKS FOR REFERENCE 12

Tank No.	Capacity, L (gal)	Maximum rated voltage per cell, V	Maximum rated current per cell, A
1	11,360 (3,000)	2 @ 15	10,000; 3,000
2	11,360 (3,000)	2 @ 15	12,000; 3,000
3	6,060 (1,600)	15	8,000
4	13,250 (3,500)	15	16,000
5	4,000 (1,060)	15	8,000
6	17,790 (4,700)	2 @ 15	2 @ 12,000
7[a]	21,580 (5,700)	2 @ 15	2 @ 12,000

[a]Plating tank was not operated during the emission test.

TABLE 4-15. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 12

TABLE 4-15. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 12.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	13B	360	98.1	606.46	22,204	1,347,000	0.0343	6.5235	366,530	48	0.75	
		total Cr	2		360	96.9	602.13	22,285	982,900	0.0252	4.8119	361,850	36	0.56	
		total Cr	3		360	91.4	610.94	23,144	1,248,033	0.0315	6.2538	139,090	122	1.9	
		Average								0.0303			69	1.1	A
		Cr+6	1	13B	360	98.1	606.46	22,204	1,399,850	0.0356	6.7795	366,530	50	0.78	
		Cr+6	2		360	96.9	602.13	22,285	1,065,100	0.0273	5.2144	361,850	39	0.61	
		Cr+6	3		360	91.4	610.94	23,144	1,350,030	0.0341	6.7649	139,090	132	2.0	
		Average								0.0323			74	1.1	A
	PBS/CMP	total Cr	1	13B	375	99.0	265.26	24,013	47.0	2.73E-006	0.00056	381,430	0.0042	6.5E-005	
		total Cr	2		375	98.9	261.24	23,674	25.5	1.51E-006	0.00031	376,200	0.0023	3.6E-005	
		total Cr	3		375	99.8	271.47	24,381	65.5	3.72E-006	0.00078	366,740	0.0060	9.3E-005	
		Average								2.65E-006			0.0042	6.4E-005	A
		Cr+6	1	13B	375.0	99.0	265.3	24,013	43.3	2.52E-006	0.00052	381,430	0.0039	5.9E-005	
		Cr+6	2		375.0	98.9	261.2	23,674	25.5	1.51E-006	0.00031	376,200	0.0023	3.6E-005	
		Cr+6	3		375.0	99.8	271.5	24,381	66.8	3.80E-006	0.00079	366,740	0.0061	9.5E-005	
		Average								2.61E-006			0.0041	6.3E-005	A

(a) PBS = packed bed scrubber; CMP = composite mesh pad.

TABLE 4-16. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 13

TABLE 4-16. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 13.

Tank Type	Type of control	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	13B	120	99.3	91.32	11,268	7,500	0.0013	0.122	17,590	6.3	0.097	
		total Cr	2		120	98.1	94.29	11,779	7,500	0.0012	0.124	28,520	3.9	0.061	
		total Cr	3		120	100.6	90.57	11,027	13,600	0.0023	0.219	11,361	17	0.27	
		total Cr	4		120	101.6	91.05	11,034	5,000	0.00085	0.0802	21,652	3.4	0.052	
		total Cr	5		120	101.3	90.52	11,191	2,250	0.00038	0.0368	20,733	1.6	0.025	
		total Cr	6		120	102.7	86.84	10,361	4,750	0.00084	0.0750	20,373	3.3	0.052	
		Average								0.00115			6.0	0.093	A
		Cr+6	1	13B	120	99.3	91.32	11,268	5,142	0.00087	0.084	17,590	4.3	0.067	
		Cr+6	2		120	98.1	94.29	11,779	6,262	0.00102	0.103	28,520	3.3	0.051	
		Cr+6	3		120	100.6	90.57	11,027	9,688	0.00165	0.156	11,361	12.5	0.19	
		Cr+6	4		120	101.6	91.05	11,034	4,483	0.00076	0.072	21,652	3.0	0.046	
		Cr+6	5		120	101.3	90.52	11,191	2,082	0.00035	0.034	20,733	1.5	0.023	
		Cr+6	6		120	102.7	86.84	10,361	3,968	0.00071	0.063	20,373	2.8	0.043	
		Average								0.00089			4.6	0.070	A

TABLE 4-17. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 14

TABLE 4-17. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 14.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	13B	120	99.7	111.58	2,904	4,555	0.00063	0.016	9,600	1.5	0.023	
		total Cr	2		120	98.1	112.74	2,983	5,346	0.00073	0.019	10,200	1.7	0.026	
		total Cr	3		120	97.1	109.67	2,929	5,829	0.00082	0.021	10,200	1.8	0.028	
		Average								0.00073			1.7	0.026	A
	FB/PB	total Cr	4	13B	120	95.9	113.2	3,061	130	1.77E-005	0.00047	10,000	0.042	0.00065	
		total Cr	5		120	97.0	112.0	2,994	104	1.43E-005	0.00037	10,200	0.033	0.00051	
		total Cr	6		120	96.7	105.2	2,820	111	1.63E-005	0.00039	10,200	0.035	0.00054	
		Average								1.61E-005			0.037	0.00057	A
	PBS	total Cr	1	13B	120	109.9	51.96	3,208	79.8	2.37E-005	0.00065	9,600	0.062	0.00095	
		total Cr	2		120	96.5	53.49	3,760	98.9	2.85E-005	0.00092	10,200	0.082	0.0013	
		total Cr	3		120	94.5	51.75	3,716	86.6	2.58E-005	0.00082	10,200	0.073	0.0011	
		Average								2.60E-005			0.072	0.0011	A
	PBS/FB/PB	total Cr	4	13B	120	101.5	47.6	3,183	14.3	4.64E-006	0.00013	10,000	0.011	0.00018	
		total Cr	5		120	94.6	50.9	3,651	11.8	3.58E-006	0.00011	10,200	0.010	0.00015	
		total Cr	6		120	98.6	48.7	3,352	8.97	2.84E-006	8.2E-005	10,200	0.0073	0.00011	
		Average								3.69E-006			0.0096	0.00015	A

(a) FB/PB = foam blanket and polypropylene balls; PBS = packed-bed scrubber

TABLE 4-18. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 15

TABLE 4-18. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 15.

Tank Type	Type of control	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Decorative Chrome	none	total Cr	1	13B	180	98.0	22,600	0.00072	0.14	97,400	2.0	0.030	
		total Cr	2		180	98.5	23,200	0.00053	0.11	104,000	1.4	0.021	
		total Cr	3		180	98.3	23,200	0.00063	0.13	89,600	1.9	0.030	
		Average						0.00063			1.7	0.027	A
	none	Cr+6	1	13B	180	98.0	22,600	0.00085	0.17	97,400	2.3	0.036	
		Cr+6	2		180	98.5	23,200	0.00056	0.11	104,000	1.5	0.023	
		Cr+6	3		180	98.3	23,200	0.00067	0.13	89,600	2.0	0.031	
		Average						0.00070			1.9	0.030	A

TABLE 4-19. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 16

TABLE 4-19. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 16.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Volum. flow rate, DSCFM	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Decorative chrome	none	Cr+6	1	13B	192	100.0	2,360	0.00037	0.0073	8,700	1.2	0.019	
		Cr+6	2		120	99.1	2,390	0.00040	0.0079	5,200	1.4	0.021	
		Cr+6	3		120	103.0	2,340	0.00043	0.0086	5,600	1.4	0.022	
		Average						0.00040			1.3	0.021	A
Decorative chrome	FB	Cr+6	4	13B	192	102.0	2,360	1.00E-006	2.90E-005	8,400	0.0050	7.7E-005	
		Cr+6	5		120	103.0	2,380	3.00E-006	5.90E-005	5,300	0.010	0.00016	
		Cr+6	6		240	102.0	2,340	2.00E-006	3.30E-005	11,900	0.0050	7.76E-005	
		Average						2.00E-006			0.0067	0.00010	A
Decorative chrome	FS	Cr+6	7	13B	240	99.3	2,340	7.80E-007	1.60E-005	11,300	0.0026	4.0E-005	
		Cr+6	8		240	98.8	2,270	5.10E-007	9.90E-006	11,700	0.0015	2.4E-005	
		Cr+6	9		180	98.5	2,240	1.50E-006	2.90E-005	8,500	0.0046	7.2E-005	
		Average						9.30E-007			0.0029	4.5E-005	A

(a) FB = foam blanket; FS = fume suppressant that consisted of a combination of foam blanket and wetting agent.

TABLE 4-20. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 17

TABLE 4-20. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 17.

Tank Type	Type of control	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	gr/A-hr	Rating
Trivalent chromium	none	total Cr	1	13B	192	95.2	101.17	8,788	36.90	5.63E-006	0.00042	17,640	0.035	0.00054	
		total Cr	2		192	91.6	115.31	10,411	156.00	2.09E-005	0.0019	17,750	0.15	0.0024	
		total Cr	3		192	90.6	112.71	10,291	61.10	8.37E-006	0.00074	16,850	0.064	0.0010	
		Average								1.16E-005			0.084	0.0013	NR
		Cr+6	1	13B	192	95.2	101.2	8,788	10.20	1.56E-006	0.00012	17,640	0.010	0.00015	
		Cr+6	2		192	91.6	115.3	10,411	14.90	1.99E-006	0.00018	17,750	0.015	0.00022	
		Cr+6	3		192	90.6	112.7	10,291	8.01	1.10E-006	0.00010	16,850	0.0083	0.00013	
		Average								1.55E-006			0.011	0.00017	NR
		Cr+3	1	13B	192	95.2	101.2	8,788	26.70	4.07E-006	0.00031	17,640	0.025	0.00039	
		Cr+3	2		192	91.6	115.3	10,411	141.10	1.89E-005	0.00168	17,750	0.14	0.0021	
		Cr+3	3		192	90.6	112.7	10,291	53.09	7.27E-006	0.00064	16,850	0.055	0.00085	
		Average								1.01E-005			0.073	0.0011	
										percent			kg/A-hr	lb/A-hr	NR
		CO2	1	3A	192	NA	NA	8,788	NA	0.7	422	17,640	250	540	
		CO2	2		192	NA	NA	10,411	NA	0.7	500	17,750	290	630	
		CO2	3		192	NA	NA	10,291	NA	0.7	494	16,850	300	660	
												Average	280	610	NR

TABLE 4-21. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 19

TABLE 4-21. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 19.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, ft	Emission factor(b) g/hr-m2	Emission factor(b) gr/hr-ft2	Rating
Chromic acid anodizing	none	total Cr	1	CARB 425	180	105.2	113.19	7,372	177.90	2.43E-005	0.0015				NR
	PPB	total Cr	1	CARB 425	240	95.2	262.5	11,854	4.60	2.70E-007	2.7E-005				NR
	PPB and AM	total Cr	2	CARB 425	360	98.5	340.6	11,909	1.50	6.80E-008					
		total Cr	3		360	93.8	406.6	11,575	2.90	1.10E-007					
	Average									8.90E-008					NR

(a) PPB = polypropylene balls; AM = antimisting agent.

(b) Tank dimensions not provided; emission factors cannot be calculated.

TABLE 4-22. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 20

TABLE 4-22. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 20.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Chromic acid	MPME	total Cr	1	CARB	240	101.6	222.58	41,408	4.20	2.91E-007	0.00010	100	0.0050	0.0072	
anodizing		total Cr	2	425	240	99.8	217.93	41,278	1.65	1.17E-007	4.1E-005	100	0.0020	0.0029	
												Average	0.0035	0.0051	D
												A-hr			
Hard chrome	none	total Cr	1	CARB	60	79.5	45.00	13,985	702.60	0.00024	0.0289	3,495	3.7	0.058	
		total Cr	2	425	60	82.3	46.64	13,881	773.10	0.00026	0.0304	3,495	4.0	0.061	
												Average	3.8	0.059	C
	AMA	total Cr	3	CARB	60	81.4	46.72	14,061	37.60	1.24E-005	0.00150	3,505	0.19	0.0030	
		total Cr	4	425	60	81.4	46.87	14,016	53.20	1.75E-005	0.00210	3,505	0.27	0.0042	
												Average	0.23	0.0036	C
	MPME	total Cr	1	CARB	180	99.5	140.33	40,805	20.30	2.23E-006	0.00078	3,495	0.30	0.0047	
		total Cr	2	425	180	100.4	140.45	41,188	17.00	1.87E-006	0.00066	3,495	0.26	0.0040	
												Average	0.28	0.0043	B
	MPME &	total Cr	3	CARB	180	100.2	136.83	39,536	19.60	2.21E-006	0.00075	3,505	0.29	0.0045	
	AM	total Cr	4	425	180	100.1	139.56	41,042	20.80	2.30E-006	0.00081	3,505	0.31	0.0048	
												Average	0.30	0.0047	B
Cyanide copper	MPME	cyanide	1	CARB	192	98.7	163.76	45,003	27.00	2.54E-006	0.00098	25	57	0.88	
plating tank		cyanide	2	426	192	99.7	164.88	44,849	31.00	2.90E-006	0.00112	25	65	1.00	
		cyanide	3		60	101.9	51.93	44,248	9.40	2.79E-006	0.00106	25	19	0.30	
		Average								2.75E-006			47	0.73	C
Cadmium plating	MPME	cyanide	1	CARB	192	100.2	162.59	24,353	988	9.38E-005	0.01957	150	189	2.9	
tank		cyanide	2	426	192	99.5	157.89	23,799	1,078	0.00011	0.02149	150	208	3.2	
		cyanide	3		60	101.1	52.61	24,970	357	0.00010	0.02241	150	68	1.0	
		Average								1.01E-004			155	2.4	C
		cadmium	1	CARB	60	102.7	52.60	24,573	45.00		0.00278	150			
		cadmium	2	424	192	100.1	160.65	24,083	1.50	1.44E-007	0.000030	150	0.29	0.0044	
		cadmium	3		192	99.4	157.92	23,835	1.50	1.47E-007	0.000030	150	0.29	0.0045	
										1.45E-007			0.29	0.0045	C

(a) MPME = mesh pad mist eliminator; AM = antimisting agent.

TABLE 4-23. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 21

TABLE 4-23. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 21.

Source	Type of control (a)	Pollutant	Run No.	Test Method	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	gr/A-hr	Rat.
Cadmium and	PBS	Total Cr	1	Mod. 8	96	101.6	60.5	20,916	5.50	1.40E-006	0.00025	240	0.76	0.012	
automatic plating		Total Cr	2		105	101.5	60.28	20,862	1.63	4.17E-007	7.5E-005	263	0.23	0.0035	
machine		Total Cr	3		105	100.9	59.58	20,738	1.58	4.10E-007	7.3E-005	263	0.22	0.0034	
		Average								7.43E-007	0.00013		0.40	0.0062	NR
		Cadmium	1	Mod. 8	96	101.6	60.5	20,916	2.93	7.48E-007	0.00013	240	0.41	0.0063	
		Cadmium	2		105	101.5	60.3	20,862	7.33	1.88E-006	0.00034	263	1.0	0.016	
		Cadmium	3		105	100.9	59.6	20,738	0.59	1.54E-007	2.7E-005	263	0.083	0.0013	
		Average								9.26E-007	0.00017		0.50	0.0077	C
		Cyanide	1	Mod. 8	96	101.6	60.5	20,916	103	2.62E-005	0.00469	240	14	0.22	
		Cyanide	2		105	101.5	60.3	20,862	297	7.61E-005	0.0136	263	41	0.64	
		Cyanide	3		105	100.9	59.6	20,738	289	7.49E-005	0.0133	263	40	0.62	
		Average								5.91E-005	0.0105		32	0.49	C
		Ammonia	1	Mod. 8	96	101.6	60.5	20,916	191	4.86E-005	0.00872	240	26	0.41	
		Ammonia	2		105	101.5	60.3	20,862	212	5.42E-005	0.00969	263	29	0.45	
		Ammonia	3		105	100.9	59.6	20,738	87.1	2.26E-005	0.00401	263	12	0.19	
		Average								4.18E-005	0.00747		23	0.35	C

(a) PBS = packed bed scrubber.

TABLE 4-24. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 22

TABLE 4-24. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 22.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	None	total Cr	1	CARB	120	93.0	96.31	12,400	9.1	1.5E-006	0.00015	853	0.16	0.0025	
		total Cr	2	425	120	93.0	96.73	12,468	6.2	9.9E-007	0.00011	700	0.14	0.0021	
		Average								1.2E-006			0.15	0.0023	D
	PBS	total Cr	1	CARB	120	102.0	94.3	13,198	6.9	1.1E-006	0.00013	853	0.14	0.0021	
		total Cr	2	425	120	101.0	94.0	13,252	6.0	9.8E-007	0.00011	700	0.14	0.0022	
		Average								1.1E-006			0.14	0.0022	D

(a) PBS = packed bed scrubber.

TABLE 4-25. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 23

TABLE 4-25. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 23.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	None	Cr+6	1	CARB	240	91.0	153.96	29,484	5530.0	0.00055	0.14	51,260	5.0	0.077	
Line L		Cr+6	2	425	240	94.0	161.80	29,986	5600.0	0.00053	0.14	47,323	5.3	0.081	
		Average								0.00054			5.1	0.079	D
		total Cr	1	CARB	240	91.0	153.96	29,484	6860.0	0.00069	0.17	51,260	6.2	0.095	
		total Cr	2	425	240	94.0	161.80	29,986	5960.0	0.00057	0.15	47,323	5.6	0.086	
		Average								0.00063			5.9	0.091	D
	PBS	Cr+6	1	CARB	240	101.0	184.89	35,209	7.0	5.84E-007		51,260			
		Cr+6	2	425	240	99.0	171.9	34,331	1.0	8.98E-008		47,323			
		Average								3.37E-007					
		total Cr	1	CARB	240	101.0	184.9	35,209	19.0	1.59E-006	0.00048	51,260	0.017	0.00026	
		total Cr	2	425	240	99.0	171.87	34,331	3.0	2.69E-007		47,323			
		Average								9.28E-007			0.017	0.00026	NR
Hard chrome	None	Cr+6	1	CARB	240	92.0	186.72	20,466	15,174	0.00125	0.22	29,774	13	0.21	
Line M		Cr+6	2	425	240	94.0	198.28	21,018	5,520	0.00043	0.077	33,376	4.2	0.065	
		Average								0.00084			8.8	0.14	D
		total Cr	1	CARB	240	92.0	186.72	20,466	10,470	0.00087	0.15	29,774	9.3	0.14	
		total Cr	2	425	240	94.0	198.28	21,018	6,277	0.00049	0.088	33,376	4.8	0.074	
		Average								0.00068			7.0	0.108	D
	PBS	Cr+6	1	CARB	240	103.0	185.52	25,071	2.5	2.08E-007		29,774			
		Cr+6	2	425	240	99.0	166.6	21,988	3.4	3.15E-007		33,376			
		Average								2.61E-007					
		total Cr	1	CARB	240	103.0	185.5	25,071	5.0	4.16E-007	8.9E-005	29,774	0.0054	8.4E-005	
		total Cr	2	425	240	99.0	166.57	21,988	39.0	3.61E-006	0.00068	29,774	0.041	0.00064	
		Average								2.01E-006			0.023	0.00036	D

(a) PBS = packed bed scrubber.

TABLE 4-26. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 24

TABLE 4-26. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 24.

Tank type	Type of control	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM		Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	PBS/FBME	total Cr	1	CARB	240	103.6	111.57	30,432	<	0.20	2.77E-008	7.2E-006	39,248	0.00033	5.1E-006	
Line L		total Cr	2	425	240	103.3	120.96	29,475		1.28	1.63E-007	4.1E-005	39,248	0.0019	2.9E-005	
		total Cr	3		240	104.4	163.97	28745	<	0.225	2.12E-008	5.2E-006	39,248	0.00024	3.7E-006	
		Average									7.07E-008			0.00082736	0.00001277	NR
Hard chrome	PBS/FBME	total Cr	1	CARB	240	102.0	317.6	18,549		3.22	1.56E-007	2.5E-005	39,248	0.0012	1.8E-005	
Line M		total Cr	2	425	240	104.9	151.88	18421	<	0.24	2.44E-008	3.9E-006	39,248	0.00018	2.7E-006	
		total Cr	3		240	105.1	149.55	19081	<	0.21	2.17E-008	3.5E-006	39,248	0.00016	2.5E-006	
		Average									6.75E-008			0.00050	0.00000767	NR

(a) PBS = packed bed scrubber, FBME = fiber bed mist eliminator.

TABLE 4-27. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 25

TABLE 4-27. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 25.

Tank type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	CARB	60	101.0	68.53	1,664	3552.70	0.00080	0.01141	807	6.4	0.10	
		total Cr	2	425	60	103.3	44.50	1,564	3795.20	0.00132	0.01764	820	9.8	0.15	
		Average								0.00106			8.1	0.12	
		Cr+6	1	CARB	60	101.0	68.5	1,664	2627.20	0.00059	0.00844	807	4.7	0.073	
		Cr+6	2	425	60	103.3	44.5	1,564	2917.00	0.00101	0.01356	820	7.5	0.12	
		Average								0.00080			6.1	0.094	
		total Cr	1	CARB	60	102.8	45.93	1,633	3423.40	0.00115	0.01610	1,633	4.5	0.069	
		total Cr	2	425	60	102.1	45.97	1,634	8526.00	0.00286	0.04009	1,525	12	0.18	
		Average								0.00201			8.2	0.13	
		Cr+6	1	CARB	60	102.8	45.9	1,633	2675.20	0.00090	0.01258	1,633	3.5	0.054	
		Cr+6	2	425	60	102.1	46.0	1,634	8379.60	0.00281	0.03940	1,525	12	0.18	
		Average								0.00186			7.6	0.12	
		total Cr	1	CARB	60	101.9	45.78	1,631	5194.10	0.00175	0.02448	2,473	4.5	0.069	
		total Cr	2	425	60	97.3	68.89	1,690	8886.20	0.00199	0.02883	2,448	5.3	0.082	
		Average								0.00187			4.9	0.076	
		Cr+6	1	CARB	60	101.9	45.8	1,631	4818.60	0.00162	0.02271	2,473	4.2	0.064	
		Cr+6	2	425	60	97.3	68.9	1,690	7123.10	0.00160	0.02311	2,448	4.3	0.066	
		Average								0.00161			4.2	0.065	
	Overall	Total Cr			Average					0.00164			7.1	0.11	A
	average	Cr+6			Average					0.00142			6.0	0.092	A
	FS/PB	total Cr	1	CARB	60	99.6	46.37	1,689	114.07	3.80E-005	0.00055	845	0.30	0.0046	
		total Cr	2	425	60	101.3	45.20	1,631	81.46	2.78E-005	0.00039	846	0.21	0.0032	
		Average								3.29E-005			0.25	0.0039	
		Cr+6	1	CARB	60	99.6	46.4	1,689	100.70	3.35E-005	0.00049	845	0.26	0.0040	
		Cr+6	2	425	60	101.3	45.2	1,631	56.40	1.93E-005	0.00027	846	0.14	0.0022	
		Average								2.64E-005			0.20	0.0031	
		total Cr	1	CARB	60	102.2	46.16	1,639	126.74	4.24E-005	0.00060	1,671	0.16	0.0025	
		total Cr	2	425	60	106.7	49.07	1,674	102.24	3.22E-005	0.00046	1,670	0.13	0.0019	
		Average								3.73E-005			0.14	0.0022	
		Cr+6	1	CARB	60	102.2	46.2	1,639	111.80	3.74E-005	0.00053	1,671	0.14	0.0022	
		Cr+6	2	425	60	106.7	49.1	1,674	82.00	2.58E-005	0.00037	1,670	0.10	0.0016	
		Average								3.16E-005			0.12	0.0019	
		total Cr	1	CARB	60	100.3	46.03	1,677	201.36	6.75E-005	0.00097	2,472	0.18	0.0027	
		total Cr	2	425	60	97.3	44.54	1,663	196.56	6.81E-005	0.00097	2,440	0.18	0.0028	
		Average								6.78E-005			0.18	0.0028	
		Cr+6	1	CARB	60	100.3	46.0	1,677	158.00	5.30E-005	0.00076	2,472	0.14	0.0022	
		Cr+6	2	425	60	97.3	44.5	1,663	161.20	5.59E-005	0.00080	2,440	0.15	0.0023	
		Average								5.44E-005			0.14	0.0022	
	Overall	Total Cr			Average					4.60E-005			0.19	0.0030	A
	average	Cr+6			Average					3.75E-005			0.16	0.0024	A

(a) FS/PB = combination of fume suppressant and polypropylene balls.

TABLE 4-28. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 26

TABLE 4-28. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 26.

Tank type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	CARB	60	97.5	46.16	1,731	1,568	0.00052	0.0078	853	4.1	0.064	
		total Cr	2	425	60	101.5	45.60	1,631	4,357	0.00147	0.0206	833	11	0.17	
		Average								0.00100			7.7	0.12	
		Cr+6	1	CARB	60	97.5	46.2	1,731	1,461	0.00049	0.0072	853	3.9	0.059	
		Cr+6	2	425	60	101.5	45.6	1,631	3,944	0.00133	0.0187	833	10	0.16	
		Average								0.00091			7.0	0.11	
		total Cr	1	CARB	60	98.3	46.71	1,724	5,540	0.00183	0.0270	1,584	7.7	0.12	
		total Cr	2	425	60	97.8	45.90	1,703	8,225	0.00277	0.0404	1,645	11	0.17	
		Average								0.00230			9.4	0.15	
		Cr+6	1	CARB	60	98.3	46.7	1,724	4,632	0.00153	0.0226	1,584	6.5	0.10	
		Cr+6	2	425	60	97.8	45.9	1,703	8,087	0.00272	0.0397	1,645	11	0.17	
		Average								0.00212			8.7	0.13	
		total Cr	1	CARB 425	60	100.2	45.92	1,664	2,691	0.00090	0.0129	2,568	2.3	0.035	
		total Cr	2		60	98.3	45.61	1,695	9,370	0.00317	0.0461	2,504	8.3	0.13	
		Average								0.00204			5.3	0.082	
		Cr+6	1	CARB	60	100.2	45.9	1,664	2,401	0.00081	0.0115	2,568	2.0	0.031	
		Cr+6	2	425	60	98.3	45.6	1,695	10,175	0.00344	0.0500	2,504	9.1	0.14	
		Average								0.00212			5.5	0.086	
	Overall	Total Cr			Average					0.00178			7.5	0.12	A
	average	Cr+6			Average					0.00172			7.1	0.11	A
	FS/PB	total Cr	1	CARB	60	100.6	46.44	1,676	61.10	2.03E-005	0.000292	853	0.16	0.0024	
		total Cr	2	425	60	101.8	46.80	1,680	21.40	7.06E-006	0.000102	855	0.054	0.00083	
		Average								1.37E-005			0.10	0.0016	
		Cr+6	1	CARB	60	100.6	46.4	1,676	56.70	1.88E-005	0.000271	853	0.14	0.0022	
		Cr+6	2	425	60	101.8	46.8	1,680							
		Average								1.88E-005			0.144	0.0022	
		total Cr	1	CARB	60	100.0	45.89	1,695	127.00	4.27E-005	0.000620	1,654	0.17	0.0026	
		total Cr	2	425	60	99.4	46.82	1,720	61.90	2.04E-005	0.000301	1,755	0.078	0.0012	
		Average								3.16E-005			0.12	0.0019	
		Cr+6	1	CARB	60	100.0	45.9	1,695	80.40	2.70E-005	0.000393	1,654	0.11	0.0017	
		Cr+6	2	425	60	99.4	46.8	1,720	68.20	2.25E-005	0.000331	1,755	0.086	0.0013	
		Average								2.48E-005			0.10	0.0015	
		total Cr	1	CARB	60	98.2	45.48	1,663	121.90	4.14E-005	0.000590	2,560	0.10	0.0016	
		total Cr	2	425	60	99.5	44.35	1,620	112.30	3.91E-005	0.000543	2,405	0.10	0.0016	
		Average								4.02E-005			0.10	0.0016	
		Cr+6	1	CARB	60	98.2	45.5	1,663	122.80	4.17E-005	0.000594	2,560	0.11	0.0016	
		Cr+6	2	425	60	99.5	44.3	1,620	108.40	3.77E-005	0.000524	2,405	0.10	0.0015	
		Average								3.97E-005			0.10	0.0016	
	Overall	Total Cr			Average					2.85E-005			0.11	0.0017	A
	average	Cr+6			Average					2.95E-005			0.11	0.0017	A

(a) FS/PB = combination of fume suppressant and polypropylene balls.

TABLE 4-29. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 27

TABLE 4-29. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 27.

Tank type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Decorative chrome	none	total Cr	1	CARB	60	108.1	108.07	2,697	1,395	0.00020	0.0046	328	6.4	0.098	
		total Cr	2	425	60	109.2	103.21	2,577	1,091	0.00016	0.0036	328	5.0	0.077	
		Average								0.00018			5.7	0.088	
		Cr+6	1	CARB	60	108.1	108.1	2,697	963	0.00014	0.0032	328	4.4	0.068	
		Cr+6	2	425	60	109.2	103.2	2,577	909	0.00014	0.0030	328	4.2	0.064	
		Average								0.00014			4.3	0.066	
		total Cr	1	CARB	60	108.0	118.39	2,623	1,693	0.00022	0.0050	454	5.0	0.076	
		total Cr	2		60	113.8	110.12	2,635	1,429	0.00020	0.0045	452	4.5	0.070	
		Average								0.00021			4.7	0.073	
		Cr+6	1	CARB	60	108.0	118.4	2,623	1,326	0.00017	0.0039	454	3.9	0.060	
		Cr+6	2	425	60	113.8	110.1	2,635	1,297	0.00018	0.0041	452	4.1	0.064	
		Average								0.00018			4.0	0.062	
		total Cr	1	CARB	60	103.6	97.97	2,601	1,433	0.00023	0.0050	908	2.5	0.039	
		total Cr	2	425	60	101.8	98.34	2,632	1,502	0.00024	0.0053	930	2.6	0.040	
		Average								0.00023			2.6	0.039	
		Cr+6	1	CARB	60	103.6	98.0	2,601	1,284	0.00020	0.0045	908	2.3	0.035	
		Cr+6	2	425	60	101.8	98.3	2,632	1,517	0.00024	0.0054	930	2.6	0.040	
		Average								0.00022			2.4	0.038	
	Overall	Total Cr			Average					0.00021			4.3	0.067	A
	average	Cr+6			Average					0.00018			3.6	0.055	A
	FS	total Cr	1	CARB	60	102.6	98.23	2,632	1.50	2.36E-007	0.000005	366	0.0066	0.00010	
		total Cr	2	425	60	104.6	99.34	2,587	8.30	1.29E-006	0.000029	375	0.035	0.00053	
		Average								7.63E-007			0.021	0.00032	
		Cr+6	1	CARB	60	102.6	98.2	2,632	0.80	1.26E-007		366			
		Cr+6	2	425	60	104.6	99.3	2,587	4.20	6.52E-007		375			
		Average								3.89E-007					
		total Cr	1	CARB	60	100.3	97.67	2,630	0.00	0.00E+000		461			
		total Cr	2	425	60	107.4	113.10	2,582	0.00	0.00E+000		440			
		Average								0.00E+000					
		Cr+6	1	CARB	60	100.3	97.7	2,630	0.80	1.26E-007		461			
		Cr+6	2	425	60	107.4	113.1	2,582	0.90	1.23E-007		440			
		Average								1.25E-007					
		total Cr	1	CARB	60	100.8	97.01	2,597	7.30	1.16E-006	0.000026	957	0.012	0.00019	
		total Cr	2	425	60	103.2	98.15	2,589	6.60	1.04E-006	0.000023	1,030	0.010	0.00016	
		Average								1.10E-006			0.011	0.00017	
		Cr+6	1	CARB	60	100.8	97.0	2,597	0.80	1.27E-007		957			
		Cr+6	2	425	60	103.2	98.1	2,589	4.70	7.39E-007		1,030			
		Average								4.33E-007					
	Overall	Total Cr			Average					9.31E-007			0.016	0.00025	A

(a) FS = fume suppressant.

TABLE 4-30. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 28

TABLE 4-30. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 28.

Tank type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Decorative chrome	none	total Cr	1	CARB	60	91.0	87.86	2,105	418	7.34E-005	0.0013	1,029	0.58	0.0090	
		total Cr	2	425	60	103.1	88.73	2,087	666	0.00012	0.0021	967	0.97	0.015	
		Average								9.46E-005			0.78	0.012	
		Cr+6	1	CARB	60	91.0	87.9	2,105	490	8.61E-005	0.0016	1,029	0.68	0.011	
		Cr+6	2	425	60	103.1	88.7	2,087	599	0.00010	0.0019	967	0.87	0.013	
		Average								9.51E-005			0.78	0.012	
		total Cr	1	CARB	60	101.8	86.76	2,066	576	0.00010	0.0018	1,011	0.81	0.013	
		total Cr	2	425	60	10.3	89.21	2,106	2,226	0.00039	0.0070	1,303	2.4	0.037	
		Average								0.00024			1.6	0.025	
		Cr+6	1	CARB	60	101.8	86.8	2,066	650	0.00012	0.0020	1,011	0.92	0.014	
		Cr+6	2	425	60	10.3	89.2	2,106	1,896	0.00033	0.0059	1,303	2.1	0.032	
		Average								0.00022			1.5	0.023	
		total Cr	1	CARB	60	105.4	90.47	2,080	1,741	0.00030	0.0053	2,227	1.1	0.017	
		total Cr	2	425	60	103.1	89.42	1,881	463	7.99E-005	0.0013	2,397	0.24	0.0038	
		Average								0.00019			0.66	0.010	
		Cr+6	1	CARB	60	105.4	90.5	2,080	1,479	0.00025	0.0045	2,227	0.92	0.014	
		Cr+6	2	425	60	103.1	89.4	1,881	309	5.32E-005	0.0009	2,397	0.16	0.0025	
		Average								0.00015			0.54	0.0083	
	Overall	Total Cr			Average					0.00018			1.0	0.016	A
	average	Cr+6			Average					0.00016			0.94	0.014	A
	FS	total Cr	1	CARB	60	102.9	92.55	2,180	7.30	1.22E-006	0.000023	862	0.012	0.00018	
		total Cr	2	425	60	102.6	95.20	2,248	4.90	7.94E-007	0.000015	765	0.0091	0.00014	
		Average								1.01E-006			0.011	0.00016	
		Cr+6	1	CARB	60	102.9	92.6	2,180	4.00	6.67E-007		862			
		Cr+6	2	425	60	102.6	95.2	2,248	4.40	7.13E-007		765			
		Average								6.90E-007					
		total Cr	1	CARB	60	103.1	94.47	2,220	6.30	1.03E-006	0.000020	1,062	0.0084	0.00013	
		total Cr	2	425	60	104.2	96.32	2,239	8.40	1.35E-006	0.000026	908	0.013	0.00020	
		Average								1.19E-006			0.011	0.00016	
		Cr+6	1	CARB	60	103.1	94.5	2,220	0.40	6.53E-008		1,062			
		Cr+6	2	425	60	104.2	96.3	2,239	0.00			908			
		Average								6.53E-008					
		total Cr	1	CARB	60	104.2	97.36	2,265	6.40	1.01E-006	0.000020	2,430	0.0037	5.7E-005	
		total Cr	2	425	60	104.2	97.10	2,258	3.80	6.04E-007		2,521			
		Average								8.09E-007			0.0037	5.7E-005	
		Cr+6	1	CARB	60	104.2	97.4	2,265	5.30	8.40E-007		2,430			
		Cr+6	2	425	60	104.2	97.1	2,258	0.00	0.00E+000		2,521			
		Average								4.20E-007					
	Overall	Total Cr								1.08E-006			0.0092	0.00014	A

(a) FS = fume suppressant.

TABLE 4-31. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 29

TABLE 4-31. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 29.

Tank type	Type of control	Pollutant	Run No.	Test meth.(a)	Samp. time, min	Isokin., %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard Chrome	None	Cr+6	1	CRSM	120	NA	80.80	3,529	9,422	0.0018	0.054	5,748	8.6	0.13	
		Cr+6	2		120	NA	68.41	3,538	43,400	0.0098	0.30	5,768	47	0.72	
		Cr+6	3		120	NA	69.77	3561	44,073	0.0098	0.30	5,768	47	0.72	
		Average								0.0071			34	0.53	D
		Cr+6	1	CRSM	120	NA	83.1	4,082	29.61	5.5E-006		5,748			
		Cr+6	2		120	NA	87.9	4,101	26.57	4.5E-006		5,768			
		Cr+6	3		120	NA	88.94	4148	13.46	0.0000023		5,768			
		Average								4.10E-006					

(a) Constant rate sampling method.

TABLE 4-32. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 30

TABLE 4-32. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 30.

Source category: Electroplating | Filename: ELEC_R30.WQ1 | Date: 07/15/96
Plant name: McDonnell Douglas Electronic Systems Company | Location: Nonrovia, CA | Ref. No.:
Process: Chromic Acid Anodizing | Test date: 1/24-2/8/90 | Process rate basis: production

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %(b)	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Chromic acid	none	total Cr	1	CARB	60	101.1	60.43	7,034	73.3	1.9E-005	0.0011	117	4.4	0.068	
anodizing		total Cr	2	425	60	97.9	60.24	7,303	81.6	2.1E-005	0.0013	99	6.0	0.093	
										gr/DSCF		Average	5.2	0.080	
		Cr+6	1	CARB	60	101.1	60.4	7,034	59.7	1.5E-005	0.0009	117	3.6	0.055	
		Cr+6	2	425	60	97.9	60.2	7,303	80.9	2.1E-005	0.0013	99	5.9	0.092	
										gr/DSCF		Average	4.8	0.073	
		total Cr	1	CARB	36	91.6	36.96	7,577	58.6	2.4E-005	0.0016	118	3.7	0.056	
		total Cr	2	425	36	96.6	36.43	7,402	18.5	7.8E-006	0.0005	106	1.3	0.020	
										gr/DSCF		Average	2.5	0.038	
		Cr+6	1	CARB	36	91.6	37.0	7,577	50.9	2.1E-005	0.0014	118	3.2	0.049	
		Cr+6	2	425	36	96.6	36.4	7,402	12.9	5.5E-006	0.0003	106	0.89	0.014	
										gr/DSCF		Average	2.0	0.031	
		total Cr	1	CARB	36	96.3	36.15	7,429	244.6	1.0E-004	0.0066	265	6.8	0.105	
		total Cr	2	425	36	95.8	35.98	7,372	204.9	8.8E-005	0.0056	256	5.9	0.091	
										gr/DSCF		Average	6.4	0.098	
		Cr+6	1	CARB	36	96.3	36.1	7,429	179.0	7.6E-005	0.0049	265	5.0	0.077	
		Cr+6	2	425	36	95.8	36.0	7,372	151.2	6.5E-005	0.0041	256	4.4	0.067	
										gr/DSCF		Average	4.7	0.072	
	Overall	Total Cr											4.7	0.072	A
	average	Cr+6											3.8	0.059	A
	FS	total Cr	1	CARB	36	95.3	36.94	7,604	11.6	4.8E-006	0.000316	247	0.35	0.0054	
		total Cr	2	425	36	97.8	37.29	7,542	12.4	5.1E-006	0.000332	265	0.34	0.0053	
										gr/DSCF		Average	0.34	0.0053	
		Cr+6	1	CARB	36	95.3	36.9	7,604	5.2	2.2E-006	0.000142	247	0.16	0.0024	
		Cr+6	2	425	36	97.8	37.3	7,542	6.0	2.5E-006	0.000161	265	0.17	0.0025	
										gr/DSCF		Average	0.16	0.0025	
		total Cr	1	CARB	36	104.0	35.42	7,608	2.1	9.1E-007	0.000060	71	0.23	0.0035	
		total Cr	2	425	36	104.3	35.60	7,696	4.0	1.7E-006	0.000114	74	0.42	0.0065	
										gr/DSCF		Average	0.32	0.0050	
		Cr+6	1	CARB	36	104.0	35.4	7,608	3.4	1.5E-006	0.000097	71	0.37	0.0057	
		Cr+6	2	425	36	104.3	35.6	7,696	3.6	1.6E-006	0.000103	74	0.38	0.0059	
										gr/DSCF		Average	0.37	0.0058	
		total Cr	1	CARB	36	102.0	34.84	7,630	8.8	3.9E-006	0.000255	86	0.80	0.012	
		total Cr	2	425	36	NS	33.86	7,409	7.9	3.6E-006	0.000229	87	0.72	0.011	
										gr/DSCF		Average	0.76	0.012	
		Cr+6	1	CARB	36	102.0	34.8	7,630	1.3	5.8E-007	0.000038	86	0.12	0.0018	
		Cr+6	2	425	36	NS	33.9	7,409	4.1	1.9E-006	0.000119	87	0.37	0.0057	
												Average	0.24	0.0038	
	Overall	Total Cr											0.48	0.0073	A
	average	Cr+6											0.26	0.0040	A

TABLE 4-32 (continued)

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %(b)	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
	FS/PB	total Cr	1	CARB	36	97.4	35.15	7,577	3.3	1.4E-006	0.000094	85	0.30	0.0047	
		total Cr	2	425	36	NS	34.62	7,511	2.7	1.2E-006	0.000077	83	0.25	0.0039	
										gr/DSCF		Average	0.28	0.0043	
		Cr+6	1	CARB	36	97.4	35.1	7,577	2.4	1.1E-006	0.000068	85	0.22	0.0034	
		Cr+6	2	425	36	NS	34.6	7,511	1.2	5.3E-007	0.000034	83	0.11	0.0017	
										gr/DSCF		Average	0.17	0.0026	
		total Cr	1	CARB	36	104.8	35.86	7,646	3.5	1.5E-006	0.000099	243	0.11	0.0017	
		total Cr	2	425	36	104.0	34.92	7,572	1.8	8.0E-007	0.000052	297	0.047	0.00073	
										gr/DSCF		Average	0.079	0.0012	
		Cr+6	1	CARB	36	104.8	35.9	7,646	2.4	1.0E-006	0.000068	243	0.076	0.0012	
		Cr+6	2	425	36	104.0	34.9	7,572	2.3	1.0E-006	0.000066	297	0.060	0.00093	
										gr/DSCF		Average	0.068	0.0011	
		total Cr	1	CARB	36	104.7	69.94	7,531	4.0	8.8E-007	0.000057	64	0.24	0.0038	
		total Cr	2	425	36	103.0	68.52	7,436	7.1	1.6E-006	0.000102	62	0.45	0.0069	
										gr/DSCF		Average	0.35	0.0053	
		Cr+6	1	CARB	36	104.7	69.9	7,531	2.3	5.1E-007	0.000033	64	0.14	0.0022	
		Cr+6	2	425	36	103.0	68.5	7,436	5.7	1.3E-006	0.000082	62	0.36	0.0056	

TABLE 4-32 (continued)

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %(b)	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor g/hr-m2	Emission factor gr/hr-ft2	Rating
Chromic acid anodizing	none	total Cr	1	CARB	60	101.1	60.43	7,034	73.3	1.9E-005	0.0011	21	0.26	0.37	
		total Cr	2	425	60	97.9	60.24	7,303	81.6	2.1E-005	0.0013	21	0.30	0.43	
										gr/DSCF		Average	0.28	0.40	
		Cr+6	1	CARB	60	101.1	60.4	7,034	59.7	1.5E-005	0.0009	21	0.21	0.30	
		Cr+6	2	425	60	97.9	60.2	7,303	80.9	2.1E-005	0.0013	21	0.30	0.43	
										gr/DSCF		Average	0.26	0.37	
		total Cr	1	CARB	36	91.6	36.96	7,577	58.6	2.4E-005	0.0016	21	0.37	0.52	
		total Cr	2	425	36	96.6	36.43	7,402	18.5	7.8E-006	0.0005	21	0.11	0.16	
										gr/DSCF		Average	0.24	0.34	
		Cr+6	1	CARB	36	91.6	37.0	7,577	50.9	2.1E-005	0.0014	21	0.32	0.46	
		Cr+6	2	425	36	96.6	36.4	7,402	12.9	5.5E-006	0.0003	21	0.080	0.11	
										gr/DSCF		Average	0.20	0.29	
		total Cr	1	CARB	36	96.3	36.15	7,429	244.6	1.0E-004	0.0066	21	1.5	2.2	
		total Cr	2	425	36	95.8	35.98	7,372	204.9	8.8E-005	0.0056	21	1.3	1.8	
										gr/DSCF		Average	1.4	2.0	
		Cr+6	1	CARB	36	96.3	36.1	7,429	179.0	7.6E-005	0.0049	21	1.1	1.6	
		Cr+6	2	425	36	95.8	36.0	7,372	151.2	6.5E-005	0.0041	21	0.94	1.4	
										gr/DSCF		Average	1.0	1.5	
	Overall average	Total Cr											0.64	0.92	A
		Cr+6											0.50	0.71	A
	FS	total Cr	1	CARB	36	95.3	36.94	7,604	11.6	4.8E-006	0.000316	21	0.073	0.10	
		total Cr	2	425	36	97.8	37.29	7,542	12.4	5.1E-006	0.000332	21	0.076	0.11	
										gr/DSCF		Average	0.075	0.11	
		Cr+6	1	CARB	36	95.3	36.9	7,604	5.2	2.2E-006	0.000142	21	0.033	0.047	
		Cr+6	2	425	36	97.8	37.3	7,542	6.0	2.5E-006	0.000161	21	0.037	0.053	
										gr/DSCF		Average	0.035	0.050	
		total Cr	1	CARB	36	104.0	35.42	7,608	2.1	9.1E-007	0.000060	21	0.014	0.020	
		total Cr	2	425	36	104.3	35.60	7,696	4.0	1.7E-006	0.000114	21	0.026	0.038	
										gr/DSCF		Average	0.020	0.029	
		Cr+6	1	CARB	36	104.0	35.4	7,608	3.4	1.5E-006	0.000097	21	0.022	0.032	
		Cr+6	2	425	36	104.3	35.6	7,696	3.6	1.6E-006	0.000103	21	0.024	0.034	
										gr/DSCF		Average	0.023	0.033	
		total Cr	1	CARB	36	102.0	34.84	7,630	8.8	3.9E-006	0.000255	21	0.059	0.084	
		total Cr	2	425	36	NS	33.86	7,409	7.9	3.6E-006	0.000229	21	0.053	0.075	
										gr/DSCF		Average	0.056	0.080	
		Cr+6	1	CARB	36	102.0	34.8	7,630	1.3	5.8E-007	0.000038	21	0.0087	0.012	
		Cr+6	2	425	36	NS	33.9	7,409	4.1	1.9E-006	0.000119	21	0.027	0.039	
												Average	0.018	0.026	
	Overall average	Total Cr											0.050	0.072	A
		Cr+6											0.025	0.036	A

TABLE 4-32 (continued)

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokin., %(b)	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor g/hr-m2	Emission factor gr/hr-ft2	Rating
	FS/PB	total Cr	1	CARB	36	97.4	35.15	7,577	3.3	1.4E-006	0.000094	21	0.022	0.031	
		total Cr	2	425	36	NS	34.62	7,511	2.7	1.2E-006	0.000077	21	0.018	0.026	
										gr/DSCF		Average	0.020	0.028	
		Cr+6	1	CARB	36	97.4	35.1	7,577	2.4	1.1E-006	0.000068	21	0.0158	0.023	
		Cr+6	2	425	36	NS	34.6	7,511	1.2	5.3E-007	0.000034	21	0.008	0.011	
										gr/DSCF		Average	0.012	0.017	
		total Cr	1	CARB	36	104.8	35.86	7,646	3.5	1.5E-006	0.000099	21	0.023	0.033	
		total Cr	2	425	36	104.0	34.92	7,572	1.8	8.0E-007	0.000052	21	0.012	0.017	
										gr/DSCF		Average	0.017	0.025	
		Cr+6	1	CARB	36	104.8	35.9	7,646	2.4	1.0E-006	0.000068	21	0.0156	0.022	
		Cr+6	2	425	36	104.0	34.9	7,572	2.3	1.0E-006	0.000066	21	0.015	0.022	
										gr/DSCF		Average	0.015	0.022	
		total Cr	1	CARB	36	104.7	69.94	7,531	4.0	8.8E-007	0.000057	21	0.013	0.019	
		total Cr	2	425	36	103.0	68.52	7,436	7.1	1.6E-006	0.000102	21	0.023	0.034	
										gr/DSCF		Average	0.018	0.026	
		Cr+6	1	CARB	36	104.7	69.9	7,531	2.3	5.1E-007	0.000033	21	0.0075	0.011	
		Cr+6	2	425	36	103.0	68.5	7,436	5.7	1.3E-006	0.000082	21	0.019	0.027	
												Average	0.013	0.019	
	Overall	Total Cr											0.018	0.026	A
	average	Cr+6											0.013	0.019	A

(a) FS = fume suppressant; PB = polypropylene balls.
(b) Not specified.

TABLE 4-33. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 31

TABLE 4-33. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 31.

Tank Type	Type of control(a)	Pollutant	Run No.	Test meth.	Samp. time, min	Isokinetic, %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	total Cr	1	Mod. 8	90	99.5	61.66	8,325	698	0.00017	0.012	4,215	2.0	0.031	
		total Cr	2		90	97.8	70.93	8,122	1,293	0.00028	0.020	3,681	3.6	0.056	
		total Cr	3		90	93.1	72.85	8,230	1,614	0.00034	0.024	3,279	5.0	0.077	
		Average								0.00027			3.5	0.055	B
	MPME	total Cr	1	Mod. 8	90	98.7	61.1	8,819	53	1.3E-005	0.0010	4,215	0.16	0.0025	
		total Cr	2		90	95.5	78.9	9,254	62	1.2E-005	0.00096	3,681	0.18	0.0027	
		total Cr	3		90	99.3	79.8	8,922	40	7.7E-006	0.00059	3,279	0.12	0.0019	
		Average								1.11E-005			0.15	0.0024	B

(a) MPME = mesh-pad mist eliminator.

TABLE 4-34. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 33

TABLE 4-34. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 33.

Source	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	filterable PM	1	5	60	98.8	58.36	20,085	87,200	0.0231	4.0	5,500	327	5.1	
		filterable PM	2		60	99.5	58.96	20,155	121,400	0.0318	5.5	5,500	453	7.0	
		filterable PM	3		60	98.2	60.72	21,029	102,400	0.0260	4.7	5,500	387	6.0	
		Average								0.0270			389	6.0	NR
		total Cr	1	5	60	98.8	58.36	20,085	18,900	0.00500	0.86	5,500	71	1.1	
		total Cr	2		60	99.5	58.96	20,155	23,500	0.00615	1.1	5,500	88	1.4	
		total Cr	3		60	98.2	60.72	21,029	21,100	0.00536	0.97	5,500	80	1.2	
		Average								0.00550			79	1.2	D
	MPME	filterable PM	1	5	60	103.0	62.3	19,605	16,500	0.00409	0.69	5,500	57	0.87	
		filterable PM	2		60	105.4	63.8	19,648	20,500	0.00496	0.84	5,500	69	1.1	
		filterable PM	3		60	105.9	64.8	19,857	21,100	0.00503	0.86	5,500	71	1.1	
		Average								0.00469			65	1.0	NR
		total Cr	1	5	60	103.0	62.25	19,605	5,300	0.00131	0.22	5,500	18	0.28	
		total Cr	2		60	105.4	63.80	19,648	4,800	0.00116	0.20	5,500	16	0.25	
		total Cr	3		60	105.9	64.78	19,857	6,300	0.00150	0.26	5,500	21	0.33	
		Average								0.00133			18	0.28	D

(a) MPME = mesh pad mist eliminator.

TABLE 4-35. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 58

TABLE 4-35. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 58.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Decorative chrome	FS	total Cr	1	Imping.	320	98.7	234.39	11,947	80.5	5.30E-006	0.00054	25,000	0.053	0.00081	
		total Cr	4		320	98.6	234.82	11,980	45.4	2.98E-006	0.00031	22,100	0.034	0.00052	
		total Cr	7		320	98.4	234.253	11,983	88.9	5.86E-006	0.00060	26,300	0.055	0.00085	
		Average								4.71E-006			0.047	0.00073	NR
		Cr+6	4		320	98.7	234.388	11,947	15.6	1.03E-006	0.00011	25,000	0.010	0.00016	
		Cr+6	5		320	98.6	234.821	11,980	13.4	8.81E-007	9.0E-005	22,100	0.0099	0.00015	
		Cr+6	6		320	98.4	234.253	11,983	20.8	1.37E-006	0.00014	26,300	0.013	0.00020	
		Average								1.09E-006			0.011	0.00017	NR
	FS	filt. PM	2	5	320	97.6	230.186	11,416	8,300	0.00056	0.0544	25,000	5.3	0.081	
		filt. PM	5		320	100.6	229.972	11,065	1,300	8.7E-005	0.0083	22,100	0.91	0.014	
		filt. PM	8		320	99.2	240.408	11,719	6,700	0.00043	0.0432	26,300	4.0	0.061	
		Average								0.00036			3.4	0.052	NR
		total Cr	2	5	320	97.6	230.186	11,416	3,500	0.00023	0.02296	25,000	2.2	0.034	
		total Cr	5		320	100.6	229.972	11,065	10,800	0.00072	0.06874	22,100	7.5	0.12	
		total Cr	8		320	99.2	240.408	11,719	16,200	0.00104	0.10446	26,300	9.6	0.15	
		Average								0.00067			6.5	0.10	NR
		Cr+6	2	5	320	97.6	230.186	11,416	800	0.00005	0.00525	25,000	0.51	0.0078	
		Cr+6	5		320	100.6	229.972	11,065	2,800	0.00019	0.0178	22,100	2.0	0.030	
		Cr+6	8		320	99.2	240.408	11,719	4,200	0.00027	0.02708	26,300	2.5	0.038	
		Average								0.00017			1.6	0.025	NR
	FS/PBS	filt. PM	3	5	288	94.2	275.95	12,477				23,300			
		filt. PM	6		288	94.6	276.54	12,443	4,100	0.00023	0.02440	20,500	2.6	0.040	
		filt. PM	9		288	94.5	275.27	12,404		0.00000		23,400			
		Average								0.00011			2.6	0.040	NR
		total Cr	3	5	320	94.2	275.95	12,477	18,800	0.00105	0.11244	23,300	12	0.18	
		total Cr	6		320	94.6	276.54	12,443	14,300	0.00080	0.08511	20,500	10	0.15	
		total Cr	9		320	94.5	275.27	12,404	14,800	0.00083	0.08822	23,400	9.1	0.14	
		Average								0.00089			10	0.16	NR
		Cr+6	3	5	320	98.7	275.95	12,477	2,100	0.00012	0.01256	23,300	1.3	0.020	
		Cr+6	6		320	98.6	276.54	12,443	2,700	0.00015	0.01607	20,500	1.9	0.029	
		Cr+6	9		320	98.4	275.27	12,404	3,200	0.00018	0.01907	23,400	2.0	0.030	
		Average								0.00015			1.7	0.027	NR

(a) FS = fume suppressant; PBS = packed bed scrubber.

TABLE 4-36. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 59

TABLE 4-36. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 59.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chrome	none	filt. PM	2	5	288	97.1	283.08	9,315	60,500	0.00330	0.26	25,000	23	0.35	
		filt. PM	5		288	100.1	274.72	8,773	38,600	0.0022	0.16	22,100	16	0.25	
		filt. PM	8		288	98.9	275.08	8,888	51,300	0.00288	0.22	26,300	18	0.28	
		Average								0.00278			19	0.29	NR
		total Cr	2	5	288	97.1	283.08	9,315	14,977	0.00082	0.06519	25,000	5.7	0.088	
		total Cr	5		288	100.1	274.72	8,773	7,993	0.00045	0.03376	22,100	3.3	0.051	
		total Cr	8		288	98.9	275.08	8,888	13,345	0.00075	0.05703	26,300	4.7	0.073	
		Average								0.00067			4.6	0.071	NR
		Cr+6	2	5	288	97.1	283.08	9,315	7,200	0.000	0.03134	25,000	2.7	0.042	
		Cr+6	5		288	100.1	274.72	8,773	3,680	0.00021	0.01554	22,100	1.5	0.024	
		Cr+6	8		288	98.9	275.08	8,888	6,520	0.00037	0.02787	26,300	2.3	0.036	
		Average								0.00032			2.2	0.034	NR
	PBS	filt. PM	3	5	288	95.9	208.92	10,410	15,500	0.00114	0.102	23,300	9.5	0.15	
		filt. PM	6		288	96.5	211.21	10,464	20,400	0.00149	0.134	20,500	14	0.22	
		filt. PM	9		288	95.8	203.93	10,171	16,100	0.00122	0.106	23,400	9.9	0.15	
		Average								0.00128			11	0.17	NR
		total Cr	3	5	288	95.9	208.92	10,410	728	5.38E-005	0.00480	23,300	0.45	0.0069	
		total Cr	6		288	96.5	211.21	10,464	305	2.23E-005	0.00200	20,500	0.21	0.0033	
		total Cr	9		288	95.8	203.93	10,171	647	4.90E-005	0.00427	23,400	0.40	0.0061	
		Average								4.17E-005			0.35	0.0054	NR
		Cr+6	3	5	288	95.9	208.92	10,410	155	1.14E-005	0.00102	23,300	0.095	0.0015	
		Cr+6	6		288	96.5	211.21	10,464	121	8.84E-006	0.00079	20,500	0.084	0.0013	
		Cr+6	9		288	95.8	203.93	10,171	174	1.32E-005	0.00115	23,400	0.11	0.0016	
		Average								1.12E-005			0.095	0.0015	NR

(a) PBS = packed bed scrubber.

TABLE 4-37. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 62

TABLE 4-37. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 62.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor g/hr-m2	Emission factor gr/hr-ft2	Rating
Chromic acid	none	total Cr	1	CARB	40	100.6	37.37	3,318	688.60	0.00028	0.00809	28	1.4	2.0	
anodizing		total Cr	2	425	40	96.0	37.31	3,271	450.00	0.00019	0.00522	28	0.91	1.3	
		Average								0.00024			1.2	1.7	B
		Cr+6	1	CARB	40	100.6	37.37	3,318	443.70	0.00018	0.00521	28	0.91	1.3	
		Cr+6	2	425	40	96.0	37.31	3,271	270.00	0.00011	0.00313	28	0.55	0.78	
		Average								0.00015			0.73	1.0	B
	AM	total Cr	3	CARB	40	106.0	40.58	3,432	34.90	1.33E-005	0.00039	28	0.068	0.098	
		total Cr	4	425	40	104.6	39.24	3,344	23.30	9.16E-006	0.00026	28	0.046	0.066	
		Average								1.12E-005			0.057	0.082	B
		Cr+6	1	CARB	40	106.0	40.58	3,432				28			
		Cr+6	2	425	40	104.6	39.24	3,344				28			
												Average			

(a) AM = antimisting agent.

TABLE 4-38. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 63

TABLE 4-38. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 63.

Source category:	Electroplating	Filename:	ELEC_R63.WQ1	Date:	07/16/96
Plant name:	Douglas Aircraft	Location:	Cypress, CA	Ref. No.:	4-63
Process:	Chromic Acid Anodizing	Test date:	August 21- Sept 11, 1989	Process rate basis:	production

Source	Type of control	Pollutant	Run No.	Test Method	Samp. time, min	Isokinetic, %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rat.
Anodizing tank (370)	none	total Cr		SCAQMD	64		46.03	1,369	228.10	7.65E-005	0.00090	33.9	13	0.20	
		total Cr	A	205	60		51.28	1,170	1130.30	0.00034	0.00341	108.0	14	0.22	
		total Cr	B		60		60.435	1177	1421.1	0.00036	0.00366	112.7	15	0.23	
												Average	14	0.22	B
		Cr+6		SCAQMD	64	0.0	46.03	1,369	208.60	7.0E-005	0.00082	33.9	12	0.18	
		Cr+6	A	205	60	0.0	51.28	1,170	982.50	0.00030	0.00297	108.0	12	0.19	
		Cr+6	B		60	0.0	60.44	1,177	1226.9	0.00031	0.00316	112.7	13	0.20	
												Average	12	0.19	B
Anodizing tank (534)		total Cr	A	SCAQMD	90		53.341	7609	1654.5	0.00048	0.03122	2,853	7.4	0.11	
		total Cr	B	205	90		51.222	7588	1659.7	0.00050	0.03252	2,853	7.8	0.12	
												Average	7.6	0.12	C
		Cr+6	A	SCAQMD	90	0.0	53.34	7,609	1367.50	0.00040	0.02580	2,853	6.2	0.095	
		Cr+6	B	205	90	0.0	51.22	7,588	1397.00	0.00042	0.02737	2,853	6.5	0.10	
												Average	6.3	0.10	C
Anodizing tank (370)	F	total Cr	A	SCAQMD	192		103.04	1,332	5.00	7.49E-007	8.55E-006	166	0.075	0.0012	
		total Cr	B	205	172		136.58	1,335	24.70	2.79E-006	3.19E-005	188	0.22	0.0034	
												Average	0.15	0.0023	C
		Cr+6	A	SCAQMD	192	0.0	103.04	1,332				166			
		Cr+6	B	205	172	0.0	136.58	1,335				188			
												Average			
	F/PB	total Cr	A	SCAQMD	192		128.93	1,340	3.20	3.83E-007	4.4E-006	160	0.040	0.00062	
		total Cr	B	205	181		118.79	1,340	14.30	1.86E-006	2.1E-005	164	0.18	0.0027	
												Average	0.11	0.0017	C
		Cr+6	A	SCAQMD	192	0.0	128.93	1,340				160			
		Cr+6	B	205	181	0.0	118.79	1,340				164			
												Average			
	F/AMA	total Cr		SCAQMD	192		125.07	1,335	2.80	3.45E-007	4.0E-006	268	0.021	0.00033	
		total Cr	A	205	170							545			
		total Cr	B		170							545			
												Average	0.02	0.0003	NR
		Cr+6		SCAQMD	192	0.0	125.07	1,335				268			
		Cr+6	A	205	170							545			
		Cr+6	B		170							Average			
	PB	total Cr	A	SCAQMD	120		113.78	1,168	755.50	1.02E-004	0.00103	262	3.6	0.055	
		total Cr	B	205	120		119.50	1,160	677.50	8.75E-005	0.00087	262	3.0	0.047	
												Average	3.3	0.051	B
		Cr+6	A	SCAQMD	120	0.0	113.78	1,168	726.70			262			
		Cr+6	B	205	120	0.0	119.50	1,160	763.00			262			
												Average			

TABLE 4-38 (continued)

Source	Type of control	Pollutant	Run No.	Test Method	Samp. time, min	Isokinetic, %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor g/hr-m2	Emission factor gr/hr-ft2	Rat.
Anodizing tank (370)	none	total Cr		SCAQMD	64		46.03	1,369	228.10	7.65E-005	0.00090	3.8	1.1	1.6	
		total Cr	A	205	60		51.28	1,170	1130.30	0.00034	0.00341	3.8	4.3	6.2	
		total Cr	B		60		60.435	1177	1421.1	0.00036	0.00366	3.8	4.7	6.7	
												Average	3.4	4.8	B
		Cr+6		SCAQMD	64	0.0	46.03	1,369	208.60	7.0E-005	0.00082	3.8	1.0	1.5	
		Cr+6	A	205	60	0.0	51.28	1,170	982.50	0.00030	0.00297	3.8	3.8	5.4	
		Cr+6	B		60	0.0	60.44	1,177	1226.9	0.00031	0.00316	3.8	4.0	5.8	
												Average	2.9	4.2	B
Anodizing tank (534)		total Cr	A	SCAQMD	90		53.341	7609	1654.5	0.00048	0.03122				
		total Cr	B	205	90		51.222	7588	1659.7	0.00050	0.03252				
															C
		Cr+6	A	SCAQMD	90	0.0	53.34	7,609	1367.50	0.00040	0.02580				
		Cr+6	B	205	90	0.0	51.22	7,588	1397.00	0.00042	0.02737				
															C
Anodizing tank (370)	F	total Cr	A	SCAQMD	192		103.04	1,332	5.00	7.49E-007	8.55E-006	3.8	0.011	0.016	
		total Cr	B	205	172		136.58	1,335	24.70	2.79E-006	3.19E-005	3.8	0.041	0.058	
												Average	0.026	0.037	C
		Cr+6	A	SCAQMD	192	0.0	103.04	1,332				3.8			
		Cr+6	B	205	172	0.0	136.58	1,335				3.8			
												Average			
	F/PB	total Cr	A	SCAQMD	192		128.93	1,340	3.20	3.83E-007	4.4E-006	3.8	0.0056	0.0080	
		total Cr	B	205	181		118.79	1,340	14.30	1.86E-006	2.1E-005	3.8	0.027	0.039	
												Average	0.016	0.023	C
		Cr+6	A	SCAQMD	192	0.0	128.93	1,340				3.8			
		Cr+6	B	205	181	0.0	118.79	1,340				3.8			
												Average			
	F/AMA	total Cr		SCAQMD	192		125.07	1,335	2.80	3.45E-007	4.0E-006	3.8	0.0050	0.0072	
		total Cr	A	205	170							3.8			
		total Cr	B		170							3.8			
												Average	0.0050	0.0072	NR
		Cr+6		SCAQMD	192	0.0	125.07	1,335				3.8			
		Cr+6	A	205	170							3.8			
		Cr+6	B		170							Average			
	PB	total Cr	A	SCAQMD	120		113.78	1,168	755.50	1.02E-004	0.00103	3.8	1.3	1.9	
		total Cr	B	205	120		119.50	1,160	677.50	8.75E-005	0.00087	3.8	1.1	1.6	
												Average	1.2	1.7	B
		Cr+6	A	SCAQMD	120	0.0	113.78	1,168	726.70			3.8			
		Cr+6	B	205	120	0.0	119.50	1,160	763.00			3.8			
												Average			

Basis for rating: All downrated due to lack of adequate documentation; further downrated if only two runs conducted.

Problems noted:

Other notes: AMA = antimisting agent; F = foam; PB = polypropylene balls

Factors not calculated if mass below quantitation limit.

TABLE 4-39. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 66

TABLE 4-39. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 66.

Tank type	Type of control(a)	Pollutant	Run No.	Test Method	Samp. time, min	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor(b) g/hr-m2	Emission factor(b) gr/hr-ft2	Rating
Chromic acid anodizing	PBS	total Cr	1	SCAQMD	468	411.66	4,382	42.14	1.58E-006	5.93E-005				
		total Cr	1	205.1	20	13.921	39,306							
		total Cr	2		480	408.23	4,206	17.05	6.45E-007	2.32E-005				
		total Cr	2		33	26.485	41855							
		Cr+6	1	SCAQMD	468	411.66	4,382	38.90	1.46E-006	5.48E-005				
		Cr+6	2	205.1	20	13.92	39,306	1.00	1.11E-006	0.00037				
		Cr+6	1		480	408.23	4,206							
		Cr+6	2		33	26.49	41,855	0.04	2.33E-008	8.36E-006				
	PBS	total Cr	1	SCAQMD	480	359.40	6,261	421.60	1.81E-005	0.00097				
		total Cr	1	205.1	23	13.115	62,575							
		total Cr	2		484	314.63	5,897	127.80	6.27E-006	0.00032				
		total Cr	2		32	19.194	56954	7.28	5.85E-006	0.0029				
		Cr+6	1	SCAQMD	480	359.40	6,261	373.95	1.61E-005	0.00086				
		Cr+6	2	205.1	23	13.12	62,575	0.35	4.12E-007	0.00022				
		Cr+6	1		484	314.63	5,897	2.01	9.86E-008	4.98E-006				
		Cr+6	2		32	19.19	56,954	0.13	1.05E-007	5.10E-005				
	PBS (Total)	total Cr	1	SCAQMD	474					0.0010				
		total Cr	1	205.1	21.5									
		total Cr	2		482					0.00034				
		total Cr	2		32.5					0.0029				
											Average			
		Cr+6	1	SCAQMD	474					0.00092				
		Cr+6	2	205.1	21.5					0.00059				
		Cr+6	1		482					5.0E-006				
		Cr+6	2		32.5					5.9E-005				
											Average			

(a) PBS = packed bed scrubber; emission factors based on sum of emission rates from both scrubbers.
(b) Tank dimensions not specified; emission factor could not be calculated.

TABLE 4-40. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 67

TABLE 4-40. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 67.

Tank type	Type of control(b)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug (c)	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Chromic acid	None	total Cr	1	CARB	75	90.8	54.33	38,042	5.65	1.60E-006	0.00052	ND	NA	NA	
anodizing		total Cr	2	425	85	93.3	50.24	34,254	2.73	8.39E-007	0.00025	ND	NA	NA	
		total Cr	3		80	91.9	50.00	34,603	0.09	2.78E-008	8.2E-006	ND	NA	NA	
		filt. PM	8		320					8.24E-007		Average			NR
		Cr+6	1	CARB	75	90.8	54.3	38,042	BDL	NA	NA	ND	NA	NA	
		Cr+6	2	425	85	93.3	50.2	34,254	BDL	NA	NA	ND	NA	NA	
		Cr+6	3		80	91.9	50.0	34,603	BDL	NA	NA	ND	NA	NA	
		total Cr	8		320							Average			NR
	WS	total Cr	1	CARB	75	100.2	47.88	40,173	3.70	1.19E-006	0.00041	ND	NA	NA	
		total Cr	2	425	85	103.9	48.79	39,486	0.36	1.14E-007	3.9E-005	ND	NA	NA	
		total Cr	3		80	101.3	48.10	33,990	0.80	2.57E-007	7.5E-005	ND	NA	NA	
		Cr+6	8		320					5.21E-007		Average			NR
		Cr+6	1	CARB	75	100.2	47.9	40,173	BDL	NA	NA	ND	NA	NA	
		Cr+6	2	425	85	103.9	48.8	39,486	BDL	NA	NA	ND	NA	NA	
		Cr+6	3		80	101.3	48.1	33,990	BDL	NA	NA	ND	NA	NA	
		filt. PM	9		288							Average			NR
Copper plating	None	copper	1	0012	73	94.3	64.07	29,628	30.0	7.23E-006	0.0018	43.4	23	0.36	
		copper	2		90	93.6	67.82	31,593	BDL	NA	NA	8.2	NA	NA	
		copper	3		80	91.3	48.72	33,923	BDL	NA	NA	13.4	NA	NA	
		total Cr	9		ERR					7.23E-006		Average	23	0.36	NR
	None	lead	1	0012	73	94.3	64.07	29,628	22.0	5.30E-006	0.0013	0	NA	NA	
		lead	2		90	93.6	67.82	31,593	16.0	3.64E-006	0.0010	0	NA	NA	
		lead	3		80	91.3	48.72	33,923	13.0	4.12E-006	0.0012	0	NA	NA	
		Cr+6	9		ERR					4.35E-006		Average			NR
	WS	copper	1	0012	73	96.7	45.44	39,508	570.00	0.00019	0.066	43.4	833	13	
		copper	2		90	98.7	46.70	39,783	120.00	3.97E-005	0.014	8.2	1,117	17	
		copper	3		80	102.5	48.33	39,645	33.00	1.05E-005	0.0036	13.4	161	2.5	
										8.13E-005		Average	704	11	C
	WS	lead	1	0012	73	96.7	45.44	39,508	66.00	2.24E-005	0.0076	0	NA	NA	
		lead	2		90	98.7	46.70	39,783	19.00	6.28E-006	0.0021	0	NA	NA	
		lead	3		80	102.5	48.33	39,645	17.00	5.43E-006	0.0018	0	NA	NA	
										1.14E-005		Average			NR
Nickel plating	None	nickel	1	0012	73	94.3	64.07	29,628	280.00	6.74E-005	0.017	85.1	111	1.7	
		nickel	2		90	93.6	67.82	31,593	190.00	4.32E-005	0.012	161.8	49	0.76	
		nickel	3		80	91.3	48.72	33,923	31.00	9.82E-006	0.0029	158.7	11	0.17	
										4.02E-005		Average	57	0.88	B
	WS	nickel	1	0012	73	96.7	45.44	39,508	6.00	2.04E-006	0.00069	85.1	4.5	0.069	
		nickel	2		90	98.7	46.70	39,783	27.00	8.92E-006	0.0030	161.8	13	0.20	
		nickel	3		80	102.5	48.33	39,645	19.20	6.13E-006	0.0021	158.7	7.9	0.12	
										5.70E-006		Average	8.4	0.13	B

TABLE 4-40. (Continued)

Tank type	Type of control(b)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen., gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Nickel plating	None	nickel	1	CARB	65	90.0	54.28	26,298	117.50	3.34E-005	0.0075	117	32	0.49	
		nickel	2	424	120	92.1	45.64	31,515	75.00	2.54E-005	0.0068	182	34	0.53	
		nickel	3		90	91.6	48.87	33,937	27.50	8.68E-006	0.0025	200	8.6	0.13	
										2.25E-005			25	0.38	C
	WS	nickel	1	CARB	65	98.4	47.27	40,387	32.50	1.06E-005	0.0037	117	15	0.24	
		nickel	2	424	120	100.2	47.64	39,983	25.00	8.10E-006	0.0028	182	14	0.21	
		nickel	3		90	99.0	46.49	39,503	12.50	4.15E-006	0.0014	200	4.8	0.074	
										7.62E-006			11	0.17	B
Cadmium plating	None	cadmium	1	0012	89	96.5	44.22	8,577	98.00	3.42E-005	0.0025	338	5.0	0.077	
		cadmium	2		73	94.7	40.92	8,090	6.30	2.38E-006	0.00016	548	0.17	0.0026	
		cadmium	3		87	97.4	42.11	8,093	7.60	2.79E-006	0.00019	653	0.19	0.0030	
										1.31E-005		Average	1.8	0.028	C
	None	zinc	1	0012	89	96.5	44.22	8,577	9,900	0.0035	0.25	0	NA	NA	
		zinc	2		73	94.7	40.92	8,090	12,000	0.0045	0.31	0	NA	NA	
		zinc	3		87	97.4	42.11	8,093	12,000	0.0044	0.31	0	NA	NA	
										0.0041		Average			NR
	WS	cadmium	1	0012	89	95.9	47.82	8,987	8.00	2.58E-006	0.00020	338	0.40	0.0061	
		cadmium	2		73	97.6	48.25	8,914	8.50	2.72E-006	0.00021	548	0.21	0.0032	
		cadmium	3		87	97.8	48.06	8,861	5.80	1.86E-006	0.00014	653	0.14	0.0022	
										2.4E-006		Average	0.25	0.0038	B
	WS	zinc	1	0012	89	95.9	47.82	8,987	11,000	0.0035	0.27	0	NA	NA	
		zinc	2		73	97.6	48.25	8,914	12,000	0.0038	0.29	0	NA	NA	
		zinc	3		87	97.8	48.06	8,861	12,000	0.0039	0.29	0	NA	NA	
										0.0037		Average			NR
Cadmium plating	None	cadmium	1	CARB	82	94.2	40.19	7,990	5.50	2.11E-006	0.00014	25	3.6	0.055	
		cadmium	2	433	70	95.0	39.37	7,759	13.75	5.39E-006	0.00036	338	0.56	0.0087	
		cadmium	3		70	94.4	41.18	8,172	9.75	3.65E-006	0.00026	23	6.0	0.093	
										3.7E-006		Average	3.4	0.052	C
	WS	cadmium	1	CARB	82	98.0	49.59	9,128	9.00	2.80E-006	0.00022	25	5.4	0.084	
		cadmium	2	433	70	95.5	48.98	9,247	10.50	3.31E-006	0.00026	338	0.41	0.0063	
		cadmium	3		70	91.7	45.31	8,907	46.00	1.57E-005	0.0012	23	28	0.43	
										7.3E-006		Average	11	0.17	C

(a) NA = not applicable, ND = no data.
(b) WS = wet scrubber.
(c) BDL = below detection limit.

TABLE 4-41. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 71

TABLE 4-41. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 71.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
High purity	PBS	total Cr	1	13B	64	96.2	39.20	16,355	199.82	7.87E-005	0.01103	38,074	0.14	0.0022	
chromium metal		total Cr	2		64	100.7	40.11	15,980	78.80	3.03E-005	0.0042	37,554	0.054	0.00083	
production		total Cr	3		64	100.7	40.91	16,160	518.15	0.00020	0.02707	37,749	0.35	0.0054	
										0.00010		Average	0.18	0.0028	B
		Cr+6	1	13B	64	96.2	39.2	16,355	167.20	6.58E-005	0.00923	38,074	0.12	0.0018	
		Cr+6	2		64	100.7	40.1	15,980	64.80	2.49E-005	0.00342	37,554	0.044	0.00068	
		Cr+6	3		64	100.7	40.9	16,160	117.20	4.42E-005	0.00612	37,749	0.078	0.0012	
										4.5E-005		Average	0.080	0.0012	B

(a) PBS = packed bed scrubber.

TABLE 4-42. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 74

TABLE 4-42. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 74.

Tank type	Type of control	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chromium	None	Cr+6	1	CARB	60	99.0	23.43	12,600	105.90	6.98E-005	0.0075	2,980	1.1	0.018	
		Cr+6	2	425	60	98.0	23.12	12,600	104.70	6.99E-005	0.0075	2,980	1.1	0.018	
		Cr+6	3		60	101.0	23.30	12,600	105.60	6.99E-005	0.0076	2,980	1.1	0.018	
										6.99E-005		Average	1.1	0.018	C

TABLE 4-43. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 75

TABLE 4-43. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 75.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor mg/hr-m2	Emission factor gr/hr-ft2	Rating
Chromic acid	none	total Cr	1	CARB	160	99.6	114.09	12,340	206	2.8E-005	0.00295	66	0.22	0.31	
anodizing		total Cr	2	425	160	99.5	116.27	12,590	235	3.1E-005	0.00337	66	0.25	0.36	
		total Cr	2		160	99.7	114.81	12,399	258	3.5E-005	0.00369	66	0.27	0.39	
		Average								3.1E-005			0.25	0.35	A
		Cr+6	1	CARB	160	99.6	114.09	12,340	180	2.4E-005	0.00258	66	0.19	0.27	
		Cr+6	2	425	160	99.5	116.27	12,590	206	2.7E-005	0.00295	66	0.22	0.31	
		Cr+6			160	99.7	114.81	12,399	227	3.1E-005	0.00324	66	0.24	0.34	
		Average								2.7E-005			0.22	0.31	A
	WS	total Cr	1	CARB	160	98.7	100.68	10,261	14.9	2.3E-006	0.00020	66	0.015	0.021	
		total Cr	2	425	160	98.2	100.05	10,220	16.5	2.5E-006	0.00022	66	0.016	0.024	
		total Cr	2		160	99.4	98.339	9920	20.3	3.2E-006	0.00027	66	0.020	0.029	
		Average								2.7E-006			0.017	0.025	A
		Cr+6	1	CARB	160	98.7	100.68	10,261	6.6	1.0E-006	8.9E-005	66	0.0066	0.0094	
		Cr+6	2	425	160	98.2	100.05	10,220	0.63	9.6E-008	8.4E-006	66	0.00062	0.00090	
		Cr+6			160	99.4	98.34	9,920	9.8	1.5E-006	0.00013	66	0.010	0.014	
		Average								8.8E-007			0.0056	0.0081	B

(a) WS = wet scrubber.

TABLE 4-44. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 77

TABLE 4-44. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 77.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard chromium	none	Cr+6	1	13B	120	102.0	106.18	7,991	25,648	0.0037	0.26	10,600	22	0.34	
		Cr+6	2		120	103.0	106.90	7,959	3,431	0.00050	0.034	5,778	5.3	0.082	
										0.00211		Average	14	0.21	B
	WS	Cr+6	1	13B	120	98.0	71.8	13,574	69.5	1.49E-005	0.0017	10,600	0.15	0.0023	
		Cr+6	2		120	97.0	80.7	12,807	135.1	2.58E-005	0.0028	5,778	0.45	0.0069	
										2.0E-005		Average	0.30	0.0046	B
Hard chromium	none	Cr+6	1	13B	120	101.0	113.25	5,974	1,163	0.00016	0.0081	3,500	2.1	0.032	
		Cr+6	2		120	101.0	109.56	5,817	829.5	0.00012	0.0058	3,306	1.6	0.025	
										0.00014		Average	1.9	0.029	B
	WS	Cr+6	1	13B	120	99.0	68.6	10,628	182.1	4.10E-005	0.0037	3,500	0.97	0.015	
		Cr+6	2		120	96.0	65.5	10,526	233.0	5.49E-005	0.0050	3,306	1.4	0.021	
										4.8E-005		Average	1.2	0.018	C
												ft2	g/hr-ft2	gr/hr-ft2	
Chromic acid anodizing	none	Cr+6	1	13B	60	96	38.58	20,522	184.9	7.4E-005	0.013	ND	NA	NA	
		Cr+6	2		120	95	77.42	20,650	12.37	2.5E-006	0.00044	ND	NA	NA	
		Cr+6	3		60	96	39.26	20,775	83	3.3E-005	0.0058	ND	NA	NA	
												Average			NR

(a) WS = wet scrubber.

TABLE 4-45. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 78

TABLE 4-45. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 78.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor mg/hr-m2	Emission factor gr/hr-ft2	Rating
Magnesium	none	total Cr	1	CARB	264	99.8	104.51	20,900	6.00	8.86E-007	0.00016	102	0.0076	0.011	
anodizing		total Cr	2	425	144	97.4	114.27	21,300	13.00	1.76E-006	0.00032	102	0.015	0.022	
		total Cr	3		144	99.1		21,300	6.10		0.00015	102	0.0070	0.010	
		Average								1.32E-006			0.010	0.014	C
		Cr+6	1	CARB	264	99.8	104.51	20,900	5.00	7.38E-007	0.00013	102	0.0063	0.0091	
		Cr+6	2	425	144	97.4	114.27	21,300	5.10	6.89E-007	0.00013	102	0.0060	0.0086	
		Cr+6	3		144	99.1		21,300	1.20		2.9E-005	102	0.0014	0.0020	
		Average								7.14E-007			0.0046	0.0066	NR
	WS	total Cr	1	CARB	264	99.2	103.94	21,100	1.00	1.48E-007	2.7E-005	102	0.0013	0.0018	
		total Cr	2	425	144	97.8	128.87	21,000	1.00	1.20E-007	2.2E-005	102	0.0010	0.0015	
		total Cr	3		144	99.7	136.33	21,800	1.00	1.13E-007	2.1E-005	102	0.0010	0.0015	
		Average								1.27E-007			0.0011	0.0016	C
		Cr+6	1	CARB	264	99.2	103.94	21,100	5.60	8.31E-007	1.5E-004	102	0.0072	0.0103	
		Cr+6	2	425	144	97.8	128.87	21,000	1.20	1.44E-007	2.6E-005	102	0.0012	0.0018	
		Cr+6	3		144	99.7	136.33	21,800	3.10	3.51E-007	6.6E-005	102	0.0031	0.0045	
		Average								4.42E-007			0.0039	0.0055	NR

(a) WS = wet scrubber.

Pages 20 and 21 missing from report

TABLE 4-46. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 81

TABLE 4-46. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 81.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard	WS	Cr+6	1	CARB	120	102.7	82.80	8,100	11.21	2.1E-006	0.00015	8,126	0.016	0.00025	
chromium		Cr+6	2	425	120	99.3	74.60	8,100	8.92	1.8E-006	0.00013	8,000	0.015	0.00022	
		Cr+6	3		120	101.5	80.70	7,970	9.87	1.9E-006	0.00013	8,168	0.014	0.00022	
										1.94E-006		Average	0.015	0.00023	B
		Total Cr	1	CARB	120	102.7	82.80	8,100	15.62	2.91E-006	0.00020	8,126	0.023	0.00035	
		Total Cr	2	425	120	99.3	74.60	8,100	17.14	3.55E-006	0.00025	8,000	0.028	0.00043	
		Total Cr	3		120	101.5	80.70	7,970	12.43	2.38E-006	0.00016	8,168	0.018	0.00028	
										2.94E-006		Average	0.023	0.00035	B

(a) WS = wet scrubber.

TABLE 4-47. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 83

TABLE 4-47. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 83.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor mg/hr-m2	Emission factor gr/hr-ft2	Rating
Chromic acid	PBS/FS	total Cr	1	CARB	120	97.4	95.00	46,840	0.69	1.12E-007	4.5E-005	73	0.0030	0.0043	
anodizing		total Cr	2	425	120	99.9	101.80	48,950	1.16	1.76E-007	7.4E-005	73	0.0050	0.0071	
(C2)		total Cr	3		120	98.8	94.90	46,140	0.48	7.81E-008	3.1E-005	73	0.0021	0.0030	
		Average								1.22E-007			0.0034	0.0048	B
		Cr+6	1	CARB	120	97.4	95.00	46,840	0.11	1.79E-008	7.2E-006	73	0.00048	0.00069	
		Cr+6	2	425	120	99.9	101.80	48,950	0.14	2.12E-008	8.9E-006	73	0.00060	0.00086	
		Cr+6	3		120	98.8	94.90	46,140	0.11	1.79E-008	7.1E-006	73	0.00048	0.00068	
		Average								1.90E-008			0.00052	0.00075	B
Chromic acid	PBS/FS	total Cr	1	CARB	120	99.7	124.70	1,018	23.70	2.93E-006	2.6E-005	31	0.0040	0.0057	
anodizing		total Cr	2	425	120	95.3	103.70	963	17.00	2.53E-006	2.1E-005	31	0.0033	0.0047	
(Helo Blade)		total Cr	3		120	97.7	106.90	968	4.80	6.93E-007	5.7E-006	31	0.00090	0.0013	
		total Cr	4		120	99.8	113.70	1,010	43.90	5.96E-006	5.2E-005	31	0.0080	0.012	
		Average								3.03E-006			0.0040	0.0058	D
		Cr+6	1	CARB	120	99.7	124.70	1,018	21.60	2.67E-006	2.3E-005	31	0.0036	0.0052	
		Cr+6	2	425	120	95.3	103.70	963	11.90	1.77E-006	1.5E-005	31	0.0023	0.0033	
		Cr+6	3		120	97.7	106.90	968	3.39	4.89E-007	4.1E-006	31	0.00063	0.00091	
		Cr+6	4		120	99.8	113.70	1,010	30.70	4.17E-006	3.6E-005	31	0.0056	0.0081	
		Average								2.28E-006			0.0030	0.0044	D

(a) PBS/FS = packed bed scrubber and fume suppressant.

TABLE 4-48. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 84

TABLE 4-48. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 84.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor mg/hr-m2	Emission factor gr/hr-ft2	Rating
Chromic acid	PBS/	Total Cr	1	CARB	120	93.0	98.9	668	3.72	5.8E-007	3.32E-006	31	0.00052	0.00074	
anodizing	MPME	Total Cr	2	425	120	100.2	85.7	699	2.36	4.2E-007	2.55E-006	31	0.00040	0.00057	
		Total Cr	3		120	98.7	86.9	720	1.38	2.5E-007	1.51E-006	31	0.00024	0.00034	
										4.17E-007		Average	0.00038	0.00055	B
		Cr+6	1	CARB	120	93.0	98.9	668	3.72	5.8E-007	3.32E-006	31	0.00052	0.00074	
		Cr+6	2	425	120	100.2	85.7	699	2.96	5.3E-007	3.19E-006	31	0.00050	0.00071	
		Cr+6	3		120	98.7	86.9	720	0.69	1.2E-007	7.56E-007	31	0.00012	0.00017	
										4.12E-007		Average	0.00038	0.00054	B

(a) PBS/MPME = packed bed scrubber and mesh pad mist eliminator.

TABLE 4-49. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 85

TABLE 4-49. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 85.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor mg/hr-m2	Emission factor gr/hr-ft2	Rating
Chromic acid	PBS/	Total Cr	1	CARB	360	97.3	288.4	27,237	<0.65	NA	NA	NA	NA	NA	
anodizing tank	MPME	Total Cr	2	425	360	99.7	295.1	27,197	<0.75	NA	NA	NA	NA	NA	
												A-hr			NR
Hard chromium	PBS/	Total Cr	1	CARB	480	100.2	417.50	26,872	0.68	2.51E-008	5.79E-006	48,000	0.00044	6.8E-006	
(Line L)	MPME	Total Cr	2	425	480	100.2	418.14	26,136	1.16	4.28E-008	9.59E-006	48,000	0.00073	1.1E-005	
										3.40E-008			0.00058	9.0E-006	C
Hard chromium	PBS/	Total Cr	1	CARB	432	102.6	392.99	16,429	0.82	3.22E-008	4.53E-006	29,160	0.00051	7.8E-006	
(Line M)	MPME	Total Cr	2	425	432	101.6	394.84	16,475	0.71	2.77E-008	3.92E-006	29,160	0.00044	6.8E-006	
										3.00E-008			0.00047	7.3E-006	C

(a) PBS/MPME = packed bed scrubber and mesh pad mist eliminator.

TABLE 4-50. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 86

TABLE 4-50. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 86.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor mg/hr-m2	Emission factor gr/hr-ft2	Rating
Chromic acid	PBS	total Cr	1	CARB	120	103.0	100.00	46,860	23.09	3.56E-006	0.0014	73	0.096	0.14	
anodizing		total Cr	2	425	120	102.0	98.40	46,570	13.50	2.12E-006	0.00085	73	0.057	0.082	
		total Cr	3		120	95.6	92.90	46,940	5.49	9.12E-007	0.00037	73	0.025	0.035	
		Average								2.20E-006			0.059	0.085	B
		Cr+6	1	CARB	120	103.0	100.00	46,860	2.30	3.55E-007	0.00014	73	0.0096	0.014	
		Cr+6	2	425	120	102.0	98.40	46,570	2.70	4.23E-007	0.00017	73	0.011	0.016	
		Cr+6	3		120	95.6	92.90	46,940	3.90	6.48E-007	0.00026	73	0.018	0.025	
		Average								4.75E-007			0.013	0.018	B
Chromic acid	PBS	total Cr	2	CARB	120	101.5	107.30	856	2.60	3.74E-007	2.7E-006	31	0.00043	0.00061	
anodizing		total Cr	3	425	120	98.9	105.50	955	3.96	5.79E-007	4.7E-006	31	0.00074	0.0011	
		total Cr	4		120	98.4	96.00	873	35.70	5.74E-006	4.3E-005	31	0.0067	0.0096	
		Average								2.23E-006			0.0026	0.0038	C
		Cr+6	2	CARB	120	101.5	107.30	856	0.86	1.24E-007	9.1E-007	31	0.00014	0.00020	
		Cr+6	3	425	120	98.9	105.50	955	2.20	3.22E-007	2.6E-006	31	0.00041	0.00059	
		Cr+6	4		120	98.4	96.00	873	27.20	4.37E-006	3.3E-005	31	0.0051	0.0073	
		Average								1.61E-006			0.0019	0.0027	C

(a) PBS = packed bed scrubber.

TABLE 4-51. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 88

TABLE 4-51. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 88.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard	PBS/PC	Total Cr	1	CARB	80	102.4	50.35	2,169	6.00	1.84E-006	3.4E-005	5,447	0.0038	5.9E-005	
chromium		Total Cr	2	425	80	102.3	48.88	2,108	7.00	2.21E-006	4.0E-005	5,473	0.0044	6.8E-005	
		Total Cr	3		80	102.3	50.58	2,181	11.30	3.45E-006	6.4E-005	5,447	0.0072	0.00011	
										2.50E-006		Average	0.0051	7.9E-005	B
	PBS/PC	Cr+6	1	CARB	80	102.4	50.35	2,169	6.20	1.90E-006	3.5E-005	5,447	0.0039	6.1E-005	
		Cr+6	2	425	80	102.3	48.88	2,108	7.90	2.49E-006	4.5E-005	5,473	0.0050	7.7E-005	
		Cr+6	3		80	102.3	50.58	2,181	7.40	2.26E-006	4.2E-005	5,447	0.0047	7.2E-005	
										2.22E-006		Average	0.0045	7.0E-005	NR

(a) PBS/PC = packed bed scrubber and polypropylene chips.

TABLE 4-52. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 89

TABLE 4-52. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 89.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard	PBS/PC	Total Cr	1	CARB	80	ND	35.75	1,527	17.7	7.64E-006	0.00010	4,760	0.013	0.00020	
chromium		Total Cr	2	425	80	ND	34.99	1,539	27.7	1.22E-005	0.00016	5,033	0.019	0.00030	
		Total Cr	3		80	ND	36.94	1,540	11.2	4.68E-006	6.2E-005	5,093	0.0073	0.00011	
										8.18E-006		Average	0.013	0.00020	C
	PBS/PC	Cr+6	1	CARB	80	ND	35.75	1,527	10.8	4.66E-006	6.1E-005	4,760	0.0078	0.00012	
		Cr+6	2	425	80	ND	34.99	1,539	6.2	2.73E-006	3.6E-005	5,033	0.0043	6.7E-005	
		Cr+6	3		80	ND	36.94	1,540	11.1	4.64E-006	6.1E-005	5,093	0.0073	0.00011	
										4.01E-006		Average	0.0065	0.00010	NR

(a) PBS/PC = packed bed scrubber and polypropylene chips.

TABLE 4-53. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 90

TABLE 4-53. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 90.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard	PB/PS	Cr+6	1	13B	128	109.2	101.57	2,324	18,590	0.0028	0.056	10,182	5.3	0.083	
chromium		Cr+6	2		128	109.0	93.32	2,138	16,266	0.0027	0.049	8,388	5.7	0.088	
										0.0028		Average	5.5	0.085	B
	PBS/ME/	Cr+6	1	13B	128	92.4	82.9	2,140	59.2	1.10E-005	0.00020	10,182	0.019	0.00030	
	PB/PS	Cr+6	2		128	94.2	83.6	2,118	22.8	4.20E-006	7.6E-005	8,388	0.0088	0.00014	
										7.62E-006		Average	0.014	0.00022	C

(a) PB = polypropylene balls; PS = plastic sheet; PBS = packed bed scrubber; ME = moisture extractor.

TABLE 4-54. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 93

TABLE 4-54. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 93.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, A-hr	Emission factor mg/A-hr	Emission factor gr/A-hr	Rating
Hard	PBS/FS	Total Cr	1	CARB	120	100.8	93.23	10,670	16.7	2.76E-006	0.00025	3,800	0.060	0.00093	
chromium		Total Cr	2	425	120	100.9	93.80	10,719	9.0	1.48E-006	0.00014	3,800	0.032	0.00050	
		Total Cr	3		120	101.1	93.99	10,718	2.9	4.76E-007	4.4E-005	3,800	0.010	0.00016	
										1.57E-006		Average	0.034	0.00053	B
	PBS/FS	Cr+6	1	CARB	120	100.8	93.23	10,670	2.0	3.31E-007	3.0E-005	3,800	0.0072	0.00011	
		Cr+6	2	425	120	100.9	93.80	10,719	1.3	2.14E-007	2.0E-005	3,800	0.0047	7.2E-005	
		Cr+6	3		120	101.1	93.99	10,718	4.7	7.72E-007	7.1E-005	3,800	0.017	0.00026	
										4.39E-007		Average	0.0096	0.00015	NR

(a) PBS/FS = packed bed scrubber and fume suppressant.

TABLE 4-55. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 94

TABLE 4-55. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 94.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor mg/hr-m2	Emission factor gr/hr-ft2	Rating
Chromic acid anodizing	none	Total Cr	1	CARB	360	100.7	264.20	24,300	15,285	0.00089	0.186	352	2.6	3.7	
		Total Cr	2	425	240	101.7	173.4	23,690	4,161	0.00037	0.075	352	1.0	1.5	
		Total Cr	3		120	102.3	89.30	24,270	2,438	0.00042	0.088	352	1.2	1.7	
										0.00056		Average	1.6	2.3	B
		Cr+6	1	CARB	360	100.7	264.2	24,300	14,092	0.00082	0.171	352	2.4	3.4	
		Cr+6	2	425	240	101.7	173.4	23,690	4,239	0.00038	0.077	352	1.1	1.5	
		Cr+6	3		120	102.3	89.3	24,270	2,203	0.00038	0.079	352	1.1	1.6	
										0.00053		Average	1.5	2.2	B
	PBS/ HEPA	Total Cr	1	CARB	360	94.2	302.30	23,340	5.07	2.6E-007	5.2E-005	352	0.00072	0.0010	
		Total Cr	2	425	240	97.1	213.2	23,950	BDL	NA	NA	352	NA	NA	
		Total Cr	3		120	100.6	116.3	25,230	BDL	NA	NA	352	NA	NA	
												Average	0.00072	0.0010	D
		Cr+6	1	CARB	360	94.2	302.3	23,340	2.57	1.3E-007	2.6E-005	352	0.00036	0.00052	
		Cr+6	2	425	240	97.1	213.2	23,950	1.66	1.2E-007	2.5E-005	352	0.00034	0.00049	
		Cr+6	3		120	100.6	116.3	25,230	0.73	9.7E-008	2.1E-005	352	0.00029	0.00042	
										1.2E-007		Average	0.00033	0.00048	B

(a) PBS/HEPA = packed bed scrubber and high efficiency particulate air filter.

TABLE 4-56. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TESTS FOR REFERENCE 95

TABLE 4-56. SUMMARY OF PARAMETERS AND RESULTS OF EMISSION TEST FOR REFERENCE 95.

Tank type	Type of control(a)	Pollutant	Run No.	Test Meth.	Samp. time, min	Isokin. %	Gas volume, DSCF	Volum. flow rate, DSCFM	Mass, ug	Concen. gr/DSCF	Emission rate, lb/hr	Process rate, ft2	Emission factor mg/hr-m2	Emission factor gr/hr-ft2	Rating
Chromic acid anodizing	none	Total Cr	1	CARB	180	100	147.3	8,397	7,400	0.00078	0.056	176	1.5	2.2	
		Total Cr	2	425	180	100	147.3	8,395	6,200	0.00065	0.047	176	1.3	1.9	
		Total Cr	3		180	100	146.3	8,336	6,100	0.00064	0.046	176	1.3	1.8	
										0.00069		Average	1.4	2.0	C
		Cr+6	1	CARB	180	100	147.3	8,397	6,000	0.00063	0.045	176	1.3	1.8	
		Cr+6	2	425	180	100	147.3	8,395	5,400	0.00057	0.041	176	1.1	1.6	
		Cr+6	3		180	100	146.3	8,336	5,300	0.00056	0.040	176	1.1	1.6	
										0.00058		Average	1.2	1.7	C
	PBS/ HEPA	Total Cr	1	CARB	180	97	183.5	8,160	BDL	NA	NA	176	NA	NA	
		Total Cr	2	425	180	98	181.2	8,013	BDL	NA	NA	176	NA	NA	
		Total Cr	3		180	97	179.2	7,958	BDL	NA	NA	176	NA	NA	
												Average			NR
		Cr+6	1	CARB	180	97	183.5	8,160	BDL	NA	NA	176	NA	NA	
		Cr+6	2	425	180	98	181.2	8,013	8.0	6.8E-007	4.7E-005	176	0.0013	0.0019	
		Cr+6	3		180	97	179.2	7,958	BDL	NA	NA	176	NA	NA	
												Average	0.0013	0.0019	NR

(a) PBS/HEPA = packed bed scrubber and high efficiency particulate air filter.

TABLE 4-57. SUMMARY OF TEST DATA FOR ELECTROPLATING

TABLE 4-57. SUMMARY OF TEST DATA FOR ELECTROPLATING

Process	APCD(a)	Pollutant	No. of runs	Data rating(b)	Emission factor (c) mg/A-hr (g/hr-m2) Minimum	Maximum	Average	gr/A-hr (gr/hr-ft2) Average	Concentration, gr/DSCF Average	Ref. No.	
Hard chromium	none	total Cr	4	A	2.7	6.9	5.1	0.078	0.00099	1	
Hard chromium	CBME	total Cr	4	A	0.26	1.2	0.68	0.011	0.00015	1	
Hard chromium	none	Cr+6	4	A	2.5	6.1	4.5	0.070	0.00088	1	
Hard chromium	CBME	Cr+6	4	A	0.24	1.0	0.59	0.0092	0.00013	1	
Hard chromium	none	total Cr	3	A	0.77	2.5	1.7	0.025	0.00041	2	
Hard chromium	CBME	total Cr	3	A	0.16	0.26	0.22	0.0033	5.2E-005	2	
Hard chromium	none	Cr+6	3	A	3.1	3.2	3.2	0.049	0.00077	2	
Hard chromium	CBME	Cr+6	3	A	0.15	0.41	0.27	0.0042	6.5E-005	2	
Hard chromium	none	filt. PM-10	3	NR	ND	ND	2.2	0.033	0.00084	2	
Hard chromium	CBME	filt. PM-10	3	NR	ND	ND	0.49	0.0076	0.00019	2	
Hard chromium	none	total Cr	3	A	7.1	11	9.1	0.14	0.0034	3	
Hard chromium	CBME	total Cr	3	A	0.15	0.16	0.15	0.0023	0.000058	3	
Hard chromium	CBME	Cr+6	3	A	0.13	0.15	0.14	0.0022	0.000054	3	
Hard chromium	none	Cr+6	3	A	7.2	11	9.2	0.14	0.0035	3	
Hard chromium	none	Cr+6	3	A	6.0	6.4	6.2	0.096	0.0013	4	
Hard chromium	MX	Cr+6	3	A	0.71	1.0	0.85	0.013	0.00019	4	
Hard chromium	MX/MPME	Cr+6	3	A	0.066	0.096	0.083	0.0013	0.000017	4	
Hard chromium	none	Cr+6	5	A	7.8	21	16	0.25	0.0050	5	
Hard chromium	MPME	Cr+6	5	A	0.015	0.063	0.042	0.00065	0.000014	5	
Hard chromium	none	Cr+6	3	A	5.4	7.5	6.6	0.10	0.0019	6	
Hard chromium	PB	Cr+6	2	B	1.4	2.2	1.8	0.028	0.00042	6	
Hard chromium	MPME	Cr+6	3	A	0.059	0.086	0.073	0.0011	0.000019	6	
Hard chromium	MPME/PB	Cr+6	2	B	0.059	0.067	0.063	0.0010	0.000013	6	
Hard chromium	none	total Cr	3	A	14	21	18	0.28	0.0031	7	
Hard chromium	PBS	total Cr	2	B	0.098	0.11	0.10	0.0016	0.000016	7	
Hard chromium	none	Cr+6	3	A	12	18	16	0.25	0.0027	7	
Hard chromium	PBS	Cr+6	2	B	0.062	0.074	0.068	0.0011	0.000011	7	
Hard chromium	none	total Cr	3	A	10	19	15	0.23	0.00069	8	
Hard chromium	PBS	total Cr	3	A	0.25	0.46	0.36	0.0056	2.3E-005	8	
Hard chromium	none	Cr+6	3	A	11	20	15	0.24	0.00073	8	
Hard chromium	PBS	Cr+6	3	A	0.25	0.48	0.37	0.0057	0.000092	8	
Hard chromium	none	Cr+6	3	A	5.0	7.7	6.0	0.092	0.00029	9	FOOTNOTE
Hard chromium	none	Cr+6	3	B	6.9	11	9.0	0.14	0.00031	9	FOOTNOTE
Hard chromium	none	Cr+6	2	B	7.9	8.0	8.0	0.12	0.00032	9	FOOTNOTE
Hard chromium	PBS	Cr+6	3	A	0.18	0.22	0.20	0.0030	1.0E-005	9	FOOTNOTE
Hard chromium	PBS	Cr+6	3	A	0.39	0.54	0.45	0.0070	0.000017	9	
Hard chromium	PBS	Cr+6	2	B	0.22	0.22	0.22	0.0034	0.0000095	9	
Hard chromium	CMP	total Cr	3	A	0.013	0.018	0.016	0.00025	4.8E-006	10	
Hard chromium	MX	total Cr	3	A	0.42	0.79	0.55	0.0084	0.00015	10	
Hard chromium	MX	total Cr	3	A	0.15	0.20	0.18	0.0027	6.4E-005	10	
Hard chromium	CMP	Cr+6	3	A	0.011	0.019	0.014	0.00022	4.5E-006	10	
Hard chromium	MX	Cr+6	3	A	0.15	0.20	0.17	0.0027	6.9E-005	10	
Hard chromium	MX	Cr+6	3	A	0.40	0.76	0.52	0.0081	0.00015	10	

TABLE 4-57. (Continued)

Process	APCD(a)	Pollutant	No. of runs	Data rating(b)	Emission factor (c) mg/A-hr (g/hr-m2) Minimum	Maximum	Average	gr/A-hr (gr/hr-ft2) Average	Concentration, gr/DSCF Average	Ref. No.
Hard chromium	none	total Cr	3	A	5.3	6.9	6.1	0.094	0.00042	11
Hard chromium	CMP	total Cr	3	A	0.063	0.090	0.079	0.0012	5.0E-006	11
Hard chromium	FS/CMP	total Cr	3	A	0.033	0.056	0.041	0.00064	0.0000035	11
Hard chromium	FS	total Cr	3	A	1.1	2.6	1.8	0.027	0.00016	11
Hard chromium	none	total Cr	3	A	36	120	69	1.1	0.030	12
Hard chromium	PBS/CMP	total Cr	3	A	0.0023	0.0060	0.0042	6.4E-005	2.7E-006	12
Hard chromium	none	Cr+6	3	A	39	130	74	1.1	0.032	12
Hard chromium	PBS/CMP	Cr+6	3	A	0.0023	0.0061	0.0041	6.3E-005	2.6E-006	12
Hard chromium	none	total Cr	6	A	1.6	17	6.0	0.093	0.0012	13
Hard chromium	none	Cr+6	6	A	1.5	12	4.6	0.070	0.00089	13
Hard chromium	none	total Cr	3	A	1.5	1.8	1.7	0.026	0.00073	14
Hard chromium	FS/PB	total Cr	3	A	0.033	0.042	0.037	0.00057	1.6E-005	14
Hard chromium	PBS	total Cr	3	A	0.062	0.082	0.072	0.0011	0.000026	14
Hard chromium	PBS/FS/PB	total Cr	3	A	0.0073	0.011	0.0096	0.00015	3.7E-006	14
Decorative chromium	none	total Cr	3	A	1.4	2.0	1.7	0.027	0.00063	15
Decorative chromium	none	Cr+6	3	A	1.5	2.3	1.9	0.030	0.00070	15
Decorative chromium	none	Cr+6	3	A	1.2	1.4	1.3	0.021	0.00040	16
Decorative chromium	FS	Cr+6	3	A	0.0050	0.010	0.0067	0.00010	2.0E-006	16
Decorative chromium	FS	Cr+6	3	A	0.0015	0.0046	0.0029	4.5E-005	0.00000093	16
Trivalent chromium	none	total Cr	3	NR	0.035	0.15	0.084	0.0013	1.2E-005	17
Trivalent chromium	none	Cr+6	3	NR	0.0083	0.015	0.011	0.00017	1.6E-006	17
Trivalent chromium	none	Cr+3	3	NR	0.025	0.14	0.073	0.0011	1.0E-005	17
Trivalent chromium	none	CO2	3	NR	250	300	280	610	NA	17
Hard chromium	none	total Cr	2	C	3.7	4.0	3.8	0.059	0.00025	20
Hard chromium	MPME	total Cr	2	B	0.26	0.30	0.28	0.0043	2.1E-006	20
Chromic acid anodizing	MPME	total Cr	2	D	0.0020	0.0050	0.0035	0.0051	2.0E-007	20
Hard chromium	FS/MPME	total Cr	2	B	0.29	0.31	0.30	0.0047	2.3E-006	20
Hard chromium	FS	total Cr	2	C	0.19	0.27	0.23	0.0036	0.000015	20
Cyanide-copper	MPME	cyanide	3	C	19	65	47	0.73	2.7E-006	20
Cadmium	MPME	cyanide	3	C	70	210	160	2.4	0.00010	20
Cadmium	MPME	cadmium	2	C	0.29	0.29	0.29	0.0045	1.5E-007	20
Cadmium	PBS	total Cr	3	NR	0.22	0.76	0.40	0.0062	7.4E-007	21
Cadmium	PBS	Cd	3	D	0.083	1.0	0.50	0.077	9.3E-007	21
Cadmium	PBS	NH3	3	D	12	29	23	0.35	4.2E-005	21
Cadmium	PBS	CN	3	D	14	41	32	0.49	5.9E-005	21
Hard chromium	none	total Cr	2	D	0.14	0.16	0.15	0.0023	0.0000012	22
Hard chromium	PBS	total Cr	2	D	0.14	0.14	0.14	0.0022	0.0000011	22
Hard chromium	none	total Cr	2	D	4.8	9.3	7.0	0.11	0.00068	23
Hard chromium	none	total Cr	2	D	5.6	6.2	5.9	0.091	0.00063	23
Hard chromium	PBS	total Cr	2	D	0.0054	0.041	0.023	0.00036	2.0E-006	23
Hard chromium	PBS	total Cr	1	NR	NA	NA	0.017	0.00026	9.3E-007	23
Hard chromium	none	Cr+6	2	D	5.0	5.3	5.1	0.079	0.00054	23
Hard chromium	none	Cr+6	2	D	4.2	13	8.8	0.14	0.00084	23
Hard chromium	PBS/FBME	total Cr	3	NR	0.00024	0.0019	0.00083	1.3E-005	7.1E-008	24
Hard chromium	PBS/FBME	total Cr	3	NR	0.00016	0.0012	0.00050	7.7E-006	6.8E-008	24

TABLE 4-57. (Continued)

Process	APCD(a)	Pollutant	No. of runs	Data rating(b)	Emission factor (c) mg/A-hr (g/hr-m2) Minimum	Maximum	Average	gr/A-hr (gr/hr-ft2) Average	Concentration, gr/DSCF Average	Ref. No.	
Hard chromium	none	total Cr	6	A	4.5	12	7.1	0.11	0.0016	25	
Hard chromium	FS/PB	total Cr	6	A	0.13	0.30	0.19	0.0030	0.000046	25	
Hard chromium	none	Cr+6	6	A	3.5	12	6.0	0.092	0.0014	25	
Hard chromium	FS/PB	Cr+6	6	A	0.10	0.26	0.16	0.0024	3.8E-005	25	
Hard chromium	none	total Cr	6	A	2.3	11	7.5	0.12	0.0018	26	3.171470306
Hard chromium	FS/PB	total Cr	6	A	0.054	0.17	0.11	0.0017	2.9E-005	26	
Hard chromium	none	Cr+6	6	A	2.0	11	7.1	0.11	0.0017	26	
Hard chromium	FS/PB	Cr+6	5	A	0.086	0.14	0.11	0.0017	3.0E-005	26	
Decorative chromium	none	total Cr	6	A	2.5	6.4	4.3	0.067	0.00021	27	
Decorative chromium	FS	total Cr	4	A	0.0066	0.035	0.016	0.00025	9.3E-007	27	
Decorative chromium	none	Cr+6	6	A	2.3	4.4	3.6	0.055	0.00018	27	
Decorative chromium	none	total Cr	6	A	0.58	2.4	1.0	0.016	0.00018	28	
Decorative chromium	FS	total Cr	5	A	0.0037	0.012	0.0092	0.00014	1.1E-006	28	
Decorative chromium	none	Cr+6	6	A	0.16	2.1	0.94	0.014	0.00016	28	
Hard chromium	none	Cr+6	3	D	8.6	47	34	0.53	0.0071	29	
Chromic acid anodizing	none	total Cr	6	A	0.11	1.5	0.64	0.92	0.000044	30	
Chromic acid anodizing	FS	total Cr	6	A	0.014	0.076	0.050	0.072	3.4E-006	30	
Chromic acid anodizing	FS/PB	total Cr	6	A	0.012	0.023	0.018	0.026	1.2E-006	30	
Chromic acid anodizing	none	Cr+6	6	A	0.080	1.1	0.50	0.71	3.4E-005	30	
Chromic acid anodizing	FS	Cr+6	6	A	0.0087	0.037	0.025	0.036	1.7E-006	30	
Chromic acid anodizing	FS/PB	Cr+6	6	A	0.0075	0.019	0.013	0.019	9.1E-007	30	
Hard chromium	none	total Cr	3	B	2.0	5.0	3.5	0.055	0.00027	31	
Hard chromium	MPME	total Cr	3	B	0.12	0.18	0.15	0.0024	1.1E-005	31	
Hard chromium	none	filt. PM	3	NR	330	450	390	6.0	0.027	33	
Hard chromium	MPME	filt. PM	3	NR	57	71	65	1.0	0.0047	33	
Hard chromium	none	total Cr	3	D	71	88	79	1.2	0.0055	33	
Hard chromium	MPME	total Cr	3	D	16	21	18	0.28	0.0013	33	
Decorative chromium	FS/PBS	filt. PM	1	NR	2.6	2.6	2.6	0.040	0.00011	58	
Decorative chromium	FS	filt. PM	3	NR	0.91	5.3	3.4	0.052	0.00036	58	
Decorative chromium	FS/PBS	total Cr	3	NR	9.1	12	10	0.16	0.00089	58	
Decorative chromium	FS	total Cr	3	NR	0.034	0.055	0.047	0.00073	4.7E-006	58	
Decorative chromium	FS	total Cr	3	NR	2.2	9.6	6.5	0.10	0.00067	58	
Decorative chromium	FS/PBS	Cr+6	3	NR	1.3	2.0	1.7	0.027	0.00015	58	
Decorative chromium	FS	Cr+6	3	NR	0.51	2.5	1.6	0.025	0.00017	58	
Decorative chromium	FS	Cr+6	3	NR	0.010	0.013	0.011	0.00017	1.1E-006	58	
Hard chromium	none	filt. PM	3	NR	16	23	19	0.29	0.0028	59	
Hard chromium	PBS	filt. PM	3	NR	10	14	11	0.17	0.0013	59	
Hard chromium	none	total Cr	3	NR	3.3	5.7	4.6	0.071	0.00067	59	
Hard chromium	PBS	total Cr	3	NR	0.21	0.45	0.35	0.0054	4.2E-005	59	
Hard chromium	none	Cr+6	3	NR	1.5	2.7	2.2	0.034	0.00032	59	
Hard chromium	PBS	Cr+6	3	NR	0.084	0.11	0.095	0.0015	1.1E-005	59	
Chromic acid anodizing	none	total Cr	2	B	0.91	1.4	1.2	1.7	0.00024	62	
Chromic acid anodizing	FS	total Cr	2	B	0.046	0.068	0.057	0.082	1.1E-005	62	
Chromic acid anodizing	none	Cr+6	2	B	0.55	0.91	0.73	1.0	0.00015	62	

TABLE 4-57. (Continued)

Process	APCD(a)	Pollutant	No. of runs	Data rating(b)	Emission factor (c) mg/A-hr (g/hr-m2) Minimum	Maximum	Average	gr/A-hr (gr/hr-ft2) Average	Concentration, gr/DSCF Average	Ref. No.
Chromic acid anodizing	none	total Cr	3	B	1.1	4.7	3.4	4.8	0.00026	63
Chromic acid anodizing	FS	total Cr	2	C	0.011	0.041	0.026	0.037	1.8E-006	63
Chromic acid anodizing	FS	total Cr	3	NR	NA	NA	0.0050	0.0072	3.5E-007	63
Chromic acid anodizing	FS/PB	total Cr	2	C	0.0056	0.027	0.016	0.023	1.1E-006	63
Chromic acid anodizing	PB	total Cr	2	B	1.1	1.3	1.2	1.7	0.000095	63
Chromic acid anodizing	none	Cr+6	3	B	1.0	4.0	2.9	4.2	0.00023	63
Copper	none	copper	1	NR	23	23	23	0.36	0.0000072	67
Copper	WS	copper	3	C	160	1100	700	11	0.000081	67
Nickel	none	nickel	3	B	11	110	57	0.88	4.0E-005	67
Nickel	WS	nickel	3	B	4.5	13	8.4	0.13	0.0000057	67
Nickel	none	nickel	3	C	8.6	34	25	0.38	0.000022	67
Nickel	WS	nickel	3	B	4.8	15	11	0.17	0.0000076	67
Cadmium	none	cadmium	3	C	0.17	5.0	1.8	0.028	0.000013	67
Cadmium	WS	cadmium	3	B	0.14	0.40	0.25	0.0038	0.0000024	67
Cadmium	none	cadmium	3	C	0.56	6.0	3.4	0.052	0.0000037	67
Cadmium	WS	cadmium	3	C	0.41	28	11	0.17	0.0000073	67
Chromium metal prod.	PBS	total Cr	3	B	0.054	0.35	0.18	0.0028	0.00010	71
Chromium metal prod.	PBS	Cr+6	3	B	0.044	0.12	0.080	0.0012	0.000045	71
Hard chromium	none	Cr+6	3	C	1.1	1.1	1.1	0.018	0.000069	74
Chromic acid anodizing	none	total Cr	3	A	0.22	0.27	0.25	0.35	3.1E-005	75
Chromic acid anodizing	none	Cr+6	3	A	0.19	0.24	0.22	0.31	2.7E-005	75
Chromic acid anodizing	WS	total Cr	3	A	0.015	0.020	0.017	0.025	2.7E-006	75
Chromic acid anodizing	WS	Cr+6	3	B	0.00062	0.010	0.0056	0.0081	8.8E-007	75
Hard chromium	none	Cr+6	2	B	5.3	22	14	0.21	0.0021	77
Hard chromium	WS	Cr+6	2	B	0.15	0.45	0.30	0.0046	2.0E-005	77
Hard chromium	none	Cr+6	2	B	1.6	2.1	1.9	0.029	0.00014	77
Hard chromium	WS	Cr+6	2	B	0.97	1.4	1.2	0.018	0.000048	77
Magnesium anodizing	none	total Cr	2	C	0.0076	0.015	0.010	0.014	1.3E-006	78
Magnesium anodizing	none	Cr+6	3	NR	0.0014	0.0063	0.0046	0.0066	0.00000071	78
Magnesium anodizing	WS	total Cr	3	C	0.0010	0.0013	0.0011	0.0016	0.000000127	78
Magnesium anodizing	WS	Cr+6	3	NR	0.0012	0.0072	0.0039	0.0055	0.000000442	78
Hard chromium	WS	total Cr	3	B	0.014	0.016	0.015	0.00023	0.0000019	81
Hard chromium	WS	Cr+6	3	B	0.018	0.028	0.023	0.00035	0.0000029	81
Chromic acid anodizing	PBS/FS	total Cr	3	B	0.0021	0.0050	0.0034	0.0048	1.2E-007	83
Chromic acid anodizing	PBS/FS	Cr+6	3	B	0.00048	0.00060	0.00052	0.00075	1.9E-008	83
Chromic acid anodizing	PBS/FS	total Cr	4	D	0.00090	0.0080	0.0040	0.0058	3.0E-006	83
Chromic acid anodizing	PBS/FS	Cr+6	4	D	0.00063	0.0056	0.0030	0.0044	2.3E-006	83
Chromic acid anodizing	PBS/MPME	total Cr	4	B	0.00024	0.00052	0.00038	0.00055	0.00000042	84
Chromic acid anodizing	PBS/MPME	Cr+6	4	B	0.00012	0.00052	0.00038	0.00054	0.00000041	84
Hard chromium	PBS/MPME	total Cr	2	C	0.00044	0.00073	0.00058	9.0E-006	3.4E-008	85
Hard chromium	PBS/MPME	total Cr	2	C	0.00044	0.00051	0.00047	7.3E-006	3.0E-008	85

TABLE 4-57. (Continued)

Process	APCD(a)	Pollutant	No. of runs	Data rating(b)	Emission factor (c) mg/A-hr (g/hr-m2) Minimum	Maximum	Average	gr/A-hr (gr/hr-ft2) Average	Concentration, gr/DSCF Average	Ref. No.
Chromic acid anodizing	PBS	total Cr	3	B	0.025	0.096	0.059	0.085	0.0000022	86
Chromic acid anodizing	PBS	Cr+6	3	B	0.0096	0.018	0.013	0.018	4.8E-007	86
Chromic acid anodizing	PBS	total Cr	4	C	0.00043	0.0067	0.0026	0.0038	2.2E-006	86
Chromic acid anodizing	PBS	Cr+6	4	C	0.00014	0.0051	0.0019	0.0027	1.6E-006	86
Hard chromium	PBS/PC	total Cr	3	B	0.0038	0.0072	0.0051	0.000079	0.0000025	88
Hard chromium	PBS/PC	Cr+6	3	NR	0.0039	0.0050	0.0045	7.0E-005	0.0000022	88
Hard chromium	PBS/PC	total Cr	3	C	0.0074	0.019	0.013	0.00020	0.0000082	89
Hard chromium	PBS/PC	Cr+6	3	NR	0.0043	0.0078	0.0065	0.00010	4.0E-006	89
Hard chromium	PB/PS	Cr+6	3	B	5.3	5.7	5.5	0.085	0.0028	90
Hard chromium	PBS/MX/PB/PS	Cr+6	3	C	0.0088	0.019	0.014	0.00022	0.0000076	90
Hard chromium	PBS/FS	total Cr	3	B	0.010	0.060	0.034	0.00053	0.0000016	93
Hard chromium	PBS/FS	Cr+6	3	NR	0.0047	0.017	0.0096	0.00015	0.000044	93
Chromic acid anodizing	none	total Cr	3	B	1.0	2.6	1.6	2.3	0.00056	94
Chromic acid anodizing	none	Cr+6	3	B	1.1	2.4	1.5	2.2	0.00053	94
Chromic acid anodizing	WS/MX/HEPA	total Cr	1	D	0.00072	0.00072	0.00072	0.0010	0.00000026	94
Chromic acid anodizing	WS/MX/HEPA	Cr+6	3	B	0.00029	0.00036	0.00033	0.00048	0.00000012	94
Chromic acid anodizing	none	total Cr	3	C	1.3	1.5	1.4	2.0	0.00069	95
Chromic acid anodizing	none	Cr+6	3	C	1.1	1.3	1.2	1.7	0.00058	95
Chromic acid anodizing	WS/MX/HEPA	total Cr	1	NR	0.0013	0.0013	0.0013	0.0019	0.00000068	95

(a) CBME = chevron blade mist eliminator, MPME = mesh pad mist eliminator, PBS = packed bed scrubber, CMP = composite mesh pad, PB = polypropylene balls, FS = fume suppressant, MX = moisture extractor, PC = polypropylene chips, PS = plastic sheet.

(b) NR = not rated.

(c) Emission factors for electroplating in units of milligrams per ampere-hour and grains per ampere-hour; emission factors for chromic acid anodizing in units of grams per hour-square meter and grains per hour-square foot. NA = not applicable. ND = no data available.

TABLE 4-58. SUMMARY OF CANDIDATE EMISSION FACTORS FOR CHROMIUM ELECTROPLATING

TABLE 4-58. SUMMARY OF CANDIDATE EMISSION FACTORS FOR CHROMIUM ELECTROPLATING

APCD(a)	Pollutant(b)	No. of tests	Emission factor(c) mg/A-hr	gr/A-hr	mg/DSCM	gr/DSCF	Rating	References
HARD CHROMIUM ELECTROPLATING								
none	chromium compounds	19	7.8	0.12	NA	NA	B	1-9,11,13-14,25-26,31,77
MX	chromium compounds	3	0.51	0.0079	0.31	0.00014	D	4,10
PB	chromium compounds	1	1.8	0.028	0.96	0.00042	D	6
FS	chromium compounds	1	1.8	0.027	0.37	0.00016	D	11
FS/PB	chromium compounds	3	0.11	0.0018	0.069	3.0E-005	D	14,25-26
PBS	chromium compounds	9	0.18	0.0027	0.047	2.1E-005	C	7-9,14,71,77,81
PBS/FS/PB	chromium compounds	3	0.016	0.00025	0.0059	2.6E-006	D	14,88,93
CBME	chromium compounds	3	0.35	0.0054	0.20	8.8E-005	D	1-3
MPME	chromium compounds	7	0.13	0.0020	0.028	1.2E-005	D	4-6,20,31
PBS/MPME	chromium compounds	2	0.00053	0.0000082	0.000073	3.2E-008	E	85
CMP	chromium compounds	4	0.026	0.00040	0.0087	3.8E-006	D	10-12
	total PM/PM-10 (d)	NA	2.1Cr	2.1Cr	2.1Cr	2.1Cr	D	
DECORATIVE CHROMIUM ELECTROPLATING								
none	chromium compounds	4	2.1	0.033	NA	NA	D	15-16,27-28
FS	chromium compounds	4	0.010	0.00015	0.0027	1.2E-006	D	16,27-28
	total PM/PM-10 (d)	NA	2.1Cr	2.1Cr	2.1Cr	2.1Cr	D	
CHROMIC ACID ANODIZING								
			g/hr-m2	gr/hr-ft2				
none	chromium compounds	5	1.4	2.0	NA	NA	D	30,62-63,75,94
PB	chromium compounds	1	1.2	1.7	NA	NA	D	63
FS	chromium compounds	3	0.044	0.064	NA	NA	D	30,62-63
FS/PB	chromium compounds	2	0.017	0.025	NA	NA	D	30,63
PBS	chromium compounds	3	0.0068	0.0096	NA	NA	D	75,86
PBS/FS	chromium compounds	1	0.00052	0.00075	NA	NA	D	83
MPME	chromium compounds	1	0.0035	0.0051	NA	NA	E	20
PBS/MPME	chromium compounds	1	0.00038	0.00054	NA	NA	D	84
WS/MX/HEPA	chromium compounds	1	0.00033	0.00048	NA	NA	D	94
	total PM/PM-10 (d)	NA	2.1Cr	2.1Cr	NA	NA	D	

(a) MX = moisture extractor, FS = fume suppressant, PB = polypropylene balls, PBS = packed bed scrubber, WS = wet scrubber, CBME = chevron blade mist eliminator, MPME = mesh-pad mist eliminator, CMP = composite mesh pad, HEPA = high efficiency particulate air filter.

(b) Emissions comprised of hexavalent chromium.

(c) Emission factors for controlled emissions from electroplating presented based on total energy input and as concentration.

(d) Factors for total PM can be estimated as the ratio of the mass of chromic acid to the mass of chromium times the corresponding emission factor for chromium compounds. Because emissions consist of a mist, the total PM factors also can be used to estimate emissions of PM-10.

TABLE 4-59. SUMMARY OF CANDIDATE EMISSION FACTORS FOR ELECTROPLATING--OTHER METALS

TABLE 4-59. SUMMARY OF CANDIDATE EMISSION FACTORS FOR ELECTROPLATING--OTHER METALS

APCD(a)	Pollutant	No. of tests	Emission factor(b) mg/A-hr	gr/A-hr	mg/DSCM	gr/DSCF	Rating	References
COPPER-SULFATE ELECTROPLATING								
WS	copper	1	700	11	0.19	8.1E-005	E	67
COPPER-CYANIDE ELECTROPLATING								
MPME	cyanide	1	47	0.73	0.0062	2.7E-006	E	20
CADMIUM-CYANIDE ELECTROPLATING								
None	cadmium	2	2.6	0.040	0.019	8.4E-006	E	67
MPME	cadmium	1	0.29	0.0045	0.00033	1.5E-007	E	20
PBS	cadmium	2	0.38	0.0058	0.0038	1.7E-006	E	21,67
MPME	cyanide	1	160	2.4	0.23	0.00010	E	20
PBS	cyanide	1	32	0.49	0.14	5.9E-005	E	21
PBS	ammonia	1	23	0.35	0.096	4.2E-005	E	21
NICKEL ELECTROPLATING								
None	nickel	2	41	0.63	0.071	3.1E-005	E	67
WS	nickel	2	10	0.15	0.015	6.7E-006	E	67

(a) MPME = mesh pad mist eliminator, PBS = packed bed scrubber, WS = unspecified wet scrubber.

(b) Emission factors in units of milligrams per ampere-hour (mg/A-hr) and grains per ampere-hour (gr/A-hr) and as concentrations in milligrams per dry standard cubic meter and grains per dry standard cubic foot.

TABLE 4-60. SUMMARY OF CANDIDATE EMISSION FACTORS FOR ELECTROPLATING--OTHER METALS

TABLE 4-60. SUMMARY OF STATISICAL ANALYSES OF EMISSION DATA

Type of plating	Hard chromium	Hard chromium	Hard chromium	Hard chromium	Cr acid anodizing
Control method	none	PBS	PBS/FS	MPME	none
Emission factor units	gr/A-hr	gr/dscf	gr/dscf	gr/dscf	gr/hr-ft2
No. of emission tests	19	9	5	7	5
Minimum value	0.025	2.9E-006	1.6E-006	2.1E-006	0.29
Maximum value	0.28	0.000045	0.0000082	0.000019	4.8
Mean value	0.12	1.9E-005	4.7E-006	1.1E-005	2.0
Standard deviation	0.074	1.2E-005	3.0E-006	6.7E-006	1.7
Variance	0.0547	1.5E-010	9.0E-012	4.5E-011	3.0
Standard error	0.017	4.1E-006	1.3E-006	2.5E-006	0.78
95% Confidence interval					
Minimum	0.085	9.4E-006	9.9E-007	5.0E-006	0.0
Maximum	0.16	2.8E-005	8.5E-006	1.7E-005	4.1

REFERENCES FOR SECTION 4

1. *Chromium Electroplaters Test Report: Greensboro Industrial Platers, Greensboro, NC.* Entropy Environmentalists, Inc., Research Triangle Park, NC. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 86-CEP-1. March 1986.

2. *Chromium Electroplaters Test Report: Consolidated Engravers Corporation, Charlotte, NC.* Peer Consultants, Inc., Rockville, MD. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 87-CEP-9. May 1987.

3. *Chromium Electroplaters Test Report: Able Machine Company, Taylors, SC.* PEI Associates, Inc., Cincinnati, OH. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 86-CEP-3. June 1986.

4. *Chromium Electroplaters Test Report: Roll Technology Corporation, Greenville, SC.* Peer Consultants, Dayton, OH. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 88-CEP-13. August 1988.

5. *Chromium Electroplaters Test Report: Precision Machine and Hydraulic, Inc., Worthington, WV.* Peer Consultants, Dayton, OH. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 88-CEP-14. September 1988.

6. *Chromium Electroplaters Test Report: Hard Chrome Specialists, York, PA.* Peer Consultants, Dayton, OH. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report-89-CEP-15. January 1989.

7. *Chromium Electroplaters Test Report: Piedmont Industrial Platers, Statesville, NC.* Entropy Environmentalists, Inc., Research Triangle Park, NC. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 86-CEP-04. September 1986.

8. *Chromium Electroplaters Test Report: Steel Heddle, Inc., Greenville, SC.* PEI Associates, Inc., Cincinnati, OH. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 86-CEP-2. June 1986.

9. *Chromium Electroplaters Test Report: Fusion, Inc., Houston, TX.* Peer Consultants, Inc., Dayton, OH. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 89-CEP-16. May 1989.

10. *Hexalavent Chromium Emission Test Report: Precision Engineering, Seattle, WA.* Advanced Systems Technology, Atlanta, GA. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 91-CEP-18. December 1991.

11. *Emission Test Report: Emission Test Results for Total Chromium Inlet and Outlet of the South Fume Scrubber. Monroe Auto Equipment, Hartwell, GA.* IEA, Research Triangle Park, NC. Report No. 192-92-25. February 1992.

12. *Chromium Electroplaters Emission Test Report: Remco Hydraulics, Inc., Willits, CA.* Advanced Systems Technology, Atlanta, GA. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 91-CEP-17. June 1991.

13. *NESHAP Screening Method Chromium, Emission Test Report, Roll Technology Corporation, Greenville, SC, EMB Report No. 87-CEP-6,* U. S. Environmental Protection Agency, Research Triangle Park, NC. September 1987.

14. *Chromium Electroplating Emissions Comparison Test: Electric Chromic and Grinding Company, Santa Fe Springs, CO*. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 91-CEP-20. February 1992.

15. *Chromium Electroplaters Test Report: GMC Delco Products Division, Livonia, MI.* Peer Consultants, Inc., Dayton, OH. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 89-CEP-7. March 1987.

16. *Chromium Electroplaters Test Report: Automatic Die Casting Specialties, Inc., St. Clair Shores, MI*. Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 89-CEP-11. April 1988.

17. *Trivalent Chromium Emission Test Report: True Temper Sports, Seneca, SC.* Prepared for U. S. Environmental Protection Agency, Research Triangle Park, NC. EMB Report 92-CEP-21. June 1992.

18. Memo from Barker, B., MRI, to Vervaert, A., EPA/ISB. Engineering Analysis--Reliable Plating and Polishing Company. May 15, 1987.

19. *NEESA 2-158A, Chromium Emissions from Chromic Acid Anodizing Operations at Building 167, Naval Aviation Depot, Naval Air Station, Hanida, CA.* Naval Energy and Environmental Support Activity. Port Hueneme, CA. March 1990.

20. *NEESA 2-165, Chromium, Cyanide, and Cadmium Emission Tests Results. Building 604 Plating Facility. Source Identification 10-PEN17008406. Naval Aviation Depot, Pensacola.* Naval Energy and Environmental Support Activity. Port Hueneme, CA. January 1991.

21. Charles K. Yee, *Source Emissions Tests at Buildings 604 and 3557 at Naval Air Rework Facility, Pensacola, Florida*, Navy Environmental Support Office, Port Hueneme, CA. September 1980.

22. *Emissions Testing Conducted For Viron International at Alameda Naval Air Station on November 30 - December 13, 1990*, TMA Thermo Analytical, Inc., Richmond, CA. January 24, 1991.

23. *Chromium and Hexavalent Chromium Emissions Results Conducted For Viron International on November 27 - December 5, 1990*, TMA Thermo Analytical, Inc., Richmond, CA. December 27, 1990.

24. David J. Cook, and Drek A. Newton, *Chromium Emission Tests Results, Building 32 Plating Facility, BAAQMD Authority to Construct: 574, Naval Aviation Depot, Alameda*, Naval Energy and Environmental Support Activity, Port Hueneme, CA. May 1991.

25. *Test Results for Fume Suppressant Certification, M&T Chemical's Fumetrol 101 in Hard Chrome Plating Tanks*, Pacific Environmental Services, Inc., Arcadia, CA. November 1, 1989.

26. *Test Results for Fume Suppressant Certification, OMI International Corporation's Foam-Lok L in Hard Chrome Plating Tanks*, Pacific Environmental Services, Inc., Arcadia, CA. November 17, 1989.

27. *Test Results for Fume Suppressant Certification, McGean Rohco's Dis Mist NP in Decorative Chrome Plating Tanks*, Pacific Environmental Services, Inc., Arcadia, CA. March 16, 1990.

28. *Test Results for Fume Suppressant Certification, Omi International's Zero-Mist in Decorative Chrome Plating Tanks*, Pacific Environmental Services, Inc., Arcadia, CA. July 13, 1990.

29. *Determination of the Efficiency of a Mesh-pad Mist Eliminator Using the Constant Rate Sampling Method*, ChromeTech, Inc., Macedonia, OH. November 15, 1990.

30. *Test Results for Fume Suppressant Certification, Autochem, Inc., M&T's Fumetrol 101 in Chrome Anodizing Tanks*, Pacific Environmental Services, Inc., Arcadia, CA. March 1990.

31. William E. Powers and Seth Forester, *Source Emission Testing of the Building 195 Plating Shop at Norfolk Naval Shipyard, Portsmouth, VA, 11-18 March 1985*, Naval Energy and Environmental Support Activity, Port Hueneme, CA. May 1985.

32. *Emissions Testing Conducted For Viron International at Alameda Naval Air Station on December 6, 1990 - January 4, 1991*, TMA Thermo Analytical, Inc., Richmond, CA. February 15, 1991.

33. *Source Test Report, Naval Air Rework Facility, Norfolk Naval Air Station, Chrome Line 1 Demister, November 22, 1986*, Environmental Source Samplers, Inc., Charlotte, NC. December 1986.

34. *Emissions Test Report. SVS/MECA™ at A Chromic Anodizing Facility, Santa Ana, CA, on December 12, 1988 by Truesdart Laboratories, Inc. Tustin, CA.* Report Dated January 11, 1989.

35. *Emissions Stack Testing at McDonnell Douglas, Torrance, CA. Source Tested: Etching Tank Scrubber (Tank 193, Bldg. 2), Anodizing Tank Scrubber (Tank 195, Bldg 2). Date Tested: October 1 and 3, 1986.* Prepared for Lathana and Watkins, Attorneys at Law. Prepared by Engineering-Science, Pasadena, CA. Revised November 12, 1986.

36. *NEESA 2-119, September 1984 (Naval Energy and Environmental Support Activity, Port Huenana, CA) Source Emission Testing and Industrial Ventilation Survey of Bldg. 210 Plating Shop at Long Beach Naval Shipyard, Long Beach, CA.* May 7-June 2, 1984.

37. *NEESA 2-157a, Chromium Emissions from Chromic Plating and Chromic Acid Anodizing Operations at Bldg. 5, Naval Aviation Depot, Naval Air Station, Alameda, CA.* March 1990.

38. State of California Air Resources Board Test of Standard Nickel-Chromium Plating Company - Test Report C-86-085. April 6, 1987.

39. *South Coast (AQMD), Source Test Report: 86-0513. Conducted at Standard Plating Co., Los Angeles, CA. Hexavalent Chromium Emitted from a Wet Scrubber Control Chromic Plating, Tank #50*. Tested November 5, 1986. Issued January 27, 1987.

40. *Emissions Stack Testing, Tarby, Inc., Huntington Beach, CA. Source Tested: Chromic Plating Tank Exhaust Scrubber. Date Tested: December 11, 1986*. Prepared by Engineering Science, Pasadena, CA. January 12, 1987.

41. *Source Test Report of a CM&E Demonstration Unit Serving a Hard Chromic Plating Tank at Electrolyzing Inc., 1947 Hooper Avenue, Los Angeles, CA 90011*. Conducted for the Metal Finishing Association of Southern California by Pacific Environmental Services, Inc., Arcadia, CA. January 25, 1989.

42. *Source Test Report of a Tri-Mar Corporation Unit Serving a Hard Chrome Plating Tank at Chrome Plating Company, 1748 Workman Street, Los Angeles, CA 90031*. Conducted for the Metal Finishing Association of Southern California. Prepared by Pacific Environmental Services, Inc., Arcadia, CA. February 28, 1989.

43. *Source Test Report of a Monsanto Enviro-Chem Demonstration Unit Serving a Hard Chrome Plating Tank at Electronic Chrome and Grinding Co., Inc. 9218-32 Dice Road, Santa Fe Springs, CA 90670*. Conducted by Metal Finishing Association of Southern California. Prepared by Pacific Environmental Services, Arcadia, CA. January 23, 1989.

44. *Source Test Report of Ceco Filters Demonstration Unit Serving a Hard Chrome Plating Tank at Chrome Plating Company, 1748 Workman Street, Los Angeles, CA*. Conducted by Metal Finishing Association of Southern California. Prepared by Pacific Environmental Services, Arcadia, CA. March 1, 1989.

45. *State of California Air Resources Board. Chrome Plating Company. Total and Hexavalent Chromium Emissions from Chromium Plating Tanks 3 and 4*. Engineering Evaluation Branch Test Report. C-86-125. Report Dated April 3, 1987.

46. *Particulate and Chromic Acid Emission Evaluation, Process Stack, Consolidated Engravers Corp., Chester, SC*. July 1983, Job Number 3294-1, Prepared by David & Floyd, Inc. Greenwood, SC.

47. *Embee Plating Test, 2136 South Hathaway, Santa Ana, CA 92705*. Prepared by Environmental Research Group, Inc. Ann Arbor, MI. April 11, 1986.

48. *Chevrolet Livonia Bumper Plant No. 4 Heil Evaporator*. Tested by the Chevrolet Central Office of Environmental Engineering Department. Tested September 24, 1979.

49. *Source Test of Intermetro Industries, 9393 Arrow Highway, Cucamonga, CA*. Prepared by Truesdail Laboratories, Inc. Tested on February 24, 1980. Prepared on April 5, 1988.

50. *Source Test of Parmaco Pacific, Inc., 1101 W. Strick Avenue, Orange, CA.* Conducted on June 9, 1987. By Truesdail Laboratories, Inc. July 21, 1987.

51. *California Air Resources Board Test of Price Pfister, Inc*. Chromium Plating Tank #1. Total and Hexavalent Chromium Emissions. Report No. C-86-106. April 3, 1987.

52. *Source Test of Chrome Crankshaft Co., 6845 Florence Place, Bell Gardens, CA.* Conducted on April 2, 1987 by Truesdail Laboratories. April 30, 1987.

53. *Source Test Report No. 87-0256 of Plato Products, Inc., 2120 East Allen Avenue, Glendora, CA.* (Also called Source Test of Gresham, Varner, Savage, 600 North Arrowhead Avenue, San Bernandino, CA) Conducted by Truesdail Laboratories. July 29, 1987.

54. *Air Pollution Potential from Electroplating Operations*. Philip Diamond. Environmental Health Laboratory. McClellan Air Force Base, CA. April 1969. Report No. 69M-15.

55. *Inlet and Outlet of Scrubber at Standard Nickel Chromium Plating Company, Total and Hexavalent Chromium*, Truesdail Laboratories, Tustin, CA. December 17, 1986.

56. *Inlet and Outlet of Scrubber Serving Chrome Dip Tank, Particulate and Chromium Removal Efficiencies*, Truesdail Laboratories, Tustin, CA. April 11, 1986.

57. Wayne A. Nakagawa, *Source Test Report 85-481, Conducted at Plato Products, Inc., 2120 E. Allen Ave., Glendora, CA, Efficiency of, and Emissions From the Scrubber Serving a Hard Chrome Plating Tank*, South Coast Air Quality Management District, El Monte, CA. September 18, 1985.

58. *NESHAP Screening Study Chromium, Emission Test Report, C.S. Ohm Manufacturing Company, Sterling Heights, MI, EMB Report No. 85-CHM-10*, U. S. Environmental Protection Agency, Research Triangle Park, NC. December 1985.

59. *NESHAP Screening Study Chromium, Emission Test Report, Carolina Plating Company, Greenville, SC, EMB Report No. 85-CHM-11*, U. S. Environmental Protection Agency, Research Triangle Park, NC. December 1985.

60. *Chromium Removal Performance Test, CECO Filter*, Eastmount Engineering, Inc., Walpole, MA. April 15, 1992.

61. *Source Emission Evaluation, Boeing Company, Plant 2, Chromic Acid Anodizing Tank 5A, Seattle, Washington, August-December 1989*, AM Test, Inc., Redmond, WA. January 30, 1990.

62. *Efficiency of Harshaw Chemical's MSP-ST For Controlling Chrome Emissions From a Chromic Acid Anodizing Tank*, Pacific Environmental Services, Arcadia, CA. March 16, 1989.

63. *Report of Hexavalent Chromium Emission Testing On The Chromic Acid Anodizing and Tri-Acid Etching Processes at Buildings 3 and 5, Douglas Aircraft Company, Long Beach, CA*, Engineering-Science, Pasadena. CA, September 14, 1989.

64. *Emissions Stack Testing at McDonnell Douglas, Torrance, CA*, Engineering-Science, Pasadena, CA. November 12, 1986.

65. *Report of Air Pollution Source Testing At Douglas Aircraft Company Tank No. 195 and Tank No. 245*, Engineering-Science, Pasadena, CA. June 28, 1989.

66. *Report of Air Pollution Source Testing At Building No. 5 Scrubbers (HA7-5, HA7-6), Douglas Aircraft Company, Long Beach, California*, Engineering-Science, Pasadena, CA, January 12, 1990.

67. *Air Toxics Sampling Report Deutsch Engineered Connecting Devices, Oceanside, California*, Kleinfelder, Inc., San Diego, CA, June 28, 1991

68. *Nickel Compliance Emission Determination of the Packed Tower Evaporator, Compliance Testing for Nickel Emissions for American Nickeloid Company, Walnutport, Pennsylvania*, BCM, Plymouth Meeting, PA, June 1988.

69. *Report to Snap-On Tools Corporation, Kenosha, Wisconsin for Stack Emission Tests, Medical Products Scrubber, July 20, 1990*, Environmental Technology & Engineering Corporation, Elm Grove, WI, 1990.

70. *Final Report: Bethlehem Steel Corporation Chrome Line Scrubber*, BCM, Plymouth Meeting, PA, January 1992.

71. *Emission Test Results for Chromium Emission Rate of the Scrubber inlet at the U.S. Chrome Corporation Facility, Batavia, New York*, IEA, Research Triangle Park, NC, November 11, 1991.

72. *Chromium and Hexavalent Chromium Emissions Testing, Del Manufacturing, Oxnard Facility, August 29-30, 1991*, BTC Environmental, Inc., Ventura, CA, 1991.

73. *Summary of Source Test Results, Chrome Plating Tanks S-2 and S-3, Francis Plating of Oakland, Report No. 90117*, Bay Area Air Quality Management District, San Francisco, CA, February 15, 1990.

74. *Summary of Source Test Results, Scrubber Inlet from S-2 and S-3, Francis Plating of Oakland, Report No. 90118*, Bay Area Air Quality Management District, San Francisco, CA, February 15, 1989.

75. *Source Test Report for Total Chromium and Hexavalent Chromium From Chromic Acid Anodizing, General Dynamics-Convair, Lindbergh Field Facility, Building #1*, TEAM Environmental Services, Inc. San Marcos, CA, March 24, 1993.

76. *Gravco, Inc., Scrubber Efficiency Evaluation Project*, AirNova, Inc., Collingswood, NJ, November 1989.

77. *Source Emission Evaluation, Hytek Finishes Company, Chrome Abatement Equipment Performance Evaluation, Kent, Washington, May 18-19, 1989*, Am Test, Inc., Redmond, WA, July 14, 1989

78. *Source Test Report 5640-01, Lockheed Missiles and Space Company, Building 103, Tank 68*, B. C. Analytical, Emeryville, CA, January 23, 1991.

79. *Summary of Source Test Results, Mare Island Naval Shipyard, Plant #44, Source A436, Report No. 88162*, Bay Area Air Quality Management District, San Francisco, CA, May 9, 1988.

80. *Summary of Source Test Results, Mare Island Naval Shipyard, Plant #44, Source A439, Report No. 88163*, Bay Area Air Quality Management District, San Francisco, CA, May 9, 1988.

81. *Measurement of Hexavalent Chromium Emissions From Hard Chrome Plating Operations at Multichrome Company, Inc.*, Pacific Environmental Services, Inc., Baldwin Park, CA, January 29, 1993.

82. *NEESA 2-176, Chromium Emission Tests Results, Building 32 Plating Facility, BAAQMD Authority to Construct: 574, Naval Aviation Depot, Alameda*, Naval Energy and Environmental Support Activity, Port Hueneme, CA, May 1991.

83. *Measurement of Chromium Emissions From Chromic Acid Anodizing Operations in Building 2 at Naval Aviation Depot, North Island, San Diego, CA*, Benmol Corporation, San Diego, CA, October 29, 1991.

84. *Measurement of Chromium Emissions From Chromic Acid Anodizing Operations in Building 2 at Naval Aviation Depot, San Diego, CA*, Pacific Environmental Services, Inc., Baldwin Park, CA, April 8, 1992.

85. *NEESA 2-197, Chromium Emission Tests Results, Building 32 Plating Facility, BAAQMD Authority to Construct: 574, Naval Aviation Depot, Alameda*, Naval Energy and Environmental Support Activity, Port Hueneme, CA, August 1992.

86. *Measurement of Chromium Emissions From Chromic Acid Anodizing Operations in Building 2 at Naval Aviation Depot, San Diego, CA*, Pacific Environmental Services, Inc., Baldwin Park, CA, August 15, 1991.

87. *Naval Undersea Warfare Center Plating Plant, Building 72, Scrubber #3, Keyport, Washington, February 4, 1993*, Am Test Air Quality, Inc., Preston, WA, March 3, 1993.

88. *Compliance Test Procedure, Pacific Hard Chrome, Tests Conducted December 3, 1991*, Chemical Data Management Systems, Dublin, CA, January 2, 1991.

89. *Compliance Test Procedure, Pacific Hard Chrome, Tests Conducted July 18-19, 1991*, Chemical Data Management Systems, Dublin, CA, June 1991.

90. *Chromium Emissions Testing per PSAPCA Test Method Determination of Hexavalent Chromium Emissions from Decorative and Hard Chrome Electroplating and Chromic Acid Anodizing, Report 292690, Asko Processing, Inc., Chrome Plate Tank 1*, Olympic Scientific, Inc., Seattle, WA, December 6, 1990.

91. *Fume Scrubber Compliance Source Test Report, Amplica Incorporated, 950 Lawrence Drive, Newbury Park, CA 91320*, Environmental Monitoring and Services, Inc., Camarillo, CA 93010, 1987.

92. *Hexavalent Chromium Emissions, Armoloy of Ohio, April 13 and 14, 1994*, Stilson Laboratories, Inc., Columbus, OH, May 26, 1994.

93. *Compliance Test Results, Babbitt Bearing, Test Date May 27, 1992*, Chemical Data Management Systems, Dublin, CA, 1992.

94. *Source Test Measurement of Chromium Emissions From Chromic Acid Anodizing Tanks at Boeing Fabrication, 700 15th Street, S.W., Auburn, WA*, Pacific Environmental Services, Inc., Baldwin Park, CA, September 24, 1991.

95. *Wright Schuchard Harbor Company, Boeing Commercial Airplane Company, Building 17-68, Chrome Anodizing Tank L-16, KCH Scrubber Inlet/Outlet, Auburn, Washington, May 9-10, 1991*, Am Test Air Quality, Inc., Preston, WA, June 10, 1991.

96. *Boeing Defense and Space Group, Plant II, Building 2-31, Fume Scrubber #3 Exhaust Stack, Seattle, Washington, August 19-20, 1991*, Am Test Air Quality, Inc., Preston, WA, September 30, 1991.

97. Written correspondence from B. Sarven, Hayden Environmental Group, Inc., Miamisburg, Ohio, to J. Hilty, RAPCA, Dayton, Ohio, Results of test on Cascade Corporation Auto Chrome Line, March 1, 1991.

98. Aydil, M. and R. King, *Estimating Hexavalent Chromium Emissions From Electroless Chromium Conversion Coating Processes*, Roy F. Weston, Santa Barbara, CA, May 1995.

99. Telephone communication from J. Baker, JMC (USA), Inc., Research Triangle Park, NC, to Richard Marinshaw, Midwest Research Institute, Cary, NC, April 30, 1996.

TABLE A-1. SUMMARY OF EMISSION FACTOR CALCULATIONS FOR HARD CHROMIUM ELECTROPLATING.

APCD(a)	Pollutant measured	Data rating(b)	Available emission factors(c) mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	Emission factors used(c) mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	Factor rating	References	
none	Total Cr	A	5.1	0.078	0.00099	2.3	5.1	0.078	0.00099	2.3		1	
none	Total Cr	A	1.7	0.025	0.00041	0.94	1.7	0.025	0.00041	0.94		2	
none	Total Cr	A	9.1	0.14	0.0034	7.8	9.1	0.14	0.0034	7.8		3	
none	Cr+6	A	6.2	0.096	0.0013	3.0	6.2	0.096	0.0013	3.0		4	
none	Cr+6	A	16	0.25	0.0050	11	16	0.25	0.0050	11		5	
none	Cr+6	A	6.6	0.10	0.0019	4.3	6.6	0.10	0.0019	4.3		6	
none	Total Cr	A	18	0.28	0.0031	7.1	18	0.28	0.0031	7.1		7	
none	Total Cr	A	15	0.23	0.00069	1.6	15	0.23	0.00069	1.6		8	
none	Cr+6	A	6.0	0.092	0.00029	0.66	6.0	0.092	0.00029	0.66		9	F
none	Total Cr	A	6.1	0.094	0.00042	0.96	6.1	0.094	0.00042	0.96		11	
none	Total Cr	A	6.0	0.093	0.0012	2.6	6.0	0.093	0.0012	2.6		13	
none	Total Cr	A	1.7	0.026	0.00073	1.7	1.7	0.026	0.00073	1.7		14	
none	Total Cr	A	7.1	0.11	0.0016	3.8	7.1	0.11	0.0016	3.8		25	
none	Total Cr	A	7.5	0.12	0.0018	4.1	7.5	0.12	0.0018	4.1		26	
none	Cr+6	B	8.0	0.12	0.00032	0.73	8.0	0.12	0.00032	0.73		9	F
none	Cr+6	B	9.0	0.14	0.00031	0.71	9.0	0.14	0.00031	0.71		9	
none	Total Cr	B	3.5	0.055	0.00027	0.62	3.5	0.055	0.00027	0.62		31	
none	Cr+6	B	1.9	0.029	0.00014	0.32	1.9	0.029	0.00014	0.32		77	
none	Cr+6	B	14	0.21	0.0021	4.8	14	0.21	0.0021	4.8		77	
none	Cr+6	A	74	1.1	0.032	74						12	
none	Total Cr	C	3.8	0.059	0.00025	0.57						20	
none	Cr+6	C	1.1	0.018	0.000069	0.16						74	
none	Total Cr	D	5.9	0.091	0.00063	1.4						23	
none	Total Cr	D	7.0	0.11	0.00068	1.6						23	
none	Cr+6	D	34	0.53	0.0071	16						29	
none	Total Cr	D	79	1.2	0.0055	13						33	
	Total Cr	NR	4.6	0.071	0.00067	1.5						59	
Candidate emission factor						Average	7.8	0.12	0.0014	3.1	B	1-9,11,13-14,25-26,31,77	
						Minimum	1.65	0.025	0.00014	0.32		0	
						Maximum	18.0	0.28	0.0050	11.44		0	
						Std Dev.	4.77	0.0740	0.0013	2.97			
						Rel Std Dev.	0.61	0.61	0.95	0.95			
						Median	6.60	0.102	0.00099	2.27			
						Geo Mean	6.3	0.098	0.00088	2.01			
						5th percentile	1.7	0.026	0.00026	0.59			
						25th percentile	5.52	0.085	0.00037	0.84			
						75th percentile	9.05	0.14	0.0018	4.21			
						95th percentile	16.20	0.25	0.0036	8.15			
MX	Cr+6	A	0.85	0.013	0.00019	0.43	0.85	0.013	0.00019	0.43		4	
MX	Cr+6	A	0.52	0.0081	0.00015	0.34	0.52	0.0081	0.00015	0.34		10	
MX	Cr+6	A	0.17	0.0027	6.9E-005	0.16	0.17	0.0027	6.9E-005	0.16		10	
Candidate emission factor						Average	0.51	0.0079	0.00014	0.31	D	4,10	

TABLE A-1. (Continued)

APCD(a)	Pollutant measured	Data rating(b)	Available emission factors(c) mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	Emission factors used(c) mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	Factor rating	References	
PB	Cr+6	B	1.8	0.028	0.00042	0.96	1.8	0.028	0.00042	0.96			6
PB/PS	Cr+6	B	5.5	0.085	0.0028	6.4							90
Candidate emission factor							1.8	0.028	0.00042	0.96	D	6	
FS	Total Cr	A	1.8	0.027	0.00016	0.37	1.8	0.027	0.00016	0.37			11
FS	Total Cr	C	0.23	0.0036	0.000015	0.034							20
Candidate emission factor							1.8	0.027	0.00016	0.37	D	11	
FS/PB	Total Cr	A	0.037	0.00057	1.6E-005	0.037	0.037	0.00057	1.6E-005	0.037			14
FS/PB	Total Cr	A	0.19	0.0030	4.6E-005	0.11	0.19	0.0030	4.6E-005	0.11			25
FS/PB	Total Cr	A	0.11	0.0017	2.9E-005	0.065	0.11	0.0017	2.9E-005	0.065			26
Candidate emission factor						Average	0.11	0.0018	3.0E-005	0.069	D	14,25-26	
PBS	Total Cr	A	0.36	0.0056	2.3E-005	0.052	0.36	0.0056	2.3E-005	0.052			8
PBS	Total Cr	A	0.072	0.0011	2.6E-005	0.059	0.072	0.0011	2.6E-005	0.059			14
PBS	Cr+6	A	0.45	0.0070	1.7E-005	0.039	0.45	0.0070	1.7E-005	0.039			9
PBS	Cr+6	A	0.20	0.0030	1.0E-005	0.023	0.20	0.0030	1.0E-005	0.023			9 F
PBS	Cr+6	B	0.22	0.0034	9.5E-006	0.022	0.22	0.0034	9.5E-006	0.022			9
PBS	Total Cr	B	0.10	0.0016	1.6E-005	0.037	0.10	0.0016	1.6E-005	0.037			7
PBS	Cr+6	A	0.080	0.0012	0.000045	0.10	0.080	0.0012	0.000045	0.10			71
WS	Cr+6	B	0.30	0.0046	2.0E-005	0.046	0.30	0.0046	2.0E-005	0.046			77
WS	Cr+6	B	0.023	0.00035	0.0000029	0.0066	0.023	0.00035	0.0000029	0.0066			81
WS	Cr+6	C	1.2	0.018	0.000048	0.11							77
PBS	Total Cr	D	0.14	0.0022	1.1E-006	0.0025							22
PBS	Total Cr	D	0.023	0.00036	2.0E-006	0.0046							23
PBS	Total Cr	NR	0.35	0.0054	4.2E-005	0.095							59
PBS	Total Cr	NR	0.017	0.00026	9.3E-007	0.0021							23
Candidate emission factor						Average	0.18	0.0027	2.1E-005	0.047	D	7-9,14,71,77,81	
						Minimum	0.023	0.00035	2.90E-006	0.0066			
						Maximum	0.45	0.0070	4.50E-005	0.10			
						Std Dev.	0.15	0.0023	1.22E-005	0.028			
						Rel Std Dev.	0.83	0.84	5.88E-001	0.59			
						Median	0.20	0.0030	1.70E-005	0.04			
						Geo Mean	0.15	0.0022	1.51E-005	0.034			
						5th percentile	0.043	0.00066	5.54E-006	0.013			
						25th percentile	0.080	0.0012	1.00E-005	0.023			
						75th percentile	0.30	0.0046	2.27E-005	0.052			
						95th percentile	0.42	0.0064	3.74E-005	0.086			
PBS/FS/PB	Total Cr	A	0.0096	0.00015	3.7E-006	0.0084	0.0096	0.00015	3.7E-006	0.0084			14
PBS/PC	Total Cr	B	0.0051	0.000079	0.0000025	0.0057	0.0051	0.000079	0.0000025	0.0057			88
PBS/FS	Total Cr	B	0.034	0.00053	0.0000016	0.0037	0.034	0.00053	0.0000016	0.0037			93
PBS/PC	Total Cr	C	0.013	0.00020	0.0000082	0.019							89
PBS/MX/PB/PS	Cr+6	C	0.014	0.00022	0.0000076	0.017							90
Candidate emission factor						Average	0.016	0.00025	2.6E-006	0.0059	D	14,88,93	

TABLE A-1. (Continued)

APCD(a)	Pollutant measured	Data rating(b)	Available emission factors(c) mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	Emission factors used(c) mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	Factor rating	References	
CBME	Total Cr	A	0.68	0.011	0.00015	0.35	0.68	0.011	0.00015	0.35			1
CBME	Total Cr	A	0.22	0.0033	5.2E-005	0.12	0.22	0.0033	5.2E-005	0.12			2
CBME	Total Cr	A	0.15	0.0023	5.8E-005	0.13	0.15	0.0023	5.8E-005	0.13			3
Candidate emission factor						Average	0.35	0.0054	8.8E-005	0.20	D	1-3	
MPME	Cr+6	A	0.042	0.00065	1.4E-005	0.032	0.042	0.00065	1.4E-005	0.032			5
MPME	Cr+6	A	0.073	0.0011	1.9E-005	0.043	0.073	0.0011	1.9E-005	0.043			6
MPME	Total Cr	B	0.28	0.0043	2.1E-006	0.0047	0.28	0.0043	2.1E-006	0.0047			20
MPME	Total Cr	B	0.15	0.0024	1.1E-005	0.025	0.15	0.0024	1.1E-005	0.025			31
FS/MPME	Total Cr	B	0.30	0.0047	2.3E-006	0.0052	0.30	0.0047	2.3E-006	0.0052			20
MX/MPME	Cr+6	A	0.083	0.0013	1.7E-005	0.039	0.083	0.0013	1.7E-005	0.039			4
MPME/PB	Cr+6	B	0.063	0.0010	1.3E-005	0.030	0.063	0.0010	1.3E-005	0.030			6
MPME	Cr+6	B	0.080	0.0012	4.5E-005	0.10						71	
MPME	Total Cr	D	18	0.28	0.0013	3.0							33
Candidate emission factor						Average	0.13	0.0020	1.2E-005	0.028	D	4-6,20,31	
						Minimum	0.042	0.00065	2.05E-006	0.0047			
						Maximum	0.30	0.0047	1.90E-005	0.043			
						Std Dev.	0.11	0.0017	6.70E-006	0.015			
						Rel Std Dev.	0.84	0.84	0.56	0.56			
						Median	0.083	0.0013	1.30E-005	0.030			
						Geo Mean	0.11	0.0017	8.43E-006	0.019			
						5th percentile	0.048	0.00076	2.11E-006	0.0048			
						25th percentile	0.068	0.0011	6.68E-006	0.015			
						75th percentile	0.22	0.0034	1.55E-005	0.035			
						95th percentile	0.30	0.0046	1.84E-005	0.042			
PBS/MPME	Total Cr	C	0.00058	9.0E-006	3.4E-008	7.8E-005	0.00058	9.0E-006	3.4E-008	7.8E-005			85
PBS/MPME	Total Cr	C	0.00047	7.3E-006	3.0E-008	6.9E-005	0.00047	7.3E-006	3.0E-008	6.9E-005			85
PBS/FBME	Total Cr	NR	0.00083	1.3E-005	7.1E-008	0.00016							24
PBS/FBME	Total Cr	NR	0.00050	7.7E-006	6.8E-008	0.00015							24
						Average	0.00053	8.2E-006	3.2E-008	7.3E-005	E		85
CMP	Cr+6	A	0.014	0.00022	4.5E-006	0.010	0.014	0.00022	4.5E-006	0.010			10
CMP	Total Cr	A	0.079	0.0012	5.0E-006	0.011	0.079	0.0012	5.0E-006	0.011			11
FS/CMP	Total Cr	A	0.041	0.00064	3.5E-006	0.0080	0.041	0.00064	3.5E-006	0.0080			11
PBS/CMP	Cr+6	A	0.0041	6.3E-005	2.6E-006	0.0060	0.0041	6.3E-005	2.6E-006	0.0060			12
Candidate emission factor						Average	0.026	0.00040	3.8E-006	0.0087	D	10-12	
						Minimum	0.004	0.000063	2.61E-006	0.0060			
						Maximum	0.079	0.0012	4.95E-006	0.011			
						Std Dev.	0.033	0.00051	1.05E-006	0.002			
						Rel Std Dev.	1.28	1.28	0.28	0.28			
						Median	0.028	0.00043	4.01E-006	0.0092			
						Geo Mean	0.021	0.00032	3.78E-006	0.0087			
						5th percentile	0.006	0.000087	2.74E-006	0.0063			
						25th percentile	0.012	0.00018	3.28E-006	0.0075			
						75th percentile	0.051	0.00078	4.63E-006	0.011			
						95th percentile	0.073	0.0011	4.89E-006	0.011			

TABLE A-1. (Continued)

(a) CBME = chevron blade mist eliminator, MPME = mesh pad mist eliminator, PBS = packed bed scrubber, CMP = composite mesh pad, PB = polypropylene balls, FS = fume suppresant, MX = moisture extractor, WS = unspecified wet scrubber, PC = polypropylene chips.

(b) NR = not rated.

(c) Emission factors in units of milligrams per ampere-hour and grains per ampere-hour (uncontrolled and controlled) and as concentrations in milligrams per dry standard cubic meter and grains per dry standard cubic foot.

07/23/96

TABLE A-2. SUMMARY OF EMISSION FACTOR CALCULATIONS FOR DECORATIVE CHROMIUM ELECTROPLATING.

	Pollutant	Data	Available emission factors(c)				Emission factors used(c)				Factor	
APCD(a)	measured	rating(b)	mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	rating	References
none	Total Cr	A	1.7	0.027	0.00063	1.4	1.7	0.027	0.00063	1.4		15
none	Cr+6	A	1.3	0.021	0.00040	0.92	1.3	0.021	0.00040	0.92		16
none	Total Cr	A	4.3	0.067	0.00021	0.48	4.3	0.067	0.00021	0.48		27
none	Total Cr	A	1.0	0.016	0.00018	0.41	1.0	0.016	0.00018	0.41		28
Candidate emission factor							2.1	0.033	0.00036	0.81	D	15-16,27-28
FS	Cr+6	A	0.0029	4.5E-005	9.3E-007	0.0021	0.0029	4.5E-005	9.3E-007	0.0021		16
FS	Cr+6	A	0.0067	0.00010	2.0E-006	0.0046	0.0067	0.00010	2.0E-006	0.0046		16
FS	Total Cr	A	0.016	0.00025	9.3E-007	0.0021	0.016	0.00025	9.3E-007	0.0021		27
FS	Total Cr	A	0.0092	0.00014	1.1E-006	0.0025	0.0092	0.00014	1.1E-006	0.0025		28
FS	Total Cr	NR	6.5	0.10	0.00067	1.5						58
FS	Total Cr	NR	0.047	0.00073	4.7E-006	0.011						58
FS/PBS	Total Cr	NR	10	0.16	0.00089	2.0						58
Candidate emission factor							0.010	0.00015	1.2E-006	0.0027	D	16,27-28

(a) FS = fume suppressant, PBS = packed bed scrubber.
(b) NR = not rated.
(c) Emission factors in units of milligrams per ampere-hour and grains per ampere-hour (uncontrolled and controlled) and as concentrations in milligrams per dry standard cubic meter and grains per dry standard cubic foot.

07/15/96

TABLE A-3. SUMMARY OF EMISSION FACTOR CALCULATIONS FOR CHROMIC ACID ANODIZING.

APCD(a)	Pollutant measured	Data rating(b)	Available emission factors(c) g/hr-m2	Available emission factors(c) gr/hr-ft2	Emission factors used(c) g/hr-m2	Emission factors used(c) gr/hr-ft2	Factor rating	References
none	Total Cr	A	0.64	0.92	0.64	0.92		30
none	Cr+6	A	0.22	0.31	0.22	0.31		75
none	Total Cr	B	1.2	1.7	1.2	1.7		62
none	Total Cr	B	3.4	4.8	3.4	4.8		63
none	Cr+6	B	1.5	2.2	1.5	2.2		94
none	total Cr	C	1.4	2.0				95
Candidate emission factor					1.4	2.0	D	30,62-63,75,94
PB	Total Cr	B	1.2	1.7	1.2	1.7		63
Candidate emission factor					1.2	1.7	D	63
FS	Total Cr	A	0.050	0.072	0.050	0.072		30
FS	Total Cr	B	0.057	0.082	0.057	0.082		62
FS	Total Cr	C	0.026	0.037	0.026	0.037		63
FS	Total Cr	NR	0.0050	0.0072				63
Candidate emission factor					0.044	0.064	D	30,62-63
FS/PB	Total Cr	A	0.018	0.026	0.018	0.026		30
FS/PB	Total Cr	C	0.016	0.023	0.016	0.023		63
Candidate emission factor					0.017	0.025	D	30,63
WS	Cr+6	B	0.0056	0.0081	0.0056	0.0081		75
PBS	Cr+6	B	0.013	0.018	0.013	0.018		86
PBS	Cr+6	C	0.0019	0.0027	0.0019	0.0027		86
Candidate emission factor					0.0068	0.0096	D	75,86
PBS/FS	Cr+6	B	0.00052	0.00075	0.00052	0.00075		83
PBS/FS	Cr+6	D	0.0030	0.0044				83
Candidate emission factor					0.00052	0.00075	D	83

TABLE A-3. (Continued)

APCD(a)	Pollutant measured	Data rating(b)	Available emission factors(c) g/hr-m2	Available emission factors(c) gr/hr-ft2	Emission factors used(c) g/hr-m2	Emission factors used(c) gr/hr-ft2	Factor rating	References
MPME	Total Cr	D	0.0035	0.0051	0.0035	0.0051		20
Candidate emission factor					0.0035	0.0051	E	20
PBS/MPME	Cr+6	B	0.00038	0.00054	0.00038	0.00054		84
Candidate emission factor					0.00038	0.00054	D	
WS/MX/HEPA	Cr+6	B	0.00033	0.00048	0.00033	0.00048		94
WS/MX/HEPA	total Cr	NR	0.0013	0.0019				95
Candidate emission factor					0.00033	0.00048	D	94

(a) PB = polypropylene balls, FS = fume suppresant, MPME = mesh-pad mist eliminator, WS = unspecified wet scrubber, MX = moisture extractor, HEPA = high efficiency particulate air filter.
(b) NR = not rated.
(c) Emission factors in units of grams per hour-square meter and grains per hour-square foot.

TABLE A-4. SUMMARY OF EMISSION FACTOR CALCULATIONS FOR NONCHROMIUM ELECTROPLATING.

APCD(a)	Pollutant measured	Data rating(b)	Available emission factors(c) mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	Emission factors used(c) mg/A-hr	gr/A-hr	gr/DSCF	mg/DSCM	Factor rating	References
COPPER-CYANIDE ELECTROPLATING												
MPME	cyanide	C	47	0.73	2.7E-006	0.0062	47	0.73	2.7E-006	0.0062		20
Candidate emission factor							47	0.73	2.7E-006	0.0062	E	20
COPPER-SULFATE ELECTROPLATING												
WS	copper	C	700	11	8.1E-005	0.19	700	11	8.1E-005	0.19		67
Candidate emission factor							700	11	8.1E-005	0.19	E	67
CADMIUM-CYANIDE ELECTROPLATING												
None	cadmium	C	1.8	0.028	1.3E-005	0.030	1.8	0.028	1.3E-005	0.030		67
None	cadmium	C	3.4	0.052	0.0000037	0.0085	3.4	0.052	0.0000037	0.0085		67
Candidate emission factor							2.6	0.040	8.4E-006	0.019	E	67
MPME	cyanide	C	160	2.4	0.00010	0.23	160	2.40	0.00010	0.23		20
Candidate emission factor							160	2.40	0.00010	0.23	E	20
MPME	cadmium	C	0.29	0.0045	1.5E-007	0.00033	0.29	0.0045	1.5E-007	0.00033		20
Candidate emission factor							0.29	0.0045	1.5E-007	0.00033	E	20
PBS	cyanide	C	32	0.49	5.9E-005	0.14	32	0.49	5.9E-005	0.14		21
Candidate emission factor							32	0.49	5.9E-005	0.14	E	21
PBS	cadmium	C	0.50	0.0077	9.3E-007	0.0021	0.50	0.0077	9.3E-007	0.0021		21
WS	cadmium	B	0.25	0.0038	0.0000024	0.0055	0.25	0.0038	2.4E-006	0.0055		67
Candidate emission factor							0.38	0.0058	1.7E-006	0.0038	E	21,67
PBS	ammonia	C	23	0.35	4.2E-005	0.096	23	0.35	4.2E-005	0.096		21
Candidate emission factor							23	0.35	4.2E-005	0.096	E	21
NICKEL ELECTROPLATING												
None	nickel	B	57	0.88	4.0E-005	0.092	57	0.88	4.0E-005	0.092		67
None	nickel	C	25	0.38	0.000022	0.050	25	0.38	0.000022	0.050		67
Candidate emission factor							41	0.63	3.1E-005	0.071	E	67
WS	nickel	B	8.4	0.13	5.7E-006	0.013	8.4	0.13	5.7E-006	0.013		67
WS	nickel	B	11	0.17	0.0000076	0.017	11	0.17	0.0000076	0.017		67
Candidate emission factor							10	0.15	6.7E-006	0.015	E	67

(a) MPME = mesh pad mist eliminator, PBS = packed bed scrubber, Ws = unspecified wet scrubber.
(b) NR = not rated.
(c) Emission factors in units of milligrams per ampere-hour and grains per ampere-hour (uncontrolled and controlled) and as concentrations in milligrams per dry standard cubic meter and grains per dry standard cubic foot.

5. AP-42 SECTION 12.20

A proposed AP-42 Section 12.20, Electroplating, is presented in the following pages as it would appear in the document.