SECOND DRAFT

BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT) BACKGROUND DOCUMENT FOR CYANIDE WASTES

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December 19, 1988

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1. INTRODUCTION

Pursuant to Section 3004(m) of the Resource Conservation and Recovery Act (RCRA), enacted as a part of the Hazardous and Solid Waste Amendments (HSWA) on November 8, 1984, the Environmental Protection Agency (EPA) is proposing treatment standards based on Best Demonstrated Available Technology (BDAT) for the cyanide-containing electroplating and metal heat treating wastes and similar off-specification product, leak, and spill wastes. These wastes are identified in 40 CFR 261.32 as F006, F007, F008, F009, F010, F011, F012, and F019 and in 40 CFR 261.33 as P013, P021, P029, P030, P063, P074, P098, P099, P104, P106, and P121. Compliance with these BDAT treatment standards is a prerequisite for the placement of the waste in units designated as land disposal units according to 40 CFR Part 268. The effective date of the final treatment standards will be June 8, 1989.

This background document provides the Agency's technical support for selecting and developing treatment standards for the constituents to be regulated for the electroplating and metal heat treating wastes. Sections 2 through 7 present information for the F-code wastes. Section 2 describes the industries affected by regulation of these wastes, explains the processes generating these wastes, and presents available waste characterization data. Section 3 specifies the applicable and demonstrated treatment technologies for these wastes and presents descriptions of those technologies. Section 4 contains performance data for the demonstrated technologies, and Section 5 analyzes these performance data to determine BDAT for each waste. In

Section 6 the rationale for selection of regulated constituents is presented, and in Section 7 the proposed BDAT treatment standards are calculated for the regulated constituents selected. Section 8 discusses associated inorganic cyanide P-code wastes and details the development of the proposed treatment standards for these wastes.

EPA's promulgated methodology for developing BDAT treatment standards is described in two separate documents: Generic Quality Assurance Project Plan for Land Disposal Restriction Program ("BDAT") (USEPA 1987) and Methodology for Developing BDAT Treatment Standards (USEPA 1988c). The second document also discusses the petition process to be followed in requesting a variance from the BDAT treatment standards.

For the purpose of determining the applicability of the proposed treatment standards, wastewaters are defined as wastes containing less than 1 percent (weight basis) total suspended solids* and less than 1 percent (weight basis) total organic carbon (TOC). Waste not meeting this definition must comply with the proposed treatment standards for nonwastewaters.

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*The term "total suspended solids" (TSS) clarifies EPA's previously used terminology of "total solids" and "filterable solids." Specifically, total suspended solids is measured by Method 209c. (Total Suspended Solids Dried at 103 to 105°C) in Standard Methods for the Examination of Water and Wastewater, 16th Edition (APHA, AWWA, and WPCF 1985).

Cyanide-containing wastes generated in metal finishing operations contain cyanide and BDAT list metals. These wastes are divided into three subcategories: metal finishing aqueous liquids (F007, F008, F009, and F011), metal finishing organic liquids (F010), and metal finishing sludges (F006, F012, and F019). Wet air oxidation followed by chemical precipitation and filtration is determined to be BDAT for cyanide and BDAT list metals for the metal finishing aqueous liquid wastewaters and for the metal finishing sludges wastewaters. For cyanide in nonwastewaters for these two subcategories, BDAT treatment standards are based on generation of these wastes from a treatment system consisting of alkaline chlorination followed by chemical precipitation and sludge dewatering. For metals in nonwastewaters, stabilization is determined to be BDAT for the metal finishing aqueous liquids and the metal finishing sludges. For cyanide in the metal finishing organic liquids wastes, incineration is determined to be BDAT for nonwastewaters and wet air oxidation is determined to be BDAT for wastewaters, such as scrubber water produced in incineration treatment of these wastes.

Testing procedures for all sample analyses performed for the regulated constituents are specifically identified in Appendix A of this background document. For cyanide, the proposed treatment standards reflect total waste concentration. The units for the total waste concentration are mg/kg (parts per million on a weight-by-weight basis) for nonwastewaters and mg/l (parts per million on a weight-by-volume basis) for wastewaters. For BDAT list metals in nonwastewaters, the proposed treatment standards reflect the leachate concentration from the

TCLP. The units for the leachate concentration are mg/l. For BDAT list metals in wastewaters, the proposed treatment standards reflect the total waste concentration, and the units are mg/l. The proposed treatment standards for the wastewater and nonwastewater forms of the metal finishing wastes are shown in Tables 1-1 through 1-4. The proposed treatment standards for the related P-code wastes are presented in Table 1-5. Wastes that, as generated, contain the regulated constituents at concentrations that do not exceed the proposed treatment standards are not restricted from land disposal units.

Table 1-1. BDAT Treatment Standards - Metal Finishing Aqueous Liquids Subcategory for F007, F008, F009, and F011

NONWASTEWATERS

Constituent	Maximum for any single grab sample: Total composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	110	Not applicable
Cyanide (amenable)	0.064	Not applicable
Cadmium	Not applicable	0.066
Chromium	Not applicable	5.2
Lead	Not applicable	0.51
Nickel	Not applicable	0.32
Silver	Not applicable	0.072

WASTEWATERS

Constituent	Maximum for any single grab sample: Total composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	12	Not applicable
Cyanide (amenable)	1.3	Not applicable
Chromium	0.32	Not applicable
Lead	0.04	Not applicable
Nickel	0.44	Not applicable

Table 1-2. BDAT Treatment Standards - Metal Finishing Organic Liquids Subcategory for F010

NONWASTEWATERS

Constituent	Maximum for any single grab sample: Total composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	1.5	Not applicable

WASTEWATERS

Constituent	Maximum for any single grab sample: Total Composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	12	Not applicable
Cyanide (amenable)	1.3	Not applicable

Table 1-3. BDAT Treatment Standards - Metals
Finishing Sludges Subcategory for F006

NONWASTEWATERS

Constituent	Maximum for any single grab sample: Total composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	110	Not applicable
Cyanide (amenable)	0.064	Not applicable

WASTEWATERS

Constituent	Maximum for any single grab sample: Total composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	12	Not applicable
Cyanide (amenable)	1.3	Not applicable

Table 1-4. BDAT Treatment Standards - Metal Finishing Sludges Subcategory for F012 and F019

NONWASTEWATERS

Constituent	Maximum for any single grab sample: Total composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	110	Not applicable
Cyanide (amenable)	0.064	Not applicable
Cadmium	Not applicable	0.066
Chromium	Not applicable	5.2
Lead	Not applicable	0.51
Nickel	Not applicable	0.32
Silver	Not applicable	0.072

WASTEWATERS

Constituent	Maximum for any single grab sample: Total composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	12	Not applicable
Cyanide (amenable)	1.3	Not applicable
Chromium	0.32	Not applicable
Lead	0.04	Not applicable
Nickel	0.44	Not applicable

Table 1-5. BDAT Treatment Standards for P013, P021, P029, P030, P063, P074, P098, P099, P104, P106, and P121

NONWASTEWATERS

Constituent	Maximum for any single grab sample: Total composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	110	Not applicable
Cyanide (amenable)	0.064	Not applicable
Copper (P029 only)	Not applicable	0.71
Nickel (P074 only)	Not applicable	0.30
Silver (P099 and P104 only)	Not applicable	0.07
Zinc (P121 only)	Not applicable	0.086

WASTEWATERS

Constituent	Maximum for any single grab sample: Total composition (mg/kg)	Maximum for any single grab sample: TCLP (mg/l)
Cyanide (total)	12	Not applicable
Cyanide (amenable)	1.3	Not applicable
Copper (P029 only)	0.42	Not applicable
Nickel (P074 only)	0.44	Not applicable
Silver (P099 and P104 only)	Reserved	Not applicable
Zinc (P121 only)	Reserved	Not applicable

2. INDUSTRIES AFFECTED AND WASTE CHARACTERIZATION

According to 40 CFR 261.32, the following wastes from electroplating, metal heat treating, and chemical conversion coating operations in the metal finishing industry are subject to the land disposal restriction prohibitions of HSWA:

Electroplating Operations

F006: Wastewater treatment sludges from electroplating operations except for the following processes: (1) sulfuric acid anodizing of aluminum; (2) tin plating on carbon steel; (3) zinc plating (segregated basis) on carbon steel; (4) aluminum or zinc-aluminum plating on carbon steel; (5) cleaning/stripping associated with tin, zinc, and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum.

F007: Spent cyanide plating bath solutions from electroplating operations.

F008: Plating bath residues from the bottom of plating baths from electroplating operations where cyanides are used in the process.

F009: Spent stripping or cleaning bath solutions from electroplating operations where cyanides are used in the process.

Heat Treating Operations

F010: Quenching bath residues from oil baths from metal heat treating operations where cyanides are used in the process.

F011: Spent cyanide solutions from salt bath pot cleaning from metal heat treating operations.

F012: Quenching wastewater treatment sludges from metal heat treating operations where cyanides are used in the process.

Chemical Conversion Coating Operations

F019: Wastewater treatment sludge from the chemical conversion coating of aluminum.

The hazardous waste F006 was regulated with the First Third scheduled wastes (53 FR 31138) except for cyanide, which is regulated with these wastes. Section 2.1 describes the industries affected by the land disposal restrictions for F006-F012 and F019, and Section 2.2 presents descriptions of the electroplating, heat treating, and chemical conversion coating processes generating these wastes. Section 2.3 presents the available waste characterization data for these wastes. Section 2.4 discusses the Agency's rationale for dividing these wastes into three separate subcategories.

2.1 Industries Affected

The listed wastes F006, F007, F008, and F009 are generated from electroplating operations where cyanides are used in the process. The listed wastes F010, F011, and F012 are generated from metal heat treating operations where cyanides are used in the process. The listed waste F019 is generated in chemical conversion coating of aluminum.

Electroplating operations consist of the following processes: (1) common and precious metals electroplating, except tin, zinc (segregated basis),* aluminum, and zinc-aluminum plating on carbon

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*Zinc plating (segregated basis) refers to noncyanidic zinc plating processes. For example, wastewater treatment sludges from zinc plating using baths formulated from zinc oxide and/or sodium hydroxide would be excluded from the listing, while sludges from baths formulated from zinc cyanide and/or sodium cyanide would not be excluded. Where both cyanidic and noncyanidic baths are used, the exclusion applies to sludges from the noncyanidic plating processes as long as they are segregated from sludges that result from cyanidic plating processes.

steel; (2) anodizing, except sulfuric acid anodizing of aluminum; (3) chemical etching and milling, except when performed on aluminum; and (4) cleaning and stripping, except when associated with tin, zinc, and aluminum plating on carbon steel.

Heat treating operations include tempering, carburizing, carbonitriding (cyaniding), nitriding, annealing, normalizing, austenizing, austempering, quenching, siliconizing, martempering, and malleabilizing.

In the preamble for the Effluent Limitations Guidelines for the Metal Finishing Industry (40 CFR Part 413), the Agency identified 13,500 facilities in the metal finishing industry that use 46 electroplating and metal finishing unit operations listed in 48 FR 32482 (including electroplating, heat treating, and chemical conversion coating).

Users of electroplating and heat treating operations generally fall under Standard Industrial Classification (SIC) code series 3000, which comprises fabricated metal products except machinery and transportation equipment; machinery except electrical; electrical and electronic machinery, equipment, and supplies; transportation equipment; measuring, analyzing, and controlling instruments; and miscellaneous manufacturing industries.

2.2 Process Description

Presented in this section are descriptions of each of the four operations that EPA has included as electroplating operations: electroplating, anodizing, chemical etching and milling, and metal

cleaning and stripping. Also provided are descriptions of the chemical conversion coating and metal heat treating operations.

2.2.1 Electroplating

Electroplating is the application of a thin surface coating of one metal upon another by electrodeposition. This surface coating is applied to provide corrosion protection, wear or erosion resistance, or antifrictional characteristics, or for decorative purposes. The electroplating of common metals includes the processes in which ferrous or nonferrous base material is electroplated with the following metals or metal alloys: copper, nickel, chromium, brass, bronze, zinc, tin, lead, cadmium, iron, aluminum, or combinations thereof. The alloy brass consists of copper and zinc; the alloy bronze consists of copper and tin. Precious metals electroplating includes the processes in which a ferrous or nonferrous base material is plated with gold, silver, palladium, platinum, rhodium, indium, ruthenium, iridium, osmium, or combinations thereof.

In electroplating, metal ions in acid, alkaline, or neutral solutions are reduced to the metal on negatively charged (cathodic) surfaces. The cathodic surfaces are the objects being plated. The metal ions in solution are usually replenished by the dissolution of metal from positively charged surfaces (anodes) or small pieces contained in inert wire or metal baskets. Replenishment by dissolving metal salts is also practiced, especially for chromium plating. In this case, an inert material must be selected for the anodes. Hundreds of different

electroplating solutions have been adopted commercially, but only two or three types are used widely for a particular metal or alloy. For example, cyanide solutions are popular for copper, zinc, brass, cadmium, silver, and gold. However, noncyanide alkaline solutions containing pyrophosphate have come into use recently for zinc and copper. Acid sulfate solutions are also used for plating zinc, copper, tin, and nickel, especially for relatively simple shapes. Cadmium and zinc are sometimes electroplated from neutral or slightly acidic chloride solutions.

Electroplating baths contain metals, metal salts, acids, alkalies, and various bath control compounds. All of these materials contribute to the wastewater streams through dragout of bath solutions on the plated parts, through batch dumps, or through floor spills. The sludge from the bottom of plating baths also contains metals and metal salts. Table 2-1 outlines some typical electroplating bath chemical compositions.

2.2.2 Anodizing

Anodizing is an electrolytic oxidation process that converts the surface of the metal to an oxide. The oxide coatings formed in anodizing provide corrosion protection, decorative surfaces, a base for painting and other coating processes, and special electrical and mechanical properties. Aluminum is the most frequently anodized material, while some magnesium and stainless steel (electropolish) and limited amounts of zinc and titanium are also treated.

Table 2-1 Chemical Compositions of Typical Electroplating Baths

Plating compound	Constituents	Concentration (g/l)
Cadmium cyanide	Cadmium oxide	22.5
	Cadmium (as metal)	19.5
	Sodium cyanide	77.9
	Sodium hydroxide	14.2
Cadmium fluoborate	Cadmium fluoborate	251.2
	Cadmium (as metal)	94.4
	Ammonium fluoborate	59.9
	Boric acid	27.0
Chromium electroplate	Chromic acid	172.3
	Sulfate	1.3
	Fluoride	0.7
Copper cyanide	Copper cyanide	26.2
	Free sodium cyanide	5.6
	Sodium carbonate	37.4
	Rochelle salt	44.9
Gold cyanide	Gold (as potassium gold cyanide)	8
	Potassium cyanide	30
	Potassium carbonate	30
	Dipotassium phosphate	30
Acid nickel	Nickel sulfate	330
	Nickel chloride	45
	Boric acid	37
Silver cyanide	Silver cyanide	35.9
	Potassium cyanide	59.9
	Potassium carbonate (min.)	15.0
	Silver (as metal)	23.8
	Free cyanide	41.2
Zinc sulfate	Zinc sulfate	374.5
	Sodium sulfate	71.5
	Magnesium sulfate	59.9

Reference: USEPA 1980.

Most anodizing is carried out by the immersion of racked parts in tanks; however, some continuous anodizing is done on large coils of aluminum, in a manner similar to continuous electroplating. For aluminum parts, the formation of the oxide occurs when the parts are made anodic in dilute sulfuric acid or dilute chromic acid solutions. The oxide layer begins formation at the outer surface of the base metal, and as the reaction proceeds, the oxide grows into the metal. The oxide formed last, known as the boundary layer, is located at the interface between the base metal and the oxide. The boundary is extremely thin and nonporous. Chromic acid anodic coatings are more protective than sulfuric acid coatings and have a relatively thick boundary layer.

2.2.3 Chemical Etching and Milling

These processes are used to produce specific design configurations and tolerances or surface appearances on parts by controlled dissolution of the base metal with chemical etchants. Included in this classification are the processes of chemical milling, chemical etching, and bright dipping. Chemical etching is the same process as chemical milling, but the rates and depths of metal removal are usually much greater in chemical milling. Typical solutions for chemical milling and etching include solutions of ferric chloride, nitric acid, ammonium persulfate, chromic acid, cupric chloride, hydrochloric acid, and combinations of these etchants. Bright dipping is a specialized form of etching that is used to remove oxide and tarnish from ferrous and nonferrous materials and is frequently performed just prior to plating.

Bright dipping solutions are usually composed of mixtures of two or more of the following acids: sulfuric, chromic, phosphoric, nitric, and hydrochloric.

2.2.4 Metal Cleaning and Stripping

Metal cleaning operations are designed to prepare metal surfaces for electroplating by removing oil, grease, dirt, and metal oxides, using water with or without a detergent or other dispersing agent. Cleaning can be done with alkaline (either electrolytically or nonelectrolytically), neutral, or acidic solutions. Nonelectrolytic cleaning, using both alkaline and acid solutions, can be done by either soak or spray methods. Acid cleaning can be referred to as pickling. Effective cleaning is also accomplished by alkaline electrolytic cleaning, or electrocleaning. Electrocleaning can be run cathodically (with the workpiece as the cathode), anodically (with the workpiece as the anode), or in periodic reversal (PR) mode, in which the current is periodically reversed from cathodic to anodic. Cleaning baths eventually become contaminated with metals derived from the cleaned parts.

Metal stripping is the chemical removal of metal plating coatings from base metal products by immersion of the plated part in an aqueous bath of appropriate chemical composition. When a plated coating on a part does not meet product quality specifications, it may be more economical to remove the metal plating and reuse the part than to scrap the entire plated part. Stripping baths can contain strong alkaline solutions of cyanide salts (to strip copper plating from steel parts, for

instance) or strong acids. The stripping solution dissolves the plated coating, leaving the base metal essentially untouched.

2.2.5 Chemical Conversion Coating

The conversion coating operation includes processes such as chromating, phosphating, metal coloring, and passivating. In chromating, a portion of the base metal is converted to a protective film formed by the coating solution. Aqueous solutions containing hexavalent chromium and other active organic or inorganic compounds are used. Chromate coatings are most frequently applied to aluminum, magnesium, cadmium, copper, brass, bronze, silver, and zinc.

Phosphating and coloring involve formation of surface metallic phosphates, oxides, or other compounds that impart a color to the metal while also forming a protective coating. Passivating is the formation of a protective film on metals, particularly stainless steel and copper, by immersion in an acid solution. Coloring is the only one of these three operations that may sometimes be used on aluminum.

2.2.6 Heat Treating

Heat treating is the modification of the physical properties of a metal piece through the application of controlled heating and cooling cycles. Heat treating is most frequently accomplished by placing the metal parts in an atmosphere (air or other gases) at the appropriate temperatures for the appropriate period of time. Heat treating can also be accomplished by placing parts (usually small items) in molten salt baths, including baths using cyanide salts. After immersion in the salt

bath, parts are removed and cooled in either a water or an oil bath or in air.

Heat treating may be used to develop a surface coating on the metal or to change the physical properties of the bulk metal. Cyanides are most often used in the heat treating operations of carburizing, carbonitriding, and nitriding, which add carbon, nitrogen, or both to the surface of the metal to form a hard surface coating.

2.3 Waste Characterization

This section presents the waste characterization data available to the Agency for the F006-F012 and F019 wastes. The major constituents in the wastes and their approximate concentrations are presented in Table 2-2, which is based on the available waste characterization data summarized in Tables 2-3 through 2-10. Tables 2-3 through 2-10 present, by waste code, the concentration for BDAT list constituents and other parameters identified for the specific wastes. These data were obtained from a variety of sources, as referenced in the tables, including literature sources and EPA sampling and analysis. Tables 2-11 and 2-12 present a major constituent summary and all waste characterization data, respectively, for K062 waste. (Tables 2-2 through 2-12 are at the end of Section 2.)

The metal finishing industry wastes are divided into three distinct groups based on the process generating the waste and the waste composition. F007, F008, F009, and F011 wastes generally contain from 1 percent cyanide (or approximately 2 percent, as NaCN) up to 15 percent

cyanide. These wastes also often contain dissolved metals (especially F007, F008, and F009, which typically contain approximately 2 percent BDAT metals) and must be treated for metals removal by chemical precipitation. F010 wastes may contain high concentrations of oil and grease, as well as cyanide concentrations similar to those of the first group. F006, F012, and F019 are wastewater treatment sludges typically containing less than 1 percent metals in a hydroxide or sulfide sludge. These wastes may contain 5 percent or more cyanide (i.e., 10 percent cyanide (as NaCN) in Table 2-2) but typically contain much less cyanide (<0.1 percent).

F007-F012 and F019 wastes contain BDAT metals and cyanides, as well as other inorganic compounds and water. Metals typically used in cyanide bath plating or metals that are stripped by cyanide stripping solutions include cadmium, copper, nickel, silver, and zinc. The concentrations of individual metals in F007, F008, and F009 wastes are dependent on the type of electroplating solutions used at the particular facility generating the waste. Additionally, F007-F009, F012, and F019 may contain low concentrations of volatile and semivolatile organic compounds.

The Agency wishes to emphasize that sludges generated from treatment of spent cyanide plating baths may also be classified as F006. An example is a wastewater treatment sludge generated from treatment of a spent cyanide plating solution (an F007 wastewater). This bath solution may be sent through cyanide destruction and chemical precipitation for metals removal separately from other wastewaters. In this case, the

precipitated residual would be F007. If the F007 waste were combined with other plant wastes (such as the listed wastes F008 or F009 or electroplating rinsewaters) before cyanide destruction and chemical precipitation treatment, then the precipitated residual from this treatment would be F006.

2.4 Determination of Waste Subcategories

In cases where EPA believes that constituents present in different waste codes can be treated to similar concentrations using the same treatment technologies, the Agency may combine the codes into a single subcategory.

Based on review of the processes generating the electroplating and metal heat treating wastes and all available data characterizing these wastes, the Agency has determined that these wastes represent three separate waste subcategories. The first subcategory, the metal finishing aqueous liquids subcategory, contains the inorganic electroplating and metal heat treating wastes that are likely to contain high concentrations of cyanide salts (F007, F008, F009, and F011). These wastes also may require treatment by chemical precipitation for dissolved metals removal. Treatment of these wastes results in generation of wastewater treatment sludges that are similar to the listed wastes F006 and F012. (Treatment sludges from treatment of F007-F009 wastes, if these wastes are mixed before or during treatment, are the listed waste F006.) The second subcategory, the metal finishing sludges subcategory, contains the wastes that are characterized as wastewater treatment sludges (F006,

F012, F019) and consequently do not require treatment by chemical precipitation to treat dissolved metals. These wastes also may not require treatment of cyanides by a cyanide destruction technology (e.g., alkaline chlorination or wet air oxidation) if the wastewaters treated to generate the F006, F012, or F019 wastes have been properly treated for cyanide prior to chemical precipitation treatment. These wastes usually contain cyanides in lower concentrations than those in the wastes in the first group. The third subcategory is the metal finishing organic liquids subcategory, which contains the waste code F010. F010 is typically generated with a high oil and grease content and little or no water and thus requires treatment for organics as well as for cyanides.

Although the concentrations of specific constituents will vary from waste code to waste code within each subcategory identified, all of the wastes within each subcategory contain similar constituents that are expected to be treatable to similar concentrations using the same technologies. EPA will therefore propose BDAT treatment standards that are applicable to all wastes in each subcategory.

Table 2-2 Summary of Waste Characteristics for F006-F012 and F019 Wastes

Constituent/parameter	Concentration (percent)			
	F006	F007	F008	F009
Cyanide (as NaCN)	<0.1-0.5	5-10	2-10	5-20
BDAT Metals				
Cadmium	0-2	0-2	0-2	0-2
Chromium	0-30	<0.1	<0.1	<0.1
Copper	0-3	0-1	0-2	0-2
Lead	0-3	<0.1	<0.1	<0.1
Nickel	0-17	0-2	0-2	0-2
Zinc	0-9	0-2	0-2	<0.1
TOTAL BDAT METALS	<0.1-30	~2	~2	~2
BDAT organics	<0.1	<0.1	<0.1	<0.1
Non-BDAT Inorganics (primarily sodium carbonate, iron, calcium hydroxide)	20-40	20-40	35-40	20
Water	30-90	55-70	55	60-70
Oil and grease	0-4	<0.1	<0.1	<0.1

Constituent/parameter	Concentration (percent)			
	F010	F011	F012	F019
Cyanide (as NaCN)	1-4	3-20	<0.1-12	<0.1-0.8
BDAT Metals				
Cadmium	-	<0.1	<0.1	<0.1
Chromium	-	<0.1	<0.1	<0.1-10
Copper	-	<0.1	<0.1	<0.1
Lead	-	<0.1	<0.1	<0.1
Nickel	-	<0.1	<0.1	<0.1
Zinc	-	<0.1	<0.1	<0.1
TOTAL BDAT METALS	<1	0.2	0.1	1-10
BDAT Organics	<0.1	<0.1	<0.1	<0.1
Non-BDAT Inorganics (primarily sodium carbonate, iron, calcium hydroxide)	-	20-80	28-36	30-40
Water	0	0-80	60	60
Oil and grease	-	<0.1	<0.1	<0.1

- = Not available

Table 2-3 F006 Waste Composition Data

Constituent/ parameter (units)	Concentration (source)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)[a]	(8)[a]
BDAT Inorganics Other Than Metals (mg/kg)									
169. Cyanide (total)	<0.1-506	84.1-226	<2	-	0.1-5.8	-	<0.025-1,970	554-859	1,800-2,860
169. Cyanide (amenable)	<0.10-0.22	<1-153	<2	-	0.1	-	0.003-162	-	-
170. Fluoride	-	-	-	268	-	-	-	-	-
BDAT Metals (mg/kg)									
154. Antimony	-	-	<10	22.4	-	-	-	221-339	<6.2
155. Arsenic	-	-	2-5	<0.4	<6.24	-	-	0.353-0.797	0.48-0.76
156. Barium	0.74-85.5	-	20-45	28.8	9-57	-	-	35.8-54.0	6.39-7.92
157. Beryllium	-	-	<2	<0.1	<97.6	-	-	<0.19	<0.05
158. Cadmium	1.3-720	1,280-4,070	10-20	0.37-1.75	<11-1,320	ND-22,000	0.003-1,180	1.63-1.97	35,500-42,900
159. Total chromium	2-49,000	147-8,610	3,200-75,000	1,650-2,625	35-730	200-137,000	<0.002-290,000	622-803	4,290-5,380
160. Copper	1.4-27,400	345-28,100	90-775	1.87-135	<6-760	-	-	10,200-13,600	7,100-8,700
161. Lead	1.69-24,500	-	85-134	184-305	<6-408	-	<0.001-13,900	9.4-11.3	<6.92-9.7
162. Mercury	-	-	<1	<0.2	<0.32	-	-	<0.144-0.616	<0.137
163. Nickel	234-23,700	1,330-26,000	7,300-49,000	11.8-17	-	-	0.06-170,000	1,170-1,470	10,300-12,500
164. Selenium	-	-	<10	<0.03	<19-<23	-	-	114-167	<0.16
165. Silver	0.51-38.9	-	<2	<0.6-<1.0	-	-	-	<1.26-1.99	<0.86
166. Thallium	-	-	<10	<20	-	-	-	<6.0	<12.7
167. Vanadium	-	-	-	1.26	-	-	-	1.75-2.5	3.66-4.44
168. Zinc	8.86-90,200	611-41,200	68-3,700	2,510-3,687	<29-220	-	-	9,130-12,200	4,160-5,320
221. Hexavalent chromium	-	-	0.14-1.0	-	0.25-25.4	-	<0.001-910	-	-

Table 2-3 (continued)

Constituent/ parameter (units)	Concentration (source)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)[a]	(8)[a]
Other Parameters									
Oil and grease (mg/g)	0.03-37.7	-	-	-	-	-	-	-	-
Moisture (%)	29.1-91.2	-	47.4-48.94	-	-	-	-	69.1-76.3	-
SP gravity (g/ml)			1.38-1.493	-	-	-	-	-	-
Acidity as $CaCO_3$ (mg/l)			1,412	-	-	-	-	-	-
Sulfide (mg/kg)	-	-	-	21	-	-	-	-	-
Total organic carbon (mg/kg)	-	-	<5,800	-	-	-	-	-	-

[a]The ranges presented represent six samples analyzed from the same process.
- = Not analyzed
ND = Not detected

References:
(1) Chemical Waste Management 1987.
(2) MRI 1987.
(3) USEPA 1986.
(4) John Deere Company 1988.
(5) Environ 1985.
(6) USEPA 1980.
(7) Versar 1986.
(8) PEI 1988.

Table 2-4 F007 Waste Composition Data

Constituent/parameter (units)	Concentration (source)			
	(1)	(2)	(3)	(4)
BDAT Inorganics Other Than Metals (mg/l)				
Cyanide (amenable)	CBI	-	-	-
Cyanide (iron)[a]	CBI	-	170	-
Cyanide (total)	CBI	4,000-67,000	41,000	2,000-15,000
Fluoride	CBI	-	-	-
BDAT Metals (mg/l)				
Cadmium	CBI	-	-	-
Chromium (total)	CBI	-	-	-
Chromium (hexavalent)	CBI	-	-	-
Copper	CBI	-	-	-
Nickel	CBI	-	-	-
Zinc	CBI	-	-	-
Non-BDAT Metals (mg/l)				
Calcium	CBI	-	-	-
Iron	CBI	-	-	-
Magnesium	CBI	-	-	-
Manganese	CBI	-	-	-
Sodium	CBI	-	-	-
BDAT Volatiles (mg/l)				
Methanol	CBI	-	-	-
Other Parameters				
Carbonate (mg/l)	CBI	-	-	-
Total solids (%)	CBI	-	-	-
Ash (%)	CBI	-	-	-
Total suspended solids (mg/l)	CBI	-	-	-
Suspended ash (mg/l)	CBI	-	-	-
Chemical oxygen demand (mg/l)	CBI	-	-	-
pH	CBI	-	-	-
Specific gravity	CBI	-	-	-

[a] Cyanide (iron) is interpreted as a measurement of cyanide not amenable to chlorination.
- = Not analyzed.

Table 2-4 (continued)

Constituent/parameter (units)	Concentration (source)				
	(5)	(5)	(5)	(5)	(6)
BDAT Inorganics Other Than Metals (mg/l)					
Cyanide (amenable)	28,200	64,200	5,700	25,600	-
Cyanide (iron)[a]	-	-	-	-	-
Cyanide (total)	30,200	66,900	8,010	27,600	20,000-25,000
Fluoride	-	-	-	-	-
BDAT Metals (mg/l)					
Cadmium	-	16,300	-	10,600	1,500
Chromium (total)	-	-	-	-	-
Chromium (hexavalent)	-	-	-	-	400
Copper	-	-	2,880	383	-
Nickel	-	-	-	-	7,000-8,000
Zinc	15,700	-	-	-	-
Non-BDAT Metals (mg/l)					
Calcium	-	-	-	-	-
Iron	-	-	-	-	-
Magnesium	-	-	-	-	-
Manganese	-	-	-	-	-
Sodium	-	-	-	-	-
BDAT Volatiles (mg/l)					
1,1-Dichloroethane	<0.002	<0.002	<0.010	0.0348	-
Methanol	-	-	-	-	-
Methylene chloride	<0.002	<0.002	0.0262	0.0324	-
Toluene	0.0137	<0.002	0.0562	0.0023	-
1,1,1-Trichloroethane	<0.002	<0.002	<0.010	0.011	-
Other Parameters					
Carbonate (mg/l)	-	-	-	-	-
Total solids (%)	-	-	-	-	-
Ash (%)	-	-	-	-	-
Total suspended solids (mg/l)	-	-	-	-	-
Suspended ash (mg/l)	-	-	-	-	-
Chemical oxygen demand (mg/l)	-	-	-	-	-
pH	-	-	-	-	-
Specific gravity	-	-	-	-	

[a] Cyanide (iron) is interpreted as a measurement of cyanide not amenable to chlorination.
- = Not analyzed.

References:

(1) USEPA 1988f.
(2) Patterson and Minear 1973.
(3) Versar 1986.
(4) USEPA 1980.
(5) MRI 1987.
(6) CyanoKEM 1987.

Table 2-5 F008 Waste Composition Data

Constituent/parameter (units)	Concentration (source)				
	(1)	(2)	(2)	(2)	(3)
BDAT Inorganics Other Than Metals (mg/kg)					
Cyanide (amenable)	-	11,700	21,700	34,200	-
Cyanide (total)	64	11,900	26,600	34,900	50,000-55,000
BDAT Metals (mg/kg)					
Cadmium	-	-	13,000	-	<100
Chromium (hexavalent)	-	-	-	-	300
Copper	-	-	-	21,600	-
Lead	-	-	-	-	150-200
Nickel	-	-	-	-	300
Zinc	-	13,100	-	-	-
BDAT Volatiles (mg/kg)					
Methylene chloride	-	<1.20	<0.008	14.4	-

- = Not analyzed.

References:
(1) USEPA 1980.
(2) MRI 1987.
(3) CyanoKEM 1987.

Table 2-6 F009 Waste Composition Data

Constituent/parameter (units)	Concentration (source)				
	(1)	(2)	(2)	(3)	(4)
BDAT Inorganics Other Than Metals (mg/l)					
Cyanide (amenable)	-	52,000-90,000	-	-	62,900
Cyanide (iron)[a]	-	-	100	-	-
Cyanide (total)	350,000	-	40,000	4,000-8,000	64,600
BDAT Metals (mg/l)					
Cadmium	-	-	-	-	-
Chromium (hexavalent)	-	-	-	-	-
Copper	-	19,000	-	-	-
Lead	-	-	-	-	-
Nickel	-	5,100-5,500	-	-	7,310
Non-BDAT Metals (mg/l)					
Iron	-	720-15,000	-	-	-

[a] Cyanide (iron) is interpreted as a measurement of cyanide not amenable to chlorination.
-. = Not analyzed.

References:
(1) USFPA 1980.
(2) Versar 1986.
(3) Patterson and Minear 1973.
(4) MRI 1987.
(5) CyanoKEM 1987.

Table 2-6 (continued)

Constituent/parameter (units)	Concentration (source)			
	(4)	(4)	(4)	(5)
BDAT Inorganics Other Than Metals (mg/l)				
Cyanide (amenable)	109,000	14,400	47,400	-
Cyanide (iron)[a]	-	-	-	-
Cyanide (total)	115,000	14,500	52,500	40,000-45,000
BDAT Metals (mg/l)				
Cadmium	388	-	-	200
Chromium (hexavalent)	-	-	-	<100
Copper	-	6,990	-	-
Lead	-	-	-	200
Nickel	-	-	7,510	12,000-15,000
Non-BDAT Metals (mg/l)				
Iron	-	-	-	-

[a] Cyanide (iron) is interpreted as a measurement of cyanide not amenable to chlorination.
- = Not analyzed.

References:
(1) USEPA 1980.
(2) Versar 1986.
(3) Patterson and Minear 1973.
(4) MRI 1987.
(5) CyanoKEM 1987.

Table 2-7 F010 Waste Composition Data

Constituent/parameter (units)	Concentration (source) (1)	(2)
BDAT Inorganics Other Than Metals (mg/kg)		
Cyanide (total)	8,530	22,000
Other Parameters		
Heat content (Btu/lb)	-	5,000
Water (%)	-	ND

- = Not analyzed
ND = Not detected

References:
(1) USEPA 1980.
(2) CyanoKEM 1988.

Table 2-8 F011 Waste Composition Data

Constituent/parameter (units)	Concentration (source) (1)	(2)	(2)	(3)
BDAT Inorganics Other Than Metals (mg/l)				
Cyanide (amenable)	I	-	34,000-35,000	-
Cyanide (total)	5,350	10,000-12,000	-	85,000-90,000
Fluoride	5.55	-	-	-
BDAT Metals (mg/l)				
Antimony	0.029	-	-	-
Barium	1.0	-	-	-
Cadmium	0.01	-	-	<100
Chromium (hexavalent)	<0.01	-	-	1,000-1,500
Chromium (total)	5.42	-	-	-
Copper	1.03	-	-	-
Lead	1.1	-	-	500-1,000
Nickel	2.88	-	-	300
Silver	0.0072	-	-	-
Vanadium	0.156	-	-	-
Zinc	0.338	-	-	-
Non-BDAT Metals (mg/l)				
Iron	27.8	-	-	-
Potassium	18,500	-	-	-
Sodium	32,200	-	-	-
Non-BDAT Inorganics Other Than Metals (mg/l)				
Carbonate	87,000	-	-	-
Chloride	21,300	-	-	-
Sulfate	90.5	-	-	-
Other Parameters				
Total solids (%)	19.7	-	-	-
Total suspended solids (%)	3.84	-	-	-
Chemical oxygen demand (mg/l)	7,140	-	-	-
Total organic carbon (mg/l)	19,500	-	-	-
Oil and grease (mg/l)	11.0	-	-	-

I = Analytical interference. Analysis of partially treated sample indicates that this value is <5120 mg/l.
- = Not analyzed.

References:
(1) USEPA 1988e.
(2) Environ 1985.
(3) CyanoKEM 1987.

Table 2-9 F012 Waste Composition Data

Constituent/parameter (units)	Concentration (source)				
	(1)	(2)	(2)	(3)	(4)
BDAT Inorganics Other Than Metals (mg/kg)					
Cyanide (total)	21	26,800	8,400	1,500	60,000-65,000
Fluoride	6.5	-	-	-	-
BDAT Metals (mg/kg)					
Barium	98	-	-	-	-
Cadmium	5.31	-	-	-	<100
Chromium (hexavalent)	-	-	-	-	350
Chromium (total)	11	-	-	-	-
Copper	307	-	-	-	-
Lead	28	-	-	-	500-600
Nickel	758	-	-	-	400-500
Silver	0.73	-	-	-	-
Vanadium	6.7	-	-	-	-
Zinc	54	-	-	-	-
BDAT Volatile Organics (μg/kg)					
Acetone	250	-	-	-	-
Chloroform	110	-	-	-	-
Methylene chloride	11	-	-	-	-
Toluene	28	-	-	-	-
BDAT Semivolatile Organics (μg/kg)					
Bis(2-ethylhexyl) phthalate	1,600	-	-	-	-
PCBs (μg/kg)					
Aroclor 1254	35	-	-	-	-
Non-BDAT Metals (mg/kg)					
Iron	2,880	-	-	-	-
Sodium	1,276	-	-	-	-
Non-BDAT Inorganics Other Than Metals (mg/kg)					
Chloride	992	-	-	-	-
Sulfate	6,900	-	-	-	-

Table 2-9 (continued)

Constituent/parameter (units)	Concentration (source)				
	(1)	(2)	(2)	(3)	(4)
Other Parameters					
Total solids (%)	60.5	-	-	-	-
Total organic carbon (mg/kg)	540	-	-	-	-
Oil and grease (mg/kg)	432	-	-	-	-
pH	-	-	-	10.5-11.0	-

- = Not analyzed

References:
(1) USEPA 1988e.
(2) USEPA 1980.
(3) Environ 1985.
(4) CyanoKEM 1987.

Table 2-10 F019 Waste Composition Data

Constituent/parameter (units)	Concentration (source)			
	(1)	(1)	(2)	(3)
BDAT Inorganics Other Than Metals (mg/kg)				
Cyanide (total)	7.76	3.93	-	<0.001-3,824
Cyanide (amenable)	7.76	ND	-	-
BDAT Metals (mg/kg)				
Cadmium	0.212	0.288	-	<0.01-28
Chromium (hexavalent)	-	-	-	<0.04-25
Chromium (total)	6,540	150	289	14-90,000
Copper	-	-	68	-
Nickel	3.25	3.08	1,275	<4-47
Other Parameters				
Total solids	-	-	-	2-35

- = Not analyzed
ND = Concentration reported as "zero"

References:
(1) MRI 1987.
(2) AES 1981.
(3) Versar 1986.

Table 2-11 Summary of Waste Characterization for K062 Waste

Constituent	Concentration (percent)
BDAT List Metals	
Chromium	<0.1 - 1
Copper	<0.1
Nickel	<0.1 - 10
TOTAL BDAT LIST METALS	1 - 10
Water	84 - 93
Other inorganics	6
TOTAL	100%

Table 2-12 K062 Waste Composition Data

Constituent/parameter (units)	Concentration (source) (1)	(2)
BDAT List Metals (mg/l)		
Arsenic	<0.1 to 3	-
Barium	<10	-
Cadmium	<5	-
Chromium (hexavalent)	0.079 to 1	0.005 to 19
Chromium (total)	6 to 7,000	2 to 12,400
Copper	5 to 865	-
Lead	<10	0.12 to 1,550
Nickel	4 to 100,310	-
Zinc	<0.4 to 9	-

References:

(1) USEPA 1986. Tables 6-1 through 6-12.

(2) Environ 1985.

3. APPLICABLE AND DEMONSTRATED TREATMENT TECHNOLOGIES

Section 2 established three subcategories for F006-F012 and F019 wastes. This section identifies the treatment technologies that are applicable to these subcategories and determines which, if any, of the applicable technologies can be considered demonstrated for the purposes of establishing BDAT.

To be applicable, a technology must be theoretically usable to treat the waste in question or to treat a waste that is similar in terms of the parameters that affect treatment selection. To be demonstrated, the technology must be employed in full-scale operation for the treatment of the waste in question or a similar waste. Technologies that are available only at research facilities or at pilot- and bench-scale operations are not considered demonstrated technologies for the purpose of identifying BDAT.

3.1 Applicable Treatment Technologies

EPA has identified five technologies as potentially applicable for treatment of cyanides in the metal finishing aqueous liquids subcategory (F007, F008, F009, and F011 wastes): (1) electrolytic oxidation; (2) chemical oxidation with several oxidizing agents, such as hypochlorite or chlorine (alkaline chlorination), permanganate, or ozone; (3) wet air oxidation; (4) high-temperature cyanide hydrolysis; and (5) SO_2/air oxidation (INCO process). Each of these may be followed by chemical precipitation, filtration, and sludge dewatering for metals removal.

Electrolytic oxidation followed by alkaline chlorination, chemical oxidation (alkaline chlorination or other methods) alone, electrolytic oxidation alone, wet air oxidation, high-temperature hydrolysis, and SO_2/air oxidation reduce the concentration of cyanide in the wastewaters or nonwastewaters treated. Chemical precipitation treatment of the wastewater residual from cyanide oxidation, followed by filtration of the treated wastewater and dewatering of the precipitated solids, reduces the concentration of metals in the wastewater and concentrates the metals in the treatment sludge in a relatively insoluble form. Filtration and dewatering may also concentrate cyanide in the treatment sludge residual. The treatment sludge metal constituents may then require further treatment by the applicable nonwastewater treatment technologies specified below for the wastes F006, F012, and F019.

EPA has identified three technologies as potentially applicable for treatment of the wastewater treatment sludges in the metal finishing sludges subcategory (F006, F012, and F019): stabilization, vitrification, and high temperature metals recovery. The first two technologies are designed to reduce the leachability of the metals; the third reduces both the total concentration and the leachability of the metals.

Stabilization chemically reduces the mobility of hazardous metal constituents in a waste. Stabilizing agents, binders, and chemicals are added to a waste to minimize the quantities of metals that leach when the

waste is in contact with water. Commonly used stabilization agents include portland cement, lime/pozzolan-based material, and cement kiln dust.

Vitrification has also been identified by the Agency as an applicable technology. A vitrification process can be used to immobilize hazardous constituents in F012 or F019 waste by producing a vitreous or glass-like mass.

EPA has also identified high temperature metals recovery technologies as applicable. High temperature metals recovery technologies reduce the concentration of some metals in the waste through volatilization and recovery of the volatilized metals and/or the metals remaining in the residual. High temperature metals recovery may result in a residual (or slag) that is land disposed.

EPA has identified incineration as the only applicable technology for wastes in the metal finishing organic liquids subcategory (F010). Incineration is a thermal treatment process that destroys the organic and oxidizable inorganic waste constituents.

3.2 Demonstrated Treatment Technologies

Available information shows that electrolytic oxidation followed by alkaline chlorination, alkaline chlorination alone, wet air oxidation, high temperature hydrolysis, and SO_2/air oxidation are demonstrated for treatment of cyanide in F007, F008, F009, and F011 wastes. EPA knows of at least one full-scale facility that uses electrolytic oxidation followed by alkaline chlorination to treat cyanide in F011 waste, at

least five facilities (there are probably many more) that use alkaline chlorination to treat cyanide in F007-F009 or F011 wastes, at least one facility that treats cyanide-containing wastes by high temperature cyanide hydrolysis, and one pilot-scale facility that has treated F007 waste by wet air oxidation. In addition, wet air oxidation and SO_2/air oxidation are used to treat similar wastes in full-scale processes. EPA believes that chemical precipitation followed by filtration and sludge dewatering is demonstrated at many facilities for treatment of BDAT metals on these wastes and similar wastes (such as K062, which was regulated with the First Third of the RCRA-listed hazardous wastes).

Available information also shows that all of the applicable technologies for treatment of BDAT metals in F012 and F019 wastes are demonstrated. The characteristics of F012 and F019 wastes (high solids content, substantial concentrations of BDAT metals, very low concentrations of oil and grease and BDAT organic constituents) would allow these wastes to be treated by the same methods used for F006. Stabilization is used by at least ten facilities to treat F006 wastes. EPA knows of two full-scale facilities that use metals recovery for F006 wastes and one full-scale facility that treats F006 waste by vitrification.

The Agency also believes that incineration is demonstrated for treatment of metal finishing organics liquids (F010). Phone contacts with generators of F010 wastes indicate that these wastes may also be

treated by an oil/water separation step, followed by recycling of the oil phase and treatment of the inorganic phase by one of the other cyanide destruction technologies discussed above.

3.3 Descriptions of Cyanide Treatment Technologies

3.3.1 Electrolytic Oxidation

3.3.2 Chemical Oxidation

3.3.3 Wet Air Oxidation

3.3.4 Incineration

3.4 Descriptions of BDAT List Metals Treatment Technologies

3.4.1 Chemical Precipitation

(1) Applicability and use of chemical precipitation. Chemical precipitation is used when dissolved metals are to be removed from solution. This technology can be applied to a wide range of wastewaters containing dissolved BDAT list metals and other metals as well. This treatment process has been practiced widely by industrial facilities since the 1940s.

(2) Underlying principles of operation. The underlying principle of chemical precipitation is that metals in wastewater are removed by the addition of a treatment chemical that converts the dissolved metal to a metal precipitate. This precipitate is less soluble than the original metal compound and therefore settles out of solution, leaving a lower concentration of the metal present in the solution. The principal chemicals used to convert soluble metal compounds to the less soluble

forms include lime ($Ca(OH)_2$), caustic (NaOH), sodium sulfide (Na_2S), and, to a lesser extent, soda ash (Na_2CO_3), phosphate, and ferrous sulfide (FeS).

The solubility of a particular compound will depend on the extent to which the electrostatic forces holding the ions of the compound together can be overcome. The solubility will change significantly with temperature; most metal compounds are more soluble as the temperature increases. Additionally, the solubility will be affected by the other constituents present in a waste. As a general rule, nitrates, chlorides, and sulfates are more soluble than hydroxides, sulfides, carbonates, and phosphates.

An important concept related to treatment of the soluble metal compounds is pH. The pH of an aqueous solution provides a measure of the extent to which a solution contains an excess of either hydrogen or hydroxide ions. The pH scale ranges from 0 to 14, with 0 being the most acidic, 14 representing the highest alkalinity or hydroxide ion (OH^-) content, and 7 being neutral.

When hydroxide is used to precipitate the soluble metal compounds, the pH is frequently monitored to ensure that sufficient treatment chemicals are added. It is important to point out that pH is not a good measure of treatment chemical addition for compounds other than hydroxides; when sulfide is used, for example, facilities might use an oxidation-reduction potential meter (ORP) correlation to ensure that sufficient treatment chemical is used.

Following conversion of the relatively soluble metal compounds to metal precipitates, the effectiveness of chemical precipitation is a function of the physical removal, which usually relies on a settling process. A particle of a specific size, shape, and composition will settle at a specific velocity, as described by Stokes' Law. For a batch system, Stokes' Law is a good predictor of settling time because the pertinent particle parameters remain essentially constant. Nevertheless, in practice, settling time for a batch system is normally determined by empirical testing. For a continuous system, the theory of settling is complicated by factors such as turbulence, short-circuiting, and velocity gradients, increasing the importance of the empirical tests.

(3) Description of the technology. The equipment and instrumentation required for chemical precipitation vary depending on whether the system is batch or continuous. Both operations are discussed below; a schematic of the continuous system is shown in Figure 3-3.

For a batch system, chemical precipitation requires only a feed system for the treatment chemicals and a second tank where the waste can be treated and allowed to settle. When lime is used, it is usually added to the reaction tank in a slurry form. In a batch system, the supernate is usually analyzed before discharge, thus minimizing the need for instrumentation.

In a continuous system, additional tanks are necessary, as well as instrumentation to ensure that the system is operating properly. In this system, the first tank that the wastewater enters is referred to as an

Figure 3-3

equalization tank. This is where the waste can be mixed in order to provide more uniformity, minimizing wide swings in the type and concentration of constituents being sent to the reaction tank. It is important to reduce the variability of the waste sent to the reaction tank because control systems inherently are limited with regard to the maximum fluctuations that can be managed.

Following equalization, the waste is pumped to a reaction tank where treatment chemicals are added; the chemicals are added automatically by using instrumentation that senses the pH of the system and then pneumatically adjusts the position of the treatment chemical feed valve such that the design pH value is achieved. Both the complexity and the effectiveness of the automatic control system will vary depending on the variation in the waste and the pH range that is needed to properly treat the waste.

An important aspect of the reaction tank design is that it be well mixed so that the waste and the treatment chemicals are both dispersed throughout the tank, in order to ensure commingling of the reactant and the treatment chemicals. In addition, effective dispersion of the treatment chemicals throughout the tank is necessary to properly monitor and thereby control the amount of treatment chemicals added.

After the waste is reacted with the treatment chemical, it flows to a quiescent tank where the precipitate is allowed to settle and subsequently be removed. Settling can be chemically assisted through the use of flocculating compounds. Flocculants increase the particle size

and density of the precipitated solids, both of which increase the rate of settling. The particular flocculating agent that will best improve settling characteristics will vary depending on the particular waste; the flocculating agent is generally selected by performing laboratory bench tests. Settling can be conducted in a large tank by relying solely on gravity, or it can be mechanically assisted through the use of a circular clarifier or an inclined separator. Schematics of the latter two separators are shown in Figures 3-4 and 3-5.

Filtration can be used for further removal of precipitated residuals both in cases where the settling system is underdesigned and in cases where the particles are difficult to settle. Polishing filtration is discussed in a separate technology section.

(4) Waste characteristics affecting performance. In determining whether chemical precipitation is likely to achieve the same level of performance on an untested waste as on a previously tested waste, EPA will examine the following waste characteristics: (a) the concentration and type of the metal(s) in the waste, (b) the concentration of total suspended solids (TSS), (c) the concentration of total dissolved solids (TDS), (d) whether the metal exists in the wastewater as a complex, and (e) the oil and grease content. These parameters affect the chemical reaction of the metal compound, the solubility of the metal precipitate, or the ability of the precipitated compound to settle.

(a) Concentration and type of metals. For most metals, there is a specific pH at which the metal hydroxide is least soluble. As a result, when a waste contains a mixture of many metals, it is not

Figure 3-4

Figure 3-5

possible to operate a treatment system at a single pH that is optimal for the removal of all metals. The extent to which this affects treatment depends on the particular metals to be removed and their concentrations. An alternative can be to operate multiple precipitations, with intermediate settling, when the optimum pH occurs at markedly different levels for the metals present. The individual metals and their concentrations can be measured using EPA Method 6010.

(b) Concentration and type of total suspended solids (TSS). Certain suspended solid compounds are difficult to settle because of either particle size or shape. Accordingly, EPA will evaluate this characteristic in assessing transfer of treatment performance. Total suspended solids can be measured by EPA Wastewater Test Method 160.2.

(c) Concentration of total dissolved solids (TDS). Available information shows that total dissolved solids can inhibit settling. The literature states that poor flocculation is a consequence of high TDS and shows that higher concentrations of total suspended solids are found in treated residuals. Poor flocculation can adversely affect the degree to which precipitated particles are removed. Total dissolved solids can be measured by EPA Wastewater Test Method 160.1.

(d) Complexed metals. Metal complexes consist of a metal ion surrounded by a group of other inorganic or organic ions or molecules (often called ligands). In the complexed form, the metals have a greater solubility and, therefore, may not be as effectively removed from solution by chemical precipitation. EPA does not have an analytical

method to determine the amount of complexed metals in the waste. The Agency believes that the best measure of complexed metals is to analyze for some common complexing compounds (or complexing agents) generally found in wastewater for which analytical methods are available. These complexing agents include ammonia, cyanide, and EDTA. The analytical method for cyanide is EPA Method 9010. The method for EDTA is ASTM Method D3113. Ammonia can be analyzed using EPA Wastewater Test Method 350.

(e) Oil and grease content. The oil and grease content of a particular waste directly inhibits the settling of the precipitate. Suspended oil droplets float in water and tend to suspend particles such as chemical precipitates that would otherwise settle out of the solution. Even with the use of coagulants or flocculants, the separation of the precipitate is less effective. Oil and grease content can be measured by EPA Method 9071.

(5) Design and operating parameters. The parameters that EPA will evaluate when determining whether a chemical precipitation system is well designed are: (a) design value for treated metal concentrations, as well as other characteristics of the waste used for design purposes (e.g., total suspended solids), (b) pH, (c) residence time, (d) choice of treatment chemical, and (e) choice of coagulant/flocculant. Below is an explanation of why EPA believes these parameters are important to a design analysis; in addition, EPA explains why other design criteria are not included in the Agency's analysis.

(a) Treated and untreated design concentrations. EPA pays close attention to the treated concentration that the system is designed to achieve when determining whether to sample a particular facility. Since the system will seldom outperform its design, EPA must evaluate whether the design is consistent with best demonstrated practice.

The untreated concentrations that the system is designed to treat are important in evaluating any treatment system. Operation of a chemical precipitation treatment system with untreated waste concentrations in excess of design values can easily result in poor performance.

(b) pH. The pH is important because it can indicate that sufficient treatment chemical (e.g., lime) has been added to convert the metal constituents in the untreated waste to forms that will precipitate. The pH also affects the solubility of metal hydroxides and sulfides and therefore directly impacts the effectiveness of removal. In practice, the design pH is determined by empirical bench testing, often referred to as "jar" testing. The temperature at which the "jar" testing is conducted is important in that it also affects the solubility of the metal precipitates. Operation of a treatment system at temperatures above the design temperature can result in poor performance. In assessing the operation of a chemical precipitation system, EPA prefers continuous data on the pH and periodic temperature conditions throughout the treatment period.

(c) Residence time. The residence time is important because it impacts the completeness of the chemical reaction to form the metal precipitate and, to a greater extent, the amount of precipitate that

settles out of solution. In practice, it is determined by "jar" testing. For continuous systems, EPA will monitor the feed rate to ensure that the system is operated at design conditions. For batch systems, EPA will want information on the design parameter used to determine sufficient settling time (e.g., total suspended solids).

(d) Choice of treatment chemical. A choice must be made as to what type of precipitating agent (i.e., treatment chemical) will be used. The factor that most affects this choice is the type of metal constituents to be treated. Other design parameters, such as pH, residence time, and choice of coagulant/flocculant agents, are based on the selection of the treatment chemical.

(e) Choice of coagulant/flocculant. This is important because these compounds improve the settling rate of the precipitated metals and allow for smaller systems (i.e., lower retention time) to achieve the same degree of settling as much larger systems. In practice, the choice of the best agent and the required amount is determined by "jar" testing.

(f) Mixing. The degree of mixing is a complex assessment that includes, among other things, the energy supplied, the time the material is mixed, and the related turbulence effects of the specific size and shape of the tank. EPA will, however, consider whether mixing is provided and whether the type of mixing device is one that could be expected to achieve uniform mixing. For example, EPA may not use data from a chemical precipitation treatment system where an air hose was placed in a large tank to achieve mixing.

3.4.2 Sludge Filtration

(1) Applicability. Sludge filtration, also known as sludge dewatering or cake-formation filtration, is a technology used on wastes that contain high concentrations of suspended solids, generally higher than 1 percent. The remainder of the waste is essentially water. Sludge filtration is applied to sludges, typically those that have settled to the bottom of clarifiers, for dewatering. After filtration, these sludges can be dewatered to 20 to 50 percent solids.

(2) Underlying principles of operation. The basic principle of filtration is the separation of particles from a mixture of fluids and particles by a medium that permits the flow of the fluid but retains the particles. As would be expected, larger particles are easier to separate from the fluid than smaller particles. Extremely small particles, in the colloidal range, may not be filtered effectively and may appear in the treated waste. To mitigate this problem, the wastewater should be treated prior to filtration to modify the particle size distribution in favor of the larger particles, by the use of appropriate precipitants, coagulants, flocculants, and filter aids. The selection of the appropriate precipitant or coagulant is important because it affects the particles formed. For example, lime neutralization usually produces larger, less gelatinous particles than does caustic soda precipitation. For larger particles that become too small to filter effectively because of poor resistance to shearing, shear resistance can be improved by the

use of coagulants and flocculants. Also, if pumps are used to feed the filter, shear can be minimized by designing for a lower pump speed or by using a low-shear type of pump.

(3) Physical description of the process. For sludge filtration, settled sludge is either pumped through a cloth-type filter medium (such as in a plate and frame filter) that allows solid "cake" to build up on the medium or drawn by vacuum through a cloth medium (such as on a drum or vacuum filter), which also allows the solids to build. In both cases, the solids themselves act as a filter for subsequent solids removal. For a plate and frame-type filter, removal of the solids is accomplished by taking the unit off line, opening the filter, and scraping the solids off. For the vacuum-type filter, cake is removed continuously. For a specific sludge, the plate and frame-type filter will usually produce a drier cake than a vacuum filter. Other types of sludge filters, such as belt filters, are also used for effective sludge dewatering.

(4) Waste characteristics affecting performance. The following characteristics of the waste will affect performance of a sludge filtration unit: (a) size of particles and (b) type of particles.

(a) Size of particles. The smaller the particle size, the more the particles tend to go through the filter medium. This is especially true for a vacuum filter. For a pressure filter (such as a plate and frame), smaller particles may require higher pressures for equivalent throughput since the smaller pore spaces between particles create resistance to flow.

(b) Type of particles. Some solids formed during metal precipitation are gelatinous in nature and cannot be dewatered well by cake-formation filtration. In fact, for vacuum filtration a cake may not form at all. In most cases, solids can be made less gelatinous by use of the appropriate coagulants and coagulant dosage prior to clarification, or after clarification but prior to filtration. In addition, the use of lime instead of caustic soda in metal precipitation will reduce the formation of gelatinous solids. Also, the addition of filter aids, such as lime or diatomaceous earth, to a gelatinous sludge will help significantly. Finally, precoating the filter with diatomaceous earth prior to sludge filtration will assist in dewatering gelatinous sludges.

(5) Design and operating parameters. For sludge filtration, the following design and operating variables affect performance: (a) type of filter selected, (b) size of filter selected, (c) feed pressure, and (d) use of coagulants or filter aids.

(a) Type of filter. Typically, a pressure-type filter (such as a plate and frame) will yield a drier cake than a vacuum-type filter and will also be more tolerant of variations in influent sludge characteristics. Pressure-type filters, however, are batch operations, so that when cake is built up to the maximum depth physically possible (constrained by filter geometry), or to the maximum design pressure, the filter is turned off while the cake is removed. A vacuum filter is a continuous device (i.e., cake discharges continuously), and will usually

be much larger than a pressure filter with the same capacity. A hybrid device is a belt filter, which mechanically squeezes sludge between two continuous fabric belts.

(b) Size of filter. As with in-depth filters, the larger the filter, the greater its hydraulic capacity and the longer the filter runs between cake discharges.

(c) Feed pressure. This parameter impacts both the design pore size of the filter and the design flow rate. It is important that the design feed pressure not be exceeded; otherwise, particles may be forced through the filter medium, resulting in ineffective treatment.

(d) Use of coagulants. Coagulants and filter aids may be mixed with filter feed prior to filtration. Their effect is particularly significant for vacuum filtration in that it may make the difference in a vacuum filter between no cake and a relatively dry cake. In a pressure filter, coagulants and filter aids will also significantly improve hydraulic capacity and cake dryness. Filter aids, such as diatomaceous earth, can be precoated on filters (vacuum or pressure) for sludges that are particularly difficult to filter. The precoat layer acts somewhat like an in-depth filter in that sludge solids are trapped in the precoat pore spaces. Use of precoats and most coagulants or filter aids significantly increases the amount of sludge solids to be disposed of; however, polyelectrolyte coagulant usage usually does not increase sludge volume significantly because the dosage is low.

4. PERFORMANCE DATA BASE

This section presents all data available to EPA on the performance of the demonstrated technologies discussed in Section 3 for treating F006-F012 and F019 wastes. These data are used elsewhere in this document for determining which technologies represent BDAT (Section 5), for selecting constituents to be regulated (Section 6), and for developing the proposed treatment standards (Section 7). In addition to full-scale demonstration data, available data may include data developed at research facilities, or through other applications at less than full-scale operation, as long as the technology is demonstrated in full-scale operation for a similar waste or wastes as defined in Section 3.

Performance data include the untreated and treated waste concentrations for a given constituent, the values of operating parameters that were measured at the time the waste was being treated, the values of relevant design parameters for the treatment technology, and data on waste characteristics that affect performance of the treatment technology. EPA has provided all such data, to the extent that they are available, in the tables found at the end of this section.

Where data are not available on the treatment of the specific wastes of concern, the Agency may elect to transfer data on the treatment of a similar waste or wastes using a demonstrated technology. To transfer data from another waste category, EPA must find that the wastes covered by this background document are no more difficult to treat (based on the

waste characteristics that affect performance of the demonstrated treatment technology) than the treated wastes from which performance data are being transferred.

4.1 Electrolytic Oxidation/Alkaline Chlorination Data

At Plant A, the Agency collected one set of untreated and treated F011 waste samples from a treatment system that consisted of electrolytic oxidation, alkaline chlorination, chemical precipitation, filtration, and sludge dewatering (shown as Sample Set No. 1 in Table 4-1). The Agency also collected one set of samples from treatment of heat treating quenching wastewaters by the same treatment system as above except for the electrolytic oxidation step (shown as Sample Set No. 2 in Table 4-1). These data show, along with design and operating information, the total concentrations of metals and cyanide in the untreated waste and treated wastewater (after precipitation of metals and filtration for removal of suspended solids) and the total and TCLP leachate concentrations of metals and cyanide in the treated nonwastewater (the precipitated solids from chemical precipitation, treated further by sludge dewatering).

4.2 Wet Air Oxidation Data

In an EPA test at Plant B, the Agency collected six sets of data for untreated and treated F007 waste using a pilot-scale wet air oxidation treatment system. These data, presented in Table 4-2, show, along with design and operating information, the total concentration of metals and cyanide in the untreated waste and the treated wastewater, as well as the

total and TCLP leachate concentrations of metals and cyanide in the nonwastewater treatment residual (reactor wall scale and reactor bottom solids).

4.3 Alkaline Chlorination Data

The Agency reviewed data submitted by Plant C on treatment of a variety of cyanide wastes by batch alkaline chlorination (CyanoKEM 1987). These data, for eight sample sets, are presented in Table 4-3. The data show concentration of cyanide in the untreated waste and the treated wastewater, as well as design and operating information for each test.

4.4 Electrolytic Oxidation Data

Table 4-4 presents 11 data sets obtained from the literature on the performance of electrolytic oxidation treatment of cyanide wastes (Easton 1967). The data show cyanide concentrations in the untreated and treated wastewater, as well as design and operating information obtained during the tests.

4.5 High-Temperature Cyanide Hydrolysis Data

Table 4-5 presents six data sets obtained from the literature from full-scale testing of high-temperature cyanide hydrolysis (Robey 1983). These data present cyanide concentrations in the untreated and treated wastes as well as operating data for each test. Wastes tested were actual F007-F009 electroplating wastes, in the form of both bulk liquids (wastewaters) and drummed solids (nonwastewaters).

4.6 Chemical Precipitation Data

The data for BDAT metals from Plant A, shown in Table 4-1, show treatment of metals in wastewater by chemical precipitation followed by filtration and sludge dewatering. Additionally, the Agency has data for chromium reduction followed by chemical precipitation, filtration, and sludge dewatering for treatment of K062 and other wastes. (See EPA's BDAT Background Document for K062 (USEPA 1988b).)

4.7 Stabilization Data

The Agency has data on treatment of BDAT list metals in F006 waste by stabilization. (See EPA's BDAT Background Document for F006 (USEPA 1988a).) EPA has not identified any treatment data for F006, F012, or F019 wastes for BDAT list metals other than the data considered in developing treatment standards for F006, for which stabilization was determined to be the "best" technology.

4.8 Incineration Data

Plant D submitted two data sets on treatment of F010 waste and a similar waste by incineration, presented in Table 4-6 (CyanoKEM 1988). These data show total cyanide concentration in both the untreated waste and the treated solid residual (ash). No data were presented for the scrubber water.

Table 4-1 Electrolytic Oxidation, Alkaline Chlorination, Chemical Precipitation, and Sludge Dewatering Data Collected by EPA at Plant A for Treatment of F011 and Heat Treating Quenching Wastewaters

Sample Set No. 1[a]

	Concentration			
	Untreated waste	Treated wastewater	Treated nonwastewater	
Constituent	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)
Antimony	0.029	<0.021	<2.1	<0.021
Barium	1.0	0.084	19	0.301
Cadmium	0.01	<0.004	1.4	0.016
Chromium (hexavalent)	<0.01	8.95	-	0.259
Chromium (total)	5.42	6.55	39	0.236
Copper	1.03	0.043	72	0.076
Lead	1.1	<0.05	22	0.011
Mercury	<0.00025	0.00022	<0.10	<0.0002
Nickel	2.88	0.58	519	3.06
Silver	0.0072	0.012	<0.20	<0.002
Vanadium	0.156	0.032	7.0	0.014
Zinc	0.338	0.03	31	0.352
Cyanide (amenable)	I	3.0 [b]	19.9	0.147
Cyanide (total)	5,350	117 [b]	99.4	0.818

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Electrolytic oxidation reactor temperature	170-180°F	175-180°F
Electrolytic oxidation reactor pH	>11.0	10.6-11.6
Alkaline chlorination reactor pH (2-step)	>11.0; 7.0-9.0	11.2; 8.0
Excess chlorine in alkaline chlorination reactor	NS	30 mg/l

I = Sample result is indeterminate because of analytical interference, but is less than 5,130 mg/l based on laboratory analysis of total and amenable cyanides for the partially treated waste.

- = Not analyzed.
NS = Not specified.

[a]Electrolytic oxidation was used only with Sample Set No. 1.
[b]Accuracy-adjusted concentration.

Reference: USEPA 1988e.

Table 4-1 (continued)

Sample Set No. 2

Constituent	Concentration			
	Untreated waste	Treated wastewater	Treated nonwastewater	
	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)
Antimony	<0.021	<0.021	<2.1	<0.021
Barium	0.158	0.102	98	0.312
Cadmium	0.057	0.0092	5.31	0.052
Chromium (hexavalent)	<0.01	0.625	-	0.436
Chromium (total)	0.175	1.63	11	0.31
Copper	1.08	0.035	307	0.354
Lead	0.063	<0.005	28	0.01
Mercury	<0.0002	0.00032	<0.1	<0.0002
Nickel	10.9	0.64	758	5.9
Silver	0.064	0.094	0.73	0.034
Vanadium	0.043	0.011	6.7	0.0061
Zinc	0.60	0.147	54	0.377
Cyanide (amenable)	29.2	<0.01	5.6	<0.01
Cyanide (total)	62.6	<0.01	34.7	<0.01

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Alkaline chlorination reactor pH	>11.0; 7.0-9.0	11.6; 7.6
Excess chlorine in alkaline chlorination reactor	NS	120 mg/l

- = Not analyzed.
NS = Not specified.

Table 4-2 Wet Air Oxidation Data Collected by EPA at Plant B for F007 Waste

Sample Set No. 1

Constituent	Concentration					
	Untreated waste	Treated wastewater	Treated nonwastewater			
			Reactor solids A[a]		Reactor solids B[b]	
	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	CBI	266	<15	-	<15	-
BDAT Inorganics						
Antimony	CBI	<4.0	<350	-	<35	-
Arsenic	CBI	<0.05	<1.0	<0.01	<1.0	<0.01
Barium	CBI	0.047	1.25	0.20	6.4	0.17
Beryllium	CBI	<0.075	<0.15	-	<1.5	-
Cadmium	CBI	<0.06	<1.25	<0.10	<1.0	<0.10
Chromium (hexavalent)	CBI	I	I	I	I	I
Chromium (total)	CBI	0.628	2.55	<0.10	6.09	<0.10
Copper	CBI	759	151,000	-	44,400	-
Lead	CBI	<1.75	<35	<2.0	<35	<2.0
Mercury	CBI	<0.015	<1.0	<0.05	<1.0	<0.05
Nickel	CBI	<0.25	33.7	-	26.5	-
Selenium	CBI	<0.045	<1.0	<0.01	<1.0	<0.01
Silver	CBI	<0.55	<10	<1.0	<8.0	<1.0
Thallium	CBI	<2.0	<40	-	<40	-
Vanadium	CBI	<0.125	<2.5	-	5.3	-
Zinc	CBI	7.91	29,600	-	139,000	-
Cyanide (amenable)	CBI	0.3	<25	-	<25	-
Cyanide (total)	CBI	11.9	<25	-	<25	-
Fluoride	CBI	4.20	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	449-487°F
Residence time	55-66 min (5.0-6.0 gal/hr)	57.1 min
Oxygen concentration (off-gas)	16-20%	17.8%
Reactor pressure	1700 psig	1690-1707 psig

[a]Reactor wall scale; one sample collected for all six sample sets.
[b]Reactor bottom solids; one sample collected for all six sample sets.

I = Matrix interference.
- = Not analyzed.

Reference: USEPA 1988f.

Table 4-2 (continued)

Sample Set No. 2

Constituent	Concentration					
			Treated nonwastewater			
	Untreated waste	Treated wastewater	Reactor solids A[a]		Reactor solids B[b]	
	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	CBI	<150	<15	-	<15	-
BDAT Inorganics						
Antimony	CBI	<4.0	<350	-	<35	-
Arsenic	CBI	<0.05	<1.0	<0.01	<1.0	<0.01
Barium	CBI	<0.03	1.25	0.20	6.4	0.17
Beryllium	CBI	<0.075	<0.15	-	<1.5	-
Cadmium	CBI	0.17	<1.25	<0.10	<1.0	<0.10
Chromium (hexavalent)	CBI	I	I	I	I	I
Chromium (total)	CBI	0.478	2.55	<0.10	6.09	<0.10
Copper	CBI	568	151,000	-	44,400	-
Lead	CBI	<1.75	<35	<2.0	<35	<2.0
Mercury	CBI	<0.015	<1.0	<0.05	<1.0	<0.05
Nickel	CBI	<0.25	33.7	-	26.5	-
Selenium	CBI	<0.045	<1.0	<0.01	<1.0	<0.01
Silver	CBI	<0.55	<10	<1.0	<8.0	<1.0
Thallium	CBI	<2.0	<40	-	<40	-
Vanadium	CBI	<0.125	<2.5	-	5.3	-
Zinc	CBI	7.48	29,600	-	139,000	-
Cyanide (amenable)	CBI	<0.25	<25	-	<25	-
Cyanide (total)	CBI	<0.25	<25	-	<25	-
Fluoride	CBI	4.02	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	440-489°F
Residence time	55-66 min (5.0-6.0 gal/hr)	60.5 min
Oxygen concentration (off-gas)	16-20%	17.0%
Reactor pressure	1700 psig	1709-1725 psig

[a]Reactor wall scale; one sample collected for all six sample sets.
[b]Reactor bottom solids; one sample collected for all six sample sets.

I = Matrix interference.
- = Not analyzed.

Table 4-2 (continued)

Sample Set No. 3

Constituent	Concentration					
			Treated nonwastewater			
	Untreated waste	Treated wastewater	Reactor solids A[a]		Reactor solids B[b]	
	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	CBI	110	<15	-	<15	-
BDAT Inorganics						
Antimony	CBI	<4.0	<350	-	<35	-
Arsenic	CBI	<0.05	<1.0	<0.01	<1.0	<0.01
Barium	CBI	0.038	1.25	0.20	6.4	0.17
Beryllium	CBI	<0.075	<0.15	-	<1.5	-
Cadmium	CBI	0.48	<1.25	<0.10	<1.0	<0.10
Chromium (hexavalent)	CBI	I	I	I	I	I
Chromium (total)	CBI	0.568	2.55	<0.10	6.09	<0.10
Copper	CBI	834	151,000	-	44,400	-
Lead	CBI	<1.75	<35	<2.0	<35	<2.0
Mercury	CBI	<0.015	<1.0	<0.05	<1.0	<0.05
Nickel	CBI	<0.25	33.7	-	26.5	-
Selenium	CBI	<0.045	<1.0	<0.01	<1.0	<0.01
Silver	CBI	<0.55	<10	<1.0	<8.0	<1.0
Thallium	CBI	<2.0	<40	-	<40	-
Vanadium	CBI	<0.125	<2.5	-	5.3	-
Zinc	CBI	4.63	29,600	-	139,000	-
Cyanide (amenable)	CBI	<0.25	<25	-	<25	-
Cyanide (total)	CBI	3.22	<25	-	<25	-
Fluoride	CBI	4.02	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	431-488°F
Residence time	55-66 min (5.0-6.0 gal/hr)	59.2 min
Oxygen concentration (off-gas)	16-20%	17.5%
Reactor pressure	1700 psig	1701-1718 psig

[a]Reactor wall scale; one sample collected for all six sample sets.
[b]Reactor bottom solids; one sample collected for all six sample sets.

I = Matrix interference.
- = Not analyzed.

Table 4-2 (continued)

Sample Set No. 4

Constituent	Concentration					
			Treated nonwastewater			
	Untreated waste	Treated wastewater	Reactor solids A[a]		Reactor solids B[b]	
	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	CBI	64	<15	-	<15	-
BDAT Inorganics						
Antimony	CBI	<4.0	<350	-	<35	-
Arsenic	CBI	<0.05	<1.0	<0.01	<1.0	<0.01
Barium	CBI	<0.30	1.25	0.20	6.4	0.17
Beryllium	CBI	<0.75	<0.15	-	<1.5	-
Cadmium	CBI	<0.60	<1.25	<0.10	<1.0	<0.10
Chromium (hexavalent)	CBI	I	I	I	I	I
Chromium (total)	CBI	<0.90	2.55	<0.10	6.09	<0.10
Copper	CBI	766	151,000	-	44,400	-
Lead	CBI	<17.5	<35	<2.0	<35	<2.0
Mercury	CBI	<0.015	<1.0	<0.05	<1.0	<0.05
Nickel	CBI	<2.5	33.7	-	26.5	-
Selenium	CBI	<0.045	<1.0	<0.01	<1.0	<0.01
Silver	CBI	<5.5	<10	<1.0	<8.0	<1.0
Thallium	CBI	<20	<40	-	<40	-
Vanadium	CBI	<1.25	<2.5	-	5.3	-
Zinc	CBI	6.26	29,600	-	139,000	-
Cyanide (amenable)	CBI	<0.25	<25	-	<25	-
Cyanide (total)	CBI	<0.25	<25	-	<25	-
Fluoride	CBI	4.07	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	424-493°F
Residence time	55-66 min (5.0-6.0 gal/hr)	53.3 min
Oxygen concentration (off-gas)	16-20%	16.5%
Reactor pressure	1700 psig	1675-1740 psig

[a]Reactor wall scale; one sample collected for all six sample sets.
[b]Reactor bottom solids; one sample collected for all six sample sets.

I = Matrix interference.
- = Not analyzed.

Table 4-2 (continued)

Sample Set No. 5

Constituent	Concentration					
			Treated nonwastewater			
	Untreated waste	Treated wastewater	Reactor solids A[a]		Reactor solids B[b]	
	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	CBI	50	<15	-	<15	-
BDAT Inorganics						
Antimony	CBI	<4.0	<350	-	<35	-
Arsenic	CBI	<0.05	<1.0	<0.01	<1.0	<0.01
Barium	CBI	<0.03	1.25	0.20	6.4	0.17
Beryllium	CBI	<0.075	<0.15	-	<1.5	-
Cadmium	CBI	<0.72	<1.25	<0.10	<1.0	<0.10
Chromium (hexavalent)	CBI	I	I	I	I	I
Chromium (total)	CBI	0.499	2.55	<0.10	6.09	<0.10
Copper	CBI	946	151,000	-	44,400	-
Lead	CBI	<1.75	<35	<2.0	<35	<2.0
Mercury	CBI	<0.015	<1.0	<0.05	<1.0	<0.05
Nickel	CBI	<0.25	33.7	-	26.5	-
Selenium	CBI	<0.045	<1.0	<0.01	<1.0	<0.01
Silver	CBI	<0.55	<10	<1.0	<8.0	<1.0
Thallium	CBI	<2.0	<40	-	<40	-
Vanadium	CBI	<0.125	<2.5	-	5.3	-
Zinc	CBI	4.07	29,600	-	139,000	-
Cyanide (amenable)	CBI	<0.25	<25	-	<25	-
Cyanide (total)	CBI	<0.25	<25	-	<25	-
Fluoride	CBI	4.06	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	417-484°F
Residence time	55-66 min (5.0-6.0 gal/hr)	51.6 min
Oxygen concentration (off-gas)	16-20%	16.6%
Reactor pressure	1700 psig	1680-1694 psig

[a]Reactor wall scale; one sample collected for all six sample sets.
[b]Reactor bottom solids; one sample collected for all six sample sets.

I = Matrix interference.
- = Not analyzed.

Table 4-2 (continued)

Sample Set No. 6

Constituent	Concentration					
			Treated nonwastewater			
	Untreated waste	Treated wastewater	Reactor solids A[a]		Reactor solids B[b]	
	Total (mg/l)	Total (mg/l)	Total (mg/kg)	TCLP (mg/l)	Total (mg/kg)	TCLP (mg/l)
BDAT Organics						
Methanol	CBI	36	<15	-	<15	-
BDAT Inorganics						
Antimony	CBI	<4.0	<350	-	<35	-
Arsenic	CBI	<0.05	<1.0	<0.01	<1.0	<0.01
Barium	CBI	<0.6	1.25	0.20	6.4	0.17
Beryllium	CBI	<1.5	<0.15	-	<1.5	-
Cadmium	CBI	<1.2	<1.25	<0.10	<1.0	<0.10
Chromium (hexavalent)	CBI	I	I	I	I	I
Chromium (total)	CBI	<1.8	2.55	<0.10	6.09	<0.10
Copper	CBI	994	151,000	-	44,400	-
Lead	CBI	<35	<35	<2.0	<35	<2.0
Mercury	CBI	<0.015	<1.0	<0.05	<1.0	<0.05
Nickel	CBI	<5.0	33.7	-	26.5	-
Selenium	CBI	<0.045	<1.0	<0.01	<1.0	<0.01
Silver	CBI	<11	<10	<1.0	<8.0	<1.0
Thallium	CBI	<40	<40	-	<40	-
Vanadium	CBI	<2.5	<2.5	-	5.3	-
Zinc	CBI	8.46	29,600	-	139,000	-
Cyanide (amenable)	CBI	<0.25	<25	-	<25	-
Cyanide (total)	CBI	<0.25	<25	-	<25	-
Fluoride	CBI	3.95	-	-	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Reactor temperature	440-480°F	412-494°F
Residence time	55-66 min (5.0-6.0 gal/hr)	50.8 min
Oxygen concentration (off-gas)	16-20%	17.0%
Reactor pressure	1700 psig	1674-1690 psig

[a]Reactor wall scale; one sample collected for all six sample sets.
[b]Reactor bottom solids; one sample collected for all six sample sets.

I = Matrix interference.
- = Not analyzed.

Table 4-3 Alkaline Chlorination Data Submitted by Plant C for Various Wastes

Sample Set No. 1[a] - for Treatment of D003 and F007

Constituent/parameter	Concentration (units) Untreated waste (mg/l)	Treated wastewater (mg/l)
BDAT Inorganics Other Than Metals		
Cyanide (amenable)	-	<1.0
Cyanide (total)	60,000	-
BDAT List Metals		
Cadmium	117	-
Chromium (total)	<100	-
Copper	4,000	-
Lead	<100	-
Nickel	1,500	-
Zinc	1,800	-
Non-BDAT List Metals		
Iron	1,700	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Alkaline chlorination reactor pH	12.5-13.0	12.9
Retention time for alkaline chlorination	2-6 hr minimum[b]	96 hr
ORP for alkaline chlorination	>200 mv	380 mv

- = Not analyzed.

[a]Batch consisted of a mixture of waste codes D003 and F007.
[b]Actual retention time is based on a "not detected" result for the analysis of the waste for amenable cyanide.

Reference: CyanoKEM 1987.

Table 4-3 (continued)

Sample Set No. 2[a] - for Mixed F006-F012, P030

Constituent/parameter	Concentration (units) Untreated waste (mg/l)	Treated wastewater (mg/l)
BDAT Inorganics Other Than Metals		
Cyanide (amenable)	-	<0.1
Cyanide (total)	11,400	-
BDAT List Metals		
Cadmium	25	-
Chromium (total)	1,300	-
Copper	3,400	-
Lead	250	-
Nickel	7,300	-
Zinc	18,500	-
Non-BDAT List Metals		
Iron	3,000	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Alkaline chlorination reactor pH	12.5-13.0	12.45
Retention time for alkaline chlorination	2-6 hr minimum[b]	24 hr
ORP for alkaline chlorination	>200 mv	345 mv

- = Not analyzed.

[a]Batch consisted of a mixture of liquids and drummed solids including waste codes F006, F007, F008, F009, F011, F012, and P030.

[b]Actual retention time is based on a "not detected" result for the analysis of the waste for amenable cyanide.

Table 4-3 (continued)

Sample Set No. 3[a] - for Treatment of F007

Constituent/parameter	Concentration (units) Untreated waste (mg/l)	Treated wastewater (mg/l)
BDAT Inorganics Other Than Metals		
Cyanide (amenable)	-	<0.1
Cyanide (total)	100	-
BDAT List Metals		
Cadmium	-	-
Chromium (total)	780	-
Copper	440	-
Lead	<100	-
Nickel	1,740	-
Zinc	<100	-
Non-BDAT List Metals		
Iron	470	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Alkaline chlorination reactor pH	12.5-13.0	12.65
Retention time for alkaline chlorination	2-6 hr minimum[b]	5.5 hr
ORP for alkaline chlorination	>200 mv	350 mv

- = Not analyzed.

[a]Batch was waste code F007.
[b]Actual retention time is based on a "not detected" result for the analysis of the waste for amenable cyanide.

Table 4-3 (continued)

Sample Set No. 4[a] - for Treatment of D003

Constituent/parameter	Concentration (units) Untreated waste (mg/l)	Treated wastewater (mg/l)
BDAT Inorganics Other Than Metals		
Cyanide (amenable)	-	<0.1
Cyanide (total)	13,000	-
BDAT List Metals		
Cadmium	-	-
Chromium (total)	-	-
Copper	<100	-
Lead	-	-
Nickel	<100	-
Zinc	-	-
Non-BDAT List Metals		
Iron	320	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Alkaline chlorination reactor pH	12.5-13.0	11.8
Retention time for alkaline chlorination	2-6 hr minimum[b]	2 hr
ORP for alkaline chlorination	>200 mv	520 mv

- = Not analyzed.

[a]Batch tested consisted of solid sodium and potassium cyanide salts of 130,000 ppm cyanide concentration (D003).

[b]Actual retention time is based on a "not detected" result for the analysis of the waste for amenable cyanide.

Table 4-3 (continued)

Sample Set No. 5[a] - for Treatment of F009

Constituent/parameter	Concentration (units) Untreated waste (mg/l)	Treated wastewater (mg/l)
BDAT Inorganics Other Than Metals		
Cyanide (amenable)	-	<1.0
Cyanide (total)	27,200	-
BDAT List Metals		
Cadmium	-	-
Chromium (total)	-	-
Copper	270	-
Lead	-	-
Nickel	1,050	-
Zinc	3,070	-
Non-BDAT List Metals		
Iron	3,320	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Alkaline chlorination reactor pH	12.5-13.0	12.6
Retention time for alkaline chlorination	2-6 hr minimum[b]	20 hr
ORP for alkaline chlorination	>200 mv	460 mv

- = Not analyzed.

[a]Waste tested was F009.
[b]Actual retention time is based on a "not-detected" result for the analysis of the waste for amenable cyanide.

Table 4-3 (continued)

Sample Set No. 6[a] - for Treatment of F011 and D002

Constituent/parameter	Concentration (units) Untreated waste (mg/l)	Treated wastewater (mg/l)
BDAT Inorganics Other Than Metals		
Cyanide (amenable)	-	<1.0
Cyanide (total)	6,000	-
BDAT List Metals		
Cadmium	-	-
Chromium (total)	-	-
Copper	-	-
Lead	-	-
Nickel	-	-
Zinc	11,000	-
Non-BDAT List Metals		
Iron	4,000	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Alkaline chlorination reactor pH	12.5-13.0	12.8
Retention time for alkaline chlorination	2-6 hr minimum[b]	48 hr
ORP for alkaline chlorination	>200 mv	424 mv

- = Not analyzed.

[a]Batch consisted of a mixture of F011 and D002.
[b]Actual retention time is based on a "not detected" result for the analysis of the waste for amenable cyanide.

Table 4-3 (continued)

Sample Set No. 7[a] - for Treatment of F009

Constituent/parameter	Concentration (units) Untreated waste (mg/l)	Treated wastewater (mg/l)
BDAT Inorganics Other Than Metals		
Cyanide (amenable)	-	<1.0
Cyanide (total)	30,000	-
BDAT List Metals		
Cadmium	-	-
Chromium (total)	-	-
Copper	-	-
Lead	-	-
Nickel	-	-
Zinc	19,250	-
Non-BDAT List Metals		
Iron	-	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Alkaline chlorination reactor pH	12.5-13.0	12.8
Retention time for alkaline chlorination	2-6 hr minimum[b]	12 hr
ORP for alkaline chlorination	>200 mv	400 mv

- = Not analyzed.

[a]Batch consisted of a mixture of F009 (zinc plating waste) and a waste hypochlorite solution.

[b]Actual retention time is based on a "not detected" result for the analysis of the waste for amenable cyanide.

Table 4-3 (continued)

Sample Set No. 8[a] - for Treatment of F007

Constituent/parameter	Concentration (units) Untreated waste (mg/l)	Treated wastewater (mg/l)
BDAT Inorganics Other Than Metals		
Cyanide (amenable)	-	<1.0
Cyanide (total)	6,000	-
BDAT List Metals		
Cadmium	-	-
Chromium (total)	<100	-
Copper	1,500	-
Lead	-	-
Nickel	-	-
Zinc	580	-
Non-BDAT List Metals		
Iron	490	-

Note: Design and operating parameters are as follows:

Parameter	Design value	Operating value
Alkaline chlorination reactor pH	12.5-13.0	12.9
Retention time for alkaline chlorination	2-6 hr minimum[b]	8 hr
ORP for alkaline chlorination	>200 mv	380 mv

- = Not analyzed.

[a]Batch was F007 waste.
[b]Actual retention time is based on a "not detected" result for the analysis of the waste for amenable cyanide.

Table 4-4 Electrolytic Oxidation Treatment Data from Literature Source A for Treatment of F007 and F009 Wastes

Constituent	Concentration (units) Untreated waste (mg/l)	Treated wastewater (mg/l)	Reaction time (days)
Sample Set #1:			
Cyanide (total)	95,000	0.1	16
Sample Set #2:			
Cyanide (total)	75,000	0.2	17
Sample Set #3:			
Cyanide (total)	50,000	0.4	10
Sample Set #4:			
Cyanide (total)	75,000	0.2	18
Sample Set #5:			
Cyanide (total)	65,000	0.2	12
Sample Set #6:			
Cyanide (total)	100,000	0.3	17
Sample Set #7:			
Cyanide (total)	55,000	0.4	14
Sample Set #8:			
Cyanide (total)	45,000	0.1	7
Sample Set #9:			
Cyanide (total)	50,000	0.4	14
Sample Set #10:			
Cyanide (total)	55,000	0.2	8
Sample Set #11:			
Cyanide (total)	48,000	0.4	12

Note: Design values for operating conditions are presented below:

Parameter	Value/Description
Temperature	200°F minimum
Total current	1,200 amp @ 6 volts
Anode current density	35 amp/ft^2

Reference: Easton 1967. Treatment of F007 and F009 copper plating wastes.

Table 4-5 High-Temperature Cyanide Hydrolysis Data from Literature Source B for Treatment of F007, F008, and F009 Wastes

Constituent	Concentration (units)		Operating Data (units)		
	Untreated waste (mg/l)	Treated wastewater (mg/l)	Maximum temperature (°F)	Maximum pressure (psi)	Reaction time at maximum temperature (hr)
Sample Set No. 1:					
Cyanide (total)	10,000	19.8	477	700	1 hr
Sample Set No. 2:					
Cyanide (total)	30,000	0.8	492	875	1 hr
Sample Set No. 3:					
Cyanide (total)	10,000	2.6	450	-[a]	1 hr
Sample Set No. 4:					
Cyanide (total)	10,000	15	460	620	1 hr
Sample Set No. 5:					
Cyanide (total)	33,000	1.2	500	875	1 hr
Sample Set No. 6:					
Cyanide (total)	38,000	2.1	458	875	1 hr

[a]Pressure gauge malfunction; 875 psi is assumed.

Reference: Robey 1983. Treatment of F007-F009 wastes containing cadmium, copper, and/or nickel cyanides.

Table 4-6 Incineration Data Submitted by Plant D for Treatment of F010

	Concentration (units)		
	Untreated waste	Treated nonwastewater	
	(mg/kg)	(total) (mg/l)	(leachate) (mg/l)
Sample Set No. 1:			
Cyanide (total)	22,000	0.45	<0.025
Sample Set No. 2:			
Cyanide (total)	20,000	0.40	<0.025
Sample Set No. 3:			
Cyanide (total)	-[a]	0.88	<0.025

[a]The treatment data were obtained from treatment of two different wastes. The three treated waste samples represent samples taken over the course of treatment of the two wastes.

Reference: CyanoKEM 1988.

5. IDENTIFICATION OF BEST DEMONSTRATED AVAILABLE TECHNOLOGY (BDAT)

This section presents the Agency's rationale for determining best demonstrated available technology (BDAT) for F006 (cyanide), F007-F012, and F019 nonwastewaters and wastewaters. To determine BDAT, the Agency examines all available performance data for the technologies that are identified as demonstrated to determine whether one of these technologies performs significantly better than the others. All performance data used for determination of best technology must first be adjusted for accuracy, as discussed in EPA's publication, Methodology for Developing BDAT Treatment Standards.* BDAT must be specifically defined for all streams associated with the management of the listed waste or wastes; this includes the original waste as well as any residual waste streams created by the treatment process.

The technology that performs best on a particular waste or waste subcategory is then evaluated to determine whether it is "available." To be available, the technology must (1) be commercially available to any generator and (2) provide "substantial" treatment of the waste, as determined through evaluation of accuracy-adjusted data. In determining whether treatment is substantial, EPA may consider data on the performance of a waste similar to the waste in question, provided that the similar waste is at least as difficult to treat.

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*Accuracy adjustment accounts for the ability of an analytical technique to recover a particular constituent from the waste in a particular test. The recovery of a constituent is determined by spiking a sample with a known amount of the target constituent and then comparing the result of analysis of the spiked sample with the result from the unspiked sample.

5.1 BDAT for the Metal Finishing Aqueous Liquids Subcategory

5.1.1 Cyanide Treatment

EPA reviewed the available treatment performance data for wastes in this subcategory for cyanide treatment technologies, presented in Section 4, to determine whether they represent the operation of well-designed and well-operated systems, whether sufficient quality assurance/quality control (QA/QC) data were collected to assess the accuracy of the treated waste analyses, and whether the data presented provide the appropriate measure of performance for the technology tested.

The treatment performance data for electrolytic oxidation followed by alkaline chlorination collected at Plant A, presented in Table 4-1, provide the appropriate measure of performance for this technology (amenable and total cyanide concentrations in the untreated waste and in both the wastewater and nonwastewater residuals). Design and operating data collected during the test indicate that the system was well designed and was well operated during the test. Additionally, the appropriate QA/QC data were supplied with these performance data.

The treatment performance data for wet air oxidation, presented in Table 4-2, also provide amenable and total cyanide concentrations in the untreated waste and in both wastewater and nonwastewater residuals. Design and operating data collected during the test indicate that the system was well designed and was well operated during the collection of five of the six sets of performance data. The appropriate QA/QC data were supplied with these performance data. The data collected for Sample

Set No. 1 show higher concentrations of both amenable and total cyanide in the feed (approximately 20 percent higher) than for any of the other five sample sets, without a corresponding increase in residence time. This may account for a poorer system performance, as shown by the data. This problem might have been alleviated in operation either by better mixing of the feed or by decreasing the feed flow rate for higher concentration feed streams. The data for Sample Set No. 1 were not considered further in the development of BDAT standards on the basis of poor system operation (insufficient reactor residence time) at the time of treatment data collection.

Treatment performance data for alkaline chlorination submitted by Plant C, presented in Table 4-3, provide total cyanide concentration in the untreated waste and amenable cyanide concentration in the treated wastewater. The design and operating data submitted indicate that the system was well designed and was well operated during the tests. No QA/QC data were submitted.

Treatment performance data for electrolytic oxidation were obtained from literature source A and are presented in Table 4-4. These data provide total cyanide concentrations for both the untreated waste and the treated wastewater. The design values given indicate that the system was well designed, and the treated waste cyanide concentration, as well as the reaction time, indicates that the system was well operated at the time of treatment data collection. No QA/QC data were given for these tests.

Treatment performance data for high temperature cyanide hydrolysis were obtained from literature source B and are presented in Table 4-5. These data provide total cyanide concentrations for both the untreated waste and the treated wastewater after subsequent chemical precipitation treatment followed by filtration to remove suspended precipitated solids. No system design data were specified. The operating data provided indicate that the system was well operated during the collection of treatment data sets Nos. 2, 3, 5, and 6. For data sets No. 1 and No. 4, the operating data indicate that low reactor pressure (700 psi and 620 psi versus 875 psi for the other four runs) contributed to the higher effluent cyanide concentration; therefore, these data sets were not further considered in assessing the performance of this technology (based on poor operation). No QA/QC data were given for these tests.

The treatment performance data for the demonstrated cyanide treatment technologies presented in Section 4 were adjusted for analytical recovery to take into account analytical interferences associated with the chemical makeup of the treated waste samples. In the QA/QC test for analytical recovery, EPA first analyzes a waste for a constituent and then adds a known amount (i.e., a spike) of the same constituent to the waste material and reanalyzes the sample for that constituent. The difference between the total amount detected after spiking and the concentration detected in the unspiked sample divided by the amount of spike added is the recovery value. (If recovery tests are run in duplicate, EPA uses the lower recovery value.) The reciprocal of the

recovery multiplied by the analytical value obtained during performance testing is the accuracy-corrected value used in comparing treatment effectiveness and subsequently in calculating treatment standards. Percent recovery values for constituents detected in the F007 and F011 wastes tested are presented in Appendix A. In the cases for which no analytical recovery data were available (Tables 4-3 through 4-5), EPA cannot directly compare these data to the data for which accuracy correction factors are available. Therefore, the data presented in Tables 4-3 through 4-5 for alkaline chlorination, electrolytic oxidation, and high-temperature cyanide hydrolysis were not considered in the determination of "best" treatment of cyanide in F007-F011 wastewaters and nonwastewaters.

Accuracy-adjusted cyanide concentrations for all data considered in developing BDAT for metal finishing aqueous liquids for wastewaters are presented in Tables 5-1 and 5-2 (all tables are at the end of the section) for amenable and total cyanide, respectively. Statistical comparison of the one data set from electrolytic oxidation followed by alkaline chlorination with the five data sets from wet air oxidation from treatment of similar wastes shows that the performance of wet air oxidation is better for both amenable and total cyanides.

EPA's determination that substantial treatment occurs for wet air oxidation is based on the reduction in both total and amenable cyanide concentrations in the waste tested. In addition to providing substantial

treatment, wet air oxidation is commercially available; therefore, this technology is "available" to treat cyanide in the wastes in the metal finishing aqueous liquids subcategory.

5.1.2 BDAT List Metals Treatment

Characterization data for F007, F008, F009, and F011 wastes show that these wastes may contain high concentrations of dissolved metals and therefore may require treatment by chemical precipitation followed by filtration and sludge dewatering. Chromium reduction may also be necessary prior to chemical precipitation if the waste has a treatable concentration of hexavalent chromium following cyanide oxidation. This treatment train can be added after application of one of the demonstrated technologies for cyanide removal, and it results in a wastewater and nonwastewater treatment residual.

(1) Wastewaters. Data on the performance of chromium reduction followed by chemical precipitation and filtration for wastewaters were developed for regulation of K062 waste. Two data sets were also presented, in Table 4-1, for chemical precipitation followed by filtration and sludge dewatering treatment of F011 waste mixed with heat treating rinsewaters. These two sets of performance data are not directly comparable because the K062 waste treated had significantly higher concentrations of BDAT list metals than the F011 waste treated. The treatment data used in regulation of K062 can be transferred to the wastewater residual from treatment of F007, F008, F009, F010 (inorganic subgroup), and F011 because these wastes have similar or lower dissolved

metals concentrations and thus will treat similarly to K062, whereas the F011 treatment data represent treatment of a waste with significantly lower metals concentrations than expected for most F007, F008, F009, and F011 wastes and thus cannot be transferred. Because the K062 treatment data are the only data available to EPA on the performance level of chromium reduction followed by chemical precipitation and filtration treatment of a waste with high BDAT metals concentration, the Agency has determined that the performance of chromium reduction followed by chemical precipitation and filtration is "best" for treatment of BDAT list metals in these wastes following cyanide treatment. As was presented for K062 (see EPA's BDAT Background Document for K062), this technology is "available" and thus meets the Agency's criteria for BDAT.

(2) Nonwastewaters. The nonwastewater treatment residual from the chemical precipitation step, either before or after dewatering, is a waste that is similar to the wastes in the metal finishing sludges subcategory. The selection of BDAT for these wastes is discussed in the next section.

5.2 BDAT for the Metal Finishing Sludges Subcategory

5.2.1 BDAT List Metals Treatment

EPA has previously promulgated treatment standards for BDAT list metal constituents for F006 based on the performance of stabilization (see EPA's BDAT Background Document for F006). EPA believes that the wastes F012 and F019 are similar to F006 both in waste composition and in the process generating the waste. These wastes are also similar to the

nonwastewater treatment residuals from treatment of F007-F009 and F011 wastes by chemical precipitation followed by filtration. It follows, therefore, that since no data on treatment of F006 or similar wastes are available other than the data used to develop stabilization treatment standards for F006, stabilization represents the best treatment for BDAT list metals for F012, F019, and the nonwastewater residuals (i.e., wastewater treatment sludges) from chemical precipitation and sludge dewatering treatment of F007, F008, F009, and F011 based on the similarities discussed above between F006 and these wastes.

5.2.2 Cyanide Treatment

For cyanide, no data are available to the Agency on treatment of F006, F012, F019, or similar wastes by any of the technologies identified as demonstrated for F007, F008, F009, and F011. As stated in Section 2.4, however, these wastes are generated from chemical precipitation treatment, which usually follows a cyanide oxidation step if the waste treated originally contained cyanide. Therefore, these wastes are not expected to contain treatable concentrations of cyanide if generated following treatment by a well-designed and well-operated cyanide treatment step. The Agency has two data sets on the generation of F012 waste from a well-designed and well-operated treatment system consisting of electrolytic oxidation followed by alkaline chlorination, chemical precipitation, filtration, and sludge dewatering (presented in Table 4-1). The accuracy-adjusted data for cyanides in this waste as generated are presented in Table 5-3. Treatment of the waste for cyanide

before generation of these wastes is the Agency's "best" technology for determination of cyanide treatment standards for F006, F012, F019, and similar wastes.

As discussed in Section 4 and previously in this section, alkaline chlorination, electrolytic oxidation, chemical precipitation, filtration, and sludge dewatering are commercially available technologies for the treatment of F007-F009, F011, and similar wastes and thus are "available" to be used to generate F006, F012, F019, and similar wastes.

Also, as shown in Table 4-1, the treatment train discussed above substantially reduces the concentration of cyanide in F012 waste compared to the waste from which it was generated. Stabilization treatment of the treatment sludges generated by chemical precipitation has been shown previously, in the case of F006, to result in substantial reductions in leachate concentrations of BDAT list metals. Therefore, the treatment train discussed above, followed by stabilization of the F006, F012, F019, or similar waste thus generated, is "available" and thus is BDAT for F006, F012, and F019 and is the basis for cyanide standards for wastewater treatment sludge residuals from the treatment of F007, F008, F009, and F011 wastes.

5.3 BDAT for the Metal Finishing Organic Liquids Subcategory

The data available to the Agency on incineration of F010 waste (presented in Table 4-6) indicate that incineration achieves a substantial reduction in cyanide concentration in the incinerator ash compared to the untreated waste. Accuracy adjustment of these data is

detailed in Table 5-4. No data were submitted on BDAT metals in the untreated waste or the ash residual. The Agency has no information as to which, if any, metals are present in F010 waste or the ash residual from incineration of this waste.

No data are available on the composition of the scrubber water from incineration of F010, but the Agency expects this scrubber water to be less difficult to treat than the other wastewaters regulated (F007 and F009 wastewaters) in terms of the concentration of cyanide and the type and concentration of BDAT list metals. Therefore, "best" technology for these scrubber waters is wet air oxidation.

Incineration and wet air oxidation are both commercially available technologies and thus are "available" for the purposes of establishing BDAT. Therefore, BDAT for the metal finishing organic liquids subcategory is incineration followed by wet air oxidation treatment of the scrubber waters.

Table 5-1 Summary of Accuracy Adjustment of Treatment Data for Amenable Cyanide in Wastewaters

	Untreated waste concentration (mg/l)	Measured treated waste concentration (mg/l)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/l)
Wet Air Oxidation					
Sample Set No. 2	CBI	<0.25	52	1.923	<0.48
Sample Set No. 3	CBI	<0.25	52	1.923	<0.48
Sample Set No. 4	CBI	<0.25	52	1.923	<0.48
Sample Set No. 5	CBI	<0.25	52	1.923	<0.48
Sample Set No. 6	CBI	<0.25	52	1.923	<0.48
Electrolytic Oxidation/Alkaline Chlorination					
Sample Set No. 1	5,350 [a]	-	-	-	3.0

[a]Value is total cyanide concentration.

- = Not available. Quantities actually measured were total cyanide and "chlorinated cyanide," which were both adjusted for accuracy. (See Appendix B for detailed calculations.)

Table 5-2 Summary of Accuracy Adjustment of Treatment Data for Total Cyanide in Wastewaters

	Untreated waste concentration (mg/l)	Measured treated waste concentration (mg/l)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/l)
Wet Air Oxidation					
Sample Set No. 2	CBI	<0.25	52	1.923	<0.48
Sample Set No. 3	CBI	3.22	52	1.923	6.19
Sample Set No. 4	CBI	<0.25	52	1.923	<0.48
Sample Set No. 5	CBI	<0.25	52	1.923	<0.48
Sample Set No. 6	CBI	<0.25	52	1.923	<0.48
Electrolytic Oxidation/Alkaline Chlorination					
Sample Set No. 1	5,350	103	88	1.136	117

Table 5-3 Summary of Accuracy Adjustment of Cyanide Data in F012 Waste as Generated

	Untreated waste concentration (mg/l)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/l)
Sample Set No. 1				
Cyanide (amenable)	-	-	-	<0.023
Cyanide (total)	99.4	102	0.98	97.4
Sample Set No. 2				
Cyanide (amenable)	-	-	-	<0.023
Cyanide (total)	34.7	93	1.08	37.3

- = Not available. Quantities actually measured were total cyanide and "chlorinated cyanide," which were both adjusted for accuracy. (See Appendix B for detailed calculations.)

Table 5-4 Summary of Accuracy Adjustment of Treatment Data for Total Cyanide in F010 Waste

	Untreated waste concentration (mg/kg)	Measured treated waste concentration (mg/kg)	Percent recovery for matrix spike test	Accuracy correction factor	Accuracy-adjusted concentration (mg/kg)
Sample Set No. 1					
Cyanide (total)	22,000	0.45	96	1.04	0.468
Sample Set No. 2					
Cyanide (total)	20,000	0.40	96	1.04	0.416
Sample Set No. 3					
Cyanide (total)	-	0.88	96	1.04	0.915

- = Not available. Only two untreated waste samples were collected.

6. SELECTION OF REGULATED CONSTITUENTS

This section presents the rationale for selection of the proposed regulated constituents for the treatment of F006-F012 and F019 wastes.

Constituents selected for regulation must satisfy the following criteria:

1. They must be on the BDAT list of regulated constituents. (Presence on the BDAT list implies the existence of approved techniques for analyzing the constituent in treated wastes.)

2. They must be present in, or suspected of being present in, the untreated waste. For example, in some cases, analytical difficulties (such as masking) may prevent a constituent from being identified in the untreated waste, but its identification in a treatment residual may lead the Agency to conclude that it is present in the untreated waste.

3. Where performance data are transferred, the selected constituents must be easier to treat than the waste constituent(s) from which performance data are transferred. Factors for assessing ease of treatment will vary according to the technology of concern. For instance, for incineration the factors include bond dissociation energy, thermal conductivity, and boiling point.

From the group of constituents that are eligible to be regulated, EPA may select a subset of constituents as representative of the broader group. For instance, out of a group of constituents that react similarly to treatment, the Agency might name only those found in the highest concentrations or those that are the most difficult to treat as regulated constituents for the purpose of setting a standard.

6.1 Identification of BDAT List Constituents

Table 6-1 shows which BDAT list constituents were analyzed for in all wastes tested by EPA, which constituents were detected, and which constituents the Agency believes may be present even though not detected

in the untreated waste on which treatment tests were performed. BDAT list metals and cyanide were detected in all of the wastes sampled.

For the F007 waste tested, one volatile organic compound was detected, methanol. One PCB compound, Aroclor 1254, was detected at a concentration slightly above the detection limit, and several volatile and semivolatile organic compounds were detected in the F012 waste tested. No other BDAT list organic compounds were detected, or are believed to be commonly present, in any of the wastes tested or any of the wastes regulated by this document based on the Agency's knowledge of the electroplating and heat treating processes. The detection of a PCB compound in the F012 waste tested is probably attributable to a cleanup of PCB transformers that had recently occurred at the plant where this waste was collected. The organic compounds detected in F012 (bis(2-ethylhexyl) phthalate, acetone, chloroform, methylene chloride, and toluene) were probably contaminants of the rinsewaters treated along with the quenching wastewaters. These organic compounds were all found at very low concentrations that are not believed to be treatable. The methanol detected in the F007 waste tested was probably a constituent of the electroplating bath, but is not commonly used in such an application; thus, it is not proposed for regulation.

6.2 Determination of Regulated Constituents

For the metal finishing aqueous liquids subcategory, EPA is proposing to regulate total and amenable cyanide in both wastewater and nonwastewater treatment residuals based on the performance of wet air

oxidation. The Agency is also proposing to regulate chromium, lead, and nickel in wastewaters and cadmium, chromium, lead, nickel, and silver in nonwastewaters. Regulated constituent selection for nonwastewaters and wastewaters is based on treatment of the effluent from wet air oxidation by chemical precipitation followed by filtration for the wastewaters and subsequent dewatering followed by stabilization of the nonwastewater residual. All of the metals listed above are commonly found in electroplating and heat treating wastes. Amenable and total cyanides are proposed for regulation based on the total waste composition analysis. EPA feels that because these standards are based on a destruction technology, the appropriate measure of performance is total waste composition. Also, because there may be a difference in performance of cyanide destruction technologies between complexed and noncomplexed cyanide, both amenable and total cyanide standards are proposed. The Agency has no data on the treatment of wastewaters for cadmium and silver by chemical precipitation, but believes that these constituents will be controlled by treatment of the other metals proposed for regulation.

The only other metals that are commonly detected in these wastes at high concentrations, according to the waste characterization data presented in Section 2, are copper and zinc. EPA is not regulating copper and zinc because the constituents are not listed in Appendix VIII of 40 CFR Part 261 as elemental constituents but rather as specific compounds (i.e., copper cyanide, zinc phosphide, and zinc cyanide). In any case, treatment of the other BDAT list metals by chemical

precipitation and/or stabilization will also reduce leachate concentrations of both of these metals in wastewater and nonwastewater treatment residuals.

For the metal finishing treatment sludges subcategory (F006, F012, and F019), EPA is proposing to regulate amenable and total cyanide in both wastewaters and nonwastewaters. For F012 and F019 wastewaters, the Agency is proposing to regulate chromium, lead, and nickel. For F012 and F019 nonwastewaters, the Agency is proposing to regulate cadmium, chromium, lead, nickel, and silver. These metals have been previously regulated for F006 nonwastewaters (see EPA's BDAT Background Document for F006).

For the metal finishing organic liquids (F010), EPA is proposing to regulate total cyanide in the total composition analysis for both wastewater and nonwastewater residuals. For incineration, the Agency believes that total cyanide is the appropriate measure of performance, as it has no evidence that complexed cyanides are any more difficult to treat by thermal treatment methods such as incineration than are free cyanides. As discussed in Section 5.3, EPA has no data on metals in this waste and has no reason to expect BDAT metals to be detected in the organic F010 waste.

Table 6-1 Status of BDAT List Constituent Presence in Untreated Tested Wastes

BDAT reference no.	Constituent	F007	F011	F012
	Volatile Organics			
222.	Acetone	ND	ND	D
1.	Acetonitrile	ND	ND	ND
2.	Acrolein	ND	ND	ND
3.	Acrylonitrile	ND	ND	ND
4.	Benzene	ND	ND	ND
5.	Bromodichloromethane	ND	ND	ND
6.	Bromomethane	ND	ND	ND
223.	n-Butyl alcohol	ND	NA	NA
7.	Carbon tetrachloride	ND	ND	ND
8.	Carbon disulfide	ND	ND	ND
9.	Chlorobenzene	ND	ND	ND
10.	2-Chloro-1,3-butadiene	ND	ND	ND
11.	Chlorodibromomethane	ND	ND	ND
12.	Chloroethane	ND	ND	ND
13.	2-Chloroethyl vinyl ether	ND	ND	ND
14.	Chloroform	ND	ND	D
15.	Chloromethane	ND	ND	ND
16.	3-Chloropropene	ND	ND	ND
17.	1,2-Dibromo-3-chloropropane	ND	ND	ND
18.	1,2-Dibromoethane	ND	ND	ND
19.	Dibromomethane	ND	ND	ND
20.	trans-1,4-Dichloro-2-butene	ND	ND	ND
21.	Dichlorodifluoromethane	ND	ND	ND
22.	1,1-Dichloroethane	ND	ND	ND
23.	1,2-Dichloroethane	ND	ND	ND
24.	1,1-Dichloroethylene	ND	ND	ND
25.	trans-1,2-Dichloroethene	ND	ND	ND
26.	1,2-Dichloropropane	ND	ND	ND
27.	trans-1,3-Dichloropropene	ND	ND	ND
28.	cis-1,3-Dichloropropene	ND	ND	ND
29.	1,4-Dioxane	ND	ND	ND
224.	2-Ethoxyethanol	ND	NA	NA
225.	Ethyl acetate	ND	NA	NA
226.	Ethyl benzene	ND	ND	ND
30.	Ethyl cyanide	ND	ND	ND
227.	Ethyl ether	ND	NA	NA
31.	Ethyl methacrylate	ND	ND	ND
214.	Ethylene oxide	ND	ND	ND
32.	Iodomethane	ND	ND	ND
33.	Isobutyl alcohol	ND	ND	ND
228.	Methanol	D	NA	NA
34.	Methyl ethyl ketone	ND	ND	ND

Table 6-1 (continued)

BDAT reference no.	Constituent	F007	F011	F012
	Volatile Organics (continued)			
229.	Methyl isobutyl ketone	ND	ND	ND
35.	Methyl methacrylate	ND	ND	ND
37.	Methacrylonitrile	ND	ND	ND
38.	Methylene chloride	ND	ND	D
230.	2-Nitropropane	ND	NA	NA
39.	Pyridine	ND	ND	ND
40.	1,1,1,2-Tetrachloroethane	ND	ND	ND
41.	1,1,2,2-Tetrachloroethane	ND	ND	ND
42.	Tetrachloroethene	ND	ND	ND
43.	Toluene	ND	ND	D
44.	Tribromomethane	ND	ND	ND
45.	1,1,1-Trichloroethane	ND	ND	ND
46.	1,1,2-Trichloroethane	ND	ND	ND
47.	Trichloroethene	ND	ND	ND
48.	Trichloromonofluoromethane	ND	ND	ND
49.	1,2,3-Trichloropropane	ND	ND	ND
231.	1,1,2-Trichloro-1,2,2-trifluoroethane	NA	NA	NA
50.	Vinyl chloride	ND	ND	ND
215.	1,2-Xylene	ND	ND	ND
216.	1,3-Xylene	ND	ND	ND
217.	1,4-Xylene	ND	ND	ND
	Semivolatile Organics			
51.	Acenaphthylene	ND	ND	ND
52.	Acenaphthene	ND	ND	ND
53.	Acetophenone	ND	ND	ND
54.	2-Acetylaminofluorene	ND	ND	ND
55.	4-Aminobiphenyl	ND	ND	ND
56.	Aniline	ND	ND	ND
57.	Anthracene	ND	ND	ND
58.	Aramite	NA	ND	ND
59.	Benz(a)anthracene	ND	ND	ND
218.	Benzal chloride	ND	NA	NA
60.	Benzenethiol	NA	ND	ND
61.	Deleted			
62.	Benzo(a)pyrene	ND	ND	ND
63.	Benzo(b)fluoranthene	ND	ND	ND
64.	Benzo(ghi)perylene	ND	ND	ND
65.	Benzo(k)fluoranhene	ND	ND	ND
66.	p-Benzoquinone	NA	ND	ND

Table 6-1 (continued)

BDAT reference no.	Constituent	F007	F011	F012
	Semivolatile Organics (continued)			
67.	Bis(2-chloroethoxy)methane	ND	ND	ND
68.	Bis(2-chloroethyl) ether	ND	ND	ND
69.	Bis(2-chloroisopropyl) ether	ND	ND	ND
70.	Bis(2-ethylhexyl) phthalate	ND	ND	D
71.	4-Bromophenyl phenyl ether	ND	ND	ND
72.	Butylbenzyl phthalate	ND	ND	ND
73.	2-sec-Butyl-4,6-dinitrophenol	ND	ND	ND
74.	p-Chloroaniline	ND	ND	ND
75.	Chlorobenzilate	ND	ND	ND
76.	p-Chloro-m-cresol	ND	ND	ND
77.	2-Chloronaphthalene	ND	ND	ND
78.	2-Chlorophenol	ND	ND	ND
79.	3-Chloropropionitrile	ND	ND	ND
80.	Chrysene	ND	ND	ND
81.	ortho-Cresol	ND	ND	ND
82.	para-Cresol	ND	ND	ND
232.	Cyclohexanone	ND	NA	NA
83.	Dibenz(a,h)anthracene	ND	ND	ND
84.	Dibenzo(a,e)pyrene	NA	ND	ND
85.	Dibenzo(a,i)pyrene	NA	ND	ND
86.	m-Dichlorobenzene	ND	ND	ND
87.	o-Dichlorobenzene	ND	ND	ND
88.	p-Dichlorobenzene	ND	ND	ND
89.	3,3'-Dichlorobenzidine	ND	ND	ND
90.	2,4-Dichlorophenol	ND	ND	ND
91.	2,6-Dichlorophenol	ND	ND	ND
92.	Diethyl phthalate	ND	ND	ND
93.	3,3'-Dimethoxybenzidine	ND	ND	ND
94.	p-Dimethylaminoazobenzene	ND	ND	ND
95.	3,3'-Dimethylbenzidine	ND	ND	ND
96.	2,4-Dimethylphenol	ND	ND	ND
97.	Dimethyl phthalate	ND	ND	ND
98.	Di-n-butyl phthalate	ND	ND	ND
99.	1,4-Dinitrobenzene	ND	ND	ND
100.	4,6-Dinitro-o-cresol	ND	ND	ND
101.	2,4-Dinitrophenol	ND	ND	ND
102.	2,4-Dinitrotoluene	ND	ND	ND
103.	2,6-Dinitrotoluene	ND	ND	ND
104.	Di-n-octyl phthalate	ND	ND	ND
105.	Di-n-propylnitrosamine	ND	ND	ND
106.	Diphenylamine	ND	ND	ND
219.	Diphenylnitrosamine	ND	ND	ND

Table 6-1 (continued)

BDAT reference no.	Constituent	F007	F011	F012
	Semivolatile Organics (continued)			
107.	1,2-Diphenylhydrazine	ND	ND	ND
108.	Fluoranthene	ND	ND	ND
109.	Fluorene	ND	ND	ND
110.	Hexachlorobenzene	ND	ND	ND
111.	Hexachlorobutadiene	ND	ND	ND
112.	Hexachlorocyclopentadiene	ND	ND	ND
113.	Hexachloroethane	ND	ND	ND
114.	Hexachlorophene	NA	ND	ND
115.	Hexachloropropene	ND	ND	ND
116.	Indeno(1,2,3-cd)pyrene	ND	ND	ND
117.	Isosafrole	ND	ND	ND
118.	Methapyrilene	ND	ND	ND
119.	3-Methylcholanthrene	NA	ND	ND
120.	4,4'-Methylenebis-(2-chloroaniline)	ND	ND	ND
36.	Methyl methanesulfonate	ND	ND	ND
121.	Naphthalene	ND	ND	ND
122.	1,4-Naphthoquinone	ND	ND	ND
123.	1-Naphthylamine	NA	ND	ND
124.	2-Naphthylamine	ND	ND	ND
125.	p-Nitroaniline	ND	ND	ND
126.	Nitrobenzene	ND	ND	ND
127.	4-Nitrophenol	ND	ND	ND
128.	N-Nitrosodi-n-butylamine	ND	ND	ND
129.	N-Nitrosodiethylamine	ND	ND	ND
130.	N-Nitrosodimethylamine	ND	ND	ND
131.	N-Nitrosomethylethylamine	ND	ND	ND
132.	N-Nitrosomorpholine	ND	ND	ND
133.	N-Nitrosopiperidine	ND	ND	ND
134.	N-Nitrosopyrrolidine	ND	ND	ND
135.	5-Nitro-o-toluidine	ND	ND	ND
136.	Pentachlorobenzene	ND	ND	ND
137.	Pentachloroethane	NA	ND	ND
138.	Pentachloronitrobenzene	ND	ND	ND
139.	Pentachlorophenol	ND	ND	ND
140.	Phenacetin	ND	ND	ND
141.	Phenanthrene	ND	ND	ND
142.	Phenol	ND	ND	ND
220.	Phthalic anhydride	ND	NA	NA
143.	2-Picoline	ND	ND	ND
144.	Pronamide	ND	ND	ND
145.	Pyrene	ND	ND	ND
146.	Resorcinol	NA	ND	ND

Table 6-1 (continued)

BDAT reference no.	Constituent	F007	F011	F012
	Semivolatile Organics (continued)			
147.	Safrole	ND	ND	ND
148.	1,2,4,5-Tetrachlorobenzene	ND	ND	ND
149.	2,3,4,6-Tetrachlorophenol	ND	ND	ND
150.	1,2,4-Trichlorobenzene	ND	ND	ND
151.	2,4,5-Trichlorophenol	ND	ND	ND
152.	2,4,6-Trichlorophenol	ND	ND	ND
153.	Tris(2,3-dibromopropyl) phosphate	ND	ND	ND
	Metals			
154.	Antimony	ND	D	ND
155.	Arsenic	ND	ND	ND
156.	Barium	ND	D	D
157.	Beryllium	ND	ND	ND
158.	Cadmium	ND-X	D	D
159.	Chromium (total)	D	D	D
221.	Chromium (hexavalent)	I-Y	ND	I
160.	Copper	D	D	D
161.	Lead	ND	D	D
162.	Mercury	D	ND	ND
163.	Nickel	ND-X	D	D
164.	Selenium	ND	ND	ND
165.	Silver	ND-X	D	D
166.	Thallium	ND	ND	ND
167.	Vanadium	ND	D	D
168.	Zinc	D	D	D
	Inorganics Other Than Metals			
169.	Cyanide	D	D	D
170.	Fluoride	D	D	D
171.	Sulfide	NA	ND	ND
	Organochlorine Pesticides			
172.	Aldrin	ND	NA	NA
173.	alpha-BHC	ND	NA	NA
174.	beta-BHC	ND	NA	NA
175.	delta-BHC	ND	NA	NA

Table 6-1 (continued)

BDAT reference no.	Constituent	F007	F011	F012
	Organochlorine Pesticides (continued)			
176.	gamma-BHC	ND	NA	NA
177.	Chlordane	ND	NA	NA
178.	DDD	ND	NA	NA
179.	DDE	ND	NA	NA
180.	DDT	ND	NA	NA
181.	Dieldrin	ND	NA	NA
182.	Endosulfan I	ND	NA	NA
183.	Endosulfan II	ND	NA	NA
184.	Endrin	ND	NA	NA
185.	Endrin aldehyde	ND	NA	NA
186.	Heptachlor	ND	NA	NA
187.	Heptachlor epoxide	ND	NA	NA
188.	Isodrin	ND	NA	NA
189.	Kepone	ND	NA	NA
190.	Methoxyclor	ND	NA	NA
191.	Toxaphene	ND	NA	NA
	Phenoxyacetic Acid Herbicides			
192.	2,4-Dichlorophenoxyacetic acid	ND	NA	NA
193.	Silvex	ND	NA	NA
194.	2,4,5-T	ND	NA	NA
	Organophosphorous Insecticides			
195.	Disulfoton	ND	NA	NA
196.	Famphur	ND	NA	NA
197.	Methyl parathion	ND	NA	NA
198.	Parathion	ND	NA	NA
199.	Phorate	ND	NA	NA
	PCBs			
200.	Aroclor 1016	ND	ND	ND
201.	Aroclor 1221	ND	ND	ND
202.	Aroclor 1232	ND	ND	ND
203.	Aroclor 1242	ND	ND	ND
204.	Aroclor 1248	ND	ND	ND
205.	Aroclor 1254	ND	ND	D
206.	Aroclor 1260	ND	ND	ND

Table 6-1 (continued)

BDAT reference no.	Constituent	F007	F011	F012
	Dioxins and Furans			
207.	Hexachlorodibenzo-p-dioxins	ND	ND	ND
208.	Hexachlorodibenzofurans	ND	ND	ND
209.	Pentachlorodibenzo-p-dioxins	ND	ND	ND
210.	Pentachlorodibenzofurans	ND	ND	ND
211.	Tetrachlorodibenzo-p-dioxins	ND	ND	ND
212.	Tetrachlorodibenzofurans	ND	ND	ND
213.	2,3,7,8-Tetrachlorodibenzo-p-dioxin	NA	ND	ND

D = Detected
ND = Not detected.
NA = Not analyzed.
I = Analytical interference (matrix effects) prevented analysis.
X = Believed to be present based on engineering analysis of waste generating process.
Y = Believed to be present based on detection in treated residuals.

References: USEPA 1988e, 1988f.

7. CALCULATION OF PROPOSED BDAT TREATMENT STANDARDS

This section presents the calculation of the proposed treatment standards using analytical treatment data for the regulated constituents selected in Section 6. The Agency bases treatment standards for regulated constituents on the performance of well-designed and well-operated BDAT treatment systems. These standards must account for analytical limitations in available performance data and must be adjusted for variabilities related to treatment, sampling, and analytical techniques and procedures.

BDAT standards are determined for each constituent by multiplying the arithmetic mean of accuracy-adjusted constituent concentrations detected in treated waste by a "variability factor" specific to each constituent for each treatment technology defined as BDAT. Accuracy adjustment of performance data has been discussed in Section 5 in relation to defining "substantial treatment." Variability factors correct for normal variations in the performance of a particular technology over time. They are designed to reflect the 99th percentile level of performance that the technology achieves in commercial operation. (For more information on the principles of calculating variability factors, see EPA's publication, Methodology for Developing BDAT Treatment Standards (USEPA 1988d).) Details on the calculation of variability factors for F006-F012 and F019 wastes are presented in this section.

Where EPA has identified BDAT for a particular waste, but because of data limitations or for some other compelling reason cannot define specific treatment standards for that waste, the Agency can require the

use of that treatment process as a technology standard. Similarly, where there are no known generators of a waste, or where EPA believes that the waste can be totally recycled or reused as a raw material, the Agency may specify a "no land disposal as generated" standard, which effectively amounts to setting the performance standard at zero for all waste constituents.

7.1 Cyanide

EPA is proposing both nonwastewater and wastewater treatment standards for amenable and total cyanide for each of the three waste subcategories established in Section 2.4. These subcategories are as follows: (1) metal finishing aqueous liquids subcategory (F007, F008, F009, and F011; (2) metal finishing sludges subcategory (F006, F012, and F019); and (3) metal finishing organic liquids subcategory (F010). Proposed cyanide standards for wastewaters for all three subcategories are based on performance data from wet air oxidation of F007 waste. Proposed nonwastewater treatment standards for the second subcategory, as generated, are based on analysis of F012 waste generated as a residual from treatment of F011 waste and heat treating quenching wastewaters by electrolytic oxidation followed by alkaline chlorination, chemical precipitation, filtration, and sludge dewatering. These proposed nonwastewater standards are also transferred to nonwastewater residuals generated by treatment of wastes in the first subcategory. Proposed nonwastewater standards for the third subcategory are based on data from treatment of F010 and a similar waste by incineration.

7.2 BDAT List Metals

EPA is proposing nonwastewater treatment standards for BDAT list metals for F007-F009, F011, F012, and F019 based on the treatment standards established for treatment of F006 by stabilization. (See EPA's Best Demonstrated Available Technology (BDAT) Background Document for F006 (USEPA 1988a).) Wastewater treatment standards for these wastes are also being established by the Agency based on transfer of the treatment standards established for treatment of K062 waste by chemical precipitation followed by filtration. (See EPA's Best Demonstrated Availability Technology (BDAT) Background Document for K062 (USEPA 1988b).)

Table 7-1 Calculation of Proposed Treatment Standards for Total and Amenable Cyanide Based on Wet Air Oxidation

Regulated constituent (units)	Accuracy-adjusted treated waste concentration[a]	Mean treated waste concentration	Variability factor (VF)	Treatment standard (total composition)
Wastewater (mg/l):				
Cyanide (amenable)	<0.48	0.48	2.8	1.3
	<0.48			
	<0.48			
	<0.48			
	<0.48			
Cyanide (total)	<0.48	1.62	7.09	12
	6.19			
	<0.48			
	<0.48			
	<0.48			

[a]See Tables 5-1 and 5-2.

Table 7-2 Calculation of Proposed Treatment Standards for Total and Amenable Cyanide Based on Generation of F012 Waste by a Well-Operated Treatment Process Consisting of Electrolytic Oxidation, Alkaline Chlorination, Chemical Precipitation, Filtration, and Sludge Dewatering

Regulated constituent (units)	Accuracy-adjusted treated waste concentration[a]	Mean treated waste concentration	Variability factor (VF)	Treatment standard (total composition)
Nonwastewater (mg/kg):				
Cyanide (amenable)	<0.023 <0.023	0.023	2.8	0.064
Cyanide (total)	97.4 37.3	67.35	1.58	110

[a]See Table 5-3.

Table 7-3 Calculation of Proposed Treatment Standards for Incineration of F010

Regulated constituent (units)	Accuracy-adjusted treated waste concentration[a]	Mean treated waste concentration	Variability factor (VF)	Treatment standard (total composition)
Nonwastewater (mg/kg):				
Cyanide (total)	0.468 0.416 0.915	0.60	2.53	1.5

[a]See Table 5-4.

Table 7-4 Proposed BDAT Treatment Standards for F007, F008, F009, and F011

Constituent	Wastewater	Nonwastewater	
	Total composition (mg/l)	Total composition (mg/kg)	TCLP (mg/l)
Cyanide (amenable)	1.3	0.064	NA
Cyanide (total)	12	110	NA
Cadmium	-	NA	0.066
Chromium	0.32	NA	5.2
Lead	0.04	NA	0.51
Nickel	0.44	NA	0.32
Silver	-	NA	0.072

NA = Not applicable.
- = No treatment standard.

Table 7-5 Proposed BDAT Treatment Standards for F006 (Cyanide)

Constituent	Nonwastewater	
	Total composition (mg/kg)	TCLP (mg/l)
Cyanide (amenable)	0.064	NA
Cyanide (total)	110	NA

NA = Not applicable.

Table 7-6 Proposed BDAT Treatment Standards for F012 and F019

Constituent	Wastewater	Nonwastewater	
	Total composition (mg/l)	Total composition (mg/kg)	TCLP (mg/l)
Cyanide (amenable)	1.3	0.064	NA
Cyanide (total)	12	110	NA
Cadmium	-	NA	0.066
Chromium	0.32	NA	5.2
Lead	0.04	NA	0.51
Nickel	0.44	NA	0.32
Silver	-	NA	0.072

NA = Not applicable.
- = No treatment standard.

Table 7-7 Proposed BDAT Treatment Standards for F010

Constituent	Wastewater	Nonwastewater	
	Total composition (mg/l)	Total composition (mg/kg)	TCLP (mg/l)
Cyanide (amenable)	1.3	-	NA
Cyanide (total)	12	1.5	NA

NA = Not applicable.
- = No treatment standard.

8. P AND U WASTE CODES

This section addresses regulation of those P and U wastes that are similar to the metal finishing cyanide wastes. These wastes, listed in Table 8-1, are identified in 40 CFR 261.33 as "discarded commercial chemical products, off-specification species, container residues, and spill residues thereof."

8.1 Industries Affected

Industries that may generate these wastes are the manufacturers of cyanide compounds listed in Table 8-1 as well as electroplaters, heat treaters, and other industries that use inorganic cyanide salts. In addition, hydrogen cyanide (P063) is a chemical intermediate used in the production of acetone cyanohydrin, adiponitrile, cyanuric chloride, methyl methacrylate, methionine, sodium cyanide, and other chemicals. Thus, P063 wastes may be generated by producers of these chemicals.

8.2 Applicable and Demonstrated Treatment Technologies

The compounds listed in Table 8-1 are soluble in water to form waste solutions that are similar in nature to the F007 and F011 wastes tested by the Agency and other wastes composing the metal finishing aqueous liquids subcategory as identified in Section 2.4. Therefore, the Agency believes electrolytic oxidation, alkaline chlorination, wet air oxidation, high-temperature cyanide hydrolysis, and SO_2/air oxidation are applicable and demonstrated to treat off-specification product, wastewater, and contaminated soil and sludge forms of the P codes listed.

Metals can be treated by chemical precipitation followed by filtration, sludge dewatering, and stabilization for wastewaters, and by stabilization for nonwastewaters.

8.3 Identification of Best Demonstrated Available Technology

Of the demonstrated technologies identified in Section 8.2, the "best" technology for cyanide treatment for these wastes is wet air oxidation. For treatment of BDAT metal constituents, the "best" technology is chemical precipitation followed by filtration and sludge dewatering. Cyanide standards for wastewater treatment sludge residuals are based on generation of these sludges by electrolytic oxidation followed by alkaline chlorination, chemical precipitation, and sludge dewatering. Determination of "best" technology and "availability" for both cyanides and metals follows the rationale that was presented in Section 5.1 for the metal finishing aqueous liquids subcategory and in Section 5.2 for the metal finishing sludges subcategory (for the treatment sludges).

8.4 Proposed Treatment Standards

All wastewater and nonwastewater residuals from treatment of these wastes must meet the wastewater and nonwastewater standards presented in Table 8-2 for the constituents listed in Table 8-1. The Agency currently has no data on treatment of silver and zinc in wastewaters by chemical precipitation.

Table 8-1 P and U Waste Codes Proposed for Regulation

Waste code	Chemical compound	Regulated constituents
P013	Barium cyanide	Cyanide
P021	Calcium cyanide	Cyanide
P029	Copper cyanide	Copper, cyanide
P030	Cyanides (soluble cyanide salts), N.O.S.	Cyanide
P063	Hydrocyanic acid, hydrogen cyanide	Cyanide
P074	Nickel cyanide	Nickel, cyanide
P098	Postassium cyanide	Cyanide
P099	Postassium silver cyanide	Silver, cyanide
P104	Silver cyanide	Silver, cyanide
P106	Sodium cyanide	Cyanide
P121	Zinc cyanide	Zinc, cyanide

Table 8-2 Proposed Treatment Standards for P-code Cyanide Wastes

Constituent	Wastewater	Nonwastewater (treatment sludge)	
	Total composition (mg/l)	Total composition (mg/kg)	TCLP (mg/l)
Cyanide (amenable)	1.3	0.064	ND
Cyanide (total)	12	110	ND
Copper (P029 only)	0.42	NA	0.71
Nickel (P074 only)	0.44	NA	0.30
Silver (P099 and P104 only)	reserved	NA	0.07
Zinc (P121 only)	reserved	NA	0.086

NA = Not applicable.

9. REFERENCES

AES. 1981. American Electroplaters' Society. Electroplating wastewater sludge characterization. Prepared for U.S. Environmental Protection Agency Industrial Environmental Research Laboratory, Cincinnati, Ohio. Prepared by American Electroplaters' Society, Inc., Winter Park, FL. EPA-600/2-81-064. NTIS PB81-190928.

APHA, AWWA, and WPCF. 1985. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Standard methods for the examination of water and wastewater. 16th ed. Washington, D.C.: American Public Health Association.

CyanoKEM. 1987. Public comment submitted in response to EPA proposed California disposal restriction levels, August 12, 1987. EPA RCRA Docket No. F-87-LDR6-FFFFF. Washington, D.C.: U.S. Environmental Protection Agency.

CyanoKEM. 1988. Submission of data on characterization and treatment of oily cyanide wastes, August 29, 1988. Washington, D.C.: U.S. Environmental Protection Agency.

Easton, John K. 1967. Electrolytic decomposition of concentrated cyanide plating wastes. J. Water Poll. Contr. Fed. 39(10):1621-1626.

Environ. 1985. Characterization of waste streams listed in 40 CFR Section 261, waste profiles, Vols. I and II. Prepared for Waste Identification Branch, Characterization and Assessment Division, Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

MRI. 1987. Midwest Research Institute. Analytical data report for six facilities included in the electroplating sampling and analysis program. Contract No. 68-01-7287, draft final report for Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

Robey, H.L. 1983. AES Research Project 53A: Cyanide destruction in a commercial-scale hydrolysis reactor. Plat. and Surf. Fin. 70:79-82.

USEPA. 1980. U.S. Environmental Protection Agency, Office of Solid Waste. RCRA listing background document. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1986. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report of treatment technology performance and operation for Envirite Corporation, York, Pennsylvania. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1987. U.S. Environmental Protection Agency, Office of Solid Waste. Generic quality assurance project plan for land disposal restrictions program ("BDAT"). Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988a. U.S. Environmental Protection Agency, Office of Solid Waste. Best demonstrated available technology (BDAT) background document for F006. EPA/530-SW-031L. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988b. U.S. Environmental Protection Agency, Office of Solid Waste. Best demonstrated available technology (BDAT) background document for K062. EPA/530-SW-88-031E. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988c. U.S. Environmental Protection Agency, Office of Solid Waste. Treatment technology background document. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988d. U.S. Environmental Protection Agency, Office of Solid Waste. Methodology for developing BDAT treatment standards. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988e. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report of treatment technology performance and operation for Woodward Governor Corporation, Rockford, Illinois. Washington, D.C.: U.S. Environmental Protection Agency.

USEPA. 1988f. U.S. Environmental Protection Agency, Office of Solid Waste. Onsite engineering report of treatment technology performance and operation for wet air oxidation of F007 at Zimpro/Passavant, Inc., in Rothschild, Wisconsin. Washington, D.C.: U.S. Environmental Protection Agency.

Versar. 1986. Summary of available waste composition data from review of literature and data bases for use in treatment technology application and evaluation for "California List" waste streams. Draft Report; Prepared under Contract No. 68-01-7053 for U.S. Environmental Protection Agency, Office of Solid Waste. Washington, D.C.: U.S. Environmental Protection Agency.

APPENDIX A

ANALYTICAL METHODS AND QA/QC

This appendix presents analytical methods and the matrix spike recovery data for the treated waste samples from testing of F007, F011, and F012 wastes.

Table A-1 Analytical Methods - Plant A

Analytical method	Method number	Reference
Cyanides (total and amenable)	9012	1

1. USEPA. 1986. U.S. Environmental Protection Agency, Office of Solid Waste. Test methods for evaluating solid waste. 3rd ed. Washington, D.C.: U.S. Environmental Protection Agency.

Table A-2 Specific Procedures or Equipment Used for Analysis of Cyanide When Alternatives or Equivalents Are Allowed in SW-846 Methods - Plant A

Analysis	SW-846 method	Sample aliquot	Alternative or equivalent allowed by SW-846 methods	Specific procedure used
Total and amenable cyanide	9012	500 ml	Hydrogen sulfide treatment may be required.	Hydrogen sulfide treatment was not required.
			A Fisher-Mulligan absorber or equivalent should be used.	A Wheaton Distilling Apparatus absorber was used.

Table A-3 Matrix Spike Recoveries for Cyanide - Plant A

Constituent	Original amount detected (μg/l)	Amount spiked (μg/l)	Spike: Amount recovered (μg/l)	Spike: Percent recovery[a]	Duplicate spike: Amount recovered (μg/l)	Duplicate spike: Percent recovery[a]	Relative percent difference[b]
Sample WGS4-101							
Cyanide, chlorinated	114,000	160,000	279,000	103	274,000	100	1.8
Cyanide, total	103,000	160,000	243,000	88	252,000	93	3.6
Sample WGS8-101							
Cyanide, chlorinated	<10	200	140	70	120	60	15
Cyanide, total	<10	200	<10	0.0[c]	<10	0.0[c]	NC
Sample WGS5-10							
Cyanide, chlorinated[d]	79.5	71.1	110	43	-	-	-
Cyanide, total[d]	99.4	69.3	170	102	173[e]	108	1.0
Cyanide, TCLP	854	1000	1820	97	1990	114	8.9
Sample WGS9-101							
Cyanide, chlorinated[d]	29.1	30.7	59.5	77	-	-	-
Cyanide, total[d]	34.7	7.99	42.1	93	44.0[f]	116	23
Cyanide, TCLP	40.8	200	225	92	222	91	1.3

NC = Not calculable.
- = No analysis performed.
[a]Percent recovery = $100\ (C_1 - C_o)\ /\ C_t$, where C_i is the amount recovered, C_o is the original amount detected.
[b]Relative percent difference = $|\ 100\ (D_1 - D_2)\ /\ [D_1 + D_2)\ /\ 2]\ |$, where D_1 and D_2 are the percent recoveries of the spike and duplicate spike.
[c]Zero percent recovery is attributed to matrix interference.
[d]Units for solids sample concentrations are mg/kg.
[e]Amount spiked for the matrix duplicate spike was 68.1 mg/kg.
[f]Amount spiked for matrix spike duplicate was 7.96 mg/kg.

Table A-4 Analytical Methods - Plant B

Analytical method	Method number	Reference
Cyanides (total and amenable)	9010	1

1. USEPA. 1986. U.S. Environmental Protection Agency, Office of Solid Waste. Test method for evaluating solid waste. 3rd ed. Washington, D.C.: U.S. Environmental Protection Agency.

Table A-5 Specific Procedures or Equipment Used for Analysis of Cyanide When Alternatives or Equivalents Are Allowed in SW-846 Methods - Plant B

Analysis	Method	Alternative or equivalent allowed	Specific equipment or procedure used
Cyanide	9010	Pretreatment with bismuth nitrate may be necessary if sulfides are present.	Pretreatment was not necessary.
		Pretreatment with sulfamic acid may be necessary if nitrites/nitrates are present.	Pretreatment was not necessary.
		A Fisher-Mulligan absorber or equivalent should be used.	An ACE smog bubbler absorber was used.
		A spectrophotometer suitable for measurements at 578 nm with a 1.0-cm cell or larger is required.	A Bausch and Lomb Model Spectronic 21 was used.

Table A-6 Matrix Spike/Matrix Spike Duplicate Results for Cyanide - Plant B

Sample number	Sample conc. (μg/l)	Spike added (μg/l)	Spike result (μg/l)	% Recovery	Spike duplicate result, (μg/l)	% Recovery	RPD
OL-03	16.11	24.75	29.16	52.7	28.97	52.0	0.7

OL-03 = Treated waste sample; Sample Set No. 3.

$$RPD = 100\ (\text{spike result} - \text{spike duplicate result})/\frac{(\text{spike result} + \text{spike duplicate result})}{2}$$