EPA REGION VII IRC
160189

United States
Environmental Protection
Agency

Office Of Water
(4303)

EPA 821-R-95-021
April 1995

EPA

Development Document For The Proposed Effluent Limitations Guidelines And Standards For The Metal Products And Machinery Phase 1 Point Source Category

U.S. Environmental Protection Agency
Region VII
Information Resource Center
726 N. 6th Street
Kansas City, KS 66101

United States
Environmental Protection
Agency

Office Of Water
(4303)

EPA 821-R-95-021
April 1995

Development Document For The Proposed Effluent Limitations Guidelines and Standards For The Metal Products And Machinery Phase I Point Source Category

U.S. Environmental Protection Agency
Region VII
Information Resource Center
901 N. 5th Street
Kansas City, KS 66101

Development Document
For
The Proposed Effluent Limitations Guidelines and Standards For The Metal Products And Machinery Phase I Point Source Category

Carol M. Browner
Administrator

Robert Perciasepe
Assistant Administrator, Office of Water

Tudor T. Davies
Director, Office of Science and Technology

Thomas P. O'Farrell
Director, Engineering and Analysis Division

Elwood H. Forsht
Chief, Chemicals and Metals Branch

William J. Cleary
Project Officer

April 1995

U.S. Environmental Protection Agency
Office of Water
Washington, DC 20460

ACKNOWLEDGEMENTS

The Environmental Protection Agency appreciates the dedicated efforts, technical expertise, and many contributions to the MP&M Phase I proposal rulemaking effort by the Radian Corporation personnel in Herndon, Virginia under contract number 68-C4-0024.

The Agency acknowledges the plant managers, engineers, and other MP&M industry representatives whose cooperation and assistance in site visitations and information gathering activities greatly contributed to the completion of the technical studies and assessments.

A number of people within EPA made major contributions to this proposal rulemaking effort. Mr. William Cleary (Project Officer, Metals Branch, Engineering and Analysis Division) was instrumental in the management of the contractor efforts, coordination among many EPA offices, and resolution of many complex issues. His deft guidance, technical expertise, and tireless efforts were essential to the successful completion of this stage of the project. Jan Goodwin (Energy Branch, Engineering and Analysis Division) also made significant contributions to the technical efforts. Lynne Tudor and Helen Jacobs (Economic and Statistical Analysis Branch, Engineering and Analysis Division) were major contributors to the overall efforts through dedicated performance related to the economic analyses and the statistical analyses, respectively. Dedicated administrative support was provided by Elizabeth Smith of the Engineering and Analysis Division. Contributions were also made by Patrick Bastek, Annette Huber, Sabita Rajvanshi, and Lisa Nelson, all of whom were previously employed in the Engineering and Analysis Division.

Jocelyn Siegel (Pollution Prevention Division, Office of Prevention, Pesticides and Toxic Substances) evaluated the pollution prevention aspects of the category. Ed Gardetto (Exposure Assessment Branch, Standards and Applied Science Division) evaluated the environmental benefits of the proposal. Legal support was provided by Karen Clark, Carrie Wehling, and Susan Lepow of EPA's Office of General Council.

Additional contributions were made by the following members of the EPA MP&M workgroup: Burnell Vincent, Bill Painter, Max Diaz, Paul Shapiro, Bryan Holtrop, Judi Kahl, Paul Almodovar, Maria Malave, Nadine Steinberg, and John Sparks.

Finally, the MP&M proposal was developed with substantial input from the regional, state and local permitting communities. In particular, Keith Silva and Greg Arthur of EPA's Region IX office provided substantial input to the development of this proposal.

TABLE OF CONTENTS

		Page
1.0	SUMMARY AND CONCLUSIONS	1-1
	1.1 Summary of the MP&M Phase I Point Source Category	1-1
	1.2 Proposed Effluent Limitations Guidelines and Standards	1-3
2.0	LEGAL AUTHORITY	2-1
	2.1 Regulatory Background	2-1
	2.1.1 Clean Water Act	2-1
	2.1.2 Section 304(m) Requirements	2-4
	2.1.3 Pollution Prevention Act	2-5
	2.2 Overview of Effluent Limitations Guidelines and Standards for Metals Industries	2-6
	2.3 Overview of the MP&M Point Source Category	2-7
3.0	APPLICABILITY	3-1
	3.1 Applicability Of MP&M Phase I And Interface With Phase II	3-1
	3.2 Applicability Interfaces Between MP&M Phase I and Previously Promulgated Metals Regulations	3-3
4.0	SUMMARY OF DATA COLLECTION ACTIVITIES	4-1
	4.1 Mini Data Collection Portfolio	4-1
	4.1.1 MDCP Recipient Selection and Mailing	4-1
	4.1.2 Information Collected	4-2
	4.1.3 MDCP Data Entry, Engineering Coding, and Analysis	4-3
	4.1.4 MDCP Mailout Results	4-3
	4.1.5 Industry Scale-Up of MDCP Data	4-4
	4.2 Data Collection Portfolio	4-4
	4.2.1 DCP Recipient Selection and Mailing	4-5
	4.2.2 Information Collected	4-6
	4.2.3 DCP Review, Coding, and Data Entry	4-8
	4.2.4 DCP Mailout Results	4-8
	4.2.5 Industry Scale-Up of DCP Data	4-9
	4.3 Site Visits	4-10
	4.3.1 Criteria for Site Selection	4-10
	4.3.2 Information Collected	4-11

TABLE OF CONTENTS (Continued)

			Page
	4.4	Wastewater and Solid Waste Sampling	4-12
	4.4.1	Criteria for Site Selection	4-13
	4.4.2	Information Collected	4-13
	4.4.3	Sample Collection and Analysis	4-14
	4.5	Existing Data Sources	4-15
	4.5.1	EPA/EAD Databases	4-15
	4.5.2	Risk Reduction Engineering Laboratory Treatability Database	4-16
	4.5.3	Fate of Priority Pollutants in Publicly Owned Treatment Works Database	4-16
	4.5.4	The Domestic Sewage Study	4-17
	4.5.5	Toxics Release Inventory Database	4-17
	4.6	References	4-24
5.0		INDUSTRY DESCRIPTION	5-1
	5.1	Number and Size of MP&M Phase I Sites	5-1
	5.2	Unit Operations Performed	5-2
	5.3	Metal Types Processed	5-5
	5.4	Water-Discharging MP&M Phase I Sites by Sector	5-6
	5.5	Water-Discharging MP&M Phase I Sites and Total Discharge Flow by Activity Combination	5-6
	5.6	Water-Discharging MP&M Phase I Sites and Total Discharge Flow by Discharge Status	5-8
	5.7	Water-Discharging MP&M Phase I Sites by Total Discharge Flow	5-8
	5.8	Contract Hauling by MP&M Phase I Sites	5-9
	5.9	MP&M Phase I Sites Not Discharging Process Water	5-9
	5.10	MP&M Unit Operations and Rinses	5-11
	5.11	Production-Normalizing Parameters and Production-Normalized Flows	5-43
	5.12	References	5-56
6.0		WASTEWATER CHARACTERISTICS	6-1
	6.1	Wastewater Characteristics by Unit Operation	6-1
	6.1.1	Hexavalent Chromium-Bearing Wastewaters	6-2
	6.1.2	Cyanide-Bearing Wastewaters	6-4
	6.1.3	Oil-Bearing Wastewaters	6-5
	6.1.4	Chelated Metal-Bearing Wastewaters	6-6

TABLE OF CONTENTS (Continued)

			Page
	6.1.5	Metal-Bearing Wastewaters	6-7
	6.1.6	Qualitative Data from the MP&M DCPs for Unidentified MP&M Unit Operations	6-8
	6.2	Treatment Influent Characteristics	6-8
7.0		INDUSTRY SUBCATEGORIZATION	7-1
	7.1	Factors Considered for Subcategorization	7-1
	7.2	Unit Operations	7-2
	7.3	Activity	7-2
	7.4	Raw Materials	7-4
	7.5	Products	7-5
	7.6	Size of Site	7-6
	7.6.1	Number of Employees	7-6
	7.6.2	Wastewater Discharge Flow Rate	7-6
	7.6.3	Production Rate	7-7
	7.7	Geographical Location	7-7
	7.8	Age	7-8
	7.9	Total Energy Requirements	7-8
	7.10	Air Pollution Control Methods	7-9
	7.11	Solid Waste Generation and Disposal	7-9
	7.12	Economic Impacts	7-9
8.0		SELECTION OF POLLUTANT PARAMETERS	8-1
	8.1	Identification of Pollutant Parameters of Concern	8-2
	8.2	Pass-Through Analysis for Indirect Dischargers	8-3
	8.3	Pollutant Parameters Selected for Regulation	8-4
	8.3.1	Priority and Nonconventional Organic Pollutants	8-5
	8.3.2	Priority Metal Pollutants	8-6
	8.3.3	Nonconventional Metal Pollutants	8-6
	8.4	References	8-20
9.0		SOURCE REDUCTION AND RECYCLING	9-1
	9.1	Categories of Source Reduction and Recycling Techniques	9-2
	9.2	Source Reduction and Recycling Technologies Used in the MP&M Industry	9-3
	9.2.1	Metal-Shaping Operations	9-3
	9.2.2	Surface Preparation and Treatment Operations	9-4

TABLE OF CONTENTS (Continued)

			Page
	9.2.3	Metal and Organic Deposition Operations	9-4
	9.2.4	Assembly Operations	9-5
9.3	References		9-61
10.0	TECHNOLOGY OPTIONS		10-1
10.1	Technologies Considered		10-1
10.2	Technology Options		10-3
	10.2.1	Option 1: End-of-Pipe Treatment	10-3
	10.2.2	Option 2: End-of-Pipe Treatment and In-Process Source Reduction and Recycling	10-5
	10.2.3	Option 1A: Tiered Option for "Low" Flow and "High" Flow Sites	10-6
	10.2.4	Option 2A: End of Pipe Treatment and In-Process Source Reduction and Recycling for "High" Flow Sites (Preferred Option)	10-7
	10.2.5	Option 3: Advanced End-of-Pipe Treatment and Recycling	10-7
10.3	Technology Descriptions for In-Process Source Reduction and Recycling Technologies		10-7
	10.3.1	Centrifugation and Pasteurization of Machining Coolants	10-8
	10.3.2	Centrifugation and Recycling of Painting Water Curtains	10-9
	10.3.3	Countercurrent Cascade Rinsing	10-10
	10.3.4	Electrolytic Recovery	10-11
	10.3.5	Flow Reduction for Rinses and Baths	10-13
	10.3.6	Ion Exchange (in-process)	10-16
	10.3.7	Reverse Osmosis (both in-process and end-of-pipe)	10-18
10.4	Technology Descriptions for Preliminary Treatment of Segregated Wastewater Streams		10-20
	10.4.1	Chemical Reduction of Chelated Metals	10-20
	10.4.2	Chemical Reduction of Hexavalent Chromium	10-22
	10.4.3	Cyanide Destruction through Alkaline Chlorination	10-23
	10.4.4	Oil/Water Separation	10-24

TABLE OF CONTENTS (Continued)

Page

10.5 Technology descriptions for End-of-Pipe Treatment Technologies 10-27
10.5.1 Chemical Precipitation and Sedimentation 10-28
10.5.2 Reverse Osmosis (End-of-Pipe) 10-31
10.5.3 Ion Exchange (end-of-pipe) 10-31
10.6 Technology Descriptions for Sludge Handling and Disposal Technologies 10-31
10.6.1 Gravity Thickening 10-32
10.6.2 Pressure Filtration 10-32
10.6.3 Sludge Drying 10-33
10.6.4 Vacuum Filtration 10-33
10.7 References 10-70

11.0 DEVELOPMENT OF LONG-TERM AVERAGES AND VARIABILITY FACTORS 11-1
11.1 Sources of Technology Performance Data 11-1
11.2 Data Editing Procedures 11-2
11.2.1 Assessment of Treatment System Performance 11-3
11.2.2 Identification of Process Upsets Occurring During Sampling 11-4
11.2.3 Identification of Pollutants Not Present in the Raw Wastewater at Sufficient Concentrations to Evaluate Removal 11-5
11.2.4 Identification of Wastewater Treatment Chemicals 11-6
11.3 Long-Term Average Concentrations and Variability Factors 11-6
11.3.1 Modified Delta-Lognormal Model 11-7
11.3.2 Option Limitations and Long-Term Average 11-11
11.4 References 11-28

12.0 COSTS OF TECHNOLOGY BASES FOR REGULATIONS 12-1
12.1 Summary of Costs 12-2
12.2 Model Site Development 12-2
12.2.1 Site Selection 12-3
12.2.2 Wastewater Stream Parameters 12-3
12.2.3 Pollutant Concentrations 12-5
12.2.4 Technology in Place 12-5

TABLE OF CONTENTS (Continued)

Page

12.3 Methodology for Estimating Costs 12-6
12.3.1 Components of Cost 12-7
12.3.2 Sources and Standardization of Cost Data 12-8
12.3.3 Design and Cost Model 12-9
12.3.4 General Assumptions 12-12
12.4 Design and Costs of Individual Technologies 12-16
12.4.1 Flow Reduction for Rinses 12-17
12.4.2 Flow Reduction for Other Operations 12-18
12.4.3 Countercurrent Cascade Rinsing 12-18
12.4.4 Centrifugation and Pasteurization of Machining Coolant 12-19
12.4.5 Centrifugation of Painting Water Curtains 12-20
12.4.6 In-Process Ion Exchange 12-20
12.4.7 Contract Hauling 12-22
12.4.8 Oil/Water Separation 12-23
12.4.9 Chemical Reduction of Hexavalent Chromium 12-25
12.4.10 Cyanide Destruction 12-27
12.4.11 Chemical Reduction of Chelated Metals 12-28
12.4.12 Chemical Precipitation and Sedimentation 12-28
12.4.13 Sludge Thickening 12-30
12.4.14 Sludge Pressure Filtration 12-30
12.4.15 End-of-Pipe Ion Exchange 12-30

13.0 POLLUTANT LOADING AND REDUCTION ESTIMATES 13-1
13.1 Data Sources 13-3
13.1.1 Data Hierarchy 13-3
13.1.2 Use of Data for Nondetected Pollutants 13-4
13.2 Calculation of Unit Operation Production-Normalized Pollutant Loadings 13-4
13.2.1 Production-Normalized Pollutant Loadings for Each Unit Operation and Metal Type Combination With Available Data 13-5
13.2.2 Production-Normalized Pollutant Loadings Modelling Within Unit Operations 13-6
13.2.3 Production-Normalized Pollutant Loadings Data Transfer Across Unit Operations 13-6

TABLE OF CONTENTS (Continued)

		Page
	13.3 Pollutant Loadings and Reductions	13-6
	13.3.1 Calculation of Industry Raw Wastewater Pollutant Loadings	13-7
	13.2.2 Calculation of Industry Baseline Pollutant Loadings	13-7
	13.3.3 Calculation of Option-Specific Industry Pollutant Loadings and Pollutant Reductions	13-8
14.0	NONWATER QUALITY IMPACTS	14-1
	14.1 Energy Requirements	14-1
	14.2 Air Emissions Impacts	14-2
	14.3 Solid Waste Generation	14-3
	14.4 References	14-6
15.0	EFFLUENT LIMITATIONS AND STANDARDS	15-1
	15.1 Technology Option	15-1
	15.2 Numerical Limitations and Standards	15-2
	15.3 Best Practicable Control Technology Currently Available (BPT)	15-3
	15.4 Best Conventional Pollutant Control Technology (BCT)	15-5
	15.5 Best Available Technology Economically Achievable (BAT)	15-6
	15.6 Pretreatment Standards for Existing Sources (PSES)	15-7
	15.7 New Source Performance Standards (NSPS) and Pretreatment Standards for New Sources (PSNS)	15-9
16.0	PERMITTING GUIDANCE	16-1
	16.1 Implementing the MP&M Phase I Effluent Guidelines	16-2
	16.1.1 Assessment of Water Use Practices	16-3
	16.1.2 Use of Historical Flow in Developing Mass-Based Limitations	16-3
	16.1.3 Use of Flow Guidance in Developing Mass-Based Limitations	16-4
	16.2 Flow Guidance for Surface Treatment Rinsing Operations	16-6
	16.2.1 Identifying Sites With Pollution Prevention and Water Conservation Practices	16-6

TABLE OF CONTENTS (Continued)

Page

16.2.2 Flow Guidance for Calculating Mass-Based Limitations 16-15
16.3 Flow Guidance for Machining Operations 16-21
16.3.1 Identifying Sites With Pollution Prevention and Water Conservation Practices 16-22
16.3.2 Flow Guidance for Calculating Mass-Based Limitations 16-28
16.4 Flow Guidance for Painting Operations 16-30
16.4.1 Identifying Sites With Pollution Prevention and Water Conservation Practices 16-30
16.4.2 Flow Guidance for Calculating Mass-Based Limitations 16-36
16.5 Flow Guidance for Cleaning Operations 16-38
16.5.1 Identifying Sites With Pollution Prevention and Water Conservation Practices 16-39
16.5.2 Flow Guidance for Calculating Mass-Based Limitations 16-45
16.6 References 16-74

LIST OF TABLES

		Page
1-1	MP&M Phase I Concentration-Based Limitations	1-4
3-1	Metal Products and Machinery (MP&M) Phase I Typical Products	3-5
4-1	Metal Constituents Measured Under the MP&M Sampling Program	4-19
4-2	Organic Constituents Measured Under the MP&M Sampling Program	4-20
4-3	Additional Parameters Measured Under the MP&M Sampling Program	4-23
5-1	Typical Unit Operations Performed at MP&M Sites	5-45
5-2	Additional Water-Using Unit Operations Performed at MP&M Sites	5-46
5-3	Number of MP&M Phase I Sites Using and Discharging Process Water by Unit Operation	5-47
5-4	MP&M Phase I Process Water Discharge Flow and Purpose of Process Water by Unit Operation	5-51
6-1	Number of Samples Collected for MP&M Phase I Unit Operations	6-10
6-2	Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Hexavalent Chromium-Bearing Unit Operations and Associated Rinses	6-13
6-3	Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Cyanide-Bearing Unit Operations and Associated Rinses	6-14
6-4	Analytical Data for Unit Operations Generating Oil-Bearing Wastewater	6-15

LIST OF TABLES (Continued)

		Page
6-5	Analytical Data for Rinses Generating Oil-Bearing Wastewater	6-18
6-6	Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Oil-Bearing Unit Operations and Associated Rinses	6-20
6-7	Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Chelated Metal-Bearing Unit Operations and Associated Rinses	6-22
6-8	Analytical Data for Wastewater from Unit Operations Generating Metal-Bearing Wastewater	6-23
6-9	Analytical Data for Wastewater from Rinses Generating Metal-Bearing Wastewater	6-26
6-10	Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Metal-Bearing Unit Operations and Associated Rinses	6-28
6-11	Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Unidentified Unit Operations	6-30
6-12	Analytical Data for Chemical Precipitation and Sedimentation Influent	6-34
7-1	Metal Products and Machinery (MP&M) Sectors and Typical Products	7-11
8-1	Priority Pollutant List	8-9
8-2	Pollutant Parameters Not Detected in Samples Collected During the MP&M Sampling Program	8-10
8-3	Pollutant Parameters Detected in Less Than Three Samples During the MP&M Sampling Program	8-12

LIST OF TABLES (Continued)

		Page
8-4	Pollutant Parameters Measured at Average Concentrations Less Than 0.1 mg/L During the MP&M Sampling Program	8-13
8-5	Pollutant Parameters Selected for Further Consideration Under MP&M Phase I	8-14
8-6	Summary of MP&M POTW Pass-Through Analysis	8-17
9-1	Typical Metal Products and Machinery Operations	9-6
9-2	Examples of Source Reduction and Recycling Technologies or Metal-Shaping Operations	9-7
9-3	Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment	9-14
9-4	Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning	9-23
9-5	Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations	9-33
9-6	Examples of Source Reduction and Recycling Technologies for Assembly Operations	9-58
10-1	MP&M Source Reduction Technologies	10-35
10-2	MP&M Recycling Technologies	10-40
10-3	MP&M End-of-Pipe Treatment and Disposal Technologies	10-42
11-1	MP&M Technology Effectiveness Data	11-13
11-2	Variability Factors and Long-Term Averages for Chemical Precipitation and Sedimentation Treatment	11-22
11-3	Long-Term Averages and Limitations for Chemical Precipitation and Sedimentation	11-26

LIST OF TABLES (Continued)

		Page
12-1	MP&M Phase I Capital and Annual Costs	12-32
12-2	Summary of End-of-Pipe Technologies In Place at MP&M Phase I Sites	12-33
12-3	MP&M Phase I Equipment Cost Equations	12-34
12-4	Components of Total Capital Investment	12-40
13-1	Summary of Pollutant Loadings by Option for MP&M Phase I Direct Dischargers	13-9
13-2	Summary of Pollutant Loadings by Option for MP&M Phase I Indirect Dischargers	13-13
13-3	Summary of Pollutant Reductions by Option for MP&M Phase I Direct Dischargers	13-17
13-4	Summary of Pollutant Reductions by Option for MP&M Phase I Indirect Dischargers	13-18
15-1	MP&M Phase I Concentration-Based Limitations	15-10
16-1	Descriptive Statistic of MP&M Data Collection Portfolio Data	16-48
16-2	Water Conservation Methods for Surface Treatment Rinses	16-53
16-3	Definitions of Pollution Prevention and Water Conservation Practices and Technologies	16-55
16-4	Factors Affecting Drag-Out	16-61
16-5	Rinse Water Required for Various Plating Processes Based on Literature Values	16-62
16-6	Adjusted Production-Normalized Flow (PNF) Data for Countercurrent Cascade Rinses MP&M Sampling Program	16-66

LIST OF TABLES (Continued)

		Page
16-7	Pollution Prevention and Water Conservation Methods Applicable to Machining Operations	16-67
16-8	Pollution Prevention and Water Conservation Methods Applicable to Painting Operations	16-69
16-9	Pollution Prevention and Water Conservation Methods Applicable to Cleaning Operations	16-70

LIST OF FIGURES

		Page
10-1	End-of-Pipe Technology Trains for MP&M Technology Options 1, 2, 1A, and 2A	10-51
10-2	In-Process Technology Trains for MP&M Technology Options 1A, 2, 2A, and 3	10-52
10-3	End-of-Pipe Technology Train for MP&M Technology Option 3	10-53
10-4	Centrifugation and Pasteurization of Machining Coolants	10-54
10-5	Centrifugation and Recycling of Painting Water Curtains	10-55
10-6	Countercurrent Cascade Rinsing	10-56
10-7	Electrolytic Recovery	10-57
10-8	Common Configurations for Application of Ion Exchange for Chemical Recovery	10-58
10-9	In-Process Reverse Osmosis	10-59
10-10	Chemical Reduction of Chelated Metals	10-60
10-11	Chemical Reduction of Hexavalent Chromium	10-61
10-12	Cyanide Destruction through Alkaline Chlorination	10-62
10-13	Chemical Emulsion Breaking	10-63
10-14	Oil Skimming	10-64
10-15	Chemical Precipitation and Sedimentation	10-65
10-16	Effect of pH on Hydroxide Precipitation	10-66
10-17	Gravity Thickening	10-67

LIST OF FIGURES (Continued)

		Page
10-18	Pressure Filtration	10-68
10-19	Vacuum Filtration	10-69
11-1	Summary of Technology Performance Data Editing Procedures	11-27
12-1	Relationship Among Options	12-41
12-2	Logic Used to Apply In-process Technologies and Practices	12-42
12-3	Logic Used to Apply End-of-Pipe Technologies and Practices	12-43
13-1	Estimation of MP&M Pollutant Loadings and Reductions	13-19
16-1	MP&M Phase I Permitting Process Flow Chart	16-71
16-2	Examples of Rinsing Configurations with Increasing Levels of Good Water Use Practices	16-72

1.0 SUMMARY AND CONCLUSIONS

Pursuant to the Clean Water Act, EPA is proposing effluent limitations guidelines and standards for the Metal Products and Machinery (MP&M) Phase I Point Source Category. This document and the administrative record for this rulemaking provide the technical basis for these effluent limitations guidelines for new and existing direct dischargers, and pretreatment standards for new and existing indirect dischargers. Direct dischargers are sites that discharge wastewater to a surface water. Indirect dischargers are sites that discharge wastewater to a publicly-owned treatment works (POTW).

Section 1.1 presents a summary of the MP&M Phase I industry. Section 1.2 summarizes the proposed effluent limitations guidelines and standards.

1.1 Summary of the MP&M Phase I Point Source Category

The MP&M Phase I Point Source Category applies to sites engaged in manufacturing, rebuilding, or maintaining finished metal parts, products, or machines within the following seven industrial sectors:

- Aerospace;
- Aircraft;
- Electronic Equipment;
- Hardware;
- Mobile Industrial Equipment;
- Ordnance; and
- Stationary Industrial Equipment.

The MP&M Phase I category includes an estimated 79,613 sites. Of these, an estimated 10,601 sites discharge process water. The majority of the sites that do not discharge water are sites which employ unit operations that do not generate process wastewater. Of the 10,601 wastewater-discharging sites, an estimated 1,797 are direct dischargers, 8,440 are indirect dischargers, and 364 are both direct and indirect dischargers.

MP&M sites perform a wide variety of process unit operations on metal parts. In general, MP&M unit operations can be characterized as belonging to one or more of the following types of unit operations:

- Metal shaping operations;
- Surface preparation operations;
- Organic deposition operations;
- Surface finishing operations; and
- Assembly operations.

At a given MP&M site, the specific unit operations performed and the sequence of operations depend on many factors, including the activity (i.e., manufacturing, rebuilding,

or maintenance), industrial sector, and type of product processed. Depending on these factors, MP&M sites perform many different combinations and sequences of unit operations. Process water is used for and discharged from many of the MP&M unit operations. For some operations, process water may or may not be used, depending on the purpose of the operation, raw materials, and final product use.

EPA estimates that MP&M Phase I sites discharge approximately 23.2 billion gallons of process wastewater per year. These wastewaters typically contain metal pollutants (e.g., aluminum, cadmium, copper, chromium, iron, nickel, zinc) and total suspended solids. Many of the MP&M wastewaters also contain oil and grease, cyanide, hexavalent chromium, and organic pollutants. The following table summarizes the amount of pollutants estimated by EPA to have been discharged from MP&M Phase I sites in 1989.

Estimated Amount of Pollutants Discharged from MP&M Phase I Sites in 1989

Pollutant	Million Pounds Discharged in 1989
Metal Pollutants	13
Organic Pollutants	2.5
Cyanide	0.17
Total Suspended Solids	20
Oil and Grease	190

Source: EPA MP&M pollutant loading estimates.

EPA identified several in-process pollution prevention and recycling and end-of-pipe treatment technologies and practices to control the discharge of pollutants from MP&M Phase I sites. These technologies and practices are summarized in the following table.

In-Process Pollution Prevention and Recycling and End-of-Pipe Treatment Technologies and Practices

In-Process Technologies and Practices	End-Of-Pipe Technologies and Practices
Flow reduction for rinses	Oil/water separation
Flow reduction for other operations (e.g., alkaline and acid treatment baths, machining coolants)	Chemical reduction of hexavalent chromium
Countercurrent cascade rinsing	Cyanide destruction
Centrifugation and pasteurization of machining coolants	Chemical reduction of chelated metals
Centrifugation of painting water curtains	Contract hauling of solvent degreasing wastewaters for off-site treatment
In-process ion exchange and electrolytic recovery	Chemical precipitation and sedimentation
	Sludge thickening
	Sludge pressure filtration
	End-of-pipe ion exchange

Source: MP&M DCPs, MP&M site visits, technical literature.

These technologies were combined into several different technology options considered by EPA for the different levels of regulatory control required by the Clean Water Act. Engineering costs were estimated for each of the technology options for a set of statistically-selected model sites. These model site costs were then statistically scaled to the MP&M Phase I category. EPA also estimated pollutant loadings and removals associated with each of the technology options. The costs, loadings, and removals were used to assess the cost-effectiveness of each technology option. EPA also used the costs to estimate the economic and financial impact on the industry of implementing the various options, including the number of potential site closures, the number of potential job losses and gains, and the ability of the site to finance the pollution controls.

1.2 Proposed Effluent Limitations Guidelines and Standards

Based on consideration of the factors discussed above, EPA developed the proposed MP&M Phase I effluent limitations guidelines and standards. The proposed effluent limitations guidelines and standards consist of mass-based limitations for all direct dischargers, for all new indirect dischargers, and for all indirect dischargers with greater than or equal to one million gallons per year of process wastewater discharge. Existing indirect dischargers with less than one million gallons per year of process wastewater discharge are exempt from the proposed regulation.

For all sites regulated under MP&M Phase I, permit writers will be required to convert the proposed concentration-based limitations to mass-based limitations using the flow guidance provided in Section 16.0. These proposed concentration-based limitations were developed based on chemical precipitation and sedimentation, used in conjunction with flow reduction, pollution prevention, and preliminary treatment technologies. However, these technologies are not mandated under the proposed effluent guidelines and pretreatment standards. Sites regulated under the proposed effluent limitations and pretreatment standards are required to meet the discharge limitations but are not required to use the technologies on which the limitations are based.

Table 1-1 presents the proposed concentration-based limitations. The technology basis described above was used to develop the limitations for all regulatory levels of control; therefore, the concentrations are the same for each level of control. The proposed rule would require that permit writers convert these limitations to mass-based limitations. EPA recommends that, for sites with good pollution prevention and water conservation technologies in place that are equivalent to those listed above, permit writers use historical flow as a basis for converting the concentration-based limitations to mass-based. For sites without these types of technologies in place, EPA recommends that permit writers do not use historical flow, but use other tools listed in Section 16.0.

Table 1-1

MP&M Phase I Concentration-Based Limitations

Pollutant or Pollutant Parameter	Maximum For Any One Day (milligrams/liter)	Monthly Average - Shall Not Exceed (milligrams/liter)
Aluminum (T)(1)	1.4	1.0
Cadmium (T)(1)	0.7	0.3
Chromium (T)(1)	0.3	0.2
Copper (T)(1)	1.3	0.6
Iron (T)(1)	2.4	1.3
Nickel (T)(1)	1.1	0.5
Zinc (T)(1)	0.8	0.4
Cyanide (T)(1)	0.03	0.02
Oil and Grease (2)	35	17
Total Suspended Solids (3)	73	36
pH	(4)	(4)

Source: MP&M Technology Effectiveness Concentration (TEC) database.

(1) These concentrations apply to BPT, BAT, PSES, NSPS, and PSNS.
(2) These concentrations apply to all levels of regulatory control. Oil and grease is proposed as an indicator for organic pollutants.
(3) These concentrations apply to BPT, BCT, and NSPS.
(4) Within 6.0 to 9.0 standard units. This applies to BPT, BCT, and NSPS
(T) Total (e.g., total aluminum, total cadmium, total cyanide).

2.0 LEGAL AUTHORITY

This regulation is being proposed under the authority of Sections 301, 304, 306, 307, 308, and 501 of the Clean Water Act (the Federal Water Pollution Control Act Amendments of 1972, 33 U.S.C. 1251 et seq., as amended by the Clean Water Act of 1977, Pub. L. 95-217, and the Water Quality Act of 1987, Pub. L. 100-4), also referred to as "the Act."

2.1 Regulatory Background

2.1.1 Clean Water Act

The Federal Water Pollution Control Act Amendments of 1972 established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Section 101(a)). To implement the Act, EPA is required to issue effluent limitations guidelines, pretreatment standards, and new source performance standards for industrial dischargers. These guidelines and standards are summarized briefly below.

1. Best Practicable Control Technology Currently Available (BPT) (Section 304(b)(1) of the Act).

   BPT effluent limitations guidelines are applicable to direct discharging sites (i.e., sites that discharge wastewater to surface water). BPT effluent limitations guidelines are generally based on the average of the best existing performance by sites of various sizes, ages, and unit processes within the category or subcategory for control of pollutants.

   In establishing BPT effluent limitations guidelines, EPA considers the total cost of achieving effluent pollutant reductions in relation to the effluent pollutant reduction benefits, the age of equipment and facilities involved, the processes used, process changes required, engineering aspects of the control technologies, nonwater quality environmental impacts, and other factors as the EPA Administrator deems appropriate. The Agency considers the category- or subcategory-wide cost of applying the technology in relation to the effluent pollutant reduction benefits. Where existing performance is uniformly inadequate, BPT may be transferred from a different subcategory or category.

2. Best Available Technology Economically Achievable (BAT) (Sections 304(b)(2)(B) and 307(a)(2) of the Act).

BAT effluent limitations guidelines are applicable to direct discharging sites. In general, BAT effluent limitations guidelines represent the best existing economically achievable performance of sites in the industrial subcategory or category. The Act establishes BAT as the principal national means of controlling the direct discharge of priority pollutants and nonconventional pollutants to waters of the United States. The factors considered in assessing BAT include the age of equipment and sites involved, the processes used, potential process changes, and nonwater quality environmental impacts. The Agency retains considerable discretion in assigning the weight to be accorded these factors. As with BPT, where existing performance is uniformly inadequate, BAT may be transferred from a different subcategory or category. BAT may include process changes or internal controls, even when these technologies are not common industry practice. BPT and BAT effluent limitations guidelines are typically established in a tiered approach, such that sites must first comply with BPT, which is then superseded by BAT after an established period of time.

3. Best Conventional Pollutant Control Technology (BCT) (Sections 301(b)(2)(E) and 304(a)(4) of the Act).

The 1977 Act included Section 301(b)(2)(E), which established BCT for discharges of conventional pollutants from existing industrial point sources. BCT effluent limitations guidelines are applicable to direct discharging sites. Section 304(a)(4) designated the following as conventional pollutants: biochemical oxygen demand (BOD), total suspended solids (TSS), fecal coliform, pH, and any additional pollutants defined by the Administrator as conventional. The Administrator designated oil and grease as an additional conventional pollutant on July 30, 1979 (44 FR 44501).

BCT is not an additional limitation, but replaces BAT for the control of conventional pollutants. BPT and BCT effluent limitations guidelines are typically established in a tiered approach, such that sites must first comply with BPT, which is then superseded by BCT after an established period of time.

In addition to other factors specified in Section 304(b)(4)(B), the Act requires that BCT limitations be established in light of a two-part "cost-reasonableness" test [American Paper Institute v. EPA,

660 F.2d 954 (4th Cir. 1981)]. EPA must find that proposed BCT limitations are "reasonable" under both parts of the test before establishing them as BCT. If the candidate BCT technology does not pass both parts of the test, BCT is established equal to BPT. Otherwise, BCT supersedes BPT. In no case may BCT be less stringent than BPT. EPA's methodology for the development of BCT limitations was issued in 1986 (51 FR 24974, July 9, 1986).

4. New Source Performance Standards (NSPS)
(Section 306 of the Act).

NSPS are applicable to direct discharging sites and are based on the best available demonstrated treatment technology. New sites have the opportunity to install the best and most efficient production processes and wastewater treatment technologies. As a result, NSPS should represent the most stringent numerical values attainable through the application of the best available control technology for all pollutants (i.e., conventional, nonconventional, and priority pollutants). In establishing NSPS, EPA is directed to take into consideration the cost of achieving the effluent pollutant reduction and any nonwater quality environmental impacts.

5. Pretreatment Standards for Existing Sources (PSES)
(Section 307(b) of the Act).

PSES are applicable to indirect discharging sites (i.e., sites that discharge to a publicly-owned treatment works (POTW)). The Act requires PSES for pollutants that pass through POTWs or interfere with POTWs' treatment processes or sludge disposal methods. The 1977 Act indicates that pretreatment standards are to be technology-based and analogous to the BAT effluent limitations guidelines for removal of priority and nonconventional pollutants. For the purpose of determining whether to promulgate national category-wide pretreatment standards, EPA generally determines if there is pass-through of a pollutant and thus a need for categorical standards. If the nation-wide average percent of a pollutant removed by well-operated POTWs achieving secondary treatment is less than the percent removed by the BAT model treatment system, then the pollutant is said to pass through the POTWs.

The General Pretreatment Regulations, which set forth the framework for the implementation of categorical pretreatment standards, are found at 40 CFR Part 403. The regulations contain a definition of pass-through that addresses local rather than national

instances of pass-through and does not use the percent removal comparison test described above (52 FR 1586, January 14, 1987).

6. Pretreatment Standards for New Sources (PSNS) (Section 307(b) of the Act).

PSNS are applicable to indirect discharging sites. Like PSES, PSNS are designed to prevent the discharges of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of POTWs. PSNS are to be issued at the same time as NSPS. New indirect dischargers, like new direct dischargers, have the opportunity to incorporate into their sites the best available demonstrated technologies. The Agency considers the same factors in promulgating PSNS that it considers in promulgating NSPS.

The following table summarizes these regulatory levels of control.

Summary of Regulatory Levels of Control

Type of Sites Regulated	BPT	BAT[a]	BCT[a]	NSPS	PSES	PSNS
Existing Direct Dischargers	X	X	X			
New Direct Dischargers				X		
Existing Indirect Dischargers					X	
New Indirect Dischargers						X
Pollutants Regulated	**BPT**	**BAT[a]**	**BCT[a]**	**NSPS**	**PSES**	**PSNS**
Priority Pollutants	X	X		X	X	X
Nonconventional Pollutants	X	X		X	X	X
Conventional Pollutants	X		X	X		

Source: Clean Water Act

[a]BPT, BAT, and BCT are typically established in a tiered approach such that sites must first comply with BPT, which is then superseded by, as applicable, BAT and BCT after an established period of time.

2.1.2 Section 304(m) Requirements

Section 304(m) of the Clean Water Act (33 U.S.C. 1314(m)), added by the Water Quality Act of 1987, requires EPA to establish schedules for (1) reviewing and revising existing effluent limitations guidelines and standards ("effluent guidelines"), and (2) promulgating new effluent guidelines. On January 2, 1990, EPA published an Effluent Guidelines Plan (55 FR 80), in which schedules were established for developing new and revised effluent guidelines for several industrial categories. In this notice, the Agency identified the Metal Products and Machinery (formerly referred to as Machinery

Manufacturing and Rebuilding) Point Source Category as requiring effluent guidelines, and identified an estimated schedule for regulatory action.

The Natural Resources Defense Council, Inc. (NRDC) and Public Citizen, Inc., challenged the Effluent Guidelines Plan in a suit filed in U.S. District Court for the District of Columbia (NRDC et al. v. Reilly, Civ. No. 89-2980). The plaintiffs charged that EPA's plan did not meet the requirements of Section 304(m). A Consent Decree in this litigation was entered by the Court on January 31, 1992. The terms of the Consent Decree are reflected in the Effluent Guidelines Plan published on September 8, 1992 (57 FR 41000). As a result of this decree, EPA established a plan to propose effluent guidelines for the Metal Products and Machinery (MP&M) Phase I Point Source Category by November 1994, and take final action by May 1996. EPA filed a motion with the court on September 28, 1994, and was granted an extension until March 31, 1995, for the EPA Administrator to sign the proposed regulation and a subsequent four-month extension for signature of the final regulation in September 1996.

2.1.3 Pollution Prevention Act

In the Pollution Prevention Act of 1990 (PPA) (42 U.S.C. 13101 et seq., Pub.L. 101-508, November 5, 1990), Congress declared pollution prevention the national policy of the United States. This act declares that pollution "should be prevented or reduced whenever feasible; pollution that cannot be prevented should be recycled or reused in an environmentally safe manner whenever feasible; pollution that cannot be recycled should be treated in an environmentally safe manner whenever feasible; and disposal or release into the environment should be employed only as a last resort..." (Sec. 6602; 42 U.S.C. 13103).

According to the PPA, source reduction reduces the generation and release of hazardous substances, pollutants, wastes, contaminants or residuals at the source, usually within a process. The term source reduction "includes equipment or technology modifications, process or procedure modifications, reformation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control. The term 'source reduction' does not include any practice which alters the physical, chemical, or biological characteristics or the volume of a hazardous substance, pollutant, or contaminant through a process or activity which itself is not integral to or necessary for the production of a product or the providing of a service." In effect, source reduction means reducing the amount of a pollutant that enters a waste stream or that is otherwise released into the environment prior to out-of-process recycling, treatment, or disposal.

The PPA directs the Agency to, among other things, "review regulations of the Agency prior and subsequent to their proposal to determine their effect on source reduction" (Sec. 6604; 42 U.S.C. 13103). This directive led the Agency to implement a pilot project called the Source Reduction Review Project (SRRP). The SRRP facilitates the

integration of source reduction in the Agency's regulations, including the technology-based effluent guidelines.

2.2 Overview of Effluent Limitations Guidelines and Standards for Metals Industries

EPA has promulgated effluent limitations guidelines and standards for 13 metals industries. These regulations cover metal manufacturing, metal forming, and component finishing, as summarized below.

Summary of Metals Industry Effluent Guidelines

Coverage Area	Title	CFR Reference
Metal and Metal Alloy Manufacturing	Iron and Steel Manufacturing[a]	40 CFR 420
	Nonferrous Metals Manufacturing	40 CFR 421
	Ferroalloy Manufacturing	40 CFR 424
Metal Forming	Iron and Steel Manufacturing[a]	40 CFR 420
	Metal Molding and Casting	40 CFR 464
	Aluminum Forming	40 CFR 467
	Copper Forming	40 CFR 468
	Nonferrous Metals Forming and Metal Powders	40 CFR 471
Component Finishing	Electroplating	40 CFR 413
	Iron and Steel Manufacturing[a]	40 CFR 420
	Metal Finishing	40 CFR 433
	Battery Manufacturing	40 CFR 461
	Coil Coating	40 CFR 465
	Porcelain Enameling	40 CFR 466
	Electrical and Electronic Component Manufacturing	40 CFR 469

Source: Code of Federal Regulations, Part 40

[a]The Iron and Steel Manufacturing category includes metal manufacturing, metal forming, and component finishing.

In 1986, the Agency reviewed the coverage of these regulations and identified a significant number of wastewater-discharging metal processing sites that were not covered by these 13 regulations. Based on the results of this review, EPA performed a

detailed analysis of these unregulated sites. This analysis resulted in the development of the Machinery Manufacturing and Rebuilding (MM&R) Point Source Category. In 1989, the Agency published a Preliminary Data Summary (PDS) for the MM&R industry, which is included in the record for this rulemaking. Based on information contained in the PDS, the MM&R category was divided into two phases and was included in EPA's January 2, 1990 Effluent Guidelines Plan (55 FR 80). On May 7, 1992, EPA changed the category name to Metal Products and Machinery (MP&M) to clarify the coverage of the category (57 FR 19748); questionnaire respondents found the MM&R label confusing and interpreted the category to apply only to machinery sites. The Agency believes that the MP&M title better describes the coverage of the category.

2.3 Overview of the MP&M Point Source Category

The MP&M Point Source Category covers facilities that generate wastewater while processing metal parts, metal products, and machinery, and includes operations performed during manufacturing, assembly, rebuilding, repair, and maintenance. The category encompasses two regulatory phases and 15 industrial sectors, as summarized below.

Sector Coverage of MP&M Phases

Phase I	Phase II
Aerospace	Bus and Truck
Aircraft	Household Equipment
Electronic Equipment	Instruments
Hardware	Motor Vehicles
Mobile Industrial Equipment	Office Machines
Ordnance	Precious and Nonprecious Metals
Stationary Industrial Equipment	Railroad
	Ships and Boats

A site is considered to be included in a sector if any of the products processed at the site are used within that sector. For example, a site manufacturing aircraft components would be included in the aircraft sector, while a site manufacturing bolts that are used in aircraft and stationary pumps would be included in both the aircraft and the stationary industrial equipment sectors. The regulatory coverage of the phases and sectors are further described in Section 3.0.

The sectors included in each phase were selected based on an analysis similar to that used to set overall priorities for the development of new and revised guidelines under Section 304(m) of the Clean Water Act. The analysis focused on the amounts and kinds of wastewater discharges created by the different sectors and the likely economic impacts of effluent limitations guidelines and standards. This analysis is discussed in EPA's Effluent Guidelines Plan (55 FR 80), which is included in the record for this rulemaking.

3.0 APPLICABILITY

The Metal Products and Machinery (MP&M) Point Source Category (including both Phase I and II) applies to industrial sites engaged in manufacturing, rebuilding, or maintaining finished metal parts, products, or machines within fifteen industrial sectors. Sites within these sectors manufacture, maintain, and rebuild products under more than 190 different Standard Industrial Classification (SIC) codes.

In developing the MP&M effluent guidelines, EPA divided the category into two phases. The MP&M Phase I effluent guidelines apply to process wastewater discharges from sites performing manufacturing, rebuilding or maintenance on a metal part, product or machine to be used in one of seven industrial sectors, while MP&M Phase II applies to wastewater discharges from eight additional sectors. These sectors are summarized in the following table.

MP&M Industrial Sectors

MP&M Phase I Sectors	MP&M Phase II Sectors
Aerospace	Bus and Truck
Aircraft	Household Equipment
Electronic Equipment	Instruments
Hardware	Motor Vehicle
Mobile Industrial Equipment	Office Machine
Ordnance	Precious and Nonprecious Metals
Stationary Industrial Equipment	Railroad
	Ships and Boats

Table 3-1 (located at the end of this section) lists typical products manufactured within MP&M Phase I. This is not an exhaustive list, but is presented to provide general guidance as to the types of products within this phase. MP&M Phase II is scheduled for promulgation approximately three years after Phase I.

Section 3.1 presents additional discussion on the applicability of MP&M Phase I, including a discussion of the interface between Phase I and Phase II. Section 3.2 presents a discussion of the regulatory interface between MP&M Phase I and existing metals industry regulations.

3.1 Applicability Of MP&M Phase I And Interface With Phase II

As discussed above, the MP&M Phase I effluent guidelines apply to process wastewater discharges from sites performing manufacturing, rebuilding, or maintenance on a metal part, product, or machine to be used in one of the seven Phase I industrial sectors. EPA expects that some products will clearly fit within certain industrial sectors while others

will be more difficult to define. Some examples of how the MP&M Phase I regulation would apply are provided below for clarification.

An example of a site clearly engaged in Phase I is a site that manufactures aircraft engines. The site would be considered in the aircraft industrial sector of MP&M. Since the aircraft sector is in MP&M Phase I, the aircraft engine manufacturer would be covered by MP&M Phase I.

An example of a site clearly engaged in Phase II is a site that manufactures school buses. The site would be considered in the bus and truck industrial sector of MP&M. Since the bus and truck industrial sector is in MP&M Phase II, the school bus manufacturer would be covered by MP&M Phase II.

An example of a site engaged in more than one MP&M Phase I industrial sector is a site that manufacturers farm tractors and farm conveyors. The site would be considered in the mobile industrial equipment and the stationary industrial equipment sectors. Since both mobile industrial equipment and stationary industrial equipment are MP&M Phase I industrial sectors, the farm tractor and farm conveyor manufacturer would be covered by MP&M Phase I.

An example of a site that could be difficult to assign to a specific MP&M industrial sector would be a car door handle manufacturing site. If a car door handle were considered a piece of hardware, then the site would be covered under MP&M Phase I (hardware industrial sector). If the door handle were considered a motor vehicle part, then the site would be covered under MP&M Phase II (motor vehicle industrial sector). In cases where products could be viewed under different industrial sectors, the industrial sector(s) which most accurately matches the market into which the product is sold should be assigned. In addition, if a metal part has a specific use in one of the fifteen MP&M industrial sectors, then the sector in which it is intended to be used is the industrial sector that should be assigned to that site. In this example, the car door handle has no uses other than operating the door of a car, and this site would be considered in the motor vehicle industrial sector (MP&M Phase II).

Another example of a site that could be difficult to assign to a specific MP&M industrial sector would be a site that manufactures pistons for use in internal combustion engines, stationary generators, automotive engines, aircraft engines, and truck engines. Since the pistons are used in a wide variety of industrial applications and are not produced for use in a specific MP&M industry, the piston manufacture should be considered to be making a fabricated metal product and be covered under MP&M Phase I (hardware).

Some MP&M sites have operations in both MP&M Phase I and Phase II industrial sectors. The MP&M Phase I effluent guidelines apply to combined wastewater discharges when a site is manufacturing, rebuilding, or maintaining finished metal products in both Phase I and Phase II sectors (i.e., MP&M Phase I covers wastewater discharges from all sites performing any operations in a Phase I industrial sector). EPA's

data collection and analysis of MP&M sites included MP&M Phase I and Phase II overlap sites. Many of these sites use the same equipment to manufacture, rebuild, and maintain goods for both Phase I and Phase II sectors, making it impossible to separate wastewater generated by operations performed in the two phases. EPA believes that regulating combined Phase I and Phase II wastewater discharges under Phase I will alleviate burdens on the permit writers and allow sites to achieve compliance more cost effectively, since they typically will have to comply with one set of limits.

An example of a site that is in MP&M Phase I and Phase II industrial sectors would be a site which manufactures hand tools and household cooking equipment. The site would be considered in the hardware and household equipment sectors. Since the hardware industrial sector is in MP&M Phase I and the household equipment industrial sector is in MP&M Phase II, the site has operations in both MP&M phases. The MP&M Phase I effluent guidelines apply to combined wastewater discharges from sites with operations in both MP&M Phase I and Phase II. As a result, if the site combined its process wastewater prior to discharge, all of the site's process wastewater (including wastewater generated in manufacturing cooking equipment) would be regulated under MP&M Phase I. If the site segregated the wastewater generated from Phase I operations from the wastewater generated from Phase II operations, the Phase I wastewater would be regulated under Phase I, while the Phase II wastewater would be regulated under Phase II.

3.2 Applicability Interfaces Between MP&M Phase I and Previously Promulgated Metals Regulations

EPA has previously established effluent limitations guidelines and standards for thirteen industries which may perform unit operations or process parts that are sometimes found in MP&M Phase I sites. These effluent guidelines are:

- Electroplating (40 CFR Part 413);
- Iron & Steel Manufacturing (40 CFR Part 420);
- Nonferrous Metals Manufacturing (40 CFR Part 421);
- Ferroalloy Manufacturing (40 CFR Part 424);
- Metal Finishing (40 CFR Part 433);
- Battery Manufacturing (40 CFR Part 461);
- Metal Molding & Casting (40 CFR Part 464);
- Coil Coating (40 CFR Part 465);
- Porcelain Enameling (40 CFR Part 466);
- Aluminum Forming (40 CFR Part 467);
- Copper Forming (40 CFR Part 468);
- Electrical & Electronic Components (40 CFR Part 469); and
- Nonferrous Metals Forming & Metal Powders (40 CFR Part 471).

With the exception of Electroplating and Metal Finishing, these existing effluent guidelines generally apply to the production of semi-finished products, while the MP&M

Phase I effluent guidelines apply to finished metal parts, products, and machines. EPA recognizes that unit operations performed in industries covered by the existing effluent guidelines generate wastewater similar to wastewater generated by unit operations performed at MP&M Phase I sites. Many MP&M sites also have operations covered by one or more of the existing metal processing effluent guidelines. In general, with the exception of the Metal Finishing effluent guidelines, the existing metals industry effluent guidelines will continue to apply to operations judged to be covered by those effluent guidelines. The MP&M Phase I effluent guidelines cover unit operations that, at present, are not covered by an existing metals regulation, that are covered by the Metal Finishing effluent guidelines, or that are covered by best professional judgment. The MP&M Phase I effluent guidelines replace the Metal Finishing effluent guidelines for sites within an MP&M Phase I industrial sector, if the sites are direct dischargers or indirect dischargers with greater than or equal to one million gallons of annual process wastewater discharge. MP&M Phase I does not apply to surface finishing job shops, independent circuit board manufacturers, or indirect dischargers with less than one million gallons of annual process wastewater discharge; these will continue to be covered by Electroplating and Metal Finishing, where appropriate.

Both MP&M Phase I and Metal Finishing apply to the same types of unit operations. EPA has included sites covered by Metal Finishing in the data collection and study of the MP&M Phase I industry and has estimated the costs and impacts on these sites to comply with the proposed MP&M Phase I regulation. EPA anticipates that the MP&M Phase I limitations will impose more stringent requirements on wastewater discharges from MP&M Phase I sites currently covered by Metal Finishing without undue economic impacts, and therefore is proposing that MP&M Phase I replace the Metal Finishing effluent guidelines for sites satisfying the MP&M Phase I criteria.

Table 3-1

Metal Products and Machinery (MP&M) Phase I Typical Products

Sector	Typical Products
Aircraft	Aircraft Aircraft engines and engine parts Aircraft parts and equipment
Aerospace	Guided missiles and space vehicles Guided missile and space vehicle propulsion Other space vehicle and missile parts
Electronic Equipment	Telephone and telegraph apparatus Radio and TV communications equipment Communications equipment Electronic tubes Electronic capacitors Electronic coils and transformers Connectors for electronic applications Electronic components Electric lamps
Hardware	Cutlery Hand and edge tools Hand saws and saw blades Screw machine products Bolts, nuts, screws, rivets, washers Metal shipping barrels, drums, kegs Iron and steel forgings Crowns and closures Metal stampings Steel springs Wire springs Miscellaneous fabricated wire products Fasteners, buttons, needles, pins Fluid power valves and hose fittings Valves and pipe fittings

Table 3-1 (Continued)

Metal Products and Machinery (MP&M) Phase I Typical Products

Sector	Typical Products
Hardware (Continued)	Fabricated metal pipe and fittings Fabricated metal products Machine tools, metal cutting types Machine tools, metal forming types Special dies and tools, die sets, jigs Machine tool accessories and measuring devices Power-driven hand tools Heating equipment Industrial furnaces and ovens Fabricated structural metal Fabricated plate work Sheet metal work Architectural and ornamental metal work Prefabricated metal buildings and components
Mobile Industrial Equipment	Farm machinery and equipment Garden tractors and lawn and garden equipment Construction machinery and equipment Mining machinery and equipment Hoists, industrial cranes and monorails Industrial trucks, tractors and trailers Tanks and tank components
Ordnance	Small arms ammunition Ammunition Small arms Ordnance and accessories
Stationary Industrial Equipment	Steam, gas hydraulic turbines, generators Internal combustion engines Oil field machinery and equipment Elevators and moving stairways Conveyors and conveying equipment Industrial patterns Rolling mill machinery and equipment Metal working machinery Textile machinery Woodworking machinery Paper industries machinery Printing trades machinery and equipment

Table 3-1 (Continued)

Metal Products and Machinery (MP&M) Phase I Typical Products

Sector	Typical Products
Stationary Industrial Equipment (Continued)	Food products machinery Special industry machinery Pumps and pumping equipment Ball and roller bearings Air and gas compressors Blowers and exhaust and ventilation fans Packaging machinery Speed changers, high-speed drivers and gears Industrial process furnaces and ovens Mechanical power transmission equipment General industrial machinery Automatic vending machines Commercial laundry equipment Refrigeration and air and heating equipment Measuring and dispensing pumps Service industry machines Fluid power cylinders and actuators Fluid power pumps and motors Scales and balances, except laboratory Industrial machinery Welding apparatus Transformers Switchgear and switchboard apparatus Motors and generators Relays and industrial controls Electric industrial apparatus Heavy construction equipment rental

Source: MP&M DCPs, MP&M site visits, technical literature.

4.0 SUMMARY OF DATA COLLECTION ACTIVITIES

This section summarizes the Agency's data collection activities for Phase I of the MP&M industry. Sections 4.1 and 4.2 summarize the purpose, recipient selection process, types of information collected, and uses of data for the MP&M mini data collection portfolio (MDCP) and the MP&M data collection portfolio (DCP), respectively. Sections 4.3 and 4.4 summarize the site visit and field sampling programs, respectively, conducted at MP&M sites.

4.1 Mini Data Collection Portfolio

In August and September 1990, EPA mailed 8,342 screener questionnaires, or MDCPs, to sites believed to be engaged in MP&M manufacturing, rebuilding, or maintenance activities. Mailout of the MDCP was the preliminary step in an extensive data-gathering effort for the MP&M category. The purpose of the MDCP was to identify sites to receive the more detailed DCP and to make a preliminary assessment of Phase I of the MP&M industry.

4.1.1 MDCP Recipient Selection and Mailing

The Agency sent the MDCP to randomly selected MP&M Phase I sites engaged in manufacturing, rebuilding, or maintenance operations. The MDCP was also sent to selected MP&M Phase II manufacturing sites to characterize the interfaces between MP&M phases. Potential recipients were identified using Standard Industrial Classification (SIC) codes. The MDCP was not sent to sites with SIC codes indicating that the sites were engaged in MP&M Phase II rebuilding or maintenance operations.

EPA calculated the number of sites to receive the MDCP within each SIC code by a coefficient of variation (CV) minimization procedure, described in Appendix B of the January 9, 1995 "Data Base Summary Report for the Metal Products and Machinery Mini Data Collection Portfolio," also referred to as the MDCP Database Report. The Agency identified more than 190 SIC codes applicable to MP&M sectors. Within each sector, EPA identified between 1 and 40 SIC codes. Based on the number of sites selected within each SIC code, the Agency purchased a list of randomly selected names and addresses from Dun & Bradstreet. This list included twice the number of sites specified by the CV minimization procedure for each SIC code. Within each SIC code, Dun & Bradstreet randomly selected the requested number of sites from the Dun & Bradstreet database. From this list of potential recipient sites, the Agency randomly selected sites to receive the MDCP.

EPA deleted sites from the Dun & Bradstreet list for the following reasons: sites had SIC codes which were inconsistent with company names; sites were corporate headquarters without manufacturing, rebuilding, or maintenance operations; or sites had insufficient mailing addresses. The remaining site names were scrambled randomly by

computer and resorted by SIC code. MDCP recipients were then selected sequentially by SIC code from the database and assigned a randomly selected site identification number. Each site identification number was assigned a corresponding barcode to track the mailout and processing of the MDCPs. Within each SIC code, MDCPs were sent to approximately 30 to 60 sites.

EPA established a toll-free helpline from August through October of 1990 to assist MDCP recipients in completing the questionnaire. This helpline received approximately 900 calls from MDCP recipients. Additional information about the MDCP mailing (e.g., a copy of the MDCP, specific mailing and processing procedures, MDCP responses, follow-up letters, and notes from helpline telephone conversations) is discussed in the following sections and is contained in the administrative record for this rulemaking.

4.1.2 Information Collected

The Agency requested the following site-specific information in the MDCP:

- Name and address of facility;
- Contact person;
- Parent company;
- Sectors in which the site manufactures, rebuilds, or maintains machines or metal components;
- SIC codes corresponding to products at the site;
- Number of employees;
- Annual revenues;
- Unit operations performed at the site;
- Whether there is process water use and/or wastewater discharge for each unit operation performed at the site; and
- Base metal(s) on which each unit operation is performed.

The Agency used a computerized database system to store and analyze data received from the MDCPs. The MDCP database and database dictionary are contained in the administrative record for this rulemaking.

4.1.3 MDCP Data Entry, Engineering Coding, and Analysis

The Agency performed a preliminary review of the MDCPs prior to data entry. As part of this effort, the Agency reviewed all documentation provided by the site, corrected errors and deficiencies, and formatted the information for data entry. In some cases, these revisions required telephone contact with site personnel. The Agency contacted more than 1,100 MDCP recipients to resolve questionnaire deficiencies and format information for data entry. Following preliminary review, scannable data (i.e., responses to multiple-choice, Mark Sense™ questions) were entered into the database using a Scantron™ reader. Each form was scanned twice, and the information was compared using a computer program as a quality control (QC) check. Nonscannable data were manually entered twice into computer files, and the computer files compared for discrepancies, resolved, and finally converted to database files.

4.1.4 MDCP Mailout Results

EPA initially mailed 8,000 MDCP questionnaires in August 1990. Based on the number of questionnaires returned undelivered, an additional 342 were mailed in September 1990. In addition, EPA received 22 unsolicited responses to the questionnaire. Of the 8,364 potential respondents to the MDCP, including those who provided unsolicited responses, 94% (7,846) received the MDCP. MDCPs for the remaining 6% (518) were returned to EPA as undeliverable. These sites were assumed to be out of business. Of the total potential respondents, 84% (6,981) returned the MDCP to EPA. A blank copy of the MDCP form and nonconfidential portions of the completed MDCPs are contained in the administrative record for this rulemaking. A summary of mailout results is presented in the following table.

Summary of MDCP Mailout Results

Number of Sites	Total Sites	Percentage of Total Potential Respondents
Mailed MDCP	8,342	---
Unsolicited Responses	22	---
Total Potential Respondents[a]	8,364	---
Received MDCP at Site[a]	7,846	94
MDCP Undelivered	518	6
Returned MDCP to EPA[a]	6,981	84
MDCP Not Returned to EPA	865	10

[a]Includes 22 unsolicited responses.

Source: MDCP Tracking System.

The number of sites engaged in MP&M operations was determined by responses to the MDCP. As shown in the following table, approximately 52% of the MDCP respondents reported that the site was engaged in MP&M operations and approximately 48% reported no MP&M operations at the site. The status of 10 of the sites could not be determined; these sites returned an incomplete MDCP and did not respond to follow-up efforts.

Summary of MDCP Respondents

Number of Sites	Total Sites	Percentage of Sites That Returned MDCP
Returned MDCP	6,981	100
Engaged in MP&M Operations	3,598	52
Not Engaged in MP&M Operations	3,373	48
Unresolved	10	<1

Source: MDCP Database.

The Agency contacted a statistically representative sample of the nonrespondent sites (i.e., sites that did not return the MDCP) and sites reporting "not engaged" in MP&M operations to determine whether sites did not respond or had indicated "not engaged" due to confusion over the scope of the MP&M industry. Many callers to the helpline questioned the MDCP applicability due to the "Machinery Manufacturing" reference in the questionnaire title. Callers at sites that produced metal products not traditionally referred to as machines (e.g., screws or hammers) did not initially understand that the MP&M industry includes metal products and machine parts as well as machines. The results of this follow-up are presented in Appendix C of the MDCP Database Report. This report is contained in the administrative record for this rulemaking.

4.1.5 Industry Scale-Up of MDCP Data

Based on the MDCP mailout results, EPA developed an MP&M Phase I industry profile. The MDCP Database Report provides estimates of the national population of MP&M Phase I sites with regard to water use characteristics, size, location, sector, unit operations, and metal types. Appendix B of the report discusses the sample size determination and statistical procedures for scale-up to the industry.

4.2 Data Collection Portfolio

Based on responses to the MDCP, EPA sent a more detailed questionnaire to a select group of water-using MP&M sites. This questionnaire, or data collection portfolio (DCP), was designed to collect detailed technical and financial information. This information was used to characterize MP&M Phase I sites, develop pollutant loadings

and reductions, and develop compliance cost estimates, as discussed throughout this document.

EPA mailed 896 DCPs in January 1991. Based on the number of DCPs returned undelivered, an additional 124 DCPs were mailed in January and February 1991, for a total of 1,020 DCPs mailed. A blank copy of the DCP is contained in the administrative record for this rulemaking. Copies of the nonconfidential portions of the completed DCPs are also contained in the administrative record for this rulemaking.

4.2.1 DCP Recipient Selection and Mailing

EPA selected 1,020 DCP recipients from the following three groups of sites:

- Water-discharging Phase I MDCP respondents (860 recipient sites);
- Water-using Phase I MDCP respondents that did not discharge process water (74 recipient sites); and
- Water-discharging sites from key Phase I companies that did not receive the MDCP (86 recipient sites).

The methods used to select sites within each group are described below.

The Agency mailed the DCP to all 860 Phase I water-discharging MDCP respondents. EPA's intent in collecting detailed data from all 860 sites was to characterize the potential variations in unit operations performed and water use practices among water-discharging sites in the MP&M Phase I industry.

The Agency mailed the DCP to a probability sample of 50 MDCP respondents that reported using but not discharging process water. These sites were selected to provide information on water-use practices at sites that use but do not discharge process water, and to determine if "zero-discharge" practices used at those sites could be used at other MP&M sites.

EPA also mailed the DCP to an additional 24 MDCP respondents that reported using but not discharging process water. These sites were selected to provide information on unit operations performed at these sites that were not expected to be sufficiently characterized by DCPs mailed to other sites. Specific reasons for selecting each of these 24 sites (i.e., unit operations expected at each site) are contained in the administrative record for this rulemaking.

EPA mailed the DCP to 86 sites that did not receive the MDCP. The Agency identified these sites to represent key companies in the MP&M Phase I industry that were not selected as DCP recipients based on the MDCP mailout. Key companies were identified

from Dun and Bradstreet company listings, the Thomas Register, Fortune Magazine's listing of the top 500 U.S. companies, and MP&M site visits at companies with annual revenues of $50 million or more that were believed to be leading companies in their particular MP&M sector. The Agency contacted each of the key companies to identify sites within the company that were engaged in MP&M operations and used process water to perform MP&M operations. Records of these follow-up telephone calls are contained in the administrative record for this rulemaking.

EPA operated a toll-free telephone helpline from January until July 1991 to assist recipients in completing the DCP. The helpline received approximately 1,400 calls from DCP recipients. Callers to the DCP helpline typically requested the following:

- Assistance with the technical sections of the DCP (e.g., technical clarification of unit operation definitions);
- Additional time to complete the questionnaire;
- Assistance with the financial sections of the DCP (these calls were referred to a separate economics helpline); or
- Clarification of the applicability of the questionnaire (i.e., did the questionnaire apply to the site?).

Records for telephone calls to the helpline and to EPA personnel are contained in the administrative record for this rulemaking.

4.2.2 Information Collected

This section describes the information collected in each part of the DCP, and the reasons for information collection. Further details on the types of information collected and the potential uses of the information are contained in the DCP instructions and the Information Collection Request (ICR) for this project. These documents are contained in the administrative record for this rulemaking.

The Agency designed the DCP to collect information necessary for the development of effluent guidelines and standards for the MP&M industry. The DCP was divided into the following six parts, described below:

- Part I - General Information;
- Part II - Process Information;
- Part III - Water Supply;
- Part IV - Wastewater Treatment and Discharge;
- Part V - Process and Hazardous Wastes; and
- Part VI - Financial and Economic Information.

Part I (questions 1 through 13) requested information necessary to identify the site, to characterize the site by certain variables (including number of employees, facility age, and location), and to confirm that the site was engaged in MP&M operations. This information included: site name, address, contact person, number of employees, facility age, average energy usage, discharge permit status, and MP&M activity (manufacturing, rebuilding, or maintenance).

Part II (questions 14 through 21) requested detailed information on MP&M products, production levels, unit operations, activity, water use for unit operations, wastewater discharge from unit operations, miscellaneous wastewater sources, waste minimization practices (e.g., pollution prevention), and air pollution control for unit operations. The site was requested to provide detailed technical information (e.g., water balance, chemical additives, metal type processed, disposition of wastewater) for each MP&M unit operation and air pollution control device using process water. This section also requested information on unique and/or auxiliary MP&M operations. This information was used to evaluate raw waste characteristics, water use and discharge practices, and sources of pollutants for each MP&M unit operation.

Part III (question 22) requested information on the water supply for the site. The site was required to specify the source water origin, average intake flow, average intake operating hours, and the percentage of water used for MP&M operations. This information was used to evaluate overall water use for the site.

Part IV (questions 23 through 33) requested detailed information on MP&M influent and effluent wastewater treatment streams and wastewater treatment operations. The information requested included: the origin of each stream contributing to the site's overall wastewater discharge; a block diagram of the wastewater treatment system; detailed technical information (e.g., wastewater stream flow rates, treatment chemical additives, system capacity, disposition of treatment sludge) for each wastewater treatment operation; self-sampling monitoring data; and capital and operating cost data. EPA collected this information to evaluate treatment in place at MP&M sites, to develop and design a cost model for Phase I of the MP&M industry, and to assess the long-term variability of MP&M effluent streams.

Part V (question 34) requested detailed information on the types, amounts, and composition of wastewater and solid/hazardous wastes generated during production or waste treatment, and the costs of solid waste disposal. This information was collected to evaluate the types and amounts of wastes currently discharged, the amount of waste that is contract hauled off site, and the cost of contract hauling wastes.

Part VI requested detailed financial and economic information from the site and the company owning the site. Information from this part presented in the Industry Profile and Economic Impact documents for Metal Products and Machinery Industry Phase I, which are both included in the administrative record for this rulemaking.

4.2.3 DCP Review, Coding, and Data Entry

The Agency completed a detailed engineering review of the DCPs, including coding responses to questions from Parts I through V of the DCPs to facilitate entry of technical data into the DCP database. The MP&M DCP Database Dictionary identifies all database codes developed for this effort. This database dictionary is contained in the administrative record for this rulemaking. The database dictionary for Section VI of the DCP is included as Appendix A of the Industry Profile document.

The Agency followed up with telephone calls to all respondents who: (1) did not provide information on operations (manufacturing, rebuilding, or maintenance) or sectors; (2) did not provide metal type or unit operation descriptions for each water-using unit operation; or (3) did not provide descriptions for each wastewater treatment operation. Other follow-up calls were made to clarify incomplete or contradictory technical or economic information. Information obtained from all follow-up calls was confirmed by sending a follow-up letter to the site.

EPA developed a database to store all technical data provided in the DCPs. The database was developed using dBASE IV® for data entry, and was converted to SAS® format for data analysis. After engineering review and coding, data from the DCPs were entered into the database using a double keypunch and verification procedure. Data from 792 DCPs were coded and entered into the DCP database. The MP&M DCP Database dictionary presents the database structure and defines each field in the DCP database and the codes that describe data in these fields.

4.2.4 DCP Mailout Results

The following table summarizes the results of the DCP mailout. Of the 1,020 sites that received the DCP, 998 responded to the survey and 22 did not. Of the sites that responded, 199 were deactivated (i.e., removed from the DCP database development process) for one of the following reasons:

- The site was out of business;
- The site did not use process water;
- The site was not engaged in MP&M operations;
- Process information at the site was Department of Defense or Department of Energy classified information; or
- The site did not respond to the data collection effort, and based on the MDCP and follow-up, was believed by EPA to have limited useful technical information to add to the DCP database.

Specific reasons for deactivation of individual sites are contained in the administrative record for this rulemaking.

The following table also shows that 87 Phase II (only) sites returned the DCP. The scope of the DCP mailout effort included only Phase I sites; these 87 sites were identified during the DCP mailing list development as Phase I sites. Upon review of the DCPs submitted by these sites, the sites were reclassified as Phase II (only) sites. As discussed in Section 3.0, all Phase I and Phase II overlap sites are included in the Phase I rulemaking.

Summary of DCP Mailout Results

Activity	Number of Sites
Mailed DCP	1,020
Deactivated[a] Non-Respondent Sites Respondent Sites	199 22 799
Received Late/Not in Database[b] Data Entered into Database	7 792
Both Phase I and Phase II[c] Phase II Only[d] Phase I Only	75 87 630

[a]Reasons for deactivating (i.e., removing from the database development process) each of these sites are presented in the administrative record for this rulemaking.
[b]These DCPs were received too late to be incorporated into the DCP database based on the court-mandated schedule for promulgation of effluent guidelines for this category.
[c]These sites are included in both phases based on the products manufactured and the economic sectors in which the products are sold.
[d]These 87 sites were identified from the MDCP database as Phase I sites. Upon review of the DCPs, the sites were reclassified as Phase II (only) sites.

Source: DCP Tracking System and Database.

4.2.5 Industry Scale-Up of DCP Data

The "Data Base Summary Report for the Metal Products and Machinery Data Collection Portfolio" provides estimates of the national population of MP&M water discharging sites with regard to size, location, sector, unit operations, metal types, discharge flow, and production normalized flows. The report includes a discussion of the statistical procedures for scale-up to the industry. The report is contained in the administrative record for this rulemaking.

4.3 Site Visits

The Agency visited 98 MP&M sites between 1986 and 1993 to collect information about MP&M unit operations, water use practices, pollution prevention and treatment technologies, and waste disposal methods, and to evaluate sites for potential inclusion in the MP&M sampling program (described in Section 4.4). In general, the Agency visited sites to encompass the range of sectors, unit operations, and wastewater treatment technologies within the MP&M industry (discussed in Section 4.3.1). The following table lists the number of sites visited within each MP&M phase and sector. The total number of site visits presented in this table exceeds 98 because some sites are classified in multiple sectors.

Number of Sites Visited Within Each MP&M Phase and Sector

Phase I Sectors	Total Number of Sites Visited	Phase II Sectors	Total Number of Sites Visited
Aerospace	13	Bus and Truck	3
Aircraft	24	Household Equipment	1
Electronic Equipment	18	Instrument	0
Hardware	14	Motor Vehicle	7
Mobile Industrial Equipment	6	Office Machines	2
Ordnance	14	Precious and Nonprecious Metals	0
Stationary Industrial Equipment	13	Railroad	3
		Ships and Boats	1

Source: MP&M Site Visits.

In addition to sites within the Phase I and Phase II sectors, the Agency visited four job-shop electroplating sites that performed in-process source reduction and recycling technologies.

4.3.1 Criteria for Site Selection

The Agency based site selection on information contained in the MP&M MDCPs and DCPs. The Agency also contacted regional EPA personnel, state environmental agency personnel, and local pretreatment coordinators to identify MP&M sites believed to be operating in-process source reduction and recycling technologies or end-of-pipe wastewater treatment technologies.

The Agency used the following four general criteria to select sites that encompassed the range of sectors and unit operations within the MP&M industry.

1. The site performed MP&M unit operations in an industrial sector in which sites had not previously been visited. To assess the variation of unit operations and water use practices across sectors, the Agency visited sites in each of the seven MP&M Phase I sectors. Site visits were also conducted at MP&M Phase II sites to assess the variation of unit operations and water use practices across the MP&M phases.

2. The site performed MP&M unit operations that had not been observed during previous site visits.

3. The site had water use practices that were believed to be representative of the best sites within an industrial sector.

4. The site operated in-process source reduction, recycling, or end-of-pipe treatment technologies considered in development of the MP&M technology options.

The Agency also attempted to visit sites of various sizes. EPA visited sites with wastewater flows ranging from less than 200 gallons per day to more than 1,000,000 gallons per day.

Site-specific selection criteria are contained in site visit reports (SVRs) prepared for each site visited by EPA. The SVRs are contained in the administrative record for this rulemaking.

4.3.2 Information Collected

During the site visits, EPA collected the following types of information:

- Unit operations performed at the site and the types of metals processed through these operations;

- Purpose of unit operations performed and purpose for any process water and chemical additions used by the unit operations;

- Types and disposition of wastewater generated at the site;

- Types of in-process source reduction and recycling technologies performed at the site;

- Cross-media impacts of in-process source reduction and recycling technologies;
- Types of end-of-pipe treatment technologies performed at the site; and
- Logistical information required for sampling.

This information is documented in the SVRs for each visited site.

4.4 Wastewater and Solid Waste Sampling

The Agency conducted sampling episodes at 27 sites between 1986 and 1993 to obtain data on the characteristics of MP&M wastewaters and solid wastes, and to assess the following: the loading of pollutants to surface waters and POTWs from MP&M sites; the effectiveness of technologies designed to reduce and remove pollutants from MP&M wastewater; and the variation of MP&M wastewater characteristics across unit operations, metal types processed in each unit operation, and sectors. The Agency also sampled wastewater at one job-shop electroplating site to characterize surface treatment operations (e.g., electroplating, chemical conversion coating) and end-of-pipe treatment systems that were comparable to MP&M unit operations and treatment systems. The following table lists the number of sites sampled within each MP&M phase and sector. The number of sampled sites presented in the table exceeds 27 because one site was classified in both the aircraft and stationary industrial equipment sectors.

Number of Sites Sampled Within Each MP&M Phase and Sector

Phase I Sectors	Total Number of Sites Sampled	Phase II Sectors	Total Number of Sites Sampled
Aerospace	2	Bus and Truck	1
Aircraft	5	Household Equipment	0
Electronic Equipment	3	Instrument	0
Hardware	3	Motor Vehicle	3
Mobile Industrial Equipment	2	Office Machines	1
Ordnance	3	Precious and Nonprecious Metals	0
Stationary Industrial Equipment	4	Railroad	1
		Ships and Boats	0

Source: MP&M Sampling Episodes.

4.4.1 Criteria for Site Selection

The Agency used information collected during MP&M site visits to identify candidate sites for sampling. The Agency used the following general criteria to select sites for sampling:

- The site performed MP&M unit operations that had not been sampled at other sites;
- The site processed metals through MP&M unit operations for which the metal type/unit operation combination had not been sampled at other sites;
- The site performed in-process source reduction, recycling, or end-of-pipe treatment technologies that were considered for technology option development; and
- The site performed unit operations in a sector in which samples had not previously been collected.

The Agency also attempted to sample at sites of various sizes. EPA sampled at sites with wastewater flows ranging from less than 200 gallons per day to more than 600,000 gallons per day.

After a site was selected for sampling, the Agency prepared a detailed sampling and analysis plan (SAP), based on the information contained in the SVR and follow-up correspondence with the site. The SAPs were prepared to ensure collection of samples that would be representative of the sampled waste streams, and contained the following types of information: site-specific selection criteria for sampling; information about site operations; sampling point locations and sample collection, preservation, and transportation procedures; site contacts; and sampling schedules.

4.4.2 Information Collected

In addition to wastewater and solid waste samples, the Agency collected the following types of information during each sampling episode:

- Dates and times of sample collection;
- Flow data corresponding to each sample;
- Production data corresponding to each sample of wastewater from MP&M unit operations;

- Design and operating parameters for source reduction, recycling, and treatment technologies characterized during sampling;
- Information about site operations that had changed since the site visit or which were not included in the SVR; and
- Temperature and pH of the sampled waste streams.

All data collected during sampling episodes are documented in the sampling episode report for each sampled site. Sampling episode reports are included in the administrative record for this rulemaking. The sampling episode reports also contain preliminary technical analyses of treatment system performance (where applicable) as compared to treatment performance data collected for previous metals industry regulatory development efforts.

4.4.3 Sample Collection and Analysis

All samples were collected, preserved, and transported according to EPA protocols as specified in EPA's Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants (1) and the MP&M Quality Assurance Plan (QAP). These documents are contained in the administrative record for this rulemaking.

In general, composite samples were collected from wastewater streams with compositions that were expected to vary over the course of a production period (e.g., overflowing rinse waters, wastewaters from continuous recycling and treatment systems). Grab samples were collected from unit operation baths or rinses that were not continuously discharged and not expected to vary over the course of a production period. Composite samples of wastewater treatment sludge were also collected. EPA collected the required types of quality control samples as described in the MP&M QAP, such as blanks and duplicate samples, to verify the precision and accuracy of sample analyses.

Samples were shipped via overnight air transportation to EPA-approved laboratories where analyses for metal and organic pollutants and additional parameters (including several water quality parameters) were performed. Metal pollutants were analyzed using EPA Method 1620 (2), volatile organic pollutants were analyzed using EPA Method 1624 (3), and semivolatile organic pollutants were analyzed using EPA Method 1625 (4). Tables 4-1 and 4-2 (at the end of this section) list the metal and organic pollutants, respectively, analyzed using these methods. Table 4-1 also lists additional metal pollutants that were analyzed in the MP&M sampling program, but, as per EPA Method 1620, were not subject to the rigorous quality assurance/quality control procedures established by the QAP. These metals analyses were used for screening purposes, and the metals were not selected for regulation in this rulemaking (see Section 8.0). Additional parameters, including several water quality parameters, were analyzed using analytical methods contained in EPA's Methods for Chemical Analysis of Water and

Wastes (5). Table 4-3 lists these parameters, along with the method and technique used to analyze for each parameter. Method descriptions are included in the MP&M QAP. The specific parameters measured in each sample are listed in the sampling episode report for each sampling episode.

Quality control measures used in performing all analyses complied with the guidelines specified in the analytical methods and in the MP&M QAP. All analytical data were reviewed to ensure that these measures were followed and that the resulting data were within the QAP-specified acceptance criteria for accuracy and precision.

As discussed previously, upon receipt and review of the analytical data for each site, a sampling episode report was written to document the sampling episode, the data collected during sampling, the analytical results, and the technical analyses of the results. The sampling and analysis plans and correspondence with site personnel are included as appendices to the sampling episode reports.

4.5 Existing Data Sources

In developing the MP&M Phase I effluent guidelines, EPA evaluated the following existing data sources:

1. EPA/EAD databases from development of effluent guidelines for other metals industries;

2. The Office of Research and Development (ORD) Risk Reduction Engineering Laboratory (RREL) treatability database;

3. The Fate of Priority Pollutants in Publicly Owned Treatment Works (50 POTW Study) database;

4. The Domestic Sewage Study; and

5. The Toxics Release Inventory (TRI) database.

These data sources and their uses for the development of the MP&M Phase I effluent guidelines are discussed below.

4.5.1 EPA/EAD Databases

As discussed in Section 2.0, EPA has promulgated effluent guidelines for 13 metals industries. In developing these effluent guidelines, EPA collected wastewater samples to characterize the unit operations and treatment systems at sites in these industries. Many of the sampled unit operations and treatment systems are operated at MP&M sites;

therefore, EPA evaluated these data for transfer to the MP&M effluent guidelines development effort.

For the MP&M Phase I pollutant loading and wastewater characterization efforts, EPA reviewed the data collected for unit operations performed at both MP&M sites and at sites in other metals industries. EPA reviewed the Technical Development Documents (TDDs), sampling episode reports, and supporting record materials for the other metals industries to identify available data. EPA transferred data for unit operations that met the following two criteria:

1. The unit operation was performed at MP&M Phase I sites; and

2. EPA had not collected analytical data for the unit operation from MP&M sites.

EPA combined these data with data collected from the MP&M sampling program.

For the MP&M technology effectiveness assessment effort, EPA reviewed data collected to characterize treatment systems sampled for the development of effluent guidelines for other metals industries. For several previous effluent guidelines, EPA used treatment data from metals industries to develop the Combined Metals Data Base (CMDB), which served as the basis for developing limits for these industries. EPA also developed a separate database used as the basis for limits for the Metal Finishing category. EPA used the CMDB and Metal Finishing data as a guide in identifying well-designed and well-operated MP&M treatment systems. EPA did not use these data in developing the MP&M technology effectiveness concentrations since sufficient data were collected from MP&M Phase I sites to develop technology effectiveness concentrations.

4.5.2 Risk Reduction Engineering Laboratory Treatability Database

EPA's Office of Research and Development (ORD) developed the Risk Reduction Engineering Laboratory (RREL) treatability database to provide data on the removal and destruction of chemicals in various types of media, including water, soil, debris, sludge, and sediment. This database contains treatability data from publicly owned treatment works (POTWs) for various pollutants. This database includes physical and chemical data for each pollutant, the types of treatment used to treat the specific pollutants, the type of wastewater treated, the size of the POTW, and the treatment concentrations achieved. EPA used this database to assess removal by POTWs of MP&M pollutants of concern.

4.5.3 Fate of Priority Pollutants in Publicly Owned Treatment Works Database

In September 1982, EPA published the Fate of Priority Pollutants in Publicly Owned Treatment Works (6), referred to as the 50 POTW Study. The purpose of this study was

to generate, compile, and report data on the occurrence and fate of the 129 priority pollutants in 50 POTWs. The report presents all of the data collected, the results of preliminary evaluations of these data, and the results of calculations to determine the following:

1. The quantity of priority pollutants in the influent to POTWs;
2. The quantity of priority pollutants discharged from the POTWs;
3. The quantity of priority pollutants in the effluent from intermediate process streams; and
4. The quantity of priority pollutants in the POTW sludge streams.

EPA used the data from this study to assess removal by POTWs of MP&M pollutants of concern.

4.5.4 The Domestic Sewage Study

In February 1986, EPA issued the Report to Congress on the Discharge of Hazardous Wastes to Publicly Owned Treatment Works (7), referred to as the Domestic Sewage Study (DSS). This report, which was based in part on the 50 POTW Study, revealed a significant number of sites discharging pollutants to POTWs which are a threat to the treatment capability of the POTW. These pollutants were not regulated by national effluent regulations. Some of the major sites identified were in the metals industries, particularly one called equipment manufacturing and assembly. This industry included sites which manufacture such products as office machines, household appliances, scientific equipment, and industrial machine tools and equipment. The DSS estimated that this category discharges 7,715 metric tons per year of priority hazardous organic pollutants which are presently unregulated. Data on priority hazardous metals discharges were unavailable for this category. Further review of the DSS revealed other categories which were related to metals industries, namely the motor vehicle category, which includes servicing of new and used cars and engine and parts rebuilding, and the transportation services category, which includes railroad operations, truck service and repair, and aircraft servicing and repair. EPA used the information in the DSS in developing the Preliminary Data Summary (PDS) for the MP&M category.

4.5.5 Toxics Release Inventory Database

The Toxics Release Inventory (TRI) database contains specific toxic chemical release and transfer information from manufacturing facilities throughout the United States. This database was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA), which Congress passed to promote planning for chemical emergencies and to provide information to the public about the presence and release of

toxic and hazardous chemicals. Each year, manufacturing facilities meeting certain activity thresholds must report the estimated releases and transfers of listed toxic chemicals to EPA and to the state or tribal entity in whose jurisdiction the facility is located. The TRI list includes more than 300 chemicals in 20 chemical categories.

EPA considered using the TRI database for developing the MP&M effluent guidelines. EPA did not use TRI data on wastewater discharges from MP&M sites because sufficient data were not available for effluent guidelines development. For example, in development of the MP&M effluent guidelines, production data were used that could be linked directly to pollutant loadings. This information was used to normalize pollutant loadings to production. The linked production and pollutant loadings data are not available in the TRI database. EPA also did not use the data on wastewater discharges because many MP&M Phase I sites don't meet the reporting thresholds for the TRI database.

Table 4-1

Metal Constituents Measured Under the MP&M Sampling Program
(EPA Method 1620)

Metal Constituents		
ALUMINUM	COBALT	SELENIUM
ANTIMONY	COPPER	SILVER
ARSENIC	IRON	SODIUM
BARIUM	LEAD	THALLIUM
BERYLLIUM	MAGNESIUM	TIN
BORON	MANGANESE	TITANIUM
CADMIUM	MERCURY	VANADIUM
CALCIUM	MOLYBDENUM	YTTRIUM
CHROMIUM	NICKEL	ZINC
Additional Metal Constituents[a] Not Subject to Rigorous QA/QC Procedures Per Method 1620:		
BISMUTH	LANTHANUM	SAMARIUM
CERIUM	LITHIUM	SCANDIUM
DYSPROSIUM	LUTETIUM	SILICON
ERBIUM	NEODYMIUM	STRONTIUM
EUROPIUM	NIOBIUM	SULFUR
GADOLINIUM	OSMIUM	TANTALUM
GALLIUM	PALLADIUM	TELLURIUM
GERMANIUM	PHOSPHORUS	TERBIUM
GOLD	PLATINUM	THORIUM
HAFNIUM	POTASSIUM	THULIUM
HOLMIUM	PRASEODYMIUM	TUNGSTEN
INDIUM	RHENIUM	URANIUM
IODINE	RHODIUM	YTTERBIUM
IRIDIUM	RUTHENIUM	ZIRCONIUM

[a]Analyses for these metals were used for screening purposes, and the metals were not selected for regulation in this rulemaking.

Source: EPA Method 1620.

Table 4-2

Organic Constituents Measured Under the MP&M Sampling Program
(EPA Methods 1624 and 1625)

Volatile Organic Constituents (EPA Method 1624)	
ACRYLONITRILE	TRANS-1,4-DICHLORO-2-BUTENE
BENZENE	TRIBROMOMETHANE
BROMODICHLOROMETHANE	TRICHLOROETHENE
BROMOMETHANE	TRICHLOROFLUOROMETHANE
CARBON DISULFIDE	VINYL ACETATE
CHLOROACETONITRILE	VINYL CHLORIDE
CHLOROBENZENE	1,1-DICHLOROETHANE
CHLOROETHANE	1,1-DICHLOROETHENE
CHLOROFORM	1,1,1-TRICHLOROETHANE
CHLOROMETHANE	1,1,1,2-TETRACHLOROETHANE
CIS-1,3-DICHLOROPROPENE	1,1,2-TRICHLOROETHANE
CROTONALDEHYDE	1,1,2,2-TETRACHLOROETHANE
DIBROMOCHLOROMETHANE	1,2-DIBROMOETHANE
DIBROMOMETHANE	1,2-DICHLOROETHANE
DIETHYL ETHER	1,2-DICHLOROPROPANE
ETHYL CYANIDE	1,2,3-TRICHLOROPROPANE
ETHYL METHACRYLATE	1,3-BUTADIENE, 2-CHLORO
ETHYLBENZENE	1,3-DICHLOROPROPANE
IODOMETHANE	1,4-DIOXANE
ISOBUTYL ALCOHOL	2-BUTANONE
M-XYLENE	2-CHLOROETHYL VINYL ETHER
METHYL METHACRYLATE	2-HEXANONE
METHYLENE CHLORIDE	2-PROPANONE
O+P XYLENE	2-PROPEN-1-OL
TETRACHLOROETHENE	2-PROPENAL
TETRACHLOROMETHANE	2-PROPENENITRILE, 2-METHYL-
TOLUENE	3-CHLOROPROPENE
TRANS-1,2-DICHLOROETHENE	4-METHYL-2-PENTANONE
TRANS-1,3-DICHLOROPROPENE	
Semivolatile Organic Constituents (EPA Method 1625)	
ACENAPHTHENE	BENZO(A)ANTHRACENE
ACENAPHTHYLENE	BENZO(A)PYRENE
ACETOPHENONE	BENZO(B)FLUORANTHENE
ALPHA-TERPINEOL	BENZO(GHI)PERYLENE
ANILINE	BENZO(K)FLUORANTHENE
ANILINE, 2,4,5-TRIMETHYL-	BENZOIC ACID
ANTHRACENE	BENZONITRILE, 3,5-DIBROMO-4-
ARAMITE	HYDROXY-
BENZANTHRONE	BENZYL ALCOHOL
BENZENETHIOL	BETA-NAPHTHYLAMINE
BENZIDINE	BIPHENYL
	BIPHENYL, 4-NITRO

Table 4-2 (Continued)

Organic Constituents Measured Under the MP&M Sampling Program
(EPA Methods 1624 and 1625)

Semivolatile Organic Constituents (EPA Method 1625) (Continued)	
BIS(2-CHLOROETHOXY)METHANE	N-EICOSANE
BIS(2-CHLOROETHYL) ETHER	N-HEXACOSANE
BIS(2-CHLOROISOPROPYL) ETHER	N-HEXADECANE
BIS(2-ETHYLHEXYL) PHTHALATE	N-NITROSODI-N-BUTYLAMINE
BUTYL BENZYL PHTHALATE	N-NITROSODIETHYLAMINE
CARBAZOLE	N-NITROSODIMETHYLAMINE
CHRYSENE	N-NITROSODIPHENYLAMINE
CIODRIN	N-NITROSOMETHYLETHYLAMINE
CROTOXYPHOS	N-NITROSOMETHYLPHENYLAMINE
DI-N-BUTYL PHTHALATE	N-NITROSOMORPHOLINE
DI-N-OCTYL PHTHALATE	N-NITROSOPIPERIDINE
DI-N-PROPYLNITROSAMINE	N-OCTACOSANE
DIBENZO(A,H)ANTHRACENE	N-OCTADECANE
DIBENZOFURAN	N-TETRACOSANE
DIBENZOTHIOPHENE	N-TETRADECANE
DIETHYL PHTHALATE	N-TRIACONTANE
DIMETHYL PHTHALATE	N,N-DIMETHYLFORMAMIDE
DIMETHYL SULFONE	NAPHTHALENE
DIPHENYL ETHER	NITROBENZENE
DIPHENYLAMINE	O-ANISIDINE
DIPHENYLDISULFIDE	O-CRESOL
ETHANE, PENTACHLORO-	O-TOLUIDINE
ETHYL METHANESULFONATE	O-TOLUIDINE, 5-CHLORO-
ETHYLENETHIOUREA	P-CHLOROANILINE
FLUORANTHENE	P-CRESOL
FLUORENE	P-CYMENE
HEXACHLOROBENZENE	P-DIMETHYLAMINOAZOBENZENE
HEXACHLOROBUTADIENE	P-NITROANILINE
HEXACHLOROCYCLOPENTADIENE	PENTACHLOROBENZENE
HEXACHLOROETHANE	PENTACHLOROPHENOL
HEXACHLOROPROPENE	PENTAMETHYLBENZENE
HEXANOIC ACID	PERYLENE
INDENO(1,2,3-CD)PYRENE	PHENACETIN
ISOPHORONE	PHENANTHRENE
ISOSAFROLE	PHENOL
LONGIFOLENE	PHENOL, 2-METHYL-4,6-DINITRO-
MALACHITE GREEN	PHENOTHIAZINE
MESTRANOL	PRONAMIDE
METHAPYRILENE	PYRENE
METHYL METHANESULFONATE	PYRIDINE
N-DECANE	RESORCINOL
N-DOCOSANE	SAFROLE
N-DODECANE	SQUALENE

Table 4-2 (Continued)

Organic Constituents Measured Under the MP&M Sampling Program
(EPA Methods 1624 and 1625)

Semivolatile Organic Constituents (EPA Method 1625) (Continued)	
STYRENE	2-NITROANILINE
THIANAPHTHENE	2-NITROPHENOL
THIOACETAMIDE	2-PHENYLNAPHTHALENE
THIOXANTHE-9-ONE	2-PICOLINE
TOLUENE, 2,4-DIAMINO-	2,3-BENZOFLUORENE
TRIPHENYLENE	2,3-DICHLOROANILINE
TRIPROPYLENEGLYCOL METHYL ETHER	2,3-DICHLORONITROBENZENE
1-BROMO-2-CHLOROBENZENE	2,3,4,6-TETRACHLOROPHENOL
1-BROMO-3-CHLOROBENZENE	2,3,6-TRICHLOROPHENOL
1-CHLORO-3-NITROBENZENE	2,4-DICHLOROPHENOL
1-METHYLFLUORENE	2,4-DIMETHYLPHENOL
1-METHYLPHENANTHRENE	2,4-DINITROPHENOL
1-NAPHTHYLAMINE	2,4-DINITROTOLUENE
1-PHENYLNAPHTHALENE	2,4,5-TRICHLOROPHENOL
1,2-DIBROMO-3-CHLOROPROPANE	2,4,6-TRICHLOROPHENOL
1,2-DICHLOROBENZENE	2,6-DI-TERT-BUTYL-P-BENZOQUINONE
1,2-DIPHENYLHYDRAZINE	2,6-DICHLORO-4-NITROANILINE
1,2,3-TRICHLOROBENZENE	2,6-DICHLOROPHENOL
1,2,3-TRIMETHOXYBENZENE	2,6-DINITROTOLUENE
1,2,4-TRICHLOROBENZENE	3-METHYLCHOLANTHRENE
1,2,4,5-TETRACHLOROBENZENE	3-NITROANILINE
1,2:3,4-DIEPOXYBUTANE	3,3'-DICHLOROBENZIDINE
1,3-DICHLORO-2-PROPANOL	3,3'-DIMETHOXYBENZIDINE
1,3-DICHLOROBENZENE	3,6-DIMETHYLPHENANTHRENE
1,3,5-TRITHIANE	4-AMINOBIPHENYL
1,4-DICHLOROBENZENE	4-BROMOPHENYL PHENYL ETHER
1,4-DINITROBENZENE	4-CHLORO-2-NITROANILINE
1,4-NAPHTHOQUINONE	4-CHLORO-3-METHYLPHENOL
1,5-NAPHTHALENEDIAMINE	4-CHLOROPHENYL PHENYL ETHER
2-(METHYLTHIO)BENZOTHIAZOLE	4-NITROPHENOL
2-CHLORONAPHTHALENE	4,4'-METHYLENEBIS(2-CHLOROANILINE)
2-CHLOROPHENOL	4,5-METHYLENE PHENANTHRENE
2-ISOPROPYLNAPHTHALENE	5-NITRO-O-TOLUIDINE
2-METHYLBENZOTHIOAZOLE	7,12-DIMETHYLBENZ(A)ANTHRACENE
2-METHYLNAPHTHALENE	

Source: EPA Methods 1624 and 1625.

Table 4-3

Additional Parameters Measured Under the MP&M Sampling Program

Parameter	EPA Method
Acidity	305.1
Alkalinity	310.1
Ammonia as Nitrogen	350.1
Chemical Oxygen Demand (COD)	410.1 410.2
Chloride	325.3
Cyanide, Total	335.2
Fluoride	340.2
Nitrogen, Total Kjeldahl	351.2
Oil and Grease	413.2
pH	150.1
Phenolics, Total Recoverable	420.2
Phosphorus, Total	365.4
Sulfate	375.4
Total Dissolved Solids (TDS)	160.1
Total Suspended Solids (TSS)	160.2

Source: Reference 5.

4.6 References

1. Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants, U.S. Environmental Protection Agency, April 1977.

2. Method 1620 Draft - Metals by Inductively Coupled Plasma Atomic Emission Spectroscopy and Atomic Absorption Spectroscopy, U.S. Environmental Protection Agency, September 1989.

3. Method 1624 Revision C - Volatile Organic Compounds by Isotope Dilution GCMS, U.S. Environmental Protection Agency, June 1989.

4. Method 1625 Revision C - Semivolatile Organic Compounds by Isotope Dilution GCMS, U.S. Environmental Protection Agency, June 1989.

5. Methods for Chemical Analysis of Water and Wastes, U.S. Environmental Protection Agency, EPA-600/4-79-020, March 1979.

6. Fate of Priority Pollutants in Publicly Owned Treatment Works, U.S. Environmental Protection Agency, EPA 440/1-82/303, September, 1982.

7. Report to Congress on the Discharge of Hazardous Wastes to Publicly Owned Treatment Works, U.S. Environmental Protection Agency, EPA 530-SW-86-004, February, 1986.

5.0 INDUSTRY DESCRIPTION

As discussed in Section 3.0, the Metal Products and Machinery (MP&M) Point Source Category covers sites that perform manufacturing, rebuilding, and maintenance activities while processing metal parts, machinery, or metal products. The category encompasses two regulatory phases comprising 15 industrial sectors. Phase I of the MP&M category consists of the following seven industrial sectors: aerospace, aircraft, electronic equipment, hardware, mobile industrial equipment, ordnance, and stationary industrial equipment. The MP&M Phase II category includes the remaining eight sectors. A list of products typically included in each Phase I sector is presented in Section 3.0. A site is considered to be included in a sector if any products processed at the site are used within that sector. MP&M sites performing any activities in the Phase I sectors are included in the Phase I category.

This section provides an overview of the MP&M Phase I industry, including the types of activities performed, the metal types processed, and detailed descriptions of each unit operation. This section also presents a discussion of the production-normalizing parameters applicable to the unit operations and production-normalized flow rates of wastewater discharged from these operations.

5.1 Number and Size of MP&M Phase I Sites

Based on results of the mini data collection portfolio (MDCP) survey, there are an estimated 79,613 MP&M Phase I sites. Additional data sources indicate that there may be as many as 91,000 MP&M Phase I sites. Chapter 3 of the MP&M Economic Impact Analysis (contained in the administrative record for this rulemaking) discusses these additional data sources. Based on data collection portfolio (DCP) survey results, an estimated 10,601 MP&M Phase I sites discharge process water.

MP&M Phase I water-discharging sites range in size from less than 10 employees to sites with tens of thousands of employees and from wastewater discharge flow rates of less than 100 gallons per year to wastewater discharge flow rates exceeding 100 million gallons per year. The following table summarizes the estimated number of MP&M Phase I sites by number of employees. This table shows that approximately 91% of MP&M Phase I sites have 500 or fewer employees. However, as discussed in Section 7.0, the number of employees at a site does not necessarily correspond with the discharge flow at the site. Section 5.7 of this report presents additional information on the estimated number of MP&M Phase I sites by discharge flow range.

MP&M Phase I Water-Discharging Sites by Number of Employees

Number of Employees	Estimated Number of Water-Discharging MP&M Phase I Sites	Percent of Water-Discharging MP&M Phase I Sites
1-10	3,108	29
11-50	1,405	13
51-100	1,806	17
101-500	3,355	32
501-1,000	423	4
1,001-5,000	445	4
5,001-10,000	30	<1
>10,000	29	<1
Total	10,601	100

Source: MP&M Phase I DCP database.

5.2 Unit Operations Performed

MP&M sites perform a wide variety of process unit operations on metal parts. The MP&M regulatory development effort initially focused on 47 unit operations (and their associated rinses) performed at MP&M sites, plus wet air pollution control operations, for a total of 48 unit operations. These unit operations are listed in Table 5-1 and are defined and described in Section 5.10. During the regulatory development effort, EPA identified additional unit operations performed at MP&M sites. These additional unit operations are listed in Table 5-2. Each MP&M unit operation can be characterized as belonging to one or more of the following types of unit operations:

- Metal shaping operations;
- Surface preparation operations;
- Metal deposition operations;
- Organic deposition operations;
- Surface finishing operations; and
- Assembly operations.

Metal shaping operations (e.g., machining, grinding, impact and pressure deformation) are mechanical operations that alter the form of raw materials into intermediate and final product forms. Surface preparation operations (e.g., alkaline treatment, barrel finishing) are chemical and mechanical operations that remove unwanted materials from or alter the chemical or physical properties of the surface prior to subsequent MP&M operations. Metal deposition operations (e.g., electroplating, metal spraying) apply a

metal coating to the part surface by chemical or physical means. Organic deposition operations (e.g., painting, corrosion preventive coating) apply an organic material to the part by chemical or physical means. Metal and organic deposition operations may be performed to protect the surface from wear or corrosion, modify the electrical properties of the surface, or alter the appearance of the surface. Surface finishing operations (e.g., chromate conversion coating, anodizing sealing) protect and seal the surface of the treated part from wear or corrosion by chemical means. Some surface finishing operations (e.g., metal coloring) may also be performed to alter the appearance of the part surface. Assembly operations (e.g., welding, soldering, testing, assembly, disassembly) are performed throughout the manufacturing, rebuilding, or maintenance process.

At a given MP&M site, the specific unit operations performed and the sequence of operations depend on many factors, including the activity (i.e., manufacturing, rebuilding, or maintenance), industrial sector, and type of product processed. Depending on these factors, MP&M sites perform many different combinations and sequences of unit operations. In general, however, MP&M products are processed in the following sequence:

- The raw material (e.g., bar stock, sheet stock, plates) undergoes some type of metal shaping process, such as impact or pressure deformation, machining, or grinding. In these operations, the raw material is shaped into intermediate forms for further processing or into final forms for assembly and shipment to the customer. Cleaning and degreasing processes are typically performed between some of the shaping operations to remove lubricants, coolants, and metal fines from the part. Heat treating operations may also be performed between shaping operations to alter the physical characteristics of the part.

- After shaping, the part typically undergoes some type of surface preparation operation, such as alkaline cleaning, acid pickling, or barrel finishing. The specific surface preparation operation used depends on the subsequent unit operations to be performed and the final use of the products. For example, prior to electroplating, parts typically undergo acid pickling to prepare the surface of the part for electroplating. Before assembly, parts typically undergo alkaline cleaning or barrel finishing. Parts undergo surface preparation operations at various stages of the production process. As mentioned above, cleaning and degreasing can occur between metal shaping operations. Additional cleaning and degreasing also occur prior to metal deposition, organic deposition, surface finishing, and assembly operations.

- Metal and organic deposition operations typically occur after shaping and surface preparation operations, and prior to surface finishing and final assembly operations. Electroplating operations typically follow alkaline and acid treatment operations, while painting operations typically follow phosphate conversion coating and alkaline treatment operations.

- Surface finishing operations are typically performed after shaping and surface preparation operations. Some surface finishing operations are performed after metal deposition operations. For example, chromate conversion coating is typically performed after acid cleaning, though this operation is sometimes performed as a sealant operation after electroplating. Some surface finishing operations are also performed prior to organic coating operations. For example, phosphate conversion coating is frequently performed prior to painting to enhance the paint adhesion.

- Assembly operations are performed at many steps of the manufacturing and rebuilding process. Disassembling operations may be performed as the first step in the rebuilding process. Assembly operations are performed to prepare the final product. Assembly may also involve some final shaping operations (e.g., drilling and grinding) and surface preparation operations (e.g., alkaline cleaning). Final assembly operations are typically the last operations performed prior to shipment to the customer.

Process water is used for and discharged from many of the unit operations listed in Tables 5-1 and 5-2. For some operations, process water may or may not be used, depending on the purpose of the operation, raw materials, and final product use. For example, some machining operations (e.g., drilling), can often be performed without a coolant, while other machining operations (e.g., milling) typically require a coolant. Process water that is used for an operation is typically discharged, but this is not always the case. Section 5.9 describes sites that use but do not discharge process water. Table 5-3 provides, for each unit operation (including associated rinses and wet air pollution control), a summary of the number of MP&M Phase I sites performing each unit operation, using process water to perform each unit operation, and discharging process water from each unit operation. The individual unit operations are described in Section 5.10. The most frequently performed water-discharging operations at MP&M Phase I sites are alkaline treatment, acid treatment, chemical conversion coating, floor cleaning, grinding, and machining. Many of the operations are typically followed by associated rinses.

Some MP&M sites perform all of these types of operations in manufacturing or rebuilding products, while others may focus on only a portion of these operations. For

example, a site in the hardware sector may start with bar stock and manufacture a final hardware product, performing machining, cleaning, electroplating, conversion coating, painting, degreasing, and assembly operations. Another hardware site may focus on painting the parts, and only perform cleaning and painting operations. A third hardware site may focus on shaping the parts, and perform only machining, cleaning, and degreasing operations.

MP&M sites that repair, rebuild, or maintain products often perform preliminary operations that may not be performed at manufacturing facilities (e.g., disassembly, cleaning, or degreasing to remove dirt and oil accumulated during use of the product). Sites that manufacture products required to meet very strict performance specifications (e.g., aerospace or electronic components) often perform unit operations, such as gold electroplating or magnetic flux testing, that may not be performed when manufacturing other products.

5.3 Metal Types Processed

MP&M sites perform unit operations on a variety of metal types. Based on DCP results, 24 different metal types were identified as processed at MP&M Phase I sites. Of these, iron, aluminum, and copper are the base metals most frequently processed. Chromium, nickel, tin, lead, and zinc are also frequently processed as metals electroplated onto base metals.

Many MP&M sites also process more than one metal type on site. The following table lists the number of water-discharging sites by number of metal types processed.

MP&M Phase I Water-Discharging Sites by Number of Metal Types Processed

Number of Metal Types	Estimated Number of Water-Discharging MP&M Phase I Sites	Percent of Water-Discharging MP&M Phase I Sites
Zero Metal Types[a]	48	<1%
One Metal Type	4,513	43%
Two Metal Types	3,359	32%
Three Metal Types	1,616	15%
Four Metal Types	451	4%
Five or More Metal Types	614	6%

Source: MP&M Phase I DCP database.

[a]Represents sites only discharging process water from floor cleaning of the metals processing area.

As shown in this table, more than half of the water-discharging MP&M sites process more than one metal type on site.

5.4 Water-Discharging MP&M Phase I Sites by Sector

The MP&M Phase I category includes seven industrial sectors. The table below summarizes the number of MP&M Phase I water-discharging sites by sector. Because some sites perform operations in more than one of the seven Phase I sectors, the sum of water-discharging sites by sector exceeds the total number of water-discharging sites (i.e., sites were multiple-counted in the table). This table indicates that the smallest number of water-discharging Phase I sites (316) are in the ordnance sector, while the largest number of water-discharging sites (4,321) are in the hardware sector.

MP&M Phase I Water-Discharging Sites by Sector

Sector	Estimated Number of Sites That Discharge Process Water[a]
Aerospace	1,465
Aircraft	1,726
Electronic Equipment	2,228
Hardware	4,321
Mobile Industrial Equipment	845
Ordnance	316
Stationary Industrial Equipment	3,133

Source: MP&M Phase I DCP database.

[a]Sites were multiple-counted by sector; therefore, the sum of sites engaged by sector exceeds the total number of sites that discharge water (10,601).

5.5 Water-Discharging MP&M Phase I Sites and Total Discharge Flow by Activity Combination

The MP&M category includes three activities: manufacturing, rebuilding, and maintenance. These activities are defined below.

- Manufacturing is the series of unit operations necessary to produce metal products, and is generally performed in a production environment.

- Rebuilding is the series of unit operations necessary to disassemble used metal products into components, replace the components or subassemblies or restore them to original function, and reassemble

the metal product. Rebuilding is generally performed in a production environment.

- Maintenance is the series of unit operations, on original or replacement components, required to keep metal products in operating condition. Maintenance is generally performed in a non-production environment.

The following table summarizes the estimated number of MP&M Phase I water-discharging sites and baseline (i.e., current) total discharge flow by activity combination. The largest number of sites (7,527) perform manufacturing only, while the smallest number of sites (117) perform rebuilding only. Sites performing only manufacturing account for approximately 19.8 billion gallons of discharge flow annually, which represents 85% of the total estimated discharge flow for the industry. In contrast, the discharge flow for the 235 sites performing both rebuilding and maintenance accounts for less than 1% of the total estimated discharge flow for the industry.

MP&M Phase I Water-Discharging Sites and Total Discharge Flow by Activity Combination

Activity	Estimated Number of Water-Discharging MP&M Phase I Sites	Total Estimated Discharge Flow (million gal/yr)[a]	Percentage of Total Water-Discharging MP&M Phase I Sites	Percentage of Total Discharge Flow
Manufacturing, Rebuilding and Maintenance	308	208	3	1
Manufacturing Only	7,527	19,800	71	85
Rebuilding Only	117	289	1	1
Maintenance Only	841	66.8	8	<1
Manufacturing and Rebuilding	1,333	1,950	13	8
Manufacturing and Maintenance	240	842	2	4
Rebuilding and Maintenance	235	0.350	2	<1
Total	10,601	23,200	100	100

Source: MP&M Phase I DCP database.

[a]Note: Based on the use of significant figures and rounding, the total reported for this column does not exactly equal the sum of the individual column values.

5.6 Water-Discharging MP&M Phase I Sites and Total Discharge Flow by Discharge Status

MP&M Phase I sites include direct discharging sites, indirect discharging sites, and sites that are both direct and indirect dischargers. An indirect discharger is a site that discharges wastewater to a publicly-owned treatment works (POTW) or a federally-owned treatment works (FOTW). A direct discharger is a site that discharges wastewater to a surface water. Sites discharging exclusively to privately-owned treatment works are considered zero dischargers that contract haul to centralized waste treatment facilities. The following table summarizes the number of MP&M Phase I water-discharging sites and baseline total discharge flow by discharge status. This table indicates that 8,440 sites are indirect dischargers, 1,797 sites are direct dischargers, and 364 sites are both direct and indirect dischargers. Indirect dischargers account for approximately 17.4 billion gallons of discharge flow annually, which represents 75% of the total estimated discharge flow for the industry. In contrast, the 1,797 direct dischargers account for approximately 8% of the total estimated discharge flow for the industry, while the 364 sites that discharge both directly and indirectly account for 17% of the total flow.

MP&M Phase I Water-Discharging Sites and Total Discharge Flow by Discharge Status

Discharge Status	Estimated Number of Water-Discharging MP&M Phase I Sites	Total Estimated Discharge Flow (million gal/yr)[a]	Percentage of MP&M Phase I Water-Discharging Sites	Percentage of Total Discharge Flow
Indirect Only	8,440	17,400	80	75
Direct Only	1,797	1,800	17	8
Direct and Indirect	364	3,920	3	17
Total	10,601	23,200	100	100

Source: MP&M Phase I DCP database.

[a]Note: Based on the use of significant figures and rounding, the total reported for this column does not exactly equal the sum of the individual column values.

5.7 Water-Discharging MP&M Phase I Sites by Total Discharge Flow

Wastewater discharge flows from MP&M sites range from less than 100 gallons per year to greater than 100 million gallons per year. The following table summarizes information on the wastewater discharge flow ranges for MP&M Phase I sites. As this table shows, sites discharging more than one million gallons per year (approximately 22% of the total Phase I sites) account for approximately 96% of the total wastewater

discharge from the industry. In contrast, sites discharging less than 10,000 gallons per year (approximately 30% of the total Phase I sites) account for less than 0.1% of the overall wastewater discharge flow for the industry.

MP&M Phase I Water-Discharging Sites by Total Discharge Flow

Discharge Flow Range (gal/yr/site)	Estimated Number of Water-Discharging MP&M Phase I Sites	Total Estimated Discharge Flow (million gal/yr)[a]	Percentage of Water-Discharging MP&M Phase I Sites	Percentage of Total Discharge Flow
$0 - 10^2$	993	0.0455	9	<1
$10^2 - 10^3$	1,297	0.498	12	<1
$10^3 - 10^4$	926	4.12	9	<1
$10^4 - 10^5$	3,056	115	29	1
$10^5 - 10^6$	2,053	676	19	3
$10^6 - 10^7$	1,760	6,210	17	27
$10^7 - 10^8$	483	12,400	5	53
$>10^8$	33	3,800	<1	16
Total	10,601	23,200	100	100

Source: MP&M Phase I DCP database.

[a]Note: Based on the use of significant figures and rounding, the total reported for this column does not exactly equal the sum of the individual column values.

5.8 Contract Hauling by MP&M Phase I Sites

Many MP&M Phase I sites contract haul some or all of their process wastewater. EPA estimates that 2,826 of the 10,601 wastewater discharging sites contract haul some wastewater generated on site. Not all sites reported the volume of wastewater that was contract hauled; therefore, EPA was not able to assess the volume of wastewater contract hauled by these sites. Sufficient data are also not available to estimate the number of MP&M Phase I sites contract hauling all wastewater generated on site.

5.9 MP&M Phase I Sites Not Discharging Process Water

Based on the results of the MDCP, EPA identified an estimated 12,361 MP&M Phase I sites that use but do not discharge process water. Based on information from the DCPs,

site visits, and technical literature, these sites achieve zero discharge of process wastewater in one of the following ways:

- Sites contract haul for off-site disposal all process wastewater generated on site;
- Sites discharge process wastewater to either on-site septic systems or deep-well injection systems;
- Sites perform end-of-pipe treatment and reuse all process wastewater generated on site;
- Sites perform either in-process or end-of-pipe evaporation to eliminate wastewater discharges; or
- Sites perform in-process recirculation and recycling to eliminate wastewater discharges.

As discussed in Section 4.0, EPA mailed DCPs to 50 statistically selected sites that were using but not discharging process water. Based on the DCP responses, five of these sites were identified as contract hauling all wastewater generated on site, eight were identified as actually discharging process wastewater, 18 were identified as having no process wastewater discharges, and 19 were identified as not engaged in MP&M. EPA mailed an additional 24 DCPs, selected for technical reasons, to sites not discharging process water. Of these, 14 were identified as actually discharging process wastewater, two were identified as having no process wastewater discharges, and 8 were identified as not engaged in MP&M.

In addition to the 20 sites discussed above as having no process wastewater discharges, 35 DCP respondents eliminated wastewater discharge by in-process or end-of-pipe evaporation, end-of-pipe treatment and reuse, or in-process recirculation and recycling. The 55 sites eliminating discharges through these methods are discussed below.

In-Process or End-Of-Pipe Evaporation. Eight DCP respondents reported discharging wastewater to either evaporators or on-site ponds or lagoons for evaporation of process wastewater. These sites typically performed less than 20 water-discharging unit operations. None of these site reported recovering the process wastewater. Sludge from the evaporators was reported as being contract hauled for off-site disposal. Information was not obtained regarding the impact of these operations on air pollution emissions from these sites. EPA believes that these types of evaporators may result in significant air emissions from MP&M sites.

End-Of-Pipe Treatment and Reuse. Three DCP respondents reported eliminating wastewater discharge through end-of-pipe treatment and reuse of all wastewater generated on site. One of these three sites operates an evaporator with an associated condenser unit to recover and reuse process wastewater. This site performs the following unit operations: alkaline cleaning, barrel finishing, phosphate conversion coating, painting, and associated rinses. This site also operates a coolant recycling system to recycle spent machining coolant. The other two sites reported recycling all spent machining coolant with units consisting of settling, skimming, and centrifuging. These two sites performed only machining operations. EPA also performed one site visit at a site that treated and reused all process wastewater using a system consisting of chemical precipitation and settling, ion exchange, and evaporation/condensation. As discussed in Sections 10 and 15, EPA considered end-of-pipe ion exchange with wastewater reuse in development of the MP&M Phase I effluent guidelines, but determined that this technology was not cost-effective in removing pollutants from MP&M Phase I sites.

In-Process Recirculation and Recycling. Forty-four sites reported eliminating wastewater discharge through in-process recirculation and recycling. Most of these sites perform fewer than three wastewater-generating unit operations; one site performs six wastewater-generating unit operations and another performs five wastewater-generating unit operations. The majority of these sites perform grinding and machining operations, in which water-based coolant is continuously recirculated through the machining unit and is not discharged. Make-up water is added for evaporation. Several sites perform heat treating operations, in which a stagnant water quench is used and not discharged. Some sites perform hydraulic testing, in which water is used to pressure test a part and is not discharged. Some sites perform surface finishing operations such as alkaline cleaning and chemical conversion coating, in stagnant baths and do not discharge wastewater. Make-up water is added for evaporation. Based on the data from MP&M sites, only sites with few unit operations are typically able to achieve zero discharge solely through in-process recirculation and recycling.

5.10 MP&M Unit Operations and Rinses

This section describes each of the 48 MP&M unit operations listed in Table 5-1 and summarizes the purpose of process water use for each operation and associated rinse. Table 5-3 provides, for each unit operation (including associated rinses), a summary of the number of MP&M sites performing each operation, using water to perform each unit operation, and discharging process water from each unit operation. Table 5-4 presents the production-normalizing parameter, median production-normalized flow, purpose of process water, and estimated total industry discharge flow for each unit operation. Production-normalizing parameters and production-normalized flows are described in Section 5.11. As shown in Table 5-4, most wastewater is discharged from associated rinses, with acid treatment rinsing and alkaline treatment rinsing generating the most wastewater of the MP&M unit operations. In addition to these unit operations, Table 5-2 lists additional, less common unit operations identified from MP&M DCPs.

Descriptions of these operations are contained in the administrative record for this rulemaking.

1. **Abrasive Blasting** is the removal of surface films from a part by using abrasive particles pneumatically impinged against the part.

   The abrasive particles used include glass or plastic beads, sand, metal shot, grit (crushed metal shot), slag, silica, pumice, or other materials such as walnut shells. Most abrasive blasting operations are dry; however, wet blasting is used where a slurry of fine abrasive is suspended in a liquid. In some cases, oil is used as the liquid carrier (e.g., manufacture of spark plugs), but the most commonly used liquid carrier is water. Water carriers sometimes contain rust inhibitors, wetting agents, or other additives. The wet process is usually operated in a cabinet, horizontal-plane turntable or similar equipment, or belt conveyor.

   The primary applications of wet abrasive blasting include: removing burrs on precision parts; producing satin or matte finishes; removing fine tool marks; and removing light mill scale, surface oxide, or welding scale. Wet blasting can be used to finish fragile items such as electronic components. Also, some aluminum parts are wet blasted to achieve a fine-grained matte finish for decorative purposes. During abrasive blasting operations, the water and abrasive are typically reused until the particle size diminishes due to impacting and fracture.

   The abrasive blasting process generates wastewater when spent abrasive and water are replaced. A rinse can follow abrasive blasting to remove abrasive and liquid carrier from the parts.

2. **Abrasive Jet Machining** is a process in which a controlled stream of abrasive-bearing fluid is directed at a part for the purpose of cutting or metal removal. This process is typically used on hard metal substrates and polymer composites.

   In this process, the media is fed from a reservoir into a high-pressure gas or liquid stream (500 to 3,000 feet per second), which propels the particles with explosive force. Abrasive jet machining is used to remove metal oxides, deburring, drilling, and cutting thin sections of metal. Process water is used as a carrier of the abrasive media. The liquid streams are typically alkaline or emulsified oil solutions.

   This process generates wastewater through solution dumps. A rinse sometimes follows the process to remove abrasive material and liquid carrier from the parts.

3. **Acid Treatment** is the application of a solution of an inorganic (mineral) acid, organic acid, or acid salt, sometimes in combination with a wetting agent or detergent, to remove oil, dirt, heat treating scale, metals, or oxide from metal surfaces.

Acid treatment is performed with various acid concentrations and is referred to as cleaning, pickling, acid dipping, acid etching, bright dipping, descaling, or desmutting. Common mineral acids used include sulfuric, hydrochloric, nitric, hydrofluoric, and chromic acids. Common organic acids used include citric, tartaric, acetic, oxalic, and gluconic acids. Sodium bisulfate and sodium pyrophosphate are commonly used acid salts.

Some acid treatment operations generate hexavalent chromium-bearing wastewater from the use of chromic acid. Chromic acid is used occasionally for cleaning cast iron and stainless steel, bright dipping of copper and copper alloys, pickling of cadmium, and cleaning of aluminum. Also, chromic acid solutions can be used as final steps in acid cleaning-phosphate conversion coating systems.

The acid treatment solution may or may not be heated. Acid treatment is performed as an immersion or spray operation. Complex shapes can require agitation with immersion or spray treatment. Acid treatment operations often follow alkaline cleaning prior to electroplating.

It should be noted that the acid treatment unit operation does not include all processes conducted in acid solutions. For example, conversion coatings performed in acid solutions are not considered part of the acid treatment unit operation. Additional examples include anodizing, electroplating, and chemical milling. The key distinguishing factors between these operations and acid treatment operations are the bath chemistries and the function of the process. These factors are discussed in the following paragraphs.

Acid cleaning can be distinguished from phosphate conversion coating (phosphating), which is a chemical conversion coating process (unit operation 12). In some instances, the use of phosphoric acid cleaning imparts a thin phosphate coating; however, the primary purpose of phosphoric acid cleaning is to clean and mildly etch the part's surface. The phosphating process is usually applied to parts prior to painting. Cleaning baths are typically formulated with at least 15% phosphoric acid and a water-soluble solvent, whereas phosphating baths contain only about 5% phosphoric acid and no solvent. Salts of magnesium and zinc are typically added to phosphating baths, but not to cleaning baths. It is common practice to measure weight gain of parts through some phosphating baths.

Some chemical conversion coatings (see unit operation 12) are formulated with chromic acid. These coatings are most often applied to aluminum, cadmium, and zinc basis metals and deposits. These processes are different from chromic acid treatment because they impart a complex metal film on the part surface to improve corrosion resistance and/or provide a good base for paint adhesion. In contrast, chromic acid cleaning removes surface oxides and other corrosion products.

Chemical machining (see unit operation 13) can be distinguished from acid etching. During chemical machining, acid solutions are used to machine metal alloys, removing a significant amount of metal from the part. In contrast, acid etching is used to clean surfaces or prepare them for subsequent finishing operations. For example, acid etching is commonly used prior to electroplating of ferrous alloys to activate the surface of the part (i.e., remove trace oxide deposits) and ensure uniform plating layer deposition.

Anodizing (unit operation 6) is performed with acid solutions that are similar to some acid treatment processes. Anodizing, which is applied primarily to aluminum parts, is performed using an electrolytic current to form an oxide coating on the part's surface. Acid treatment is also used for aluminum parts, but as a nonelectrolytic immersion process.

Wastewaters generated from acid treatment include spent solutions and rinsewaters. During use, the acid content of the process solution is diminished through reactions with metal and impurities present on the parts being processed. Spent solutions are typically batch dumped and treated or disposed of off site. In some cases, spent acid solutions are used as treatment chemicals to adjust the pH of other MP&M wastewater. Most acid treatment operations, including chromic acid treatment, are followed by a rinse to remove residual acid. Acid treatment rinsewaters are typically discharged to treatment or reused in other rinse tanks.

4. **Adhesive Bonding** is the joining of two or more pieces of material by applying thermoset, thermoplastic, or chemically reactive cure adhesive to the contact surfaces.

   Adhesive bonding is typically a dry operation, although, in some cases, contact cooling water is used.

5. **Alkaline Treatment** is the nonelectrolytic application of alkaline solution to a metal surface for the purpose of cleaning, degreasing, or chemical etching.

Alkaline cleaning and degreasing are performed to remove oily dirt or solid soils from parts. These processes are commonly applied after parts have been processed in unit operations that use oil and grease (e.g., machining) and prior to finishing operations, such as electroplating. Most alkaline cleaning and degreasing solutions include three major types of constituents: (1) builders, such as alkali hydroxides and carbonates, which are the source of alkalinity in the cleaner; (2) organic or inorganic additives, which promote better cleaning or affect the metal surface in some way; and (3) surfactants. Sodium cyanide is also used in some cleaning formulations as a complexing agent and/or to prevent staining of brass and copper work; however, its use has diminished because of environmental concerns with cyanide. Alkaline cleaners are typically heated and applied by immersion or spray methods. Immersion operations sometimes include mechanical action (e.g., stirring, pumping) or ultrasonic agitation.

Emulsion cleaning is an alkaline treatment (typically performed in the pH range of 7 to 9) that uses common organic solvents (e.g., kerosene, mineral oil, glycols, and benzene) dispersed into water with the aid of an emulsifying agent. Depending on the solvent used, cleaning is performed at temperatures from room temperature to 82°C (180°F). The process is often used as a replacement for vapor degreasing. Rinsing normally follows emulsion cleaning.

Alkaline etching is an alkaline treatment process usually associated with aluminum finishing. This process is typically performed by immersing parts for one to three minutes in a hot solution containing alkalis such as sodium hydroxide. Alkaline etching removes a thin surface layer and is used to eliminate scratches, nicks, and other surface imperfections. Common etching depths range from 3 to 20 micrometers (μm). Alkaline etching is typically preceded by a nonetching aluminum cleaning and rinsing, and followed by a thorough rinsing and usually desmutting. Smut (copper, iron, or other aluminum alloy constituents that are not soluble in sodium hydroxide) forms on the surface of the part during etching.

Wastewaters generated from alkaline treatment include spent solutions and rinsewaters. Alkaline treatment solutions become contaminated during use from the introduction of soils and/or dissolution of the base metal, and they are typically batch dumped for treatment or disposal. Alkaline treatment operations are typically followed by a water rinse that is discharged to treatment.

6. **Anodizing** is an electrolytic oxidation process which converts the surface of the metal to an insoluble oxide. These oxide coatings increase surface wear resistance, improve corrosion protection, provide decorative finishes, provide a base for painting and other coating processes, and provide special electrical properties.

Aluminum is the most frequently anodized material, while magnesium is also commonly anodized. Common aluminum anodizing processes are performed using chromic, sulfuric, boric/sulfuric, or other acid solution chemistries. Anodized coatings are typically considered either decorative or "hard". Hard anodizing is used when mechanical properties such as hardness or wear resistance are required.

Most anodizing involves immersing racked parts in tanks, although continuous anodizing is performed on coils of aluminum. For aluminum parts, the oxide is formed when the parts are anodically polarized in acid solutions. The oxide layer begins forming on the surface, and, as the reaction proceeds, the oxide layer thickens as more metal is oxidized.

The sulfuric acid process is widely used for aluminum alloys except for parts subject to stress or containing recesses in which the sulfuric acid solution can collect and attack the aluminum. Chromic acid anodic coatings have a relatively thick boundary layer and are more protective than sulfuric acid coatings. For these reasons, chromic acid can be used if the part cannot be completely rinsed. Conventional chromic and sulfuric acid anodized coatings range in thickness from 2.5 to 25 μm. Hard anodized coatings, which are applied using higher unit amperages and reduced temperatures, range in thickness from 25 to 300 μm. Hard coatings are used for parts requiring higher resistance to wear, erosion, and corrosion.

Many parts are colored after anodizing. Anodizing coloring can be accomplished in several ways, but the most common method is organic dyeing. Other methods include electrolytic coloring and precipitation pigmentation. When applicable, anodizing coloring is performed prior to sealing.

Following anodizing, parts are typically rinsed, then proceed through a sealing operation that improves the corrosion resistance of the coating. Common sealants include chromic acid, nickel acetate, nickel-cobalt acetate, sodium dichromate, and hot water. A rinse sometimes follows the sealing operation.

Wastewaters generated from anodizing include spent anodizing solutions, sealants, and rinsewaters. Because of the anodic nature of the process, anodizing solutions become contaminated with the base metal being processed. These solutions eventually reach an intolerable concentration of dissolved metal and require treatment or disposal. Rinsewaters following anodizing, coloring, and sealing steps are typically discharged to treatment.

7. **Assembly** is the fitting together of manufactured parts or components into a complete part, product, or machine.

Assembly operations are typically dry; however, special circumstances can require water for cooling or buoyancy. Also, rinsing may be necessary under some conditions.

8. **Barrel Finishing** (also referred to as mass finishing and tumbling) is the removal of burrs, scale, and oxides by finishing in a rotating barrel or vibrating unit with an abrasive media, water, and chemical additives.

Barrel finishing obtains a uniformity of surface finish typically not possible by hand finishing. For large quantities of small parts, barrel finishing is generally the most economical method of cleaning and surface conditioning.

Parts to be finished are placed in a rotating barrel or vibrating unit with an abrasive media (e.g., ceramic chips, pebbles). Water and chemical additives are sometimes added to assist in the operation. Alkaline detergents are typically used as chemical additives. As the barrel rotates, the upper layer of the part slides toward the lower side of the barrel, causing the burr removal, abrasion, or polishing. Similar results can also be accomplished in a vibrating unit, where the entire contents of the container are in constant motion, or in a centrifugal unit, which compacts the load of media and parts as the unit spins and generates up to 50 times the force of gravity. Spindle finishing is a similar process, where parts to be finished are mounted on fixtures and exposed to a rapidly moving abrasive slurry.

Wastewater generated by barrel finishing includes spent process solutions and rinses. Following the finishing process, the contents of the barrel are unloaded. Process wastewater is either discharged continuously during the process, discharged after finishing, or collected and reused. The parts are sometimes given a final rinse to remove particles of abrasive media from part surfaces.

9. **Brazing** is a thermal process in which a filler metal with a melting point lower than that of the base metal is used to form a metallurgical bond. Bonding results from the intimate contact produced by the dissolution of a small amount of base metal in the molten filler metal, without fusion of the base metal. Brazing and soldering operations are similar; the term brazing is used when the temperature of the filler exceeds 425°C (800°F).

   This process usually does not require process water. However, brazing can be followed by quenching or cooling in a solution of water or emulsified oils. A rinse step may also be included, especially after an oil quench. The quenching/cooling water and rinse water are typically discharged after they accumulate contaminants.

10. **Burnishing** is the sizing or finishing of a part (previously machined or ground) by displacing, rather than removing, minute surface irregularities. Burnishing is accomplished with a smooth point or line-contact and with fixed or rotating tools.

    Lubricants or soap solutions can be used to cool tools used in burnishing operations. Wastewater is generated from burnishing operations through process solution dumps and rinsing.

11. **Calibration** is the application of thermal, electrical, or mechanical energy to set or establish reference points, often in comparison to standards, for a component or complete assembly.

    Calibration is typically a dry unit operation. However, a limited number of applications can require process water (e.g., calibration of pumps or flow meters).

12. **Chemical Conversion Coating** is the process of forming a protective coating on the surface of a metal. Chemical conversion coating includes chromate conversion coating (chromating), phosphate conversion coating (phosphating), metal coloring, and passivating.

    These coatings are applied to previously deposited metal or base metal to increase corrosion-protection and lubricity, prepare the surface for additional coatings, or create a specific surface appearance.

    In **chromate conversion coating**, metals are coated with solutions of hexavalent chromium and other compounds by chemical treatment. Chromate conversion coatings may be used as a "stand-alone" surface preparation or as a part of a multi-stage plating or finishing operation. Many aluminum alloys are treated with a chromate conversion coating as a

precursor to organic coating. Plating layers such as zinc or cadmium are frequently treated with a chromate conversion coating to generate a more passive, corrosion resistant film. Most chromate coatings are applied through chemical immersion, although spray or brush application can be used. Variations in process solution formulation can impart a range of colors to the coatings, including colorless, iridescent yellow, brass, brown, and olive drab. Following chromating, parts are rinsed to prevent further surface reactions between the chromating solution and the base metal.

Phosphate conversion coatings are applied for one or more of the following reasons: to provide a base for paints and other organic coatings; to condition surfaces for cold forming operations by providing a base for drawing compounds and lubricants; to impart corrosion resistance to the metal surface by the coating itself; or to provide a suitable base for corrosion-resistant oils or waxes. Phosphate conversion coatings are formed by immersing parts in a dilute solution that can contain phosphoric acid, phosphate salts, accelerators, and other chemicals. Metal types processed in this operation typically include iron, steel, aluminum, zinc-plated steel and zinc/aluminum alloy-plated steel. The method of applying the phosphate coating depends on the size and shape of the part to be coated. Small parts can be coated in barrels immersed in the phosphating solution. Large parts, such as steel sheet and strip, are spray coated or passed continuously through the phosphating solution. Most phosphated parts that are to be painted are given a post-treatment seal. The post-treatments vary from simple chromic acid solutions to complex proprietary formulations that do not contain chromium. A deionized water rinse is typically used after post-treatment.

Metal coloring by chemical conversion coating produces a large group of decorative finishes. Metal coloring includes the formation of oxide conversion coatings. In this operation, the metal surface is converted into an oxide or similar metallic compound, giving the part the desired color. The most common colored finishes are used on copper, steel, zinc, and cadmium. Metal coloring treatments include antiquing, bluing, blackening, and other processes. For example, black oxide is a finish used on steel parts to provide an attractive appearance and to offer improved corrosion resistance. Usually, the black oxide process follows heat treating. Parts are placed in a heated bath (285°F), typically formulated with 80 ounces per gallon of sodium hydroxide and sodium or potassium nitrate; sodium dichromate is also used in some bath formations. Proprietary baths are also available. Following black oxide treatment, the parts are usually rinsed and sealed. Various sealants are used (e.g., light oil and dry-to-touch sealant). The primary purpose of these sealants is to protect the surface from atmospheric humidity.

Passivation forms a protective film on metals, particularly stainless steel and copper, by immersing parts in an acid solution. Stainless steel is passivated to dissolve embedded iron particles and to form a thin oxide film on the surface of the metal. Typical solutions for passivating stainless steel include nitric acid and nitric acid with sodium dichromate. Copper is passivated with a solution of ammonium sulfate and copper sulfate, forming a blue-green patina on the surface of the metal that reduces the reactivity of the surface. Rinsing is typically required after passivation, especially for parts with recessed surfaces that can retain process solution.

Wastewater generated by chemical conversion coating operations includes spent process solutions and rinses. Discarded process solutions include both the chemical conversion coating solutions and post-treatment sealant solutions. These solutions are commonly discharged when contaminated with the base metal or other impurities. Also, chromium-based solutions, which are typically formulated with hexavalent chromium, lose operating strength when the hexavalent chromium reduces to trivalent chromium during use. Rinsing normally follows each process step, except after some sealants, which dry on the part surface.

13. **Chemical Machining** (chemical milling) is the controlled dissolution and removal of a metal with chemical reagents or etchants to produce specific design configurations or tolerances.

Chemical machining is typically performed by applying a masking agent to cover a portion of the part's surface, then treating the exposed (unmasked) surface with the chemical machining solution.

Chemical machining and chemical etching (either acid or alkaline etching) are similar processes, except the rates and depths of metal removal are usually much greater in chemical machining. Typical solutions for chemical machining and etching include sodium hydroxide, ferric chloride, nitric acid, ammonium persulfate, chromic acid, cupric chloride, hydrochloric acid, and combinations of these reagents. Chemical machining of aluminum is a common process used in the aerospace industry for structural components, and is usually performed using a concentrated sodium hydroxide solution.

Wastewater generated by chemical machining operations includes spent process solutions and rinses. Process solutions are commonly discharged after becoming contaminated with the base metal. Rinsing normally follows chemical machining.

14. **Corrosion Preventive Coating** is the application of compounds to metal surfaces to create barrier films that protect against corrosion.

Many corrosion preventive materials are also formulated to function as lubricants or as a base for paint. Typical applications include assembled machinery or equipment in standby storage; finished parts in stock or spare parts for replacement; tools such as drills, taps, dies, and gauges; and mill products such as sheet, strip, rod, and bar.

Corrosion preventive coating compounds are applied by spraying, dipping, brushing, or wiping, depending on the type of compound used and the configuration of the part.

Corrosion preventive coatings can be divided into seven general categories: petrolatum compounds, oil compounds, hard dry-film compounds, solvent-cutback petroleum-based compounds, emulsion compounds, water-displacing polar compounds, and fingerprint removers and neutralizers. Emulsion compounds are the primary types in which process water is used. Emulsion compounds are oil-in-water emulsions containing 8 to 12% oil. They are typically purchased as concentrates and diluted with water at ratios of 1 part concentrate to 4-10 parts water. In some instances, these compounds are used in power washers.

Wastewater generated from corrosion preventive coating operations includes spent process solutions and rinses. Process solutions are discharged when they become contaminated with impurities or are depleted of constituents. Corrosion preventative coatings are not typically followed by an associated rinse, but rinsing is sometimes performed to remove the coating before further processing.

15. **Disassembly** is the process of systematically removing components from a vehicle, machine, or other product, typically for the purpose of inspection, testing, maintenance, or rebuilding.

Disassembly is typically a dry operation. However, cleaning or rinsing procedures are sometimes integrated into the disassembly process.

16. **Electrical Discharge Machining (EDM)**, also known as spark machining or electronic erosion, is a process that removes metal from a part by the formation of an electrical spark between an electrode, shaped to the required contour, and the part.

This operation is performed primarily for machining carbides, hard nonferrous alloys, and other hard-to-machine materials. The EDM cutting tool can be made from a soft, easily worked material such as brass, because the tool has no direct contact with the part. The tool works in conjunction with a fluid, which is fed to the part under pressure. The fluid serves as a dielectric, washing particles of eroded metal from the part or tool and maintaining a uniform resistance to the current flow. Common fluids used in the process include air, petroleum oils, kerosene, silicone oils, deionized water, polar liquids, and aqueous ethylene glycol solutions.

The majority of electrical discharge machining processes are operated dry. In some cases, water is used in the process, and wastewater is generated by the discharge of water-based dielectric fluids.

17. **Electrochemical Machining** is the controlled electrolytic removal of metal from a part by maintaining the part in close proximity to a shaped tool. In this process, the metal part is the anode, the formed tool is the cathode, and the applied potential causes a selective dissolution of metal from the part. By controlling the current distribution, metal is removed from the part only in those areas directly adjacent to the cathode tool.

Since the surface finish of the electrode tool will be reproduced in the surface of the part, electrode shape and size tolerances are important. While copper is frequently used as the electrode, brass, graphite, and copper-tungsten are also used. The tool must be an electrical conductor, easy to machine, corrosion resistant, and able to conduct the quantity of current needed. Various electrolytes are used, including sodium chloride, sulfur dioxide, ammonia, and hydrocyanic acid solutions.

Wastewater generated by electrochemical machining includes spent electrolytes and rinses.

18. **Electrolytic Cleaning** is the removal of soil, scale, or surface oxide from a metal part using an aqueous solution and electric current. The electrolyte is typically alkaline; however, electrolytic acid cleaning is also performed.

Electrolytic alkaline cleaning produces a cleaner surface than nonelectrolytic methods of alkaline cleaning. This method uses strong agitation, gas evolution in the solution, and oxidation-reduction reactions that occur during electrolysis. In addition, dirt particles become electrically charged and are repelled from the part surface. Some cleaning processes polarize the parts anodically while other processes polarize the parts cathodically. During periodic reverse cleaning, parts are alternately polarized anodically and cathodically. Periodic reverse cleaning improves

smut removal, accelerates cleaning, and results in a more active surface for subsequent surface finishing operations. Alkaline electrocleaners are formulated with combinations of alkali (usually sodium hydroxide and sodium carbonate), wetting agents, soaps, and chelators. Sodium cyanide is sometimes used in electrolytic cleaning formulations as a chelating agent and/or to prevent staining of brass and copper parts; however, its use has diminished due to environmental concerns.

Electrolytic acid cleaners are sometimes used as a final cleaner before electroplating. Sulfuric acid is most frequently used as the electrolyte. As with electrolytic alkaline cleaning, the effectiveness of the process is enhanced by the mechanical scrubbing effect caused by cathodic gas generation at the part/solution interface. Time cycles are typically less than two minutes.

Wastewater generated from electrolytic cleaning operations includes spent process solutions and rinses. Electrolytic cleaning solutions become contaminated during use due to dissolving of the base metal and the introduction of contaminants. As the performance of the solution diminishes, it is typically batch dumped for treatment or disposal. Process solution disposal can be required frequently (e.g., weekly) for high-production operations. Following electrolytic cleaning, thorough rinsing is used to remove residual cleaner and prevent the contamination of subsequent process baths.

19. **Electroplating** is the application of a thin surface coating of one metal upon another by electrodeposition. Electroplating is performed to provide corrosion protection, wear or erosion resistance, antifrictional characteristics, electrical conductivity, or decoration.

In electroplating, metal ions in acid, alkaline, or neutral solutions are reduced on the cathodic surfaces of the parts being plated. The metal ions in solution are typically replenished by dissolving metal from anodes contained in inert wire or metal baskets. Replenishment with metal salts or oxides is also practiced, especially for chromium electroplating (chromium trioxide is often added as a source of chromium). In addition to water and the metal being deposited, electroplating solutions often contain agents that form complexes with the metal being deposited, stabilizers to prevent hydrolysis, buffers for pH control, catalysts to assist in deposition, chemical aids for dissolving anodes, and miscellaneous ingredients that modify the process to attain specific properties. Cyanide, usually in the form of sodium or potassium cyanide, is frequently used as a complexing agent for zinc, cadmium, copper, and precious metal baths.

Metal parts can be electroplated in barrels, on racks, or continuously from a spool coil. Electroplating processes are operated both manually and automatically. Automated electroplating machines are used mostly for high-production items. Parts are typically cleaned prior to electroplating using alkaline and acid solutions. Following electroplating, post-electroplating processes, such as sealing and conversion coating, can be used.

Between the different process steps, the parts and fixtures are rinsed. This reduces the carry-over of process chemicals that would otherwise contaminate subsequent process solutions. Following electroplating processes, rinses are sometimes used to capture drag-out for treatment or recovery. A common application of drag-out rinsing is following chromium electroplating. Drag-out rinses are also used with nonchromium electroplating processes, such as nickel chloride or copper cyanide electroplating. Overflow rinses are sometimes used following drag-out rinsing as a secondary rinsing step.

Wastewater generated from electroplating operations includes spent process solutions and rinses. Electroplating solutions occasionally become contaminated during use due to dissolution of the base metal and/or the introduction of other contaminants. As this happens, the performance of the electroplating solutions diminishes. Spent concentrated solutions are typically treated for contaminant removal and reused, processed in a wastewater treatment system, or sent off site for disposal. Rinsewaters, including some drag-out rinse tank solutions, are typically treated on site.

20. **Electron Beam Machining** is the removal of material from a metal part by a high-energy electron beam. At the point where the energy of the electrons is focused, sufficient thermal energy is generated to vaporize the metal substrate.

Electron beam machining is typically carried out in a vacuum. While the metal-removal rate of electron beam machining is approximately 0.01 milligrams per second, the process is accurate and is especially adapted for micromachining. There is a minimal heat-affected zone and no pressure is applied to the part, allowing close tolerances to be maintained. The process results in X-ray emissions, which requires that the work area be shielded to absorb radiation. At present, the process is used for drilling holes as small as 0.0508 mm (0.002 in.), cutting slots, and shaping small parts.

Electron beam machining is a dry process; however, some operations can discharge wastewater as a result of quenching.

21. **Electropolishing** is the process of smoothing a metal using an electrolyte and a direct current. Electropolishing is a reverse electrodeposition operation that is performed anodically (the part being polished is the anode) in a concentrated acid or alkaline solution. When current is applied, a polarized film forms on the metal surface, through which metal ions diffuse. In this process, areas of surface roughness on parts serve as high-current density areas and are dissolved at rates greater than the lower portions of the metal surface.

During electropolishing, metal removal is usually limited to 2.5 to 65 μm. Metals are electropolished to improve appearance, reflectivity, and corrosion resistance. Base metals processed by electropolishing include aluminum, copper and copper alloys, zinc, low-alloy steel, and stainless steel. Common electrolytes include sodium hydroxide and combinations of sulfuric acid, phosphoric acid, and chromic acid.

Wastewater generated from electropolishing operations includes spent process solutions and rinses. Electropolishing generates metal ions that build up over time in the process solution. Eventually, the concentration of dissolved metals increases beyond tolerable levels and the process becomes ineffective. Typically, a portion of the bath is decanted and some fresh chemicals are added, or the entire solution is discharged and replaced with fresh constituent chemicals. Concentrated solutions are typically processed in a wastewater treatment system or sent off site for disposal. Rinsing is critical to removal of the corrosive film of drag-out remaining on the parts. Rinsing can involve several steps and include hot immersion or spray rinses. Wastewaters from rinsing are typically treated on site.

22. **Floor Cleaning** is the removal of dirt, debris, process solution spills, etc. from process area floors.

Floor cleaning can be performed wet or dry, and includes techniques such as vacuum cleaning, machine scrubbing, dry sweeping, hose rinsing, and mopping.

Wastewater is generated during floor cleaning when spilled solutions are encountered or when water is used to clean the floor. Wastewater from floor cleaning is typically treated on site or discharged to a POTW.

23. **Grinding** is the removal of stock from a part using a tool consisting of abrasive grains held by a rigid or semi-rigid binder.

The grinding tool is usually in the form of a disk (the basic shape of grinding wheels), but can also be in the form of a cylinder, ring, cup, stick, strip, or belt. The most common grinding tool abrasives are aluminum oxide, silicon carbide, and diamond. Typically, the process involves using a grinding fluid that cools the tool and part, and removes debris or metal fines.

Metal working fluids used in grinding operations are similar to those used for machining. These metal working fluids are used primarily for cooling and lubricating metal surfaces during grinding operations. The most common grinding fluid is water-soluble oil coolant (typically prepared by mixing a concentrate with water in a 1:30 ratio to produce a working fluid with a 98% water content). The fluid is contained in a reservoir that is integrated with the grinder or in a separate tank or sump. The fluid is circulated over the working surface and returned to the sump. After grinding, parts are sometimes rinsed to remove coolant and debris. The coolant reservoir is sometimes rinsed, and the water is assimilated into the working fluid.

Wastewater generated from grinding operations includes spent coolants and rinses. Metal working fluids become spent for a number of reasons, including increased biological activity (i.e., the fluids become rancid) or decomposition of the coolant additives. When metal working fluids no longer meet performance requirements, they are removed from their reservoirs and treated for reuse or disposal, or disposed of off site. Rinsewaters are typically assimilated into the working fluid or treated on site.

24. **Heat Treating** is the modification of the physical property of a part through the application of controlled heating and cooling cycles.

Heat treating includes aging, annealing, austempering, austenitizing, carburizing, cyaniding, malleabilizing, martempering, nitriding, normalizing, siliconizing, and tempering. Parts are heated in ovens or in molten salt solutions and then cooled by quenching in aqueous solutions (e.g., brine solutions), neat oils (pure oils with little or no impurities), oil/water emulsions, or air. Heat treating is typically a dry operation, but wastewater can be generated from spent molten salt solutions, quench water, and rinses. Descriptions of the specific types of heat treating are presented below.

Aging is a general term for changes in the properties of certain metals and alloys that occur at ambient or moderately elevated temperatures after hot working or heat treatment.

Annealing is a general term for heating a part to and holding at a suitable temperature followed by controlled cooling. Annealing is used primarily to soften metals and to simultaneously produce desired changes in microstructure or other properties.

Austempering is a heat treatment for ferrous alloys in which a part is quenched from the austenitizing temperature at a sufficient rate to avoid forming ferrite or pearlite, and then holding the metal at a constant temperature until transformation to bainite is complete.

Austenitizing is the formation of austenite by heating a ferrous alloy at or above the temperature necessary for the transformation.

Carburizing is a heat treatment process for ferrous alloys that increases the hardness of the part surface due to diffusion of carbon into the metal surface.

Cyaniding is a heat treating or case hardening process in which a metal is heated in a molten salt bath containing cyanide to cause simultaneous absorption of carbon and nitrogen at the surface.

Malleabilizing is the annealing of white cast iron so that some or all of the combined carbon is transformed into graphite or, in some instances, so that part of the carbon is removed completely.

Martempering is the quenching of an austenitized ferrous alloy in a medium that is at a temperature in the upper part of, or slightly above, the martensite range, and holding the alloy in the medium until the temperature throughout the alloy is uniform. The alloy is then allowed to cool in air through the martensite range.

Nitriding is a hardening process in which a part is placed in contact with a nitrogenous material, usually ammonia or molten cyanide, to introduce nitrogen into the surface layer.

Normalizing is the heating of a ferrous alloy to a temperature above the transformation range and then cooling in air to a temperature substantially below the transformation range.

Siliconizing is the diffusion of silicon into solid metal, usually steel, at an elevated temperature.

Tempering is the reheating of hardened steel or cast iron to decrease hardness and increase roughness.

25. **Hot Dip Coating** is the coating of parts by immersion in molten metal bath, leaving a thin layer of molten metal on the part surface.

In hot dip coating, the molten metal coats the part, and an alloy is formed at the interface of the two metals. Galvanizing (zinc coating on iron and steel products) is the most common hot dip coating. It is applied for corrosion protection on structural steel, reinforcing steel, corrugated pipe, highway guard rail, and numerous other products. Other hot dip coatings include aluminum coating of steel, aluminum-zinc alloy coating of steel sheet and wire, tin coating of steel and cast iron, and lead alloy coating of steel.

Pre-processing and post-processing steps for this process vary among the different coatings. Most processes begin with cleaning the metal surface to remove surface contaminants. Cleaning can include degreasing, pickling, salt bath treatment, and/or abrasive blasting. Prior to coating, flux is applied to facilitate and speed the reaction of molten metal with the base metal. Flux is applied in several different ways, including: as an aqueous solution in which the part is briefly dipped before immersion in the molten metal; as a molten fused layer or cover on the top of the molten bath; or as a paste that is applied to the work surface. Following the application of molten metal, the parts are air dried and/or quenched. Various quench baths are used, including water, dilute hydrochloric or citric acid, kerosene, and oil.

Hot dip coating is typically dry, but wastewater can be generated during the fluxing or quenching. Wastewaters can include spent flux, quench process solutions, or associated rinses.

26. **Impact Deformation** is the application of an impact force to a part such that the part is permanently deformed or shaped. Impact deformation operations include coining, forging, heading, high-energy rate forming, peening, shot peening, and stamping.

Natural and synthetic oils, light greases, and pigmented lubricants are used in impact deformation operations. Pigmented lubricants include whiting, lithapone, mica, zinc oxide, molybdenum disulfide, bentonite, flour, graphite, white lead, and soap-like materials.

Impact deformation operations are typically dry, but wastewater can be generated from lubricant discharge and from rinsing operations associated with the process. Descriptions of the specific types of impact deformation are presented below.

Coining is a closed-die striking operation, usually performed cold, in which all surfaces of the work are confined or restrained. Coining results in a well-defined imprint of the die upon the work.

Forging is the plastic deformation of a metal, usually hot, into desired shapes by the application of a compressive force, with or without dies.

Heading is the upsetting of wire, rod, or bar stock in dies to form an expanded area or head.

High energy rate forming (HERF) is a group of special forming processes in which metal undergoes deformation at high velocity. Explosive forming, electrohydraulic forming, and electromagnetic forming are the most common HERF processes.

Peening is the mechanical working of metal by hammer blows or shot impingement (shot peening).

Stamping is a general term covering almost all press operations, including blanking, hot or cold forming, drawing, bending, and coining.

27. **Laminating** is the adhesive bonding of layers of metal, plastic, or wood to form a part.

Water is not typically used for this operation.

28. **Laser Beam Machining** is the removal of metal from a part using a highly focused monochromatic, collimated beam of light.

Laser beam machining is a thermal process in which metal removal is largely accomplished by evaporation, although some material is removed in the liquid state at high velocity. Since the metal removal rate can be precisely controlled, laser beam machining is used for such jobs as drilling microscopic holes in carbides or diamond wire drawing dies and removing metal in the balancing of high-speed rotating machinery. Laser machining creates a small heat-affected zone and can be applied effectively to nonmetallic or hard materials.

Water is not typically used for this operation.

29. **Machining** is the general process of removing stock from a part by forcing a cutting tool through the part and removing a chip of base material. Machining operations include boring, broaching, chamfering, cutoff, drilling, hobbing, milling, planing, reaming, sawing, shaping, shaving, shearing, slotting, tapping, threading, and turning.

Various types of metal working fluids are used in machining operations, the choice of which depends on the type of machining being performed and operator preference. The fluids can be categorized into four groups: straight oil (neat oils), synthetic, semisynthetic, and water-soluble oil. The most commonly used metal working fluid is water-soluble oil coolant, which is prepared by mixing a concentrate with water in a 1:15 to 1:25 ratio to produce a working fluid with a 90% or greater water content.

Machining operations generate wastewater from the discharge of working fluid or rinse water. Metal working fluids are periodically discarded because of reduced performance or development of a rancid odor. In most cases, the fluids that contain a large percentage of oil are contract hauled as solid waste for disposal or recovery. Some fluids, particularly those with high water content, are treated on site as wastewater. Coolant degradation is caused mainly by contamination with tramp oil and dirt and by bacterial growth, which can be accelerated by oil contamination. After machining, parts are sometimes rinsed to remove coolant and metal chips. The coolant reservoir is sometimes rinsed, and the rinse water is assimilated into the working fluid.

Descriptions of the specific types of machining are presented below.

Boring is the enlargement of a hole by removing metal with a single or multiple point cutting tool moving parallel to the axis of rotation of the work or tool.

Broaching is cutting with a tool that consists of a bar having a single edge or a series of cutting edges (i.e., teeth) on its surface. The cutting edges of multiple-tooth, or successive single-tooth, broaches increase in size and/or change in shape. The broach cuts in a straight line of axial direction when motion is produced in relation to the part, which can also be rotating. To shape the required surface contour, the entire cut is made in one or more passes over the part.

Chamfering (beveling) is the process of making a sloping surface on the edge of a metal surface.

Cutoff is the severing or slotting of any material or part, usually with a thin abrasive wheel.

Drilling is the formation of a hole with a rotary, end-cutting tool having one or more cutting lips and one or more helical or straight flutes or tubes for ejecting chips or passing a cutting fluid.

Hobbing is the cutting of gears by use of a tool resembling a worm gear, having helically spaced cutting teeth. In a single-thread hob, the rows of teeth advance exactly one pitch as the hob makes one revolution.

Milling is the cutting of a part using a rotary tool with one or more teeth. The teeth engage the part and remove material as the part moves past the rotating cutter.

Planing is the production of flat surfaces by linear reciprocal motion of the part and the table to which it is attached relative to a stationary single-point cutting tool.

Reaming is the process of forming, sizing, or contouring a previously formed hole using a rotary cutting tool (reamer) with one or more cutting elements (teeth).

Sawing is the use of a toothed blade or disc to sever parts or cut contours.

Shaping is the use of single point tools fixed to a ram reciprocated in a linear motion past the part.

Shearing is the severing or cutting of a part by forcing a sharp edge or opposed sharp edges into the part, stressing the material to the point of shear failure and separation.

Slotting is the process of cutting a narrow aperture or groove with a reciprocating tool, cutter, or broach.

Tapping is the use of a cylindrical cutting tool having two or more peripheral cutting elements to cut internal threads of a desired size and form. Tapping is a combination of rotary and axial motion; the leading end of the tap cuts the thread while the tap is supported by the thread it produces.

Threading is the process of cutting external threads on a cylindrical surface.

Turning is the removal of material by forcing a cutting tool against the surface of a rotating part.

30. **Metal Spraying** is the application of a metallic coating to a part by projecting molten fragments of metal through a cone of flame or an electric arc onto the part. Metal spraying processes include plasma-arc spray, inert-atmosphere and low-pressure chamber spray, electric-arc spray, high-velocity oxy-fuel spray, and flame spray.

Metal spray coatings can be sprayed from rod or wire stock or from powdered material. The basic process involves feeding the material (e.g., wire) into a flame where it is melted. The molten stock is then stripped from the end of the wire and atomized by a high-velocity stream of compressed air or other gas which propels the material onto a prepared substrate or part. Depending on the substrate, bonding occurs due to mechanical interlock with a roughened surface, localized diffusion and alloying, and/or Van der Waals forces (i.e., mutual attraction and cohesion between two surfaces).

Metal spray coatings are used for a wide range of special applications, including the following: insulating layers in applications, such as induction heating coils; electromagnetic interference shielding; thermal barriers for rocket engines; nuclear moderators; films for hot isostatic pressing; and dimensional restoration of worn parts.

Metal spraying is sometimes performed in front of a "water curtain" (a circulated water stream used to trap overspray) or a dry filter exhaust hood which captures the overspray and fumes. With water curtain systems, water is recirculated from a sump or tank. Wastewater is generated when the sump or tank is periodically discharged. Metal spraying is not typically followed by rinsing.

31. **Painting** is the application of an organic coating to a part.

This operation includes the application of coatings such as paint varnish, lacquer, shellac, and plastics by processes such as spraying, dipping, brushing, roll coating, lithographing, and wiping.

Spray painting, the most common application technique, can be used with nearly all varieties of paint. The paint can be sprayed manually or automatically, hot or cold, and it may be atomized with or without compressed air. **Electrostatic painting** is a method of spray painting that applies electrostatically charged paint particles to a part with an opposite charge, followed by thermal fusing of the paint particles to form a cohesive paint film. By charging the part differently than the particles, the paint is attracted to the part surface, resulting in improved coverage.

Another common method of painting is **electropainting** (i.e., electrophoretic painting, electrodeposited epoxy, e-coat, etc.), which involves coating a part by making it anodic or cathodic in a bath that is an aqueous emulsion of the coating material. The electrodeposition bath contains stabilized resin, disperse pigment, surfactants, and sometimes organic solvents in water. Electropainting is used primarily for primer coats because it consistently produces a uniform, corrosion resistant coating. During this process, precleaned parts are immersed into the coating tank (paint) and electrically polarized. The polarization causes paint deposition after which the parts are removed from the bath. Parts then pass through a rinsing system. The typical rinsing procedure comprises several stages and can include dip and spray rinsing. Ultrafiltration is commonly used to separate and recover paint solids from the rinse water and to recycle the water.

Other processes included under this unit operation are printing, silk screening, and stenciling.

Water is used in painting operations as a solvent (water-borne formulations), for rinsing, for cleanup, and for water-wash (or curtain) type spray booths. Paint spray booths typically use most of the water in this unit operation. Spray booths capture overspray (i.e., paint that misses the product during application), control the introduction of contaminants to the workplace and environment, and reduce the likelihood of explosions and fires. Paint booths are categorized by the method of collecting the overspray.

The two primary types of paint booths are dry filter and water wash booths. Dry filter booths use filter media (usually paper or cloth filters) to screen out the paint solids by pulling prefiltered air through the booth, past the spraying operation, and through the filter media. Water use with dry filter units is limited to cleaning painting equipment (e.g., rinsing guns and lines) when water-borne paints are used. The operation of dry filter units is essentially dry when solvent-based paints are used. Water-wash booths use a "water curtain" to capture paint overspray by pulling air containing

entrained paint overspray through a circulated water stream which "scrubs" the overspray from the air. Although there are numerous design variations among water-wash booths, the two primary categories are side draft and downward draft. The basic difference between the two types is how air is directed through the system to capture the paint overspray. Side-draft units are typically used by small manufacturing operations and the downdraft design is used with large, continuous operations. Water is periodically added to paint booth reservoirs to compensate for evaporative losses, and chemicals are periodically added to improve paint sludge formation. The sump water is periodically discharged, usually during general system cleaning or maintenance. The discharge rate depends on various factors, including booth design, paint type, overspray rate, and the water treatment methods used. The sump water can be treated at the source (e.g., using filtration, activated carbon adsorption, or centrifugation) and reused instead of being discharged. Water is also used with water-wash systems for cleaning painting equipment and the booth.

32. **Plating** is the application of a metallic coating without using external electrical energy. This unit operation includes electroless plating, immersion plating, mechanical plating, and vapor plating.

Electroless plating is a chemical reduction process which depends on the catalytic reduction of a metallic ion in an aqueous solution containing a reducing agent, and the subsequent deposition of metal without using an electrical current. It has found widespread use in industry due to several unique advantages over conventional electroplating. Electroless plating provides uniform plating thickness on all areas of the part regardless of the configuration or geometry of the part. Also, an electroless-plated surface is dense and virtually nonporous. Copper and nickel electroless plating are the most common. The basic ingredients in an electroless plating solution are: (1) a source of metal, usually a salt; (2) a reducing agent to reduce the metal to its base state; (3) a chelating (or complexing) agent to hold the metal in solution (so the metal will not plate out indiscriminately); and (4) various buffers and other chemicals designed to maintain bath stability and increase bath life.

Immersion plating (displacement or cementation plating) is a chemical plating process in which a thin metal deposit is obtained by chemically displacing the base metal. Unlike electroless plating, it is not an autocatalytic process. In this process, a more noble (i.e., less electrochemically active) metal in the plating solution deposits onto a less noble (i.e., more electrochemically active) substrate as the result of substrate oxidation. A common example of immersion plating is the deposition of zinc on aluminum (zincating). This coating is often applied

as a base for chromium plating on aluminum parts. Numerous other metals can be applied by immersion coating, including brass, bronze, cadmium, copper, lead, nickel, and precious metals.

Mechanical plating is the deposition of a metallic coating on a part using a cold welding process in which the plating metal is applied to the surface as a result of contact with solid metal powder. Metal powder, parts, glass beads (or other impacting media), water, and chemicals are tumbled together in a rotary barrel to obtain the desired coating. Coatings from 5 μm to 75 μm can be deposited. The most common metals used for coatings are zinc and cadmium and alloys of these metals. Mechanical plating is subject to the same cleaning and rinsing operations used before and after electroplating operations.

Vapor plating is the process of decomposition of a metal or compound upon a heated surface by reduction or decomposition of a volatile compound at a temperature below the melting point of either the deposit or the base material. The reduction is accomplished by thermal dissociation or reaction with the base metal.

Wastewater generated from plating operations includes spent process solutions and rinses. Plating solutions become contaminated during use due to dissolving of the base metal, the introduction of other contaminants, and/or the decomposition of bath constituents. Concentrated solutions are typically treated to remove contaminants and reused, processed in a wastewater treatment system, or sent off site for disposal. Rinsing follows most plating processes to remove residual plating solution and prevent contamination of subsequent process baths. Rinsewaters are typically treated on site.

33. **Plasma Arc Machining** is the process of removing material from or shaping of a part using a high-velocity jet of high-temperature ionized gas.

In plasma arc machining, a gas (nitrogen, argon, or hydrogen) is passed through an electric arc, causing the gas to become ionized, and raised to temperatures exceeding 16,650°C (30,000°F). The relatively narrow plasma jet melts and displaces the part material in its path. Because plasma machining does not depend on a chemical reaction between the gas and the part, and because plasma temperatures are extremely high, the process can be used on almost any metal, including those that are resistant to oxygen-fuel gas cutting. The method is used mainly for profile cutting of stainless steel and aluminum alloys.

Although plasma arc machining is typically a dry process, process water is used for water injection plasma arc torches. In these cases, a constricted swirling flow of process water surrounds the cutting arc. This operation may also be performed immersed in a water bath. In both cases, the process water is used to stabilize the arc, to cool the part, and to contain smoke and fumes.

34. **Polishing** is a mechanical finishing operation in which abrasives are used to remove surface defects (e.g., scratches, pits, tool marks) from parts.

Polishing is usually performed with either a belt or wheel which is precoated with an abrasive compound. The base metal being polished and the desired extent of metal removal dictate the choice of compound. Lubricants are applied to wheels and belts to extend their life and to improve surface finish. Wheel lubricants are usually made of animal tallow, fatty acids, and waxes. Belt lubricants are similar, but are sometimes applied in liquid form. Some lubricants used for belts and wheels are water soluble. Following polishing, many parts are buffed to refine the surface finish. Buffing can produce finishes ranging from semibright to mirror bright or high luster. Buffing is included in the polishing unit operation. It is usually performed using a revolving cloth or sisal buffing wheel which is coated with a suitable compound. Liquid buffing compounds are used extensively for large-volume production on semiautomated or automated buffing equipment.

Polishing operations are typically dry, although some operations are performed with liquid compounds or associated rinses.

35. **Pressure Deformation** is the application of a force (at a slower rate than with impact deformation) to permanently deform or shape a part. Pressure deformation includes bending, crimping, drawing, embossing, flaring, forming, necking, and rolling.

Natural and synthetic oils, light greases, and pigmented lubricants are used in pressure deformation operations. Pigmented lubricants include whiting, lithapone, mica, zinc oxide, molybdenum disulfide, bentonite, flour, graphite, white lead, and soap-like materials.

Pressure deformation is typically dry, but wastewater is sometimes generated from the discharge of lubricants or from rinsing operations associated with the process. Descriptions of the specific type of pressure deformation are presented below.

Bending is the turning or forcing of a part by a brake press or other device from a straight or even condition to a curved or angular condition.

Crimping is the forming of relatively small corrugations to: (1) set down and lock a seam; (2) create an arc in a strip of metal; or (3) reduce an existing arc or diameter.

Drawing is the reduction of cross-sectional area and the increasing of length by pulling metal through conical taper dies.

Embossing is the raising of a design in relief against a surface.

Flaring is the forming of an outward acute-angle flange on a tubular part or the forming of a flange by using the head of a hydraulic press.

Forming is making a change (other than shearing or blanking) in the shape or contour of a metal part without intentionally altering its thickness.

Necking is the reducing of cross-sectional area of a part in a localized area by stretching, or the reducing of the diameter of a portion of the length of a cylindrical shell or tube.

Rolling is the reducing of cross-sectional area of metal stock, or otherwise shaping metal products, through the use of rotating rollers.

36. **Rinsing** is the use of water to remove foreign material from the surface of parts or process equipment. In this definition, rinsing is either not specifically associated with a specific unit operation or is associated with multiple unit operations. As such, the rinsing unit operation is different from rinsing associated with electroplating, plating, cleaning, and other unit operations described in this section. An example of a rinsing operation is a central rinse tank that services multiple unit operations, such as machining, grinding, cleaning, and quenching.

37. **Salt Bath Descaling** is the removal of surface oxides or scale from a part by immersion of the part in a molten salt bath or a hot salt solution.

Salt bath descaling solutions can contain molten salts, caustic soda, sodium hydride, and chemical additives. Molten salt baths are used in a salt bath-water quench-acid dip sequence to remove oxides from stainless steels and other corrosion-resistant alloys. In this process, the part is typically immersed in the molten salt (temperatures range from 400 to 540°C), quenched with water, and then dipped in acid. Oxidizing, reducing, or

electrolytic salt baths can be used depending upon the oxide to be removed.

Wastewater generated from salt bath descaling operations includes spent process solutions, quenches, and rinses.

38. **Soldering** is a thermal process in which a filler metal with a melting point lower than that of the base metal is used to form a metallurgical bond. The metals are bonded by the dissolution of a small amount of base metal in the molten filler metal, without fusion of the base metal. Soldering and brazing operations are similar; the term soldering is used where the temperature range falls below 425°C (800°F).

Some soldering operations use a flux. Fluxes are aqueous or nonaqueous material used to dissolve, remove, or prevent the formation of surface oxides on the part. Fluxes are frequently corrosive and are removed with a variety of solvents and/or aqueous cleaning solutions.

Except for the use of aqueous fluxes, soldering is typically a dry operation; however, a quench or rinse sometimes follows soldering to cool the part or remove excess flux or other foreign material from its surface. Recent developments in soldering technology have focused on fluxless solders and fluxes that can be cleaned off with water.

39. **Solvent Degreasing** removes oils and grease from the surface of a part by using organic solvents, including aliphatic petroleum (e.g., kerosene, naphtha), aromatics (e.g., benzene, toluene), oxygenated hydrocarbons (e.g., ketones, alcohol, ether), and halogenated hydrocarbons (e.g., 1,1,1-trichloroethane, trichloroethylene, methylene chloride).

Solvent cleaning can be accomplished in either the liquid or vapor phase. Solvent vapor degreasing is normally quicker than solvent liquid degreasing. However, ultrasonic vibration is sometimes used with liquid solvents to decrease the required immersion time with complex shapes. Solvent cleaning is often used as a precleaning operation prior to alkaline cleaning, as a final cleaning of precision parts, or as a surface preparation for some painting operations. Solvent degreasing operations are typically not followed by rinsing, although rinsing is performed in some cases.

Some DCP respondents reported performing solvent degreasing operations using a mixture of an organic solvent and water (see solvent degreasing results in Tables 5-3 and 5-4). However, for the purpose of this regulation, the Agency is defining solvent degreasing to preclude the use of water in

this unit operation. The Agency considers these "aqueous degreasing" operations as emulsion cleaners (discussed under unit operation 5).

40. **Sputtering** is a vacuum coating process in which a metallic or nonmetallic part is coated with thin films of metal. The surface to be coated is bombarded with positive ions in a gas discharge tube, which is evacuated to a low pressure. The source of ions can be either an ion beam or a plasma discharge into which the material to be bombarded is immersed.

Sputtering differs from vacuum metalizing (unit operation 46) in that the sputtering coating material is removed by momentum transfer from a solid cathode or target rather than being vaporized by a heat source.

Sputtering can be used as either a method of surface etching or coating. The most widely used process is surface coating using plasma discharge. This process is used mostly by the electronics industry to manufacture components such as thin film capacitors, video discs, and piezoelectric transducers. Other applications include the deposition of hard, protective coatings on high-speed steel cutting tools.

Sputtering is typically operated as a dry process.

41. **Stripping** is the removal of metallic or organic coatings from base metals.

Stripping is commonly performed as part of the manufacturing process to recover parts that have been improperly coated or as a part of maintenance and rebuilding to restore parts to a usable condition.

Metallic coating stripping most often uses chemical baths, although mechanical means (e.g., grinding, abrasive blasting) are also used. Chemical stripping of metals is performed either as an electrolytic or chemical process, depending on various factors (e.g., type of coating and base metal, bath chemistry).

Wastewater generated from metallic coating stripping operations includes process solutions and rinses. These stripping solutions become contaminated due to dissolution of the base metal. Eventually, the concentration of dissolved metals increases beyond tolerable levels, and the stripping process becomes ineffective. Typically, the entire solution is discharged. Concentrated solutions are usually processed in a wastewater treatment system or sent off site for disposal. Rinsing is a critical step in the stripping process, because it is needed to remove the corrosive film remaining on the parts. Wastewaters from stripping rinses are typically treated on site.

Organic coatings (including paint) are stripped using thermal, mechanical, and chemical means. Thermal methods include burn-off ovens, fluidized beds of sand, and molten salt baths. Mechanical methods include scraping and abrasive blasting (unit operation number 1). Various abrasive media are used (e.g., steel shot, sand, plastic media, dry ice) depending on the base material, paint type, and available equipment. Chemical paint strippers include alkali solutions, acid solutions, and solvents (e.g., acetone, methylene chloride).

Wastewater generated from organic coating stripping operations includes process solutions (limited mostly to chemical paint strippers) and rinses.

42. **Testing** is the application of thermal, electrical, or mechanical energy to determine the suitability or functionality of a base metal, coating, component, or complete assembly.

Testing is usually performed to replicate some aspect of the working environment. Testing is often performed in accordance with standard procedures, such as those published by the American Society for Testing and Materials (ASTM), German Industrial Standards (DIN), and the International Standardization Organization (ISO).

Testing sometimes involves the use of process solutions. Examples of "wet tests" include dye penetrant testing, hydraulic testing, magnetic flux testing, and salt spray testing. Some of these tests can also include rinses. Other types of tests frequently performed, which are typically dry but may generate wastewater under certain circumstances, include electrical testing, performance testing, X-ray testing, and ultrasonic testing.

Wastewater generated from testing operations includes spent process solutions and rinses.

43. **Thermal Cutting** is the cutting, slotting, or piercing of a part using an oxyacetylene oxygen lance or an electric arc cutting tool.

Thermal cutting is typically a dry process, except for the use of contact cooling waters and rinses.

44. **Thermal Infusion** is the application of a fused zinc, cadmium, or other metal coating to a ferrous part by infusing the surface of the part with metal powder or dust in the presence of heat. In this operation, a high-temperature fusion agent, such as nickel or iron-based metal with a small amount of boron or silicon, is deposited on the base metal and subsequently fused to the surface.

Wastewater is not typically discharged from this operation.

45. **Ultrasonic Machining** is a mechanical process designed to effectively machine hard, brittle materials. This process removes material using abrasive grains. The grains are carried in a liquid between the tool and the part and bombard the work surface at high velocity. This action gradually chips away minute particles of material in a pattern controlled by the tool shape and contour. A transducer causes an attached tool to oscillate linearly at a frequency of 20,000 to 30,000 times per second at an amplitude of 0.0254 to 0.127 millimeters (0.001 to 0.005 inches). The tool motion is produced as part of a sound wave energy transmission line which causes the tool material to change its normal length by contraction and expansion. The tool holder is threaded to the transducer and oscillates linearly at ultrasonic frequencies, driving the grit particles into the part. The cutting particles, boron carbide and similar materials, are of a 280-mesh size or finer, depending upon the accuracy and the finish desired. Ultrasonic machining operations include drilling, tapping, coiling, and the making of openings in all types of dies.

Ultrasonic machining is used principally for machining materials such as carbides, tool steels, ceramics, glass, gem stones, and synthetic crystals, and is typically a dry process.

46. **Vacuum Metalizing** is the coating of a part with metal by flash heating metal vapor in a high-vacuum chamber containing the part. In this process, which is carried out at pressures of less than 10^{-4} to 10^{-5} torr, the vapor condenses on all exposed surfaces.

Aluminum deposits comprise about 90% of the volume of vacuum metalizing. Other metals used include cadmium, chromium, copper, gold, selenium, silver, and titanium. Both decorative and functional coatings are applied by this method. Decorative coatings are widely used in the automotive (e.g., rearview mirrors), home appliance, and costume jewelry industries. Functional applications include deposits for electrical components and corrosion protection.

Vacuum metalizing is typically a dry process.

47. **Welding** is the joining of two or more pieces of material by applying heat, pressure, or both, with or without filler material, to produce a localized union through substrate metal fusion. Included in this process are arc welding, cold welding, electron beam welding, gas welding, laser beam welding, and resistance welding.

Welding is typically a dry process, except for the occasional use of cooling or rinsewaters. Descriptions of the specific types of welding are presented below.

Arc welding fuses metals together by heating them with an arc, with or without the application of pressure, and with or without the use of filler metal.

Cold welding is a solid-state welding process in which pressure is used at room temperature to coalesce metals with substantial deformation at the weld.

Electron beam welding coalesces metals with the heat obtained from a concentrated beam composed primarily of high-energy electrons impinging upon the surfaces to be joined.

Gas welding (oxyfuel gas welding) fuses metals together by heating them with gas flames. The flames result from combustion of a specific fuel gas such as acetylene, hydrogen, natural gas, or propane. The process can be used with or without the application of pressure to the joint, and with or without adding any filler material.

Laser beam welding joins metal parts using the heat obtained by directing a beam from a laser onto the weld joint.

Resistance welding is welding with resistance heating and pressure. In this process, the electric current flows through and heats the part.

48. **Wet Air Pollution Control** is the process of removing chemicals, fumes, or dusts that are entrained in air streams exhausted from process tanks or production areas using process water.

Most frequently, wet air pollution control devices are applied to electroplating, cleaning, and coating processes. Two common devices include the wet packed scrubber and the composite mesh pad mist eliminator.

The wet packed scrubber consists of a spray chamber filled with packing material. Water is continuously sprayed onto the packing and the air stream is pulled through the packing by a fan. Contaminants in the air stream are absorbed by the water spray and the air is released to the atmosphere. A single scrubber often serves numerous process tanks; however, the air streams are typically segregated by source into chromium, cyanide, and acid/alkaline sources. The water is recirculated in the

scrubber until it reaches a moderate dissolved solids concentration. A blow-down then occurs, where a portion of the scrubber water is discharged to treatment and replaced with fresh water. The spent scrubber water is usually segregated into chromium, cyanide, and acid/alkaline sources. When scrubbers are applied to cleaning and solvent degreasing operations, the spent scrubber water can contain organics.

Composite mesh pads are most frequently used to control the emissions from hard chromium electroplating and chromic acid anodizing. The composite mesh pad mist eliminator removes chromic acid from the airstream by slowing the velocity of the air and causing the entrained chromic acid droplets to impinge onto fiber pads. The pads are periodically washed with a small volume of water and the chromium-bearing solution is returned to the bath or discharged to treatment.

5.11 Production-Normalizing Parameters and Production-Normalized Flows

To evaluate the volume of water discharged and the mass of pollutants generated by each MP&M unit operation, EPA used a production-based approach. The Agency calculated production-normalized flow rates (i.e., the volume of wastewater discharged per unit of production) and production-normalized pollutant loadings (i.e., the mass of pollutants generated per unit of production) for each MP&M unit operation and associated rinse. EPA used a production-based approach to evaluate water discharge and pollutant loadings because pollutant loadings and wastewater discharge flow rates depend on the amount of production processed through the unit operation or rinse. The selection of production-normalizing parameters (PNPs) and the calculation of production-normalized flow rates (PNFs) are discussed below. The calculation of production-normalized pollutant loadings and industry pollutant estimates are discussed in Section 13.0.

Production-normalizing parameters are production units (e.g., mass of raw material processed) used to normalize the volume of wastewater discharged and mass of pollutant generated by a unit operation. Because production through a unit operation varies across sites in the MP&M Phase I industry, production-normalizing parameters were identified for each unit operation to allow EPA to compare water use characteristics across sites with varying productions.

The Agency considered the following as potential PNPs for MP&M unit operations: surface area of parts processed, mass of parts processed, mass of metal removed while processing parts, mass of material applied while processing parts, volume of material applied while processing parts, and airflow (standard cubic feet) through air pollution control equipment (for wet air pollution control unit operations). Table 5-4 presents the PNP selected for each unit operation. Because most MP&M unit operations involve treatment of the part's surface, surface area (SA) of parts processed was selected as the

PNP for most unit operations. For unit operations that involve substantial removal of metal from the part surface (e.g., machining), mass of metal removed (MMR) was selected as the PNP. For all wet air pollution control operations, airflow (standard cubic feet, or SCF) through the pollution control device was selected as the PNP.

EPA calculated PNFs for each unit operation based on responses to the DCP. The PNFs were calculated by dividing the wastewater discharge flow for an operation by the production in the appropriate PNP units for the operation. Table 5-4 presents the median production-normalized flow rate for each unit operation, as calculated from DCP responses.

Table 5-1

Typical Unit Operations Performed at MP&M Sites

Unit Operation Name			
1.	Abrasive Blasting	25.	Hot Dip Coating
2.	Abrasive Jet Machining	26.	Impact Deformation
3.	Acid Treatment	27.	Laminating
4.	Adhesive Bonding	28.	Laser Beam Machining
5.	Alkaline Treatment	29.	Machining
6.	Anodizing	30.	Metal Spraying
7.	Assembly	31.	Painting
8.	Barrel Finishing	32.	Plating
9.	Brazing	33.	Plasma Arc Machining
10.	Burnishing	34.	Polishing
11.	Calibration	35.	Pressure Deformation
12.	Chemical Conversion Coating	36.	Rinsing
13.	Chemical Machining	37.	Salt Bath Descaling
14.	Corrosion Preventive Coating	38.	Soldering
15.	Disassembly	39.	Solvent Degreasing
16.	Electrical Discharge Machining	40.	Sputtering
17.	Electrochemical Machining	41.	Stripping
18.	Electrolytic Cleaning	42.	Testing
19.	Electroplating	43.	Thermal Cutting
20.	Electron Beam Machining	44.	Thermal Infusion
21.	Electropolishing	45.	Ultrasonic Machining
22.	Floor Cleaning	46.	Vacuum Metalizing
23.	Grinding	47.	Welding
24.	Heat Treating	48.	Wet Air Pollution Control

Source: MP&M Phase I DCP database.

Table 5-2

Additional Water-Using Unit Operations Performed at MP&M Sites[a]

Unit Operation Name	Number of DCP Recipients Performing Unit Operation
Impregnation	5
Impregnation-Rinse	3
Phosphor Deposition	1
Phosphor Deposition-Rinse	1
Printed Circuit Board Manufacturing Operations	10
Printed Circuit Board Manufacturing Operations-Rinse	10
X-Ray Film-Developing	5
X-Ray Film-Developing-Rinse	1
X-Ray Film-Fixer	3
X-Ray Film-Fixer-Rinse	2
Phosphate Conversion Coating Pretreatment	3
Dielectric Coating	1
Plate Making-Precoat	1
Plate Making-Developing	1
Plate Making-Developing Rinse	1
Galvanizing Pretreatment	1
Shot Tower-Lead Shot Manufacturing	1
Masking for Chemical Machining	1
Metallic Fiber Cloth Manufacturing	1

Source: MP&M Phase I DCP database.

[a]These unit operations were identified based on responses to the January 1991 DCP mailout.

Table 5-3

Number of MP&M Phase I Sites Using and Discharging Process Water by Unit Operation[a]

Unit Operation	Number of Sites Performing Unit Op	Number of Sites Performing Unit Op Wet	Number of Sites Generating Wastewater[b] from Unit Op	Percentage of Sites Performing Unit Op Wet	Percentage of Sites Generating Wastewater[b] from Wet Op[d]
1. Abrasive Blasting	4,133	196	196	5	100
1R. Abrasive Blasting Rinse	228	228	180	100	79
2. Abrasive Jet Machining	894	804	804	90	100
2R. Abrasive Jet Machining Rinse	41	41	0	100	0
3. Acid Treatment	3,546	3,288	3,156	93	96
3R. Acid Treatment Rinse	3,408	3,408	3,296	100	97
4. Adhesive Bonding	2,308	74	74	3	100
4R. Adhesive Bonding Rinse	50	50	0	100	0
5. Alkaline Treatment	4,296	4,258	4,167	99	98
5R. Alkaline Treatment Rinse	2,680	2,680	2,566	100	96
6. Anodizing	331	328	289	99	88
6R. Anodizing Rinse	302	302	281	100	93
7. Assembly	6,761	73	73	1	100
7R. Assembly Rinse	118	118	47	100	40
8. Barrel Finishing	3,238	2,946	2,872	91	97
8R. Barrel Finishing Rinse	896	896	800	100	89
9. Brazing	2,803	32	0	1	0
9R. Brazing Rinse	398	398	362	100	91
10. Burnishing	1,055	177	177	17	100
10R. Burnishing Rinse	83	83	62	100	74
11. Calibration	1,680	17	17	1	100
11R. Calibration Rinse	16	16	0	100	0
12. Chemical Conversion Coating	3,155	3,052	2,847	97	93
12R. Chemical Conversion Coating Rinse	2,792	2,792	2,467	100	88
13. Chemical Machining	161	154	109	95	71
13R. Chemical Machining Rinse	136	136	130	100	95

[a]All data is based on a scale-up of MP&M Phase I DCP information.
[b]These totals include sites generating process wastewater that is contract-hauled off site.
[c]Solvent degreasing operations reported as using process water are discussed under emulsion cleaning (see unit operation #5).
[d]This percentage is calculated by dividing the number of sites generating wastewater from the unit operation by the number of sites performing the operation wet.

Table 5-3 (Continued)

Number of MP&M Sites Using and Discharging Process Water by Unit Operation[a]

Unit Operation		Number of Sites Performing Unit Op	Number of Sites Performing Unit Op Wet	Number of Sites Generating Wastewater[b] from Unit Op	Percentage of Sites Performing Unit Op Wet	Percentage of Sites Generating Wastewater[b] from Wet Op[d]
14.	Corrosion Preventive Coating	2,064	461	406	22	88
14R.	Corrosion Preventive Coating Rinse	139	139	71	100	51
15.	Disassembly	2,002	0	0	0	0
15R.	Disassembly Rinse	12	12	0	100	0
16.	Electrical Discharge Machining	1,672	449	422	27	94
16R.	Electrical Discharge Machining Rinse	12	12	0	100	0
17.	Electrochemical Machining	195	106	103	54	97
17R.	Electrochemical Machining Rinse	104	104	104	100	100
18.	Electrolytic Cleaning	454	454	443	100	97
18R.	Electrolytic Cleaning Rinse	452	452	387	100	86
19.	Electroplating	957	955	760	>99	80
19R.	Electroplating Rinse	892	892	825	100	92
20.	Electron Beam Machining	25	0	0	0	0
20R.	Electron Beam Machining Rinse	0	0	0	0	0
21.	Electropolishing	149	105	100	71	94
21R.	Electropolishing Rinse	69	69	69	100	100
22.	Floor Cleaning	6,369	3,006	2,949	47	98
22R.	Floor Cleaning Rinse	884	884	134	100	15
23.	Grinding	6,911	3,385	1,723	49	51
23R.	Grinding Rinse	185	185	78	100	42
24.	Heat Treating	2,513	473	391	19	83
24R.	Heat Treating Rinse	296	296	125	100	42
25.	Hot Dip Coating	158	33	4	21	12
25R.	Hot Dip Coating Rinse	66	66	29	100	44
26.	Impact Deformation	3,426	191	108	6	56

[a]All data is based on a scale-up of MP&M Phase I DCP information.
[b]These totals include sites generating process wastewater that is contract-hauled off site.
[c]Solvent degreasing operations reported as using process water are discussed under emulsion cleaning (see unit operation #5).
[d]This percentage is calculated by dividing the number of sites generating wastewater from the unit operation by the number of sites performing the operation wet.

Table 5-3 (Continued)

Number of MP&M Sites Using and Discharging Process Water by Unit Operation[a]

Unit Operation	Number of Sites Performing Unit Op	Number of Sites Performing Unit Op Wet	Number of Sites Generating Wastewater[b] from Unit Op	Percentage of Sites Performing Unit Op Wet	Percentage of Sites Generating Wastewater[b] from Wet Op[d]
26R. Impact Deformation Rinse	79	79	33	100	42
27. Laminating	821	0	0	0	0
27R. Laminating Rinse	0	0	0	0	0
28. Laser Beam Machining	1,109	0	0	0	0
28R. Laser Beam Machining Rinse	0	0	0	0	0
29. Machining	8,603	5,167	3,595	60	70
29R. Machining Rinse	360	360	141	100	39
30. Metal Spraying	787	60	40	8	67
30R. Metal Spraying Rinse	21	21	0	100	0
31. Painting	5,837	1,049	886	18	85
31R. Painting Rinse	447	447	136	100	30
32. Plating	378	298	283	79	95
32R. Plating Rinse	298	298	292	100	98
33. Plasma Arc Machining	951	233	233	25	100
33R. Plasma Arc Machining Rinse	0	0	0	0	0
34. Polishing	2,733	133	128	5	96
34R. Polishing Rinse	119	119	76	100	64
35. Pressure Deformation	5,350	230	199	4	86
35R. Pressure Deformation Rinse	45	45	45	100	100
36. Rinsing	1,758	1,174	1,168	67	99
37. Salt Bath Descaling	83	27	27	32	100
37R. Salt Bath Descaling Rinse	37	37	37	100	100
38. Soldering	4,280	299	299	7	100
38R. Soldering Rinse	609	609	517	100	85
39. Solvent Degreasing[c]	6,316	92	92	1	100
39R. Solvent Degreasing Rinse	242	242	220	100	91

[a]All data is based on a scale-up of MP&M Phase I DCP information.
[b]These totals include sites generating process wastewater that is contract-hauled off site.
[c]Solvent degreasing operations reported as using process water are discussed under emulsion cleaning (see unit operation #5).
[d]This percentage is calculated by dividing the number of sites generating wastewater from the unit operation by the number of sites performing the operation wet.

Table 5-3 (Continued)

Number of MP&M Sites Using and Discharging Process Water by Unit Operation[a]

Unit Operation	Number of Sites Performing Unit Op	Number of Sites Performing Unit Op Wet	Number of Sites Generating Wastewater[b] from Unit Op	Percentage of Sites Performing Unit Op Wet	Percentage of Sites Generating Wastewater[b] from Wet Op[d]
40. Sputtering	120	0	0	0	0
40R. Sputtering Rinse	0	0	0	0	0
41. Stripping	1,486	655	626	44	96
41R. Stripping Rinse	966	966	842	100	87
42. Testing	3,722	1,171	1,066	31	91
42R. Testing Rinse	473	473	372	100	79
43. Thermal Cutting	1,963	180	110	9	61
43R. Thermal Cutting Rinse	0	0	0	0	0
44. Thermal Infusion	46	21	21	47	100
44R. Thermal Infusion Rinse	21	21	0	100	0
45. Ultrasonic Machining	28	0	0	0	0
45R. Ultrasonic Machining Rinse	0	0	0	0	0
46. Vacuum Metalizing	54	0	0	0	0
46R. Vacuum Metalizing Rinse	0	0	0	0	0
47. Welding	6,842	163	163	2	100
47R. Welding Rinse	36	36	23	100	63
48. Wet Air Pollution Control	987	987	821	100	83

Source: MP&M Phase I DCP database.

[a]All data is based on a scale-up of MP&M Phase I DCP information.
[b]These totals include sites generating process wastewater that is contract-hauled off site.
[c]Solvent degreasing operations reported as using process water are discussed under emulsion cleaning (see unit operation #5).
[d]This percentage is calculated by dividing the number of sites generating wastewater from the unit operation by the number of sites performing the operation wet.

Table 5-4

MP&M Phase I Process Water Discharge Flow and Purpose of Process Water by Unit Operation

Unit Operation	PNP	Median PNF (gal/PNP)	Purpose of Process Water Use				Total Estimated Industry Discharge Flow[b] (million gal/yr)
			Typically Dry or Not Performed	Process Solution or Rinse	Coolant/ Lubricant/ Flux	Other (see operation description)	
1. Abrasive Blasting	SA	1.03	✓	✓			5.81
1R. Abrasive Blasting Rinse	SA	2.36		✓			11.4
2. Abrasive Jet Machining	MMR	1,060[a]	✓	✓			33.8
2R. Abrasive Jet Machining Rinse	MMR	NA	✓	✓			0
3. Acid Treatment	SA	0.034		✓			110
3R. Acid Treatment Rinse	SA	2.48		✓			3,320
4. Adhesive Bonding	SA	0.022	✓			✓	0.464
4R. Adhesive Bonding Rinse	SA	NA	✓				0
5. Alkaline Treatment	SA	0.050		✓			780
5R. Alkaline Treatment Rinse	SA	1.06		✓			4,230
6. Anodizing	SA	0.032		✓			6.12
6R. Anodizing Rinse	SA	0.678		✓			707
7. Assembly	SA	0.252	✓			✓	19.0
7R. Assembly Rinse	SA	NA	✓	✓			0.340
8. Barrel Finishing	SA	1.17		✓			704
8R. Barrel Finishing Rinse	SA	1.96		✓			81.0
9. Brazing	SA	NA	✓				0
9R. Brazing Rinse	SA	10.1		✓			3.64
10. Burnishing	SA	8.02			✓		1.59
10R. Burnishing Rinse	SA	NA	✓	✓			26.5
11. Calibration	SA	NA	✓			✓	0.00180
11R. Calibration Rinse	SA	NA	✓				0

[a]Note: The PNF for abrasive jet machining is based on only 2 data points.
[b]These totals do not include process wastewater that is contract hauled off site.
[c]Note: Solvent degreasing operations reported as using process water are discussed under emulsion cleaning (see unit operation #5).

PNP - Production normalizing parameter. Either surface area (measured in square feet), mass of metal removal (measured in pounds removed), or airflow (measured in standard cubic feet of air).
PNF - Production normalized flow.
NA - Not available. Insufficient flow and production data provided in DCPs.
SA - Surface area of parts.
MMR - Mass of metal removed from parts.
SCF - Standard cubic feet of air.

Table 5-4 (Continued)

MP&M Process Water Discharge Flow and Purpose of Process Water by Unit Operation

Unit Operation	PNP	Median PNF (gal/PNP)	Purpose of Process Water Use				Total Estimated Industry Discharge Flow[b] (million gal/yr)
			Typically Dry or Not Performed	Process Solution or Rinse	Coolant/ Lubricant/ Flux	Other (see operation description)	
12. Chemical Conversion Coating	SA	0.019		✓			622
12R. Chemical Conversion Coating Rinse	SA	0.260		✓			2,100
13. Chemical Machining	SA	0.055		✓			2.24
13R. Chemical Machining Rinse	SA	10.4		✓			346
14. Corrosion Preventive Coating	SA	0.008	✓	✓			14.6
14R. Corrosion Preventive Coating Rinse	SA	0.558	✓	✓			51.1
15. Disassembly	SA	NA	✓				0
15R. Disassembly Rinse	SA	NA	✓				0
16. Electrical Discharge Machining	MMR	4.38	✓	✓			1.70
16R. Electrical Discharge Machining Rinse	MMR	NA	✓				0
17. Electrochemical Machining	SA	NA		✓			37.1
17R. Electrochemical Machining Rinse	SA	3.87		✓			28.3
18. Electrolytic Cleaning	SA	0.049		✓			57.1
18R Electrolytic Cleaning Rinse	SA	1.51		✓			1,620
19. Electroplating	SA	0.060		✓			14.9
19R. Electroplating Rinse	SA	4.91		✓			1,180
20. Electron Beam Machining	SA	NA	✓				0
20R. Electron Beam Machining Rinse	SA	NA	✓				0

[a]Note: The PNF for abrasive jet machining is based on only 2 data points.
[b]These totals do not include process wastewater that is contract hauled off site.
[c]Note: Solvent degreasing operations reported as using process water are discussed under emulsion cleaning (see unit operation #5).

PNP - Production normalizing parameter. Either surface area (measured in square feet), mass of metal removal (measured in pounds removed), or airflow (measured in standard cubic feet of air).
PNF - Production normalized flow.
NA - Not available. Insufficient flow and production data provided in DCPs.
SA - Surface area of parts.
MMR - Mass of metal removed from parts.
SCF - Standard cubic feet of air.

Table 5-4 (Continued)

MP&M Process Water Discharge Flow and Purpose of Process Water by Unit Operation

Unit Operation	PNP	Median PNF (gal/PNP)	Purpose of Process Water Use				Total Estimated Industry Discharge Flow[b] (million gal/yr)
			Typically Dry or Not Performed	Process Solution or Rinse	Coolant/ Lubricant/ Flux	Other (see operation description)	
21. Electropolishing	SA	NA		✓			0.0394
21R. Electropolishing Rinse	SA	NA		✓			14.1
22. Floor Cleaning	SA	0.005		✓			120
22R. Floor Cleaning Rinse	SA	0.095		✓			2.43
23. Grinding	MMR	0.369			✓		60.7
23R. Grinding Rinse	MMR	1.99		✓			6.93
24. Heat Treating	SA	1.00	✓	✓		✓	594
24R. Heat Treating Rinse	SA	7.43	✓	✓			128
25. Hot Dip Coating	SA	NA	✓		✓	✓	0.000638
25R. Hot Dip Coating Rinse	SA	NA	✓	✓			73.2
26. Impact Deformation	SA	0.174	✓		✓		30.2
26R. Impact Deformation Rinse	SA	NA	✓	✓			0.562
27. Laminating	SA	NA	✓				0
27R. Laminating Rinse	SA	NA	✓				0
28. Laser Beam Machining	SA	NA	✓				0
28R. Laser Beam Machining Rinse	SA	NA	✓				0
29. Machining	MMR	0.053			✓		99.1
29R. Machining Rinse	MMR	7.78	✓	✓			1.23
30. Metal Spraying	SA	2.25	✓			✓	0.0967
30R. Metal Spraying Rinse	SA	NA	✓				0
31. Painting	SA	0.025	✓	✓		✓	309
31R. Painting Rinse	SA	0.099	✓	✓			1,020

[a]Note: The PNF for abrasive jet machining is based on only 2 data points.
[b]These totals do not include process wastewater that is contract hauled off site.
[c]Note: Solvent degreasing operations reported as using process water are discussed under emulsion cleaning (see unit operation #5).

PNP - Production normalizing parameter. Either surface area (measured in square feet), mass of metal removal (measured in pounds removed), or airflow (measured in standard cubic feet of air).
PNF - Production normalized flow.
NA - Not available. Insufficient flow and production data provided in DCPs.
SA - Surface area of parts.
MMR - Mass of metal removed from parts.
SCF - Standard cubic feet of air.

Table 5-4 (Continued)

MP&M Process Water Discharge Flow and Purpose of Process Water by Unit Operation

Unit Operation	PNP	Median PNF (gal/PNP)	Purpose of Process Water Use				Total Estimated Industry Discharge Flow[b] (million gal/yr)
			Typically Dry or Not Performed	Process Solution or Rinse	Coolant/ Lubricant/ Flux	Other (see operation description)	
32. Plating	SA	0.030		✓			5.02
32R. Plating Rinse	SA	6.87		✓			196
33. Plasma Arc Machining	MMR	4.00	✓			✓	36.2
33R. Plasma Arc Machining Rinse	MMR	NA	✓				0
34. Polishing	SA	1.44	✓			✓	23.1
34R. Polishing Rinse	SA	13.9	✓	✓			13.9
35. Pressure Deformation	SA	0.011	✓		✓		41.3
35R. Pressure Deformation Rinse	SA	NA	✓	✓			31.3
36. Rinsing	SA	0.509		✓			694
37. Salt Bath Descaling	SA	NA		✓			484
37R. Salt Bath Descaling Rinse	SA	1.50		✓			5.07
38. Soldering	SA	27.8	✓		✓	✓	18.5
38R. Soldering Rinse	SA	3.03	✓	✓			72.4
39. Solvent Degreasing[c]	SA	0.094	✓				20.0
39R. Solvent Degreasing Rinse	SA	2.86	✓	✓			53.7
40. Sputtering	SA	NA	✓				0
40R. Sputtering Rinse	SA	NA	✓				0
41. Stripping	SA	0.300		✓			13.8
41R. Stripping Rinse	SA	7.84		✓			273
42. Testing	SA	1.35		✓			491
42R. Testing Rinse	SA	0.875		✓			94.5

[a]Note: The PNF for abrasive jet machining is based on only 2 data points.
[b]These totals do not include process wastewater that is contract hauled off site.
[c]Note: Solvent degreasing operations reported as using process water are discussed under emulsion cleaning (see unit operation #5).

PNP - Production normalizing parameter. Either surface area (measured in square feet), mass of metal removal (measured in pounds removed), or airflow (measured in standard cubic feet of air).
PNF - Production normalized flow.
NA - Not available. Insufficient flow and production data provided in DCPs.
SA - Surface area of parts.
MMR - Mass of metal removed from parts.
SCF - Standard cubic feet of air.

Table 5-4 (Continued)

MP&M Process Water Discharge Flow and Purpose of Process Water by Unit Operation

Unit Operation	PNP	Median PNF (gal/PNP)	Purpose of Process Water Use				Total Estimated Industry Discharge Flow[b] (million gal/yr)
			Typically Dry or Not Performed	Process Solution or Rinse	Coolant/ Lubricant/ Flux	Other (see operation description)	
43. Thermal Cutting	SA	0.134			✓		2.31
43R. Thermal Cutting Rinse	SA	NA	✓				0
44. Thermal Infusion	SA	NA	✓			✓	1.15
44R. Thermal Infusion Rinse	SA	NA	✓				0
45. Ultrasonic Machining	SA	NA	✓				0
45R. Ultrasonic Machining Rinse	SA	NA	✓				0
46. Vacuum Metalizing	SA	NA	✓				0
46R. Vacuum Metalizing Rinse	SA	NA	✓				0
47. Welding	SA	0.071	✓		✓		19.0
47R. Welding Rinse	SA	30.7	✓	✓			27.4
48. Wet Air Pollution Control	SCF	0.0002				✓	1,610

Source: MP&M Phase I DCP database.

[a]Note: The PNF for abrasive jet machining is based on only 2 data points.
[b]These totals do not include process wastewater that is contract hauled off site.
[c]Note: Solvent degreasing operations reported as using process water are discussed under emulsion cleaning (see unit operation #5).

PNP - Production normalizing parameter. Either surface area (measured in square feet), mass of metal removal (measured in pounds removed), or airflow (measured in standard cubic feet of air).
PNF - Production normalized flow.
NA - Not available. Insufficient flow and production data provided in DCPs.
SA - Surface area of parts.
MMR - Mass of metal removed from parts.
SCF - Standard cubic feet of air.

5.12 References

1. Cubberly, William H. (ed.). Tool and Manufacturing Engineers Handbook, Desk Edition, Society of Manufacturing Engineers, Dearborne, MI, 1989.

2. Detrisac, M. Arthur. "Treatable Cleaners," Metal Finishing, September 1991.

3. Development Document for Effluent Limitations Guidelines and Standards for the Metal Finishing Point Source Category. U.S. Environmental Protection Agency, EPA 440/1-83/091, June 1983.

4. Mohler, J.B. "Alkaline Cleaning for Electroplating," Metal Finishing, September 1984.

5. Wood, William G. (Coordinator). The New Metals Handbook, Vol. 5. Surface Cleaning, Finishing, and Coating, American Society for Metals, May 1990.

6. Lowenheim, Frederick A., Electroplating Fundamentals of Surface Finishing, McGraw-Hill Book Company, New York, NY, 1978.

7. Murphy, Michael (ed.). Metal Finishing Guidebook and Directory Issue '93, Metal Finishing, January 1993.

6.0 WASTEWATER CHARACTERISTICS

This section summarizes the characteristics of wastewaters discharged from Metal Products and Machinery (MP&M) unit operations and raw wastewater entering end-of-pipe treatment operations. Characteristics of MP&M treated effluent wastewaters are presented in Section 11.0. The data presented in this section were obtained from the MP&M data collection portfolios (DCPs) and the MP&M sampling program (discussed in Sections 4.2 and 4.4, respectively). The DCP requested sites to indicate which pollutants were known or believed to be present on site, as well as which unit operations were the sources of these pollutants. Through the sampling program, the Agency obtained analytical data for the unit operations and treatment system influent and effluent streams known or believed to contain toxic pollutants at MP&M sites.

Section 6.1 summarizes analytical data for wastewaters from MP&M unit operations. Section 6.2 summarizes analytical data for influent wastewater streams to chemical precipitation and sedimentation, cyanide destruction, and oil/water separation systems. These technologies were used as the basis for calculating the MP&M Phase I limitations. Tables 6-1 through 6-12 are located at the end of this section.

6.1 Wastewater Characteristics by Unit Operation

As discussed in Section 5.0, EPA evaluated data for 48 distinct unit operations performed at MP&M Phase I sites. During the MP&M Phase I data-gathering efforts, EPA identified several additional unit operations performed at MP&M Phase I sites. Many of the MP&M unit operations were reported in the DCPs as discharging process water, and many also have associated rinses that discharge process water. Several of these unit operations and associated rinses have been divided into suboperations for the purposes of estimating compliance costs (see Section 12.0) and pollutant loadings (see Section 13.0). EPA divided the list of 48 operations into 132 suboperations (including rinses) that were reported by DCP respondents as discharging process water. Table 6-1 lists the 132 suboperations.

During the MP&M sampling program, EPA collected wastewater samples from 70 of the MP&M suboperations. Table 6-1 lists the number of wastewater samples collected from these suboperations. The 70 suboperations represent operations discharging approximately 90% of the MP&M Phase I process wastewater. Wastewater characteristics for the other 93 suboperations were modelled based on the samples collected for these 70 suboperations, as discussed in Section 13.0.

Wastewaters generated from MP&M unit operations can be classified into the following types based on their composition and treatment requirements:

- Hexavalent chromium-bearing wastewaters;
- Cyanide-bearing wastewaters;

- Oil-bearing wastewaters;
- Chelated metal-bearing wastewaters; and
- Metal-bearing wastewaters.

The unit operations generating each of these types of wastewater are discussed below, along with the pollutants and treatment requirements associated with each type. For each type of wastewater, the following data are presented:

- A summary of analytical data collected from the unit operations generating that type of wastewater. The summary lists, for each pollutant analyzed, the number of samples analyzed, the number of times the pollutant was detected, and the minimum, maximum, mean, and median detected concentrations.

- A summary of analytical data from rinses associated with the unit operations generating that type of wastewater. This summary presents the same information as the summary described above.

- A summary of DCP responses identifying pollutants known or believed to be present in wastewaters from the unit operations and rinses generating that type of wastewater.

Unit operation-specific analytical data for the operations sampled during the MP&M sampling program are contained in the administrative record for this rulemaking.

6.1.1 Hexavalent Chromium-Bearing Wastewaters

The following MP&M unit operations and associated rinses generate hexavalent chromium-bearing wastewaters.

Unit Operations and Rinses That Generate Hexavalent Chromium-Bearing Wastewater

Unit Operation	Associated Rinse
Anodizing Sealant (with hexavalent chromium)	Anodizing Sealant (with hexavalent chromium) - Rinse
Chemical Conversion Coating Sealant (with hexavalent chromium)	Chemical Conversion Coating Sealant (with hexavalent chromium) - Rinse
Chromate Conversion Coating	Chromate Conversion Coating - Rinse
Chromic Acid Anodizing	Chromic Acid Anodizing - Rinse
Chromic Acid Treatment	Chromic Acid Treatment - Rinse
Chromium Electroplating	Chromium Electroplating - Rinse
Electroplating Sealant (with hexavalent chromium)	Electroplating Sealant (with hexavalent chromium) - Rinse
Wet Air Pollution Control for Chromium-Bearing Operations	Not Applicable

Source: MP&M DCPs, MP&M site visits, technical literature.

These wastewaters generally require preliminary treatment to reduce hexavalent chromium to trivalent chromium prior to commingling with other types of wastewaters for further end-of-pipe treatment. Chromium reduction technologies generally involve using reducing agents, such as sodium metabisulfite, under acidic conditions to reduce hexavalent chromium to trivalent chromium. Section 10.0 discusses in detail the chromium reduction technologies used in the MP&M industry.

Hexavalent chromium is present in the wastewater as a component of the process bath (e.g., chromic acid anodizing, chromate conversion coating, chromium electroplating). The following table summarizes the analytical data collected during the MP&M sampling program for chromium in wastewater from unit operations and associated rinses that generate hexavalent chromium-bearing wastewater.

Summary of Analytical Data for Chromium From Hexavalent Chromium-Bearing Wastewaters

Source of Pollutant	Number of Samples Analyzed	Number of Detects	Minimum Detected Concentration (mg/L)	Maximum Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
Unit Operations Generating Hexavalent Chromium-Bearing Wastewater	28	28	0.360	39,000	23,500	2,210
Rinses Generating Hexavalent Chromium-Bearing Wastewater	37	37	0.027	1,760	222	12.8

Source: MP&M Sampling Program.

The concentrations represent the concentration of total chromium in the wastewater; based on the process chemistry of the unit operations (e.g., the chromium is present in the hexavalent form in a chromic acid solution), the Agency believes that most of the chromium present in these wastewaters is in the hexavalent form. For the purposes of estimating compliance costs, the Agency assumed that all chromium in these wastewaters is in the hexavalent form.

Table 6-2 summarizes qualitative data contained in response to the MP&M DCPs, indicating the pollutant parameters known or believed to be present in wastewaters from unit operations and rinses that generate hexavalent chromium-bearing wastewater. As shown in Table 6-2, chromium was the pollutant identified most frequently as known or believed to be present in these wastewaters.

6.1.2 Cyanide-Bearing Wastewaters

The following MP&M unit operations and associated rinses generate cyanide-bearing wastewaters.

Unit Operations and Rinses That Generate Cyanide-Bearing Wastewater

Unit Operation	Associated Rinse
Alkaline Cyanide Cleaning	Alkaline Cyanide Cleaning - Rinse
Cyaniding Quench	Cyaniding Quench - Rinse
Electrolytic Cleaning (with cyanide)	Electrolytic Cleaning (with cyanide) - Rinse
Electroplating (with cyanide)	Electroplating (with cyanide) - Rinse
Wet Air Pollution Control for Cyanide-Bearing Operations	Not Applicable

Source: MP&M DCPs, MP&M site visits, technical literature.

These wastewaters generally require preliminary treatment to oxidize cyanide to carbon dioxide and nitrogen. This process generally entails using chlorine as either chlorine gas or sodium hypochlorite, under alkaline conditions, in a two-step process. In the first step, cyanides are oxidized to form cyanates and, in the second step, cyanates are oxidized to form carbon dioxide and nitrogen. Section 10.0 discusses in detail cyanide destruction technologies used in the MP&M industry.

Cyanide is present in the wastewater as a component of electroplating and cleaning baths. The following table summarizes the analytical data collected during the MP&M sampling program for cyanide from unit operations and their associated rinses that generate cyanide-bearing wastewater. Cyanide electroplating baths and rinses also contain several metal pollutants (typically cadmium, copper, or silver) depending on the type of metal being electroplated. In samples of these electroplating wastewaters, the metal being applied has been detected at concentrations of up to 43,400 mg/L in the electroplating solution and 23,500 mg/L in the electroplating rinse.

Summary of Analytical Data for Cyanide From Cyanide-Bearing Wastewaters

Source of Pollutant	Number of Samples Analyzed	Number of Detects	Minimum Detected Concentration (mg/L)	Maximum Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
Unit Operations Generating Cyanide-Bearing Wastewater	12	12	0.120	100,000	20,200	9,990
Rinses Generating Cyanide-Bearing Wastewater	14	13	0.430	51,000	10,400	10.0

Source: MP&M Sampling Program.

Table 6-3 summarizes qualitative data contained in the MP&M DCPs indicating the pollutant parameters known or believed to be present in wastewaters from unit operations and rinses that generate cyanide-bearing wastewater. As shown in Table 6-3, cyanide and copper were the pollutants most frequently known to be present in wastewater from cyanide-bearing operations and rinses, while cyanide and cadmium were the pollutants most frequently believed to be present in these wastewaters. Copper and cadmium are typical metals present in electroplating baths.

6.1.3 Oil-Bearing Wastewaters

The following MP&M unit operations and associated rinses generate oil-bearing wastewaters.

Unit Operations and Rinses That Generate Oil-Bearing Wastewater

Unit Operation	Associated Rinse
Alkaline Treatment (requiring oil treatment)	Alkaline Treatment (requiring oil treatment) - Rinse
Corrosion Preventive Coating	Corrosion Preventive Coating - Rinse
Dye Penetrant Testing	Dye Penetrant Testing - Rinse
Floor Cleaning	Floor Cleaning - Rinse
Grinding	Grinding - Rinse
Heat Treating (requiring oil treatment)	Heat Treating (requiring oil treatment) - Rinse
Impact Deformation	Impact Deformation - Rinse
Machining	Machining - Rinse
Magnetic Flux Testing	Magnetic Flux Testing - Rinse
Pressure Deformation	Pressure Deformation - Rinse
Solvent Degreasing	Solvent Degreasing - Rinse

Source: MP&M DCPs, MP&M site visits, technical literature.

These wastewaters generally require preliminary treatment to separate oil from the wastewater. If the oils are free or floating, then the oil and water can generally be separated using physical means such as oil skimming or ultrafiltration. If the oil is emulsified, techniques such as chemical emulsion breaking may be used prior to physical separation. These oil/water separation technologies also remove organic pollutants that are more soluble in oil than in water. Section 10.0 discusses in detail oil/water separation technologies used in the MP&M industry.

Tables 6-4 and 6-5 summarize the analytical data collected during the MP&M sampling program for wastewater from unit operations and their associated rinses, respectively, that generate oil-bearing wastewater. Oil/water emulsions are typically used as coolants and lubricants in machining, grinding, and deformation operations. Oil is also present as a contaminant in wastewater from cleaning operations. The maximum concentration of oil and grease detected in wastewater from the unit operations was 570,000 mg/L (from a machining coolant), while the maximum concentration of oil and grease detected in the wastewater from the rinses associated with these unit operations was 2,700 mg/L.

Table 6-6 summarizes qualitative data contained in the MP&M DCPs indicating the pollutant parameters known or believed to be present in wastewaters from unit operations and rinses that generate oil-bearing wastewater. As shown in Table 6-6, 1,1,1-trichloroethane, chromium, copper, lead, nickel, and zinc were the pollutants most frequently known or believed to be present in wastewater from oil-bearing operations and rinses.

6.1.4 Chelated Metal-Bearing Wastewaters

Electroless plating operations and rinses are the most common MP&M operations that generate chelated metal-bearing wastewaters. Some cleaning operations also generate chelated metal-bearing wastewaters. Chelating agents are used in these unit operations to prevent metals from precipitating out of solution in the process bath. These chelated metals are not effectively removed by typical chemical precipitation and sedimentation treatment units. Therefore, these wastewaters generally require preliminary treatment to break down the metal chelates. This preliminary treatment may consist of chemical reduction using reducing agents such as sodium borohydride, hydrazine, or sodium hydrosulfite; high-pH precipitation using calcium hydroxide; or filtering the chelated metals out of solution. Section 10.0 discusses in detail the chelated metal-bearing wastewater treatment technologies used in the MP&M industry.

During the MP&M sampling program, the Agency collected samples of electroless nickel plating solutions and rinses that generate chelated metal-bearing wastewater. The following table summarizes the analytical data for nickel in these samples.

Summary of Analytical Data for Nickel in Electroless Plating Wastewaters

Source of Pollutant	Number of Samples Analyzed	Number of Detects	Minimum Detected Concentration (mg/L)	Maximum Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
Electroless Nickel Plating Solution	2	2	5,030	6,280	5,660	5,660
Electroless Nickel Plating Rinse	6	6	2.43	378	102	46.6

Source: MP&M Sampling Program.

Other metals typically plated using electroless plating include copper, gold, palladium, and cobalt. The Agency expects the concentration of the plated metals in these solutions and associated rinses to be similar to the concentrations measured for nickel during the MP&M sampling program.

Table 6-7 summarizes qualitative data contained in the MP&M DCPs indicating the pollutant parameters known or believed to be present in wastewaters from unit operations and rinses that generate chelated metal-bearing wastewater. As shown in Table 6-7, nickel was most frequently known or believed to be present in wastewater from chelated metal-bearing wastewaters.

6.1.5 Metal-Bearing Wastewaters

All of the MP&M unit operations generate metal-bearing wastewaters. These wastewaters include those classified in the four types of wastewater described previously. After preliminary treatment for selected streams, these wastewaters are generally treated using chemical precipitation and sedimentation. This process involves precipitating the metals under alkaline conditions, usually by adding calcium or sodium hydroxide, and settling the precipitated metals, usually by clarification. Section 10.0 discusses in detail metal-bearing wastewater treatment technologies used in the MP&M industry.

Tables 6-8 and 6-9 summarize the analytical data collected during the MP&M sampling program for wastewater from unit operations and associated rinses, respectively, that generate metal-bearing wastewater. As shown in these tables, the priority metal pollutants most commonly detected in samples of these wastewaters were cadmium, chromium, copper, nickel, and zinc. Nonconventional metal pollutants frequently detected include aluminum, boron, iron, magnesium, manganese, and molybdenum. Metal pollutants are typically present either in the base metal processed or in process solutions. The maximum concentrations of these metal pollutants detected in wastewater from the unit operations ranged from 7,150 to 374,000 mg/L (for electroplating solutions), while the maximum concentrations in the associated rinses ranged from 6.82

to 2,830 mg/L. These wastewaters also typically contained oil and grease and total suspended solids.

Table 6-10 summarizes qualitative data contained in the MP&M DCPs indicating the pollutant parameters known or believed to be present in wastewaters from unit operations and rinses that generate metal-bearing wastewater. As shown in Table 6-10, chromium, copper, and nickel were the pollutants most frequently known to be present in wastewater from metal-bearing operations and rinses, while chromium and lead were the pollutants most frequently believed to be present in these wastewaters.

6.1.6 Qualitative Data from the MP&M DCPs for Unidentified MP&M Unit Operations

Table 6-11 summarizes qualitative data contained in the MP&M DCPs indicating the pollutant parameters known or believed to be present in wastewaters generated by unspecified MP&M unit operations. Although the specific unit operations generating these wastewaters were not identified in the DCPs, the data provided in the DCPs identify pollutant parameters that are known or believed to be present in raw MP&M wastewater prior to end-of-pipe treatment.

As shown in Table 6-11, copper, lead, and zinc were the pollutants most frequently known to be present in these wastewaters, while chromium, copper, and nickel were the pollutants most frequently believed to be present in these wastewaters.

6.2 Treatment Influent Characteristics

Table 6-12 summarizes analytical data collected during the MP&M sampling program for influent wastewaters to chemical precipitation and sedimentation treatment systems. As shown in this table, the priority metal pollutants most frequently detected in samples of these wastewaters collected during the MP&M sampling program were chromium, copper, nickel, and zinc. Nonconventional metal pollutants frequently detected include aluminum, boron, iron, magnesium, and manganese. The maximum concentrations of these metal pollutants ranged from 59.8 to 3,880 mg/L. These wastewaters also contain oil and grease and total suspended solids.

The following table summarizes the analytical data collected for cyanide in influent wastewaters to cyanide destruction systems. The streams also contained metal pollutants and total suspended solids.

Summary of Analytical Data for Cyanide in Cyanide Destruction Influent Streams

Number of Samples Analyzed	Number of Detects	Minimum Detected Concentration (mg/L)	Maximum Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
20	20	0.062	119	25.3	8.75

Source: MP&M Sampling Program.

The following table summarizes the analytical data collected for oil and grease in influent wastewater to oil skimming, chemical emulsion breaking, and ultrafiltration treatment systems. These streams also contain organic pollutants, metal pollutants, and total suspended solids.

Summary of Analytical Data for Oil and Grease in Oil/Water Separation Influent Streams

Number of Samples Analyzed	Number of Detects	Minimum Detected Concentration (mg/L)	Maximum Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
23	23	16	262,000	22,000	170

Source: MP&M Sampling Program.

Table 6-1

Number of Samples Collected for MP&M Phase I Unit Operations

Unit Operation	No. of Samples Collected	Unit Operation	No. of Samples Collected
Abrasive Blasting	3	Assembly	0
Abrasive Blasting-Rinse	3	Assembly-Rinse	0
Abrasive Jet Machining	1	Barrel Finishing	6
Abrasive Jet Machining-Rinse	0	Barrel Finishing-Rinse	0
Acid Treatment (with chromic acid)	2	Brazing	0
Acid Treatment (with chromic acid)-Rinse	5	Brazing-Rinse	0
Acid Treatment	18	Burnishing	0
Acid Treatment-Rinse	22	Burnishing-Rinse	0
Adhesive Bonding	0	Calibration	0
Adhesive Bonding-Rinse	0	Chromate Conversion Coating	9
Alkaline Treatment (requiring oil treatment)	23	Chromate Conversion Coating-Rinse	16
Alkaline Treatment (requiring oil treatment)-Rinse	11	Chemical Conversion Coating Sealant (with hexavalent chromium)	4
Alkaline Treatment (with cyanide)	0	Chemical Conversion Coating Sealant (with hexavalent chromium)-Rinse	0
Alkaline Treatment (with cyanide)-Rinse	0	Chemical Conversion Coating (without hexavalent chromium)	12
Alkaline Treatment	20	Chemical Conversion Coating (without hexavalent chromium)-Rinse	22
Alkaline Treatment-Rinse	28	Chemical Conversion Coating Sealant (without hexavalent chromium)	2
Acid Anodizing (with chromic acid)	1	Chemical Conversion Coating Sealant (without hexavalent chromium)-Rinse	3
Acid Anodizing (with chromic acid)-Rinse	1	Chemical Machining	5
Anodizing Sealant (with hexavalent chromium)	2	Chemical Machining-Rinse	9
Anodizing Sealant (with hexavalent chromium)-Rinse	4	Corrosion Preventive Coating	5
Anodizing (without hexavalent chromium)	6	Corrosion Preventive Coating-Rinse	0
Anodizing (without hexavalent chromium)-Rinse	8	Disassembly	0
Anodizing Sealant (without hexavalent chromium)	3	Disassembly-Rinse	0
Anodizing Sealant (without hexavalent chromium)-Rinse	4	Electrical Discharge-Machining	0

Table 6-1 (Continued)

Number of Samples Collected for MP&M Phase I Unit Operations

Unit Operation	No. of Samples Collected	Unit Operation	No. of Samples Collected
Electrochemical Machining	1	Machining	12
Electrochemical Machining-Rinse	2	Machining-Rinse	0
Electrolytic Cleaning (with cyanide)	1	Metal Spraying	
Electrolytic Cleaning (with cyanide)-Rinse	1	Painting (including water curtains)	0
Electrolytic Cleaning (without cyanide)	6	Painting-Rinse	0
Electrolytic Cleaning (without cyanide)-Rinse	12	Painting-Electrophoretic	2
Electroplating (with chromium)	4	Plating—Electroless and Immersion	6
Electroplating (with chromium)-Rinse	11	Plating—Electroless and Immersion-Rinse	0
Electroplating (with cyanide)	8	Plating-Mechanical and Vapor	0
Electroplating (with cyanide)-Rinse	13	Plating-Mechanical and Vapor-Rinse	1
Electroplating (without hexavalent chromium or cyanide)	12	Plasma Arc Machining	0
Electroplating (without hexavalent chromium or cyanide)-Rinse	18	Polishing	0
Electron Beam Machining	0	Polishing-Rinse	0
Electropolishing	1	Pressure Deformation	0
Electropolishing-Rinse	1	Pressure Deformation-Rinse	1
Floor Cleaning	6	Rinsing	1
Grinding	5	Rinsing—Multiple Unit Operation	0
Grinding-Rinse	0	Salt Bath Descaling	3
Heat Treating Quench	3	Salt Bath Descaling-Rinse	0
Heat Treating Quench-Rinse	5	Soldering	0
Heat Treating (solution) Quench	2	Soldering-Rinse	0
Heat Treating (solution) Quench-Rinse	0	Solvent Degreasing	0
Heat Treating (cyaniding) Quench	0	Solvent Degreasing-Rinse	0
Heat Treating (cyaniding) Quench-Rinse	0	Sputtering	9
Hot Dip Coating	0	Stripping-Metallic Coating	3
Hot Dip Coating-Rinse	0	Stripping-Metallic Coating-Rinse	4
Impact Deformation	1	Stripping-Organic Coating	7
Impact Deformation-Rinse	0	Stripping-Organic Coating-Rinse	2
Laminating	0	Testing-Dye Penetrant	3
Laser Beam Machining	0	Testing-Dye Penetrant-Rinse	0

Table 6-1 (Continued)

Number of Samples Collected for MP&M Phase I Unit Operations

Unit Operation	No. of Samples Collected	Unit Operation	No. of Samples Collected
Testing-Hydraulic	0	Thermal Cutting	3
Testing-Hydraulic-Rinse	0	Thermal Infusion	0
Testing-Electrical	0	Thermal Infusion-Rinse	0
Testing-Performance	0	Ultrasonic Machining	0
Testing-Performance-Rinse	0	Ultrasonic Machining-Rinse	0
Testing-Magnetic Flux	0	Vacuum Metalizing	0
Testing-Magnetic Flux-Rinse	0	Welding	0
Testing-Ultrasonic	0	Welding-Rinse	0
Testing-Ultrasonic-Rinse	0	Wet Air Pollution Control - Chromium-bearing furans	6
Testing-Salt Spray	0	Wet Air Pollution Control - Cyanide-bearing furans	4
Testing-Radiographic	0	Wet Air Pollution Control - Acid/Alkaline-bearing furans	5
Testing Undefined	0	Wet Air Pollution Control - Other Fumes and Dusts	6

Source: MP&M Sampling Program.

Table 6-2

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Hexavalent Chromium-Bearing Unit Operations and Associated Rinses

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS		
CADMIUM	6	1
CHROMIUM	75	11
COPPER	6	1
CYANIDE	7	1
LEAD	9	2
NICKEL	7	2
SILVER	3	1
ZINC	12	2
NONCONVENTIONAL ORGANIC POLLUTANTS		
2-BUTANONE	0	1
NONCONVENTIONAL METAL ORGANIC POLLUTANTS		
BARIUM	1	1

Source: MP&M DCPs.

Table 6-3

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Cyanide-Bearing Unit Operations and Associated Rinses

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS		
CADMIUM	7	2
CHROMIUM	2	0
COPPER	18	0
CYANIDE	27	3
LEAD	2	0
NICKEL	3	0
SILVER	8	1
ZINC	5	0

Source: MP&M DCPs.

Table 6-4

Analytical Data for Unit Operations Generating Oil-Bearing Wastewater(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
PRIORITY POLLUTANTS						
ACROLEIN	5	1	0.161	0.161	0.161	0.161
1,1,1-TRICHLOROETHANE	5	2	0.010	0.012	0.011	0.011
4-CHLORO-3-METHYLPHENOL	5	4	42.113	91.125	60.149	53.678
METHYLENE CHLORIDE	5	1	0.028	0.028	0.028	0.028
PHENOL	5	1	1.695	1.695	1.695	1.695
BIS(2-ETHYLHEXYL) PHTHALATE	5	1	143.047	143.047	143.047	143.047
TOLUENE	5	4	0.094	0.653	0.245	0.117
ANTIMONY	53	28	0.008	0.328	0.093	0.041
ARSENIC	54	31	0.001	1.740	0.142	0.015
BERYLLIUM	54	22	0.000	0.260	0.014	0.001
CADMIUM	54	44	0.005	8.100	1.028	0.132
CHROMIUM	54	53	0.007	255.000	5.445	0.157
COPPER	54	52	0.006	81.500	5.687	1.415
CYANIDE	2	1	0.050	0.050	0.050	0.050
LEAD	54	40	0.050	53.900	3.606	0.608
MERCURY	54	23	<0.001	0.033	0.004	<0.001
NICKEL	54	52	0.013	80.900	2.446	0.218
SELENIUM	53	17	0.001	0.789	0.058	0.002
SILVER	54	34	0.004	3.140	0.245	0.011
THALLIUM	53	16	0.002	0.036	0.016	0.021
ZINC	54	53	0.021	561.000	20.077	2.170
CONVENTIONAL POLLUTANTS						
OIL AND GREASE	54	54	5.000	570,000	33,900	2,150
TOTAL SUSPENDED SOLIDS	54	53	2.000	27,200	1,940	445
NONCONVENTIONAL ORGANIC POLLUTANTS						
2-BUTANONE	5	1	0.074	0.074	0.074	0.074
2-PROPANONE	5	4	0.172	0.228	0.198	0.196
ALPHA-TERPINEOL	5	1	14.055	14.055	14.055	14.055
HEXANOIC ACID	5	3	1.624	36.619	14.507	5.279

(a)This table presents data only for pollutants that were detected in these wastewaters during the MP&M sampling program. In addition to the pollutants listed, 77 priority organic and 133 nonconventional organic pollutants were analyzed for in five samples and not detected.

Table 6-4 (Continued)

Analytical Data for Unit Operations Generating Oil-Bearing Wastewater(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
NONCONVENTIONAL ORGANIC POLLUTANTS (Continued)						
ISOBUTYL ALCOHOL	5	3	0.012	0.019	0.016	0.016
N-DOCOSANE	5	2	30.686	140.634	85.660	85.660
N-DODECANE	5	2	20.758	36.773	28.766	28.766
N-EICOSANE	5	1	13.130	13.130	13.130	13.130
N-HEXACOSANE	5	2	23.388	108.717	66.053	66.053
N-HEXADECANE	5	3	5.067	95.275	54.328	62.642
N-OCTACOSANE	5	2	20.008	61.093	40.550	40.550
N-OCTADECANE	5	2	62.896	263.958	163.427	163.427
N-TETRACOSANE	5	2	31.441	116.220	73.831	73.831
N-TETRADECANE	5	2	25.153	48.532	36.842	36.842
N-TRIACONTANE	5	2	9.158	31.895	20.527	20.527
TRIPROPYLENEGLYCOL METHYL ETHER	5	2	413.473	10489.094	5451.283	5451.283
NONCONVENTIONAL METAL POLLUTANTS						
ALUMINUM	54	48	0.039	197.000	20.331	2.405
BARIUM	54	49	0.002	31.980	3.065	0.308
BORON	54	51	0.061	543.000	54.691	1.560
CALCIUM	54	53	2.080	474.000	70.924	52.600
COBALT	54	37	0.009	283.000	7.789	0.039
IRON	54	54	0.131	496.000	34.332	16.150
MAGNESIUM	54	51	1.200	99.800	18.664	12.900
MANGANESE	54	52	0.004	24.100	1.911	0.487
MOLYBDENUM	54	43	0.008	3.780	0.433	0.200
SODIUM	54	54	1.610	31000.000	1940.161	314.730
TIN	54	34	0.030	8.250	0.407	0.085
TITANIUM	54	41	0.002	1.550	0.206	0.039
VANADIUM	54	33	0.007	0.150	0.045	0.023
YTTRIUM	54	27	0.001	0.181	0.019	0.003

(a)This table presents data only for pollutants that were detected in these wastewaters during the MP&M sampling program. In addition to the pollutants listed, 77 priority organic and 133 nonconventional organic pollutants were analyzed for in five samples and not detected.

Table 6-4 (Continued)

Analytical Data for Unit Operations Generating Oil-Bearing Wastewater(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
OTHER NONCONVENTIONAL POLLUTANTS						
ACIDITY	49	23	1.000	250000.000	10972.087	8.000
TOTAL ALKALINITY	50	49	22.000	54000.000	5822.878	1900.000
AMMONIA AS NITROGEN	27	26	0.160	460.000	21.687	1.450
CHEMICAL OXYGEN DEMAND	36	36	430.000	890000.000	67447.222	9900.000
CHLORIDE	47	44	7.000	2300.000	221.686	140.950
FLUORIDE	50	49	0.050	25.000	2.650	0.690
SULFATE	48	40	26.000	46000.000	2855.100	226.000
TOTAL DISSOLVED SOLIDS	54	54	510.000	411420.000	31422.426	7250.000
TOTAL KJELDAHL NITROGEN	27	27	0.200	580.000	94.943	43.000
TOTAL PHOSPHORUS	25	25	0.020	7170.000	337.844	18.700
TOTAL RECOVERABLE PHENOLICS	37	32	0.017	79.000	6.536	0.194

Source: MP&M Sampling Program.

(a)This table presents data only for pollutants that were detected in these wastewaters during the MP&M sampling program. In addition to the pollutants listed, 77 priority organic and 133 nonconventional organic pollutants were analyzed for in five samples and not detected.

Table 6-5

Analytical Data for Rinses Generating Oil-Bearing Wastewater(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
PRIORITY POLLUTANTS						
1,1,1-TRICHLOROETHANE	2	1	0.023	0.023	0.023	0.023
1,1-DICHLOROETHANE	2	1	0.039	0.039	0.039	0.039
METHYLENE CHLORIDE	2	1	0.016	0.016	0.016	0.016
PHENOL	2	1	8.280	8.280	8.280	8.280
ANTIMONY	13	5	0.006	0.077	0.038	0.021
ARSENIC	14	8	0.001	0.067	0.025	0.014
BERYLLIUM	14	2	0.001	0.002	0.002	0.002
CADMIUM	14	12	0.005	11.900	1.013	0.015
CHROMIUM	14	9	0.011	0.213	0.101	0.110
COPPER	14	12	0.013	1.990	0.299	0.126
LEAD	14	6	0.050	0.754	0.418	0.398
MERCURY	14	2	0.000	0.002	0.001	0.001
NICKEL	14	6	0.014	0.230	0.085	0.047
SELENIUM	13	2	0.001	0.002	0.002	0.002
SILVER	14	5	0.005	0.024	0.012	0.006
THALLIUM	13	2	0.002	0.021	0.012	0.012
ZINC	14	14	0.019	1.420	0.492	0.400
CONVENTIONAL POLLUTANTS						
OIL AND GREASE	11	11	34.000	2700.000	630.091	44.000
TOTAL SUSPENDED SOLIDS	14	13	3.000	280.000	91.538	68.000
NONCONVENTIONAL ORGANIC POLLUTANTS						
2-PROPANONE	2	1	0.321	0.321	0.321	0.321
ALPHA-TERPINEOL	2	2	65.300	67.324	66.312	66.312
BENZYL ALCOHOL	2	2	2.729	24.800	13.765	13.765
N-DODECANE	2	2	12.316	20.200	16.258	16.258
N-HEXADECANE	2	2	46.591	52.700	49.645	49.645
N-TETRACOSANE	2	1	17.002	17.002	17.002	17.002
N-TETRADECANE	2	2	153.020	160.000	156.510	156.510
TRICHLOROFLUOROMETHANE	2	1	0.036	0.036	0.036	0.036

(a)This table presents data only for pollutants that were detected in these wastewaters during the MP&M sampling program. In addition to the pollutants listed, 80 priority organic and 141 nonconventional organic pollutants were analyzed for in five samples and not detected.

Table 6-5 (Continued)

Analytical Data for Rinses Generating Oil-Bearing Wastewater(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
NONCONVENTIONAL METAL POLLUTANTS						
ALUMINUM	14	9	0.055	7.970	1.891	0.190
BARIUM	14	13	0.002	0.740	0.181	0.071
BORON	14	12	0.019	290.000	24.437	0.206
CALCIUM	14	14	0.940	114.000	29.062	20.312
COBALT	14	4	0.007	0.011	0.010	0.010
IRON	14	13	0.067	19.560	4.251	1.030
MAGNESIUM	14	14	0.137	20.700	8.476	10.555
MANGANESE	14	13	0.004	0.802	0.192	0.076
MOLYBDENUM	14	8	0.010	0.076	0.031	0.019
SODIUM	14	14	3.840	1860.000	192.338	45.400
TIN	14	9	0.030	0.056	0.042	0.036
TITANIUM	14	9	0.003	0.054	0.015	0.007
VANADIUM	14	3	0.007	0.010	0.009	0.010
YTTRIUM	14	3	0.002	0.020	0.008	0.003
OTHER NONCONVENTIONAL POLLUTANTS						
ACIDITY	10	6	1.000	25.000	11.500	11.000
TOTAL ALKALINITY	10	10	18.000	3800.000	535.900	126.500
AMMONIA AS NITROGEN	4	4	0.020	0.870	0.352	0.260
CHEMICAL OXYGEN DEMAND	7	7	212.000	11560.000	2064.429	340.000
CHLORIDE	10	10	3.000	300.000	44.950	19.350
FLUORIDE	10	10	0.100	0.860	0.536	0.600
SULFATE	10	10	12.000	643.390	133.013	71.500
TOTAL DISSOLVED SOLIDS	14	14	34.000	2300.000	744.929	693.000
TOTAL KJELDAHL NITROGEN	4	3	0.360	6.300	2.887	2.000
TOTAL PHOSPHORUS	5	5	0.060	11.000	4.026	2.160
TOTAL RECOVERABLE PHENOLICS	8	7	0.020	0.800	0.347	0.160

Source: MP&M Sampling Program.

(a)This table presents data only for pollutants that were detected in these wastewaters during the MP&M sampling program. In addition to the pollutants listed, 80 priority organic and 141 nonconventional organic pollutants were analyzed for in five samples and not detected.

Table 6-6

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Oil-Bearing Unit Operations and Associated Rinses

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS		
BENZENE	2	2
CARBON TETRACHLORIDE	2	0
1,2-DICHLOROETHANE	3	1
1,1,1-TRICHLOROETHANE	37	40
HEXACHLOROETHANE	0	1
1,1-DICHLOROETHANE	2	1
1,1,2-TRICHLOROETHANE	1	2
1,1,2,2-TETRACHLOROETHANE	0	2
4-CHLORO-3-METHYLPHENOL	0	1
CHLOROFORM	0	2
1,2-DICHLOROBENZENE	1	0
2,4-DIMETHYLPHENOL	1	0
ETHYLBENZENE	1	3
FLUORANTHENE	0	1
METHYLENE CHLORIDE	7	8
CHLOROMETHANE	2	1
NAPHTHALENE	5	10
PHENOL	6	2
BIS(2-ETHYLHEXYL) PHTHALATE	3	1
DI-N-BUTYL PHTHALATE	0	2
TETRACHLOROETHENE	5	7
TOLUENE	7	8
TRICHLOROETHENE	10	7
ANTIMONY	1	6
ARSENIC	7	2
BERYLLIUM	1	9
CADMIUM	30	16
CHROMIUM	60	33

Table 6-6 (Continued)

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Oil-Bearing Unit Operations and Associated Rinses

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANT POLLUTANTS (Continued)		
COPPER	65	32
CYANIDE	6	2
LEAD	48	25
MERCURY	4	0
NICKEL	71	39
SELENIUM	4	4
SILVER	21	12
THALLIUM	1	0
ZINC	56	26
NONCONVENTIONAL ORGANIC POLLUTANTS		
1,4-DIOXANE	0	3
2-BUTANONE	7	6
2-PROPANONE	4	12
4-METHYL-2-PENTANONE	4	4
O-CRESOL	3	1
P-CRESOL	3	0
STYRENE	1	0
NONCONVENTIONAL METAL POLLUTANTS		
BARIUM	5	3

Source: MP&M DCPs.

Table 6-7

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Chelated Metal-Bearing Unit Operations and Associated Rinses

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS		
CHLOROFORM	1	0
ARSENIC	1	0
CADMIUM	2	0
CHROMIUM	2	0
COPPER	6	0
CYANIDE	5	1
LEAD	2	0
NICKEL	12	1
SELENIUM	1	0
SILVER	4	0
ZINC	5	1

Source: MP&M DCPs.

Table 6-8

Analytical Data for Wastewater from Unit Operations Generating Metal-Bearing Wastewater(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
PRIORITY POLLUTANTS						
BENZENE	9	1	0.019	0.019	0.019	0.019
2,4-DINITROTOLUENE	9	2	22.400	24.400	23.400	23.400
2,6-DINITROTOLUENE	9	2	6.670	7.280	6.975	6.975
ETHYLBENZENE	9	1	0.020	0.020	0.020	0.020
METHYLENE CHLORIDE	9	3	0.011	6.759	2.267	0.030
NITROBENZENE	9	1	0.119	0.119	0.119	0.119
2-NITROPHENOL	9	1	2.290	2.290	2.290	2.290
2,4-DINITROPHENOL	9	2	235.000	434.000	334.500	334.500
N-NITROSODIMETHYLAMINE	9	2	6.170	7.170	6.670	6.670
PHENOL	9	2	0.120	34.287	17.203	17.203
DIBENZO(A,H)ANTHRACENE	9	1	0.034	0.034	0.034	0.034
TRICHLOROETHENE	9	1	0.015	0.015	0.015	0.015
ANTIMONY	143	80	0.002	12.600	0.605	0.051
ARSENIC	143	91	0.001	18.000	0.772	0.021
BERYLLIUM	143	68	0.001	3.870	0.191	0.006
CADMIUM	143	106	0.003	57100.000	554.661	0.067
CHROMIUM	143	130	0.006	108000.000	1736.286	1.355
COPPER	143	131	0.005	36900.000	373.071	2.540
CYANIDE	13	12	0.003	0.170	0.058	0.050
LEAD	143	93	0.044	7150.000	145.651	0.834
MERCURY	143	75	0.000	0.045	0.004	0.001
NICKEL	143	123	0.014	84623.000	2412.302	1.400
SELENIUM	143	65	0.001	8.130	0.281	0.020
SILVER	143	91	0.005	2.855	0.187	0.021
THALLIUM	143	54	0.002	5.060	0.130	0.020
ZINC	142	132	0.008	12200.000	383.309	2.265
CONVENTIONAL POLLUTANTS						
OIL AND GREASE	133	120	0.250	780,000.000	6622.441	4.500
TOTAL SUSPENDED SOLIDS	141	134	1.000	110,000.000	1476.056	83.000

(a)This table presents data only for pollutants that were detected in these wastes during the MP&M sampling program. In addition to the pollutants listed, 72 priority organic and 133 nonconventional organic pollutants were analyzed in nine samples and not detected.

Table 6-8 (Continued)

Analytical Data for Wastewater from Unit Operations Generating Metal-Bearing Wastewater(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
NONCONVENTIONAL ORGANIC POLLUTANTS						
1,4-DINITROBENZENE	9	2	1.070	3.920	2.495	2.495
2-BUTANONE	9	4	0.223	38.300	11.936	4.610
2-HEXANONE	9	1	5.016	5.016	5.016	5.016
2-PROPANONE	9	6	0.084	11.900	3.917	0.643
4-METHYL-2-PENTANONE	9	2	0.124	1.154	0.639	0.639
ALPHA-TERPINEOL	9	1	0.035	0.035	0.035	0.035
BENZOIC ACID	9	3	5.500	91.249	49.883	52.900
HEXANOIC ACID	9	2	5.880	19.300	12.590	12.590
M-XYLENE	9	1	0.020	0.020	0.020	0.020
N,N-DIMETHYLFORMAMIDE	9	1	0.028	0.028	0.028	0.028
N-DECANE	9	1	3.514	3.514	3.514	3.514
N-DODECANE	9	1	1.272	1.272	1.272	1.272
O+P XYLENE	9	1	0.910	0.910	0.910	0.910
P-CRESOL	9	1	0.010	0.010	0.010	0.010
P-NITROANILINE	9	1	26.100	26.100	26.100	26.100
TRICHLOROFLUOROMETHANE	9	1	0.106	0.106	0.106	0.106
NONCONVENTIONAL METAL POLLUTANTS						
ALUMINUM	143	114	0.041	34900.000	1156.526	5.214
BARIUM	143	113	0.003	70.078	1.475	0.100
BORON	143	125	0.010	7090.000	281.202	0.872
CALCIUM	143	137	0.804	1935.700	93.160	35.900
COBALT	143	88	0.005	225.000	7.709	0.372
IRON	143	131	0.011	374000.000	5932.148	8.140
MAGNESIUM	143	123	0.152	1100.000	74.099	16.500
MANGANESE	143	119	0.002	4790.000	80.586	0.291
MOLYBDENUM	143	113	0.009	197.000	4.572	0.230
SODIUM	143	141	1.250	383000.000	14177.100	341.000
TIN	143	86	0.030	44000.000	889.976	0.333
TITANIUM	143	93	0.003	14300.000	374.890	0.165

(a)This table presents data only for pollutants that were detected in these wastes during the MP&M sampling program. In addition to the pollutants listed, 72 priority organic and 133 nonconventional organic pollutants were analyzed in nine samples and not detected.

Table 6-8 (Continued)

Analytical Data for Wastewater from Unit Operations Generating Metal-Bearing Wastewater(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
NONCONVENTIONAL METAL POLLUTANTS (Continued)						
VANADIUM	143	85	0.004	1540.000	38.967	0.046
YTTRIUM	143	69	0.001	0.900	0.057	0.008
OTHER NONCONVENTIONAL POLLUTANTS						
ACIDITY	127	84	1.000	650000.000	67034.746	450.000
TOTAL ALKALINITY	128	106	1.000	890000.000	50284.962	409.000
AMMONIA AS NITROGEN	49	45	0.060	43000.000	2052.480	8.600
CHEMICAL OXYGEN DEMAND	71	68	5.000	600000.000	23232.199	2050.000
CHLORIDE	132	109	1.000	316000.000	6933.957	75.000
FLUORIDE	132	121	0.100	57000.000	1400.536	2.500
SULFATE	132	122	1.000	755000.000	26376.491	135.000
TOTAL DISSOLVED SOLIDS	141	139	27.000	1000000.00	97188.288	14000.000
TOTAL KJELDAHL NITROGEN	51	49	0.480	40000.000	2474.514	14.190
TOTAL PHOSPHORUS	48	43	0.020	11000.000	760.100	7.500
TOTAL RECOVERABLE PHENOLICS	54	42	0.004	135.000	8.561	0.620

Source: MP&M Sampling Program.

(a)This table presents data only for pollutants that were detected in these wastes during the MP&M sampling program. In addition to the pollutants listed, 72 priority organic and 133 nonconventional organic pollutants were analyzed in nine samples and not detected.

Table 6-9

Analytical Data for Wastewater from Rinses Generating Metal-Bearing Wastewater

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Dete Concentrati (mg/L)
PRIORITY POLLUTANTS						
ANTIMONY	157	69	0.002	0.083	0.017	0.0
ARSENIC	157	77	0.001	0.090	0.011	0.0
BERYLLIUM	157	64	0.001	0.059	0.004	0.0
CADMIUM	157	100	0.002	6.930	0.205	0.0
CHROMIUM	157	132	0.007	105.000	2.630	0.1
COPPER	157	147	0.003	100.000	2.248	0.0
CYANIDE	9	9	0.010	1.500	0.422	0.0
LEAD	157	77	0.020	6.820	0.287	0.0
MERCURY	157	75	0.000	0.004	0.000	0.0
NICKEL	157	129	0.010	300.430	10.256	0.0
SELENIUM	157	71	0.001	0.196	0.013	0.0
SILVER	157	97	0.004	0.097	0.011	0.0
THALLIUM	157	63	0.001	0.039	0.007	0.0
ZINC	157	128	0.008	177.000	5.487	0.1
CONVENTIONAL POLLUTANTS						
OIL AND GREASE	113	99	0.280	110.000	9.885	2.5
TOTAL SUSPENDED SOLIDS	156	134	2.000	1200.000	69.033	14.0
NONCONVENTIONAL METAL POLLUTANTS						
ALUMINUM	157	115	0.031	76.900	1.995	0.2
BARIUM	157	119	0.001	1.600	0.076	0.0
BORON	157	137	0.010	21.791	0.657	0.1
CALCIUM	157	156	0.033	204.000	39.264	25.6
COBALT	157	69	0.008	11.000	0.456	0.01
IRON	157	147	0.016	2830.000	60.132	0.27
MAGNESIUM	157	150	0.416	26.000	10.395	10.95
MANGANESE	157	125	0.001	23.300	1.164	0.01
MOLYBDENUM	157	96	0.006	13.400	0.282	0.01
SODIUM	157	157	0.277	19700.000	462.302	48.90
TIN	157	86	0.015	4.667	0.163	0.03
TITANIUM	157	75	0.002	18.100	0.780	0.00

Table 6-9 (Continued)

Analytical Data for Wastewater from Rinses Generating Metal-Bearing Wastewater

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
NONCONVENTIONAL METAL POLLUTANTS (Continued)						
VANADIUM	157	71	0.005	1.100	0.066	0.010
YTTRIUM	157	67	0.001	0.025	0.003	0.003
OTHER NONCONVENTIONAL POLLUTANTS						
ACIDITY	99	70	1.000	180000.000	3550.297	11.550
TOTAL ALKALINITY	100	91	1.000	8600.000	427.679	72.000
AMMONIA AS NITROGEN	26	19	0.100	31.000	2.105	0.360
CHEMICAL OXYGEN DEMAND	43	39	6.000	2500.000	219.605	53.000
CHLORIDE	104	103	1.200	65000.000	1336.952	24.000
FLUORIDE	104	99	0.100	140.000	5.751	0.920
SULFATE	104	104	1.000	6200.000	144.663	48.500
TOTAL DISSOLVED SOLIDS	156	156	20.000	120000.000	2497.577	410.000
TOTAL KJELDAHL NITROGEN	35	33	0.100	27.000	2.930	1.000
TOTAL PHOSPHORUS	32	30	0.020	750.000	67.534	1.850
TOTAL RECOVERABLE PHENOLICS	37	27	0.006	16.000	0.628	0.010

Source: MP&M Sampling Program.

Table 6-10

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Metal-Bearing Unit Operations and Associated Rinses

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS		
ACRYLONITRILE	1	0
BENZENE	11	4
CARBON TETRACHLORIDE	0	1
CHLOROBENZENE	1	1
HEXACHLOROBENZENE	0	1
1,2-DICHLOROETHANE	0	1
1,1,1-TRICHLOROETHANE	5	16
HEXACHLOROETHANE	0	1
4-CHLORO-3-METHYLPHENOL	0	1
CHLOROFORM	2	0
ETHYLBENZENE	7	13
METHYLENE CHLORIDE	9	20
CHLOROMETHANE	0	1
ISOPHORONE	1	0
NAPHTHALENE	2	6
PHENOL	11	4
BIS(2-ETHYLHEXYL) PHTHALATE	1	1
DI-N-BUTYL PHTHALATE	0	1
DI-N-OCTYL PHTHALATE	0	1
DIMETHYL PHTHALATE	1	0
ANTHRACENE	1	0
DIBENZO(A,H)ANTHRACENE	0	1
TETRACHLOROETHENE	1	0
TOLUENE	37	51
TRICHLOROETHENE	3	2
VINYL CHLORIDE	0	1
ANTIMONY	3	7
ARSENIC	8	4
BERYLLIUM	1	5
CADMIUM	37	13

Table 6-10 (Continued)

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Metal-Bearing Unit Operations and Associated Rinses

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS (Continued)		
CHROMIUM	95	29
COPPER	95	26
CYANIDE	22	6
LEAD	84	38
MERCURY	11	4
NICKEL	106	24
SELENIUM	6	7
SILVER	36	18
THALLIUM	2	0
ZINC	82	25
NONCONVENTIONAL ORGANIC POLLUTANTS		
2-BUTANONE	14	41
2-PROPANONE	12	29
4-METHYL-2-PENTANONE	6	22
ISOBUTYL ALCOHOL	4	6
O-CRESOL	1	0
STYRENE	1	4
NONCONVENTIONAL METAL POLLUTANTS		
BARIUM	15	2

Source: MP&M DCPs.

Table 6-11

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Unidentified Unit Operations

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS		
ACENAPHTHENE	1	0
ACROLEIN	2	0
ACRYLONITRILE	2	0
BENZENE	4	6
BENZIDINE	1	0
CARBON TETRACHLORIDE	5	1
CHLOROBENZENE	4	0
1,2,4-TRICHLOROBENZENE	2	0
HEXACHLOROBENZENE	1	0
1,2-DICHLOROETHANE	4	0
1,1,1-TRICHLOROETHANE	11	9
HEXACHLOROETHANE	2	0
1,1-DICHLOROETHANE	4	0
1,1,2-TRICHLOROETHANE	2	0
1,1,2,2-TETRACHLOROETHANE	2	0
CHLOROETHANE	2	0
BIS(2-CHLOROETHYL) ETHER	1	0
2-CHLOROETHYLVINYL ETHER	1	0
2-CHLORONAPHTHALENE	1	0
2,4,6-TRICHLOROPHENOL	1	0
CHLOROFORM	16	3
1,2-DICHLOROBENZENE	2	1
1,3-DICHLOROBENZENE	2	0
1,4-DICHLOROBENZENE	3	0
3,3'-DICHLOROBENZIDINE	1	0
1,1-DICHLOROETHENE	4	0
TRANS-1,2-DICHLOROETHENE	2	0
2,4-DICHLOROPHENOL	2	0

Table 6-11 (Continued)

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Unidentified Unit Operations

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS (Continued)		
1,2-DICHLOROPROPANE	2	0
TRANS-1,3-DICHLOROPROPENE	1	0
2,4-DIMETHYLPHENOL	1	0
2,4-DINITROTOLUENE	2	0
2,6-DINITROTOLUENE	1	0
ETHYLBENZENE	6	0
FLUORANTHENE	1	0
4-CHLOROPHENYL PHENYL ETHER	1	0
4-BROMOPHENYL PHENYL ETHER	1	0
BIS(2-CHLOROISOPROPYL) ETHER	1	0
BIS(2-CHLOROETHOXY) METHANE	1	0
METHYLENE CHLORIDE	9	3
CHLOROMETHANE	1	1
BROMOMETHANE	1	0
TRIBROMOMETHANE	3	1
BROMODICHLOROMETHANE	6	0
DIBROMOCHLOROMETHANE	3	0
HEXACHLOROBUTADIENE	2	0
ISOPHORONE	1	0
NAPHTHALENE	2	2
NITROBENZENE	1	0
2-NITROPHENOL	1	0
4-NITROPHENOL	1	0
2,4-DINITROPHENOL	1	0
N-NITROSODIMETHYLAMINE	1	0
N-NITROSODIPHENYLAMINE	1	0
N-NITROSODI-N-PROPYLAMINE	1	0
PENTACHLOROPHENOL	2	0

Table 6-11 (Continued)

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Unidentified Unit Operations

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS (Continued)		
PHENOL	8	4
BIS(2-ETHYLHEXYL) PHTHALATE	5	0
BUTYL BENZYL PHTHALATE	2	0
DI-N-BUTYL PHTHALATE	1	0
DI-N-OCTYL PHTHALATE	1	0
DIETHYL PHTHALATE	1	0
DIMETHYL PHTHALATE	1	1
BENZO(A)ANTHRACENE	1	0
BENZO(A)PYRENE	2	0
BENZO(B)FLUORANTHENE	1	0
BENZO(K)FLUORANTHENE	1	0
CHRYSENE	1	0
ACENAPHTHYLENE	1	0
BENZO(GHI)PERYLENE	1	0
FLUORENE	1	0
PHENANTHRENE	1	0
DIBENZO(A,H)ANTHRACENE	2	0
INDENO(1,2,3-CD)PYRENE	1	0
PYRENE	1	0
TETRACHLOROETHENE	6	2
TOLUENE	9	4
TRICHLOROETHENE	5	2
VINYL CHLORIDE	4	0
ANTIMONY	3	4
ARSENIC	10	2
BERYLLIUM	1	3
CADMIUM	32	8
CHROMIUM	32	15
COPPER	37	17

Table 6-11 (Continued)

Pollutant Parameters Identified in the MP&M Data Collection Portfolios for Unidentified Unit Operations

Pollutant Parameter	No. of "Known to be Present" Responses	No. of "Believed to be Present" Responses
PRIORITY POLLUTANTS (Continued)		
CYANIDE	28	0
LEAD	35	12
MERCURY	13	2
NICKEL	33	18
SELENIUM	15	1
SILVER	26	4
THALLIUM	4	0
ZINC	41	11
NONCONVENTIONAL ORGANIC POLLUTANTS		
2-CHLOROPHENOL	1	0
1,2,4,5-TETRACHLOROBENZENE	0	1
1,2-DIBROMOETHANE	0	1
2,3,4,6-TETRACHLOROPHENOL	0	1
2-BUTANONE	9	5
2-PROPANONE	9	6
3-METHYLCHOLANTHRENE	0	1
4-METHYL-2-PENTANONE	2	1
ANILINE	0	1
CARBON DISULFIDE	1	1
DIPHENYLAMINE	0	1
ISOBUTYL ALCOHOL	0	2
O-CRESOL	1	0
P-CRESOL	1	0
PENTACHLOROBENZENE	0	1
PYRIDINE	1	1
STYRENE	1	3
NONCONVENTIONAL METAL POLLUTANTS		
BARIUM	9	5

Source: MP&M DCPs.

Table 6-12

Analytical Data for Chemical Precipitation and Sedimentation Influent(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentratio (mg/L)
PRIORITY POLLUTANTS						
1,1,1-TRICHLOROETHANE	11	2	0.019	0.084	0.052	0.052
CHLOROFORM	11	2	0.060	0.413	0.236	0.236
METHYLENE CHLORIDE	11	1	0.172	0.172	0.172	0.172
BROMODICHLOROMETHANE	11	2	0.016	0.027	0.021	0.021
NAPHTHALENE	11	1	0.010	0.010	0.010	0.010
PHENOL	11	5	0.042	0.634	0.213	0.115
BIS(2-ETHYLHEXYL) PHTHALATE	11	6	0.011	0.172	0.108	0.134
FLUORENE	11	1	0.010	0.010	0.010	0.010
PHENANTHRENE	11	1	0.012	0.012	0.012	0.012
TETRACHLOROETHENE	11	2	1.007	1.107	1.057	1.057
ANTIMONY	58	16	0.003	0.367	0.043	0.010
ARSENIC	62	31	0.002	0.530	0.034	0.010
BERYLLIUM	62	19	0.000	0.355	0.067	0.019
CADMIUM	62	42	0.006	27.000	2.098	0.191
CHROMIUM	62	61	0.006	1,350.000	30.831	3.060
COPPER	62	62	0.030	125.000	7.438	0.554
CYANIDE	23	18	0.015	21.100	2.495	0.269
LEAD	62	27	0.051	159.000	6.344	0.251
MERCURY	60	9	0.000	0.012	0.002	0.000
NICKEL	62	56	0.030	608.000	43.656	0.933
SELENIUM	58	8	0.003	0.090	0.029	0.021
SILVER	62	34	0.007	4.230	0.292	0.047
THALLIUM	58	2	0.003	0.006	0.004	0.004
ZINC	62	55	0.029	100.470	11.956	0.801
CONVENTIONAL POLLUTANTS						
OIL AND GREASE	56	48	0.630	1,100.000	111.411	18.038
TOTAL SUSPENDED SOLIDS	62	58	6.000	4,650.000	432.393	109.518

(a)This table presents data only for pollutants that were detected in these wastewaters during the MP&M sampling program. In addition to the pollutants listed, 74 priority organic and 129 nonconventional organic pollutants were analyzed for in eleven samples and not detected.

Table 6-12 (Continued)

Analytical Data for Chemical Precipitation and Sedimentation Influent(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
NONCONVENTIONAL ORGANIC POLLUTANTS						
1-METHYLFLUORENE	11	2	0.012	0.016	0.014	0.014
1-METHYLPHENANTHRENE	11	2	0.015	0.016	0.015	0.015
2-METHYLNAPHTHALENE	11	3	0.011	0.047	0.027	0.023
2-PROPANONE	11	10	0.056	0.596	0.212	0.091
ALPHA-TERPINEOL	11	2	0.013	0.018	0.016	0.016
BENZOIC ACID	11	4	0.104	0.618	0.255	0.150
CARBON DISULFIDE	11	1	0.545	0.545	0.545	0.545
DIBENZOFURAN	11	1	0.018	0.018	0.018	0.018
HEXANOIC ACID	11	2	0.010	0.015	0.013	0.013
N-DECANE	11	3	0.011	0.031	0.018	0.013
N-DODECANE	11	4	0.017	0.198	0.096	0.084
N-EICOSANE	11	4	0.018	0.034	0.022	0.019
N-HEXACOSANE	11	2	0.016	0.031	0.024	0.024
N-HEXADECANE	11	5	0.017	0.061	0.037	0.035
N-OCTADECANE	11	4	0.012	0.043	0.028	0.028
N-TETRACOSANE	11	2	0.011	0.018	0.015	0.015
N-TETRADECANE	11	4	0.016	0.124	0.057	0.044
N-TRIACONTANE	11	1	0.026	0.026	0.026	0.026
STYRENE	11	1	0.188	0.188	0.188	0.188
TRICHLOROFLUOROMETHANE	11	4	0.031	0.109	0.051	0.033
NONCONVENTIONAL METAL POLLUTANTS						
ALUMINUM	62	54	0.093	59.832	7.068	3.343
BARIUM	62	49	0.010	9.910	0.318	0.080
BORON	62	56	0.165	9.160	1.207	0.864
CALCIUM	62	62	7.890	369.150	80.281	36.750
COBALT	62	31	0.010	25.800	2.591	0.030
IRON	62	62	0.148	3,880.000	251.960	6.220
MAGNESIUM	62	57	0.349	442.500	52.025	18.400
MANGANESE	62	61	0.004	16.000	1.535	0.221

(a)This table presents data only for pollutants that were detected in these wastewaters during the MP&M sampling program. In addition to the pollutants listed, 74 priority organic and 129 nonconventional organic pollutants were analyzed for in eleven samples and not detected.

Table 6-12 (Continued)

Analytical Data for Chemical Precipitation and Sedimentation Influent(a)

Pollutant Parameter	No. of Samples Analyzed	No. of Detects	Min. Detected Concentration (mg/L)	Max. Detected Concentration (mg/L)	Mean Detected Concentration (mg/L)	Median Detected Concentration (mg/L)
NONCONVENTIONAL METAL POLLUTANTS (Continued)						
MOLYBDENUM	62	41	0.008	1.600	0.184	0.058
SODIUM	62	62	15.600	3,470.000	479.535	214.500
TIN	62	26	0.026	1.710	0.460	0.230
TITANIUM	62	44	0.003	1.690	0.149	0.038
VANADIUM	62	18	0.006	0.160	0.049	0.019
YTTRIUM	62	20	0.002	0.085	0.010	0.005
OTHER NONCONVENTIONAL POLLUTANTS						
ACIDITY	57	37	3.000	24,770.135	2,106.192	210.000
TOTAL ALKALINITY	58	36	2.390	510.000	157.995	133.000
AMMONIA AS NITROGEN	53	49	0.021	150.000	11.814	1.780
CHEMICAL OXYGEN DEMAND	56	52	18.000	14,000.000	1,575.374	380.000
CHLORIDE	59	55	12.000	9,500.000	416.810	150.000
FLUORIDE	59	58	0.130	29.000	3.191	1.631
SULFATE	59	58	40.000	6,125.000	496.585	292.500
TOTAL DISSOLVED SOLIDS	62	62	19.000	34,000.000	3,408.351	991.000
TOTAL KJELDAHL NITROGEN	53	50	0.110	120.000	16.341	6.690
TOTAL PHOSPHORUS	52	51	0.180	525.000	36.760	10.000
TOTAL RECOVERABLE PHENOLICS	51	28	0.007	20.000	1.909	0.024

Source: MP&M Sampling Program.

(a)This table presents data only for pollutants that were detected in these wastewaters during the MP&M sampling program. In addition to the pollutants listed, 74 priority organic and 129 nonconventional organic pollutants were analyzed for in eleven samples and not detected.

7.0 INDUSTRY SUBCATEGORIZATION

In developing technology-based regulations for Phase I of the Metal Products and Machinery (MP&M) category, the Agency considered various factors to determine an appropriate approach for subcategorization of the category. The Clean Water Act requires EPA to assess several factors, including manufacturing processes, products, size of site, geographic location, site age, water use practices, and wastewater characteristics. For MP&M Phase I, the Agency also considered factors such as activity and nonwater quality environmental impacts (e.g., energy usage, air emissions, solid waste generation). As shown in this section, Phase I of the MP&M category is not characterized by sets of unique core unit operations, raw materials, and wastewater characteristics that require subcategorization. In addition, other factors considered, including economic impacts of the proposed regulation, were not found to be the basis of subcategorization. Therefore, EPA did not subcategorize the MP&M Phase I category.

Section 7.1 presents the factors considered for subcategorization of the MP&M Phase I category. Sections 7.2 through 7.12 present discussions of each of these factors.

7.1 Factors Considered for Subcategorization

The factors considered for subcategorization were selected based on factors required by the Clean Water Act and additional factors applicable to the MP&M Phase I industry. These factors are:

- Unit operations (production processes);
- Activity;
- Raw materials;
- Products;
- Size of site;
- Geographic location;
- Age;
- Total energy requirements;
- Air pollution control methods;
- Solid waste generation and disposal;
- Economic impacts of the regulation;
- Water use practices; and
- Wastewater characteristics.

The remainder of this section discusses these factors. Water use practices and wastewater characteristics are discussed throughout and are not presented under a separate heading.

7.2 Unit Operations

Within the MP&M Phase I category, 48 unit operations are typically performed along with associated rinses. Many of these unit operations use and discharge process water. As shown in Section 6.0, wastewaters generated by different unit operations have different characteristics. For example, machining wastewaters typically contain high concentrations of oil and grease, while electroplating wastewaters contain high concentrations of metals. However, as shown by the analyses described in this section, wastewater characteristics for any unit operation are expected to be similar across all subcategorization factors, with the exception of raw materials (discussed in Section 7.4). The unit operations are considered to be the building blocks, or subdivisions, within the MP&M Phase I category.

The characteristics of wastewaters generated by the unit operations were used to identify applicable in-process pollution prevention and end-of-pipe treatment technologies for MP&M wastewaters. In the example above, machining wastewaters require oil/water separation followed by chemical precipitation and sedimentation, while the electroplating wastewaters may require chromium reduction or cyanide destruction (depending on the type of electroplating performed) followed by chemical precipitation and sedimentation. By using the unit operations as building blocks, EPA identified appropriate types of in-process pollution prevention and end-of-pipe treatment technologies for MP&M sites, based on the types of operations performed on site. These technologies were used to estimate compliance costs (Section 12.0) and pollutant loadings and reductions (Section 13.0).

7.3 Activity

MP&M Phase I sites performed one or more of the following activities: manufacturing, rebuilding, and maintenance. These activities are defined below.

- Manufacturing is the series of unit operations necessary to produce metal products. Manufacturing is generally performed in a production environment.

- Rebuilding is the series of unit operations necessary to disassemble used metal products into components, replace the components or subassemblies or restore them to original function, and reassemble the metal product. Rebuilding is generally performed in a production environment.

- Maintenance is the series of unit operations, on original or replacement components, required to keep metal products in operating condition. Maintenance is generally performed in a non-production environment.

The Agency did not subcategorize by activity because the MP&M Phase I unit operations are performed in the same manner and generate the same types of waste regardless of activity.

Based on the data collection portfolio (DCP) results, the percentage of water-discharging MP&M Phase I sites performing each of the activity combinations listed above are as follows.

Percentage of Water-Discharging Sites Performing Each Activity Combination

Activity	Percentage
Manufacturing Only	71
Rebuilding Only	1
Maintenance Only	8
Manufacturing and Rebuilding	13
Manufacturing and Maintenance	2
Rebuilding and Maintenance	2
Manufacturing, Rebuilding, and Maintenance	3

Source: MP&M Phase I DCP Database.

With the exception of the initial cleaning steps for rebuilding and maintenance (discussed below), wastewater characteristics do not vary across activity. Results of analyses of the DCP database indicate that the production-normalized flow rate (volume of wastewater discharged per unit of production) for each unit operation does not depend on the activity. EPA used the production-normalized flow rate to assess subcategorization across activity because the amount of pollutant discharged from a MP&M unit operation is related to the production rate through the unit operation. The ratio of wastewater discharge rate to production rate influences the characteristics of wastewater generated by the operation (i.e., pollutant concentrations in wastewater from a cleaning rinse with a production-normalized flow of 2 gallons/square foot are expected to be approximately twice as high as pollutant concentrations in wastewater from a cleaning rinse with production-normalized flow of 4 gallons/square foot). Information collected during site visits at MP&M Phase I sites supports these conclusions.

The initial cleaning steps associated with rebuilding and maintenance may have unique wastewater characteristics because of the presence of oil and grease not present in cleaning steps associated with manufacturing. Based on analytical data collected at rebuilding sites, these wastewaters may require additional preliminary treatment capacity

(e.g., oil/water separation), but do not impact the overall treatability of wastewater from rebuilding sites. Therefore, EPA did not subcategorize based on these initial rebuilding and maintenance cleaning steps. The impact of the oil and grease was accounted for in the development of compliance cost estimates and pollutant loading estimates (discussed in Sections 12.0 and 13.0, respectively).

7.4 Raw Materials

Raw materials at MP&M Phase I sites consist of base metals processed (e.g., bar stock, sheet stock, ingots, formed parts) and applied materials (e.g., paint; corrosion preventive coating; metal applied during electroplating, electroless plating, and metal spraying).

Data from the DCP database and engineering site visits indicate that the wastewater discharge rates from unit operations are not dependent on the base metal processed or material applied. The base metal or material applied affects the site's wastewater characteristics. For example, a site processing only copper will have higher concentrations of copper than other metals, while a site processing steel and nickel and performing zinc electroplating will have higher concentrations of iron, nickel, and zinc than other metals. However, the impact on wastewater characteristics was accounted for in calculating technology effectiveness concentrations (discussed in Section 11.0) and pollutant loading estimates (discussed in Section 13.0).

More than half of the DCP respondents process more than one base metal type. Based on the DCP results, the percentage of water-discharging MP&M Phase I sites by the number of metal types processed are shown in the following table.

Percentage of Water-Discharging Sites by Number of Metal Types Processed

One metal type	43%
Two metal types	32%
Three metal types	15%
Four metal types	4%
Five or more metal types	6%

Source: MP&M DCP Phase I Database.

Based on DCP results, 24 different metal types were identified as processed at MP&M Phase I sites. Sites also periodically change metal types. At sites processing multiple metal types, individual unit operations frequently process more than one metal type (e.g., a machining operation can process nickel, aluminum, and iron parts). Additionally, not all metal types processed at a site are processed through all unit operations. For

example, a site may process aluminum and iron base metals. Anodizing is performed on the aluminum, and zinc electroplating on the iron. Both metals share the same alkaline and acid treatments. Subcategorizing by base metal type would place the anodizing operation in the aluminum subcategory, the electroplating operation in either the zinc or iron subcategory, and the alkaline and acid treatments in both the aluminum and iron subcategories. The Agency did not subcategorize by base metal or material applied because the wastewater discharge rates from unit operations are not dependent on base metal or material applied. The effect of base metal or material applied on wastewater characteristics was accounted for in calculating pollutant loadings and technology effectiveness concentrations.

7.5 Products

The MP&M Phase I category is divided into seven industrial sectors: aerospace, aircraft, electronic equipment, hardware, mobile industrial equipment, ordnance, and stationary industrial equipment. The sector determination reflects the products manufactured at the site. Table 3-1 lists the types of products typically processed within each of the sectors. An analysis by sector therefore includes an analysis of products manufactured, rebuilt, or maintained at MP&M sites. The Agency did not subcategorize by product, because no unique sets of unit operations and wastewater characteristics were identified by product, and the unit operations are not performed differently across sector. These reasons are discussed below.

A review of the DCP database and site visit information indicates that no core sets of unit operations exist for any sector. Most MP&M unit operations are not unique to a particular sector, and are performed across all sectors. Based on the DCP database, the most frequently performed wastewater-generating unit operations (e.g., acid treatment, alkaline treatment, chemical conversion coating, grinding, machining) are performed in all sectors. The unit operations that are rarely performed (e.g., abrasive jet machining) are not performed in all sectors, but are also not limited to a single sector. Based on information obtained from site visits and sampling episodes, the less common unit operations do not affect the overall treatability of wastewaters generated at sites performing these unit operations. Because the major wastewater-generating unit operations are performed across all sectors, and other unit operations performed in specific sectors do not affect treatability, raw wastewaters have similar treatability across MP&M Phase I sectors.

The Agency collected analytical data from sites within each of the seven Phase I sectors. A review of these data indicate that the wastewater characteristics do not vary significantly across sectors.

EPA reviewed the DCP database to assess if unit operations are performed differently across sectors. EPA used the production-normalized flow (wastewater discharge rate per unit of production) as an indicator to assess water use practices across sectors. The

review of the DCP database indicates that the production-normalized flow rate for an operation is not dependent on sector. For example, a site performing nickel electroplating of stationary industrial equipment components can achieve the same production-normalized flow rate (and therefore would have similar wastewater characteristics) as another site performing a similar nickel electroplating operation for aerospace components.

7.6 Size of Site

EPA used the following parameters as relative measures of the size of MP&M sites: number of employees, wastewater discharge flow rate, and production rate. An assessment of these parameters as a basis for subcategorization is presented below.

7.6.1 Number of Employees

Raw materials, unit operations, and wastewater characteristics are independent of the number of site employees. A review of the DCP database shows that production-normalized flows do not depend on the number of employees. A correlation between the number of employees and wastewater generation is difficult to develop due to variations in staff. Fluctuations can occur for many reasons, including shift differences, clerical and administrative support, maintenance workers, efficiency of site operations, degree of automation, and market fluctuations. For these reasons, the Agency did not subcategorize by number of employees.

7.6.2 Wastewater Discharge Flow Rate

The Agency did not subcategorize by site wastewater discharge flow rate because the wastewater characteristics for a site are independent of the overall wastewater discharge flow rate from a site. Wastewater characteristics are primarily a function of the raw materials, unit operations, and water use practices at a site, and not the site's overall wastewater discharge flow rate. For example, a site performing one machining operation on steel and discharging 100 gallons per year of wastewater would have similar wastewater characteristics as a site performing 1,000 machining operations on steel and discharging 100,000 gallons per year, provided the sites have similar water use practices. A review of the DCP database shows that water use practices, as measured by production-normalized flow rates, do not depend on the overall wastewater discharge flow rate from a site. The raw materials and unit operations also do not vary by overall site discharge flow rate.

For indirect discharges (sites discharging to publicly owned treatment works (POTWs)) EPA developed a regulatory implementation scheme based on wastewater discharge flow rate. This is discussed in Sections 10.0 and 15.0. Existing indirect dischargers with annual process water discharge flow rates of less than one million gallons are exempt from the MP&M Phase I pretreatment standards. All other indirect dischargers are

required to comply with mass-based standards. This scheme was developed to facilitate implementation of this regulation, and not as a means to subcategorize the MP&M Phase I category.

7.6.3 Production Rate

The Agency did not subcategorize by site production rate because the production rate through a MP&M Phase I site does not reflect the production rate through process wastewater-generating unit operations, and the production-normalized flow for an operation does not depend on the overall production rate for the site. For example, three sites may each process 100 tons of steel annually. One site may process all of the steel through an electroplating line, the second may perform dry assembly for 95 tons and process 5 tons through a machining operation, and the third may process 40 tons through an electroplating line, 40 tons through a machining operation, and 20 tons through dry assembly. All three sites would be expected to have different wastewater discharge rates and wastewater characteristics. However, the production-normalized flow rates and hence the wastewater characteristics for electroplating at the first and third sites would be expected to be similar, whereas the production-normalized flow rates for the machining operations at the second and third sites would be expected to be similar. Because the wastewater characteristics depend on the unit operations performed, and not the overall production rate for the site, EPA did not subcategorize by site production rate.

7.7 Geographical Location

MP&M Phase I sites are located throughout the United States. Sites are not limited to any one geographical location, but approximately two-thirds are located east of the Mississippi, with additional concentrations of sites in Texas and California. EPA did not subcategorize based on geographical location because location does affect the ability of sites to comply with the MP&M Phase I rulemaking.

Geographical location may impact costs if additional land is required to install treatment systems, since the cost of the land will vary depending on whether the site is located in an urban or rural location. The treatment systems used to treat MP&M wastewaters typically do not have large land requirements, as demonstrated by the fact that many MP&M Phase I sites are located in urban settings. Therefore, the Agency did not subcategorize based on land availability.

Water availability is another function of geographical location. Limited water supply encourages conservation by efficient use of water, including recycle and reuse. Therefore, insufficient water availability encourages the early installation of practices advisable for the entire category to reduce treatment costs and improve pollutant removals.

7.8 Age

The percentage of water-discharging sites by the decade in which they were built is listed below. This information is based upon the DCP respondents that reported the date their site was built.

Percentage of Wastewater-Discharging Sites by Decade Built

Decade Built	Percentage of Sites
Before 1920	4%
1920 through 1929	3%
1930 through 1939	2%
1940 through 1949	8%
1950 through 1959	8%
1960 through 1969	13%
1970 through 1979	40%
1980 through 1989	21%
1990(a)	1%

(a)The DCP was mailed on January 2, 1991.

Source: MP&M Phase I DCP Database.

A majority of the sites have been built since 1960. Although the DCP respondents report a wide range of ages, these sites must be continually modernized to remain competitive. Most of the sites visited during the MP&M Phase I site visit program had recently modernized some area of their site. Modernization of production processes and air pollution control equipment produces similar wastes among all sites of various ages. While the relative age of a site may be important in considering the economic impact of a guideline, site age does not impact wastewater characteristics. Therefore, site age was not selected as a basis for subcategorization.

7.9 Total Energy Requirements

Total energy requirements was not selected as a basis for subcategorization because energy requirements are not meaningfully related to wastewater generation and pollutant discharge. The estimated impacts of this regulation on energy consumption in the United States is an energy increase of approximately 0.007 percent (see Section 14.0). EPA estimated the energy requirements associated with each of the MP&M Phase I technology options and considered these in estimating compliance costs (see Section 12.0).

7.10 Air Pollution Control Methods

Many sites control air emissions using wet air pollution control units that affect the wastewater flow rate from the site. However, based on data collected during the MP&M Phase I sampling program, wastewaters generated by these devices do not affect the effectiveness of technologies used to control MP&M wastewaters. Wet air pollution control units are considered as additional unit operations within the MP&M Phase I category, but not as a means of subcategorizing the category.

7.11 Solid Waste Generation and Disposal

Physical and chemical characteristics of solid waste generated by the MP&M Phase I category are determined by the raw materials, unit operations, and types of air pollution control in use. Therefore, this factor does not provide a primary basis for subcategorization. EPA considered the amount of sludge generated as a result of the MP&M Phase I technology options, and included disposal of these sludges in the compliance cost estimates (see Section 12.0) and nonwater quality impact assessments (see Section 14.0).

7.12 Economic Impacts

EPA considered subcategorizing the MP&M Phase I category based on economic characteristics of MP&M Phase I sites. EPA evaluated economic data to determine if some groups of sites with common economic characteristics, such as revenue size, were in a better or worse financial condition than others. However, statistical analyses of the financial conditions of sites showed no significant pattern of variation across various possible subcategories.

The economic characteristics of any group of sites is likely to differ from any other group of sites. EPA used two statistical tools, linear regression and logistic regression, to determine if these differences were random differences due to the normal variations characteristic of all MP&M Phase I businesses, or whether these differences were systematically and predictably related to some shared economic characteristic.

These statistical tools were used to test for systematic variations in the financial condition and performance of sites grouped according to the following economic characteristics:

- Primary Line of Business: Sites were assigned to MP&M Phase I sectors according to the sector in which they earned most of their revenues. The financial condition and performance of sites across sectors did not vary in a statistically significant way.

- Customer Type: Sites indicated the percentage of revenues they earned from three customer types--government, domestic non-government, and foreign customers. When sites were grouped according to their dependence on each of these customer types, statistical analyses found no significant differences in the financial condition or performance of the various groups.

- MP&M Activity: Sites indicated the percentage of revenues they earned from each of three categories of activities--manufacturing, rebuilding, and maintenance. Financial condition and performance did not vary systematically with variations in dependence on the three activities.

- Revenue Size: Sites grouped by revenue size did not differ in financial condition or performance in a statistically significant way.

Appendix D of the economic profile document, Industry Profile for the Metal Products and Machinery Industry (Phase I), documents the methodology and findings in detail. This document is located in the administrative record for this rulemaking. Based on these analyses, EPA found no basis for subcategorizing the MP&M Phase I category based on economic characteristics.

Table 7-1

Metal Products and Machinery (MP&M) Sectors and Typical Products

Sector	Typical Products
Aircraft	Aircraft Aircraft engines and engine parts Aircraft parts and equipment
Aerospace	Guided missiles and space vehicles Guided missile and space vehicle propulsion Other space vehicle and missile parts
Electronic Equipment	Telephone and telegraph apparatus Radio and TV communications equipment Communications equipment Electronic tubes Electronic capacitors Electronic coils and transformers Connectors for electronic applications Electronic components Electric lamps
Hardware	Cutlery Hand and edge tools Hand saws and saw blades Screw machine products Bolts, nuts, screws, rivets, washers Metal shipping barrels, drums, kegs Iron and steel forgings Crowns and closures Metal stampings Steel springs Wire springs Miscellaneous fabricated wire products Fasteners, buttons, needles, pins Fluid power valves and hose fittings Valves and pipe fittings

Table 7-1 (Continued)

Metal Products and Machinery (MP&M) Sectors and Typical Products

Sector	Typical Products
Hardware (Continued)	Fabricated metal pipe and fittings Fabricated metal products Machine tools, metal cutting types Machine tools, metal forming types Special dies and tools, die sets, jigs Machine tool accessories and measuring devices Power-driven hand tools Heating equipment Industrial furnaces and ovens Fabricated structural metal Fabricated plate work Sheet metal work Architectural and ornamental metal work Prefabricated metal buildings and components
Mobile Industrial Equipment	Farm machinery and equipment Garden tractors and lawn and garden equipment Construction machinery and equipment Mining machinery and equipment Hoists, industrial cranes and monorails Industrial trucks, tractors and trailers Tanks and tank components
Ordnance	Small arms ammunition Ammunition Small arms Ordnance and accessories
Stationary Industrial Equipment	Steam, gas hydraulic turbines, generators Internal combustion engines Oil field machinery and equipment Elevators and moving stairways Conveyors and conveying equipment Industrial patterns Rolling mill machinery and equipment Metal working machinery Textile machinery Woodworking machinery Paper industries machinery Printing trades machinery and equipment

Table 7-1 (Continued)

Metal Products and Machinery (MP&M) Sectors and Typical Products

Sector	Typical Products
Stationary Industrial Equipment (Continued)	Food products machinery Special industry machinery Pumps and pumping equipment Ball and roller bearings Air and gas compressors Blowers and exhaust and ventilation fans Packaging machinery Speed changers, high-speed drivers and gears Industrial process furnaces and ovens Mechanical power transmission equipment General industrial machinery Automatic vending machines Commercial laundry equipment Refrigeration and air and heating equipment Measuring and dispensing pumps Service industry machines Fluid power cylinders and actuators Fluid power pumps and motors Scales and balances, except laboratory Industrial machinery Welding apparatus Transformers Switchgear and switchboard apparatus Motors and generators Relays and industrial controls Electric industrial apparatus Heavy construction equipment rental

Source: MP&M DCPs, MP&M site visits, technical literature.

8.0 SELECTION OF POLLUTANT PARAMETERS

The Agency conducted a study of MP&M wastewaters to determine the presence or absence of priority, conventional, and nonconventional pollutant parameters. Priority pollutant parameters are defined in Section 307(a)(1) of the Clean Water Act (CWA). The list of priority pollutant parameters, presented in Table 8-1, consists of 126 specific priority pollutants listed in 40 CFR Part 423, Appendix A. Section 301(b)(2) of the CWA obligates EPA to regulate priority pollutants if they are determined to be present at significant concentrations. Conventional pollutant parameters are defined in Section 304(a)(4) of the CWA and include biochemical oxygen demand, total suspended solids, oil and grease, pH, and fecal coliform. These pollutant parameters are subject to regulation as specified in Sections 304(b)(1)(A), 304(a)(4), 301(b)(2)(E), and 306 of the CWA. Nonconventional pollutant parameters are those that are neither priority nor conventional pollutant parameters. Sections 301(b)(2)(F) and 301(g) of the CWA give EPA the authority to regulate nonconventional pollutant parameters, as appropriate, based on technical and economic considerations.

The Agency considered 330 metal and organic pollutant parameters listed in The 1986 Industrial Technology Division List of Analytes (1) for potential regulation under MP&M Phase I. Samples collected during the MP&M sampling program were not analyzed for two pollutant parameters initially considered by the Agency for regulation: 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and asbestos. TCDD and asbestos are not expected to be present in MP&M wastewaters because they have not been found to be present in any of the raw materials used in MP&M processes, nor are they believed to be generated by any of the processes. The Agency also considered 15 conventional and other nonconventional pollutant parameters for potential regulation under MP&M. These 343 pollutant parameters for which the Agency analyzed are identified in Section 4.0.

The Agency did not consider biochemical oxygen demand (BOD_5) and fecal coliform for regulation under MP&M Phase I. These two pollutant parameters are not included in the 343 pollutant parameters discussed above. Biochemical oxygen demand, a measurement of the dissolved oxygen used by microorganisms to biodegrade organic matter under aerobic conditions, is a widely used measure of general organic pollution in wastewater. Though BOD_5 is a useful gross measure of organic pollution, it does not measure the concentrations of specific pollutant parameters. As discussed in Section 8.3, the Agency used oil and grease as a indicator for regulation of specific organic pollutants. The presence of fecal coliform bacteria, a microorganism that resides in the intestinal tract of humans or other warm-blooded animals, indicates that wastewater has been contaminated with feces from humans or other warm-blooded animals. EPA does not expect fecal coliform to be present in wastewaters from MP&M sites.

Section 8.1 discusses the criteria used to identify pollutant parameters of concern (i.e., considered for regulation) under MP&M Phase I; Section 8.2 presents the results of a

pass-through analysis used to select pollutant parameters considered for pretreatment standards; and Section 8.3 discusses the criteria used to select pollutant parameters for regulation.

8.1 Identification of Pollutant Parameters of Concern

Pollutant parameters of concern were identified using data from over 700 samples of wastewater from MP&M unit operations and influents to treatment collected during the MP&M sampling program described in Section 4.0. In assessing the 343 pollutant parameters, the Agency used criteria set forth in paragraph 8(a)(iii) of the Natural Resources Defense Council (NRDC) Consent Decree (2) for identifying pollutant parameters of concern.

Pollutant parameters that met any of the following criteria were excluded from consideration for regulation.

- The pollutant parameter was not detected in any sample collected during the MP&M sampling program.
- The pollutant parameter was detected in a small number of sources. For the MP&M program, "small" was defined as less than three samples collected during the MP&M sampling program.
- The average concentration of the pollutant parameter in samples of wastewater from MP&M unit operations and influents to chemical precipitation and sedimentation treatment was less than concentrations achievable by treatment. For the MP&M program, "concentration achievable by treatment" was defined as 0.1 mg/L. The average concentration was calculated assuming that nondetected pollutants were equal to the detection limit.
- The pollutant parameter was analyzed for screening purposes and was not analyzed for in a quantitative manner (i.e., analysis for the pollutant parameter was not subject to quality assurance/quality control (QA/QC) procedures).

Of the 343 pollutant parameters initially considered by the Agency for potential regulation under MP&M, 70 were identified as pollutant parameters of concern. The

other 273 pollutant parameters were not identified as pollutant parameters of concern for the following reasons:

- One-hundred and seventy (170) pollutant parameters were not detected in samples of wastewater from MP&M unit operations and influents to treatment. These pollutant parameters are listed in Table 8-2.

- Fifty-two (52) of the remaining pollutant parameters were detected in less than three samples collected during the MP&M sampling program. These pollutant parameters are listed in Table 8-3.

- Nine (9) of the remaining pollutant parameters were detected at average concentrations that were less than 0.1 mg/L. These pollutant parameters are listed in Table 8-4.

- Forty-two (42) metal pollutants were not analyzed for in a quantitative manner. Analysis for these parameters was not subject to the QA/QC procedures required by analytical Method 1620. These metal pollutant analyses were used for screening purposes and, based on the screening results, were not considered for regulation. These pollutants are listed in Table 4-2.

The pollutant parameters identified as pollutant parameters of concern include 25 priority pollutant parameters (13 priority organic pollutants, 11 priority metal pollutants, and cyanide), 3 conventional pollutant parameters, and 42 nonconventional pollutant parameters (18 organic pollutants, 13 metal pollutants, and 11 other nonconventional pollutant parameters). These pollutant parameters, along with the number of times each pollutant parameter was analyzed and detected, and the corresponding mean concentration (excluding nondetected pollutants), are shown in Table 8-5.

8.2 Pass-Through Analysis for Indirect Dischargers

Section 307(b) of the CWA requires the Agency to promulgate pretreatment standards for existing sources (PSES) and new sources (PSNS). Pretreatment standards are established to ensure removal of pollutants which pass through publicly owned treatment works (POTWs). The Agency evaluated POTW pass-through for the MP&M pollutant parameters of concern, listed in Table 8-5. In determining whether a pollutant is expected to pass through a POTW, the Agency compared the nation-wide average percentage of a pollutant removed by well-operated POTWs performing secondary treatment to the percentage removed by BAT treatment systems. Pollutants are considered to pass through POTWs if the average percentage removed by BAT

treatment systems is greater than the average percentage removed by well-operated POTWs.

The Agency calculated the percentage of a pollutant removed by BAT treatment systems using the data collected to develop long-term average technology effectiveness concentrations for MP&M treatment systems. These data are discussed in Section 11.0. The nation-wide average pollutant removals by well-operated POTWs performing secondary treatment were obtained from the Fate of Priority Pollutants in Publicly Owned Treatment Works (3), referred to as the 50-POTW Study, and the Risk Reduction Engineering Laboratory (RREL) treatability database Release 4.0, developed by EPA's Office of Research and Development.

Table 8-6 presents, for each MP&M pollutant parameter of concern, the BAT percentage removal and the average POTW percent removal, and identifies which pollutants were determined to pass through POTWs. As discussed further in Section 10.0, the Agency believes that the primary mechanism for removal of organic pollutants in MP&M wastewaters is oil/water separation. Therefore, the BAT percentage removals for organic pollutants presented in Table 8-6 are based on removals by oil/water separation units.

The Agency determined that, for 19 MP&M pollutants of concern, the BAT percentage removal is greater than the POTW percentage amounts; therefore, these pollutants are considered to pass through POTWs.

8.3 Pollutant Parameters Selected for Regulation

This section presents the pollutant parameters selected for limitation in the MP&M Phase I category. These parameters were chosen from the list of 70 MP&M pollutant parameters of concern discussed above. Although all 70 MP&M pollutant parameters of concern were used to estimate compliance costs, pollutant loadings, and pollutant reductions, only certain parameters were selected for limitation. The following discussion provides EPA's rationale for the selection and exclusion of individual pollutant parameters of concern.

The selection of pollutant parameters for regulation was based on sampling analysis data and on information gathered in the DCPs and site visits. The sampling analysis data, DCP data, and site visit information are all discussed in Section 4.0. In order to select the pollutant parameters for regulation, the pollutant parameters of concern were first grouped into seven categories: priority organic pollutants, nonconventional organic pollutants, priority metal pollutants, nonconventional metal pollutants, cyanide, conventional pollutant parameters, and other nonconventional pollutant parameters. These categories and the pollutant parameters within them are presented in Table 8-5. The selection of parameters from each of these groups is presented below.

8.3.1 Priority and Nonconventional Organic Pollutants

As discussed in Section 8.1, the list of MP&M pollutant parameters of concern includes 13 priority organic pollutants and 18 nonconventional organic pollutants. A number of different organic constituents are used in MP&M operations, but organic constituents are infrequently detected in MP&M wastewater treatment influent streams. As shown in Table 6-12, only ten of the 84 priority organic pollutants were detected in MP&M wastewater treatment influent streams, and only 20 of the 149 nonconventional organic pollutants were detected. The majority of the detected organic pollutants were detected in fewer than three samples. The types of organic constituents used in MP&M operations continues to expand as MP&M sites respond to the changing manufacturing climate. For example, due to the phase-out of certain chlorinated compounds under the Montreal Protocol and under other air pollution control requirements, many MP&M sites are in the process of switching to alternate solvents.

Organic pollutants are used in several MP&M unit operations, as shown by the analytical data collected at MP&M sites, data contained in the MP&M DCPs, and technical literature. However, as discussed above, organic pollutants are infrequently detected in MP&M Phase I wastewater treatment influent streams. The unit operations generating organic pollutant-bearing wastewaters typically generate less wastewater than other operations at MP&M sites. Therefore, the organic pollutants from these operations are diluted after commingling with other MP&M process wastewaters. When organic pollutants are detected in the wastewater treatment influent streams, they are usually present at concentrations of less than 0.1 milligrams per liter (see Table 6-12).

EPA considered setting limitations for specific organic pollutants of concern but decided against this approach for the following reasons: a wide variety of organic pollutants are in use at MP&M sites; organic pollutants are typically not detected or detected at low concentrations in raw wastewater from MP&M sites; and, MP&M sites are continuing to switch to alternate solvents in response to the changing manufacturing climate.

EPA considered establishing limitations for Total Toxic Organics (TTO), which would reflect the sum of concentrations achieved for several specific organic pollutants identified during the MP&M sampling program. However, because of the diversity in the types of cleaners, coolants, paints, and other organic pollutant-bearing solutions used in the MP&M industry, as well as the current industry trends in identifying substitutes for organic solvent degreasing, EPA did not have sufficient analytical data to identify and regulate all organic pollutants in use at MP&M sites. Therefore, EPA rejected TTO as an approach to controlling organic pollutant discharges.

After considering and rejecting the two alternatives discussed above, EPA is proposing to use oil and grease as an indicator for monitoring for organic pollutants that have the potential to be present in MP&M wastewaters. EPA is using oil and grease as an indicator since most of the organic pollutants detected in MP&M wastewaters during the

MP&M sampling program are more soluble in oil than in water, and as such would partition to the oil layer. Thus, removal of oil and grease will result in significant removal of these pollutants. Data for oil-water separation systems collected during the MP&M sampling program show removals between 63 and 90 percent for organic pollutants across the oil-water separation systems. These data support the conclusion that the organic pollutants will partition to the oil layer. In addition, most of the organic pollutants detected in MP&M wastewaters are insoluble in water, further supporting that these pollutants will partition to the oil layer.

EPA believes that the use of oil and grease as an indicator will provide regulatory control of organic pollutants while allowing the flexibility to control organic pollutants used at MP&M Phase I sites but not identified during the MP&M sampling program.

8.3.2 Priority Metal Pollutants

As discussed in Section 8.1, the list of MP&M pollutant parameters of concern includes 11 priority metal pollutants. Of these metals, cadmium, chromium, copper, nickel, and zinc were found at significant concentrations in the raw wastewater. These metals are commonly used in the MP&M category. As a result, cadmium, chromium, copper, nickel and zinc were selected as pollutant parameters for regulation.

The six other priority metal pollutants on the list of MP&M pollutant parameters of concern were antimony, arsenic, lead, selenium, silver and thallium. Although these metal pollutants were analyzed for in nearly all samples collected during the development of the proposed MP&M Phase I rule, they were rarely detected at treatable concentrations (i.e., 0.1 milligrams per liter) in the influent to the treatment systems sampled. As shown in Table 6-12, the median detected concentrations for all these pollutants except lead was less than 0.1 milligrams per liter. EPA considered establishing limitations for lead, since lead is known to have several adverse human health effects. However, lead was not detected in 35 of the 62 wastewater treatment samples, and the median detected concentration in the influent to the treatment systems was 0.251 milligrams per liter. Since these six metal pollutants were rarely found at treatable concentrations in the raw wastewater prior to treatment, EPA did not include them on the list of pollutant parameters for regulation.

8.3.3 Nonconventional Metal Pollutants

As discussed in Section 8.1, the list of MP&M pollutant parameters of concern includes 13 nonconventional metal pollutants. Because EPA did not have sufficient data to set limits for all of these metal types, EPA is proposing to regulate aluminum and iron as indicator metals for removal of non-regulated metal pollutants that may be processed at MP&M sites. Aluminum is most effectively removed in chemical precipitation and sedimentation systems at a pH between 7.5 and 8 standard units, while iron is most effectively removed at a pH of approximately 10.5 standard units. Most metal pollutants

that may be present in MP&M wastewaters are effectively removed in this pH range. Therefore, removal of aluminum and iron will indicate effective removal of other metal pollutants. Although iron and aluminum can be used as water treatment chemicals, EPA believes that regulation of these pollutants will control discharges of non-regulated metals that are processed at MP&M sites. Furthermore, control of aluminum and iron to the appropriate concentrations, especially when used as treatment chemicals, would ensure optimal operation of the wastewater treatment system.

The other 11 nonconventional metal pollutants were analyzed for in nearly all samples collected during the development of the MP&M Phase I rule. Of these, barium, cobalt, molybdenum, titanium, and vanadium were detected in wastewater treatment influent streams at median concentrations less than 0.1 milligrams per liter (see Table 6-12). EPA believes that the discharge of the other six pollutants will be adequately controlled by regulating aluminum and iron.

Cyanide

As discussed in Section 8.1, the list of MP&M pollutant parameters of concern includes the priority pollutant cyanide. Cyanide is commonly used in the unit operations performed at MP&M sites. Therefore, cyanide was also selected for regulation.

Conventional Pollutant Parameters

As discussed in Section 8.1, the list of MP&M pollutant parameters of concern includes three conventional pollutants: oil and grease, pH, and total suspended solids. EPA is proposing to regulate all three of these conventional parameters, as discussed below.

Oil and grease can cause odor and taste problems with water and kill aquatic organisms. Also, as discussed above, organic pollutants found in the MP&M category are more likely to partition to the oil layer then to the water layer. Oil and grease is a significant pollutant parameter in the MP&M category. Therefore, EPA is proposing to regulate oil and grease as a conventional pollutant parameter in addition to regulating oil and grease as an indicator for organics (as discussed above).

EPA is proposing a pH range limit in order to assure that the pH of the wastewater discharged from MP&M Phase I sites is within the neutral range.

Total suspended solids (TSS) can serve to control the discharge of harmful pollutants. TSS is a particularly important parameter when using chemical precipitation and sedimentation systems, since the metal pollutants are removed as precipitated metal hydroxides. Solids that remain in suspension can contain high concentrations of these metal hydroxides. EPA is proposing to include TSS as a regulated parameter.

Other Nonconventional Pollutant Parameters

As discussed in Section 8.1, the list of MP&M pollutant parameters of concern includes 11 other nonconventional pollutants. These parameters were analyzed for in nearly all samples collected during the development of the MP&M Phase I rule as a qualitative means of determining the performance of the treatment systems. EPA has used these data to understand the performance of the treatment systems sampled, but EPA does not propose to include any of these other nonconventionals on the list of parameters for regulation.

Table 8-1

Priority Pollutant List(a)

1	Acenaphthene
2	Acrolein
3	Acrylonitrile
4	Benzene
5	Benzidine
6	Carbon Tetrachloride (Tetrachloromethane)
7	Chlorobenzene
8	1,2,4-Trichlorobenzene
9	Hexachlorobenzene
10	1,2-Dichloroethane
11	1,1,1-Trichloroethane
12	Hexachloroethane
13	1,1-Dichloroethane
14	1,1,2-Trichloroethane
15	1,1,2,2-Tetrachloroethane
16	Chloroethane
17	Removed
18	Bis(2-chloroethyl) Ether
19	2-Chloroethyl Vinyl Ether (mixed)
20	2-Chloronaphthalene
21	2,4,6-Trichlorophenol
22	Parachlorometa Cresol (4-Chloro-3-Methylphenol)
23	Chloroform (Trichloromethane)
24	2-Chlorophenol
25	1,2-Dichlorobenzene
26	1,3-Dichlorobenzene
27	1,4-Dichlorobenzene
28	3,3'-Dichlorobenzidine
29	1,1-Dichloroethene
30	1,2-Trans-Dichloroethene
31	2,4-Dichlorophenol
32	1,2-Dichloropropane
33	1,3-Dichloropropylene (Trans-1,3-Dichloropropene)
34	2,4-Dimethylphenol
35	2,4-Dinitrotoluene
36	2,6-Dinitrotoluene
37	1,2-Diphenylhydrazine
38	Ethylbenzene
39	Fluoranthene
40	4-Chlorophenyl Phenyl Ether
41	4-Bromophenyl Phenyl Ether
42	Bis(2-Chloroisopropyl) Ether
43	Bis(2-Chloroethoxy) Methane
44	Methylene Chloride (Dichloromethane)
45	Methyl Chloride (Chloromethane)
46	Methyl Bromide (Bromomethane)
47	Bromoform (Tribromomethane)
48	Dichlorobromomethane (Bromodichloromethane)
49	Removed
50	Removed
51	Chlorodibromomethane (Dibromochloromethane)
52	Hexachlorobutadiene
53	Hexachlorocyclopentadiene
54	Isophorone
55	Naphthalene
56	Nitrobenzene
57	2-Nitrophenol
58	4-Nitrophenol
59	2,4-Dinitrophenol
60	4,6-Dinitro-o-Cresol (Phenol, 2-methyl-4,6-dinitro)
61	N-Nitrosodimethylamine
62	N-Nitrosodiphenylamine
63	N-Nitrosodi-n-propylamine (Di-n-propylnitrosamine)
64	Pentachlorophenol
65	Phenol
66	Bis(2-ethylhexyl) Phthalate
67	Butyl Benzyl Phthalate
68	Di-n-butyl Phthalate
69	Di-n-octyl Phthalate
70	Diethyl Phthalate
71	Dimethyl Phthalate
72	Benzo(a)anthracene (1,2-Benzanthracene)
73	Benzo(a)pyrene (3,4-Benzopyrene)
74	Benzo(b)fluoranthene (3,4-Benzo fluoranthene)
75	Benzo(k)fluoranthene (11,12-Benzofluoranthene)
76	Chrysene
77	Acenaphthylene
78	Anthracene
79	Benzo(ghi)perylene (1,12-Benzoperylene)
80	Fluorene
81	Phenanthrene
82	Dibenzo(a,h)anthracene (1,2,5,6-Dibenzanthracene)
83	Indeno(1,2,3-cd)pyrene (2,3-o-Phenylenepyrene)
84	Pyrene
85	Tetrachloroethylene (Tetrachloroethene)
86	Toluene
87	Trichloroethylene (Trichloroethene)
88	Vinyl Chloride (Chloroethylene)
89	Aldrin
90	Dieldrin
91	Chlordane (Technical Mixture & Metabolites)
92	4,4'-DDT (p,p'-DDT)
93	4,4'-DDE (p,p'-DDX)
94	4,4'-DDD (p,p'-TDE)
95	Alpha-endosulfan
96	Beta-endosulfan
97	Endosulfan Sulfate
98	Endrin
99	Endrin Aldehyde
100	Heptachlor
101	Heptachlor Epoxide
102	Alpha-BHC
103	Beta-BHC
104	Gamma-BHC (Lindane)
105	Delta-BHC
106	PCB-1242 (Arochlor 1242)
107	PCB-1254 (Arochlor 1254)
108	PCB-1221 (Arochlor 1221)
109	PCB-1232 (Arochlor 1232)
110	PCB-1248 (Arochlor 1248)
111	PCB-1260 (Arochlor 1260)
112	PCB-1016 (Arochlor 1016)
113	Toxaphene
114	Antimony (total)
115	Arsenic (total)
116	Asbestos (fibrous)
117	Beryllium (total)
118	Cadmium (total)
119	Chromium (total)
120	Copper (total)
121	Cyanide (total)
122	Lead (total)
123	Mercury (total)
124	Nickel (total)
125	Selenium (total)
126	Silver (total)
127	Thallium (total)
128	Zinc (total)
129	2,3,7,8-Tetrachlorodibenzo-p-Dioxin

Source: Clean Water Act

(a)Priority pollutants are numbered 1 through 129 but include 126 pollutants since EPA removed three pollutants from the list (Numbers 17, 49, and 50).

Table 8-2

Pollutant Parameters Not Detected in Samples Collected During the MP&M Sampling Program

Priority Pollutant Parameters	
3 Acrylonitrile	72 Benzo(a)anthracene
5 Benzidine	74 Benzo(b)fluoranthene
6 Tetrachloromethane	75 Benzo(k)fluoranthene
8 1,2,4-Trichlorobenzene	76 Chrysene
9 Hexachlorobenzene	77 Acenaphthylene
12 Hexachloroethane	83 Indeno(1,2,3-cd)pyrene
14 1,1,2-Trichloroethane	88 Vinyl Chloride
16 Chloroethane	89 Aldrin
18 Bis(2-chloroethyl)ether	90 Dieldrin
21 2,4,6-Trichlorophenol	91 Chlordane
26 1,3-Dichlorobenzene	92 4,4'-DDT
28 3,3'-Dichlorobenzidine	93 4,4'-DDE
31 2,4-Dichlorophenol	94 4,4'-DDD
32 1,2-Dichloropropane	95 Alpha-endosulfan
33 trans-1,3-Dichloropropene	96 Beta-endosulfan
37 1,2-Diphenylhydrazine	97 Endosulfan Sulfate
39 Fluoranthene	98 Endrin
40 4-Chlorophenyl Phenyl Ether	99 Endrin Aldehyde
41 4-Bromophenyl Phenyl Ether	100 Heptachlor
43 Bis(2-chloroethoxy)methane	101 Heptachlor Epoxide
45 Chloromethane	102 Alpha-BHC
46 Bromomethane	103 Beta-BHC
47 Tribromomethane	104 Gamma-BHC
51 Dibromochloromethane	105 Delta-BHC
52 Hexachlorobutadiene	106 PCB-1242
53 Hexachlorocyclopentadiene	107 PCB-1254
54 Isophorone	108 PCB-1221
60 Phenol, 2-Methyl-4,6-Dinitro-	109 PCB-1232
62 N-Nitrosodiphenylamine	110 PCB-1248
63 Di-n-propylnitrosamine	111 PCB-1260
64 Pentachlorophenol	112 PCB-1016
69 Di-n-octyl Phthalate	113 Toxaphene
70 Diethyl Phthalate	

Table 8-2 (Continued)

Pollutant Parameters Not Detected in Samples Collected During the MP&M Sampling Program

Nonconventional Pollutant Parameters	
Aniline, 2,4,5-Trimethyl-	Squalene
Aramite	Thianaphthene
Benzanthrone	Thioacetamide
Benzenethiol	Thioxanthe-9-one
Benzonitrile, 3,5-Dibromo-4-Hydroxy-	Toluene, 2,4-Diamino-
Beta-Naphthylamine	trans-1,4-Dichloro-2-Butene
Biphenyl, 4-Nitro	Triphenylene
Carbazole	Vinyl Acetate
Chloroacetonitrile	1-Bromo-2-Chlorobenzene
Ciodrin	1-Bromo-3-Chlorobenzene
cis-1,3-Dichloropropene	1-Chloro-3-Nitrobenzene
Crotonaldehyde	1-Naphthylamine
Crotoxyphos	1-Phenylnaphthalene
Dibenzothiophene	1,1,1,2-Tetrachloroethane
Dibromomethane	1,2-Dibromo-3-Chloropropane
Dimethyl Sulfone	1,2-Dibromoethane
Diphenylamine	1,2,3-Trichlorobenzene
Diphenyl Ether	1,2,3-Trichloropropane
Diphenyldisulfide	1,2,3-Trimethoxybenzene
Ethyl Cyanide	1,2,4,5-Tetrachlorobenzene
Ethyl Methacrylate	1,3-Butadiene, 2-Chloro-
Ethyl Methanesulfonate	1,3-Dichloropropane
Ethylenethiourea	1,3-Dichloro-2-Propanol
Hexachloropropene	1,3,5-Trithiane
Iodomethane	1,4-Naphthoquinone
Isosafrole	1,5-Naphthalenediamine
Longifolene	2-(Methylthio)Benzothiazole
m-Xylene	2-Isopropylnaphthalene
Malachite Green	2-Methylbenzothioazole
Mestranol	2-Phenylnaphthalene
Methapyrilene	2-Picoline
Methyl Methacrylate	2-Propen-1-ol
Methyl Methanesulfonate	2-Propenenitrile, 2-Methyl-
N-Nitrosodi-n-butylamine	2,3-Benzofluorene
N-Nitrosodiethylamine	2,3-Dichloroaniline
N-Nitrosomethylethylamine	2,3-Dichloronitrobenzene
N-Nitrosmethylphenylamine	2,3,4,6-Tetrachlorophenol
N-Nitrosomorpholine	2,3,6-Trichlorophenol
N-Nitrosopiperidine	2,6-Di-Tert-Butyl-p-Benzoquinone
o-Anisidine	2,6-Dichloro-4-Nitroaniline
o-Toluidine	2,6-Dichlorophenol
o-Toluidine, 5-Chloro-	3-Chloropropene
p-Chloroaniline	3-Methylcholanthrene
p-Dimethylaminoazobenzene	3-Nitroaniline
Pentachlorobenzene	3,3'-Dimethoxybenzidine
Pentachloroethane	3,6-Dimethylphenanthrene
Perylene	4-Aminobiphenyl
Phenacetin	4-Chloro-2-Nitroaniline
Phenothiazine	4,4'-Methylenebis(2-Chloroaniline)
Pronamide	4,5-Methylene Phenanthrene
Pyridine	5-Nitro-o-toluidine
Resorcinol	7,12-Dimethylbenz(a)anthracene
Safrole	

Source: MP&M Phase I Sampling Data

Table 8-3

Pollutant Parameters Detected in Less Than Three Samples During the MP&M Sampling Program

Priority Pollutant Parameters	
1 Acenaphthene	36 2,6-Dinitrotoluene
2 Acrolein (2-Propenal)	42 Bis(2-Chloroisopropyl) Ether
4 Benzene	56 Nitrobenzene
7 Chlorobenzene	58 4-Nitrophenol
10 1,2-Dichloroethane	59 2,4-Dinitrophenol
15 1,1,2,2-Tetrachloroethane	61 N-Nitrosodimethylamine
19 2-Chloroethyl Vinyl Ether	67 Butyl Benzyl Phthalate
20 2-Chloronaphthalene	71 Dimethyl Phthalate
24 2-Chlorophenol	73 Benzo(a)pyrene
25 1,2-Dichlorobenzene	78 Anthracene
27 1,4-Dichlorobenzene	79 Benzo(ghi)perylene
29 1,1-Dichloroethene	80 Fluorene
30 trans-1,2-Dichloroethene	82 Dibenzo(a,h)anthracene
34 2,4-Dimethylphenol	84 Pyrene
35 2,4-Dinitrotoluene	87 Trichloroethene
Nonconventional Pollutant Parameters	
Acetophenone	p-Nitroaniline
Aniline	Pentamethylbenzene
Biphenyl	Styrene
Carbon Disulfide	Tripropyleneglycol methyl ether
Dibenzofuran	1,2:3,4-Diepoxybutane
Diethyl Ether	1,4-Dinitrobenzene
N,N-Dimethylformamide	1,4-Dioxane
o+p-Xylene	2-Hexanone
o-Cresol	2-Nitroaniline
p-Cresol	2,4,5-Trichlorophenol
p-Cymene	4-Methyl-2-pentanone

Source: MP&M Phase I Sampling Data

Table 8-4

Pollutant Parameters Measured at Average Concentrations Less Than 0.1 mg/L During the MP&M Sampling Program

Priority Pollutant Parameters	Nonconventional Pollutant Parameters
23 Chloroform	Isobutyl Alcohol
48 Bromodichloromethane	Trichlorofluoromethane (formerly priority pollutant number 49)
117 Beryllium	Yttrium
123 Mercury	1-Methylfluorene
	1-Methylphenanthrene

Source: MP&M Phase I Sampling Data

Table 8-5

Pollutant Parameters Selected for Further Consideration Under MP&M Phase I

Pollutant Parameter	Number of Times Analyzed	Number of Times Detected	Average Concentration in Samples From Unit Operations and Treatment Influents (mg/L)
Priority Pollutant Parameters			
11 1,1,1-Trichloroethane	55	22	9.88
13 1,1-Dichloroethane	49	8	0.45
22 4-Chloro-3-methylphenol	39	7	171.23
38 Ethylbenzene	46	5	8.27
44 Methylene chloride	87	53	497.80
55 Naphthalene	51	14	3.33
57 2-Nitrophenol	40	4	4.20
65 Phenol	71	37	14.74
66 Bis(2-ethylhexyl) phthalate	45	16	13.18
68 Di-n-butyl phthalate	41	3	1.23
81 Phenanthrene	41	7	1.07
85 Tetrachloroethene	46	9	54.80
86 Toluene	48	14	0.35
114 Antimony	733	299	7.70
115 Arsenic	745	358	0.24
118 Cadmium	745	514	156.51
119 Chromium	745	643	1,285.76
120 Copper	745	698	330.83
121 Cyanide	190	169	2,355.01
122 Lead	745	425	62.65
124 Nickel	733	620	385.97
125 Selenium (a)	709	234	0.086
126 Silver	723	420	0.22
127 Thallium	711	213	0.11
128 Zinc	722	653	134.28

(a)Selenium was detected in many of the MP&M unit operations at concentrations greater than 0.1 mg/L, and was therefore considered for regulation.
NA - Not applicable.

Table 8-5 (Continued)

Pollutant Parameters Selected for Further Consideration Under MP&M Phase I

Pollutant Parameter	Number of Times Analyzed	Number of Times Detected	Average Concentration in Samples From Unit Operations and Treatment Influents (mg/L)
Conventional Pollutant Parameters			
Oil and Grease	609	527	5,937.42
pH	289	289	NA
Total Suspended Solids	605	540	957.24
Nonconventional Organic Pollutant Parameters			
Alpha-terpineol	29	12	13.64
Benzoic acid	43	13	59.21
Benzyl alcohol	38	6	6.42
Hexanoic acid	38	9	7.71
N-Decane	41	10	6.73
N-Docosane	41	9	38.34
N-Dodecane	44	20	103.77
N-Eicosane	45	15	30.33
N-Hexacosane	41	10	41.67
N-Hexadecane	44	21	36.39
N-Octacosane	40	6	30.429
N-Octadecane	43	15	97.68
N-Tetracosane	39	7	45.27
N-Tetradecane	44	18	56.66
N-Triacontane	41	7	16.25
2-Butanone	56	21	11.09
2-Methylnaphthalene	41	8	9.11
2-Propanone	42	27	1.50
Nonconventional Metal Pollutant Parameters			
Aluminum	723	578	249.30
Barium	730	596	4.65
Boron	745	671	54.16

(a)Selenium was detected in many of the MP&M unit operations at concentrations greater than 0.1 mg/L, and was therefore considered for regulation.
NA - Not applicable.

Table 8-5 (Continued)

Pollutant Parameters Selected for Further Consideration Under MP&M Phase I

Pollutant Parameter	Number of Times Analyzed	Number of Times Detected	Average Concentration in Samples From Unit Operations and Treatment Influents (mg/L)
Nonconventional Metal Pollutant Parameters (Continued)			
Calcium	742	722	64.96
Cobalt	748	376	2.69
Iron	744	700	1,080.34
Magnesium	745	655	31.43
Manganese	745	645	16.02
Molybdenum	745	451	5.70
Sodium	742	735	4,150.37
Tin	741	364	69.70
Titanium	734	449	79.91
Vanadium	734	340	9.854
Other Nonconventional Pollutant Parameters			
Acidity	446	357	22,543.03
Ammonia as Nitrogen	306	279	366.99
Chemical Oxygen Demand (COD)	278	251	9,533.41
Chloride	489	440	5,646.01
Fluoride	488	456	380.66
Sulfate	484	455	8,111.44
Total Alkalinity	386	320	17,239.12
Total Dissolved Solids	601	597	29,448.55
Total Kjeldahl Nitrogen	323	309	487.53
Total Phosphorus	268	243	112.68
Total Recoverable Phenolics	226	148	1.55

Source: MP&M Phase I Sampling Data

Table 8-6

Summary of MP&M POTW Pass-Through Analysis

Pollutant Parameter(a)	BAT Percent Removal	POTW Percent Removal	Passes Through? (Yes/No)
Priority Pollutant Parameters			
11 1,1,1-Trichloroethane	NA	90	NA
13 1,1-Dichloroethane	NA	70	NA
22 4-Chloro-3-methylphenol	NA	63	NA
38 Ethylbenzene	NA	94	NA
44 Methylene chloride	NA	54	NA
55 Naphthalene	NA	95	NA
57 2-Nitrophenol	NA	27	NA
65 Phenol	23	95	**No**
66 Bis(2-ethylhexyl) phthalate	NA	60	NA
68 Di-n-butyl phthalate	17	79	**No**
81 Phenanthrene	NA	95	NA
85 Tetrachloroethene	NA	85	NA
86 Toluene	NA	96	NA
114 Antimony	NA	71	NA
115 Arsenic	NA	91	NA
118 Cadmium	97	90	**Yes**
119 Chromium	99	91	**Yes**
120 Copper	95	84	**Yes**
121 Cyanide	>99	70	**Yes**
122 Lead	96	92	**Yes**
124 Nickel	98	51	**Yes**
125 Selenium	NA	34	NA
126 Silver	99	92	**Yes**
127 Thallium	NA	54	NA
128 Zinc	98	78	**Yes**

NA - Not applicable. Sufficient data not available to calculate BAT percent removal and to assess pass-through.
(a)Calcium, magnesium, and sodium are not presented in this table because these are typical wastewater treatment chemicals at MP&M sites. Additionally, pH and total alkalinity are not presented because these are used as performance parameters for chemical precipitation and sedimentation systems.
(b)Oil and grease is proposed for regulation as an indicator parameter for organic pollutants for pretreatment standards.

Table 8-6 (Continued)

Summary of MP&M POTW Pass-Through Analysis

Pollutant Parameter(a)	BAT Percent Removal	POTW Percent Removal	Passes Through? (Yes/No)
Conventional Pollutant Parameters			
Oil and Grease (b)	62	97	**No**
Nonconventional Organic Pollutant Parameters			
Alpha-terpineol	NA	95	NA
Benzoic acid	NA	81	NA
Benzyl alcohol	NA	78	NA
Hexanoic acid	NA	84	NA
N-Decane	NA	9	NA
N-Docosane	NA	88	NA
N-Dodecane	79	95	**No**
N-Eicosane	NA	92	NA
N-Hexacosane	70	71	**No**
N-Hexadecane	70	71	**No**
N-Octacosane	NA	71	NA
N-Octadecane	73	71	**Yes**
N-Tetracosane	NA	71	NA
N-Tetradecane	90	71	**Yes**
N-Triacontane	NA	71	NA
2-Butanone	NA	92	NA
2-Methylnaphthalene	63	28	**Yes**
2-Propanone	90	84	**Yes**

NA - Not applicable. Sufficient data not available to calculate BAT percent removal and to assess pass-through.
(a)Calcium, magnesium, and sodium are not presented in this table because these are typical wastewater treatment chemicals at MP&M sites. Additionally, pH and total alkalinity are not presented because these are used as performance parameters for chemical precipitation and sedimentation systems.
(b)Oil and grease is proposed for regulation as an indicator parameter for organic pollutants for pretreatment standards.

Table 8-6 (Continued)

Summary of MP&M POTW Pass-Through Analysis

Pollutant Parameter(a)	BAT Percent Removal	POTW Percent Removal	Passes Through? (Yes/No)
Nonconventional Metal Pollutant Parameters			
Aluminum	94	17	**Yes**
Barium	NA	90	NA
Boron	NA	70	NA
Cobalt	>99	5	**Yes**
Iron	97	83	**Yes**
Manganese	98	41	**Yes**
Molybdenum	NA	52	NA
Tin	NA	65	NA
Titanium	98	69	**Yes**
Vanadium	NA	42	NA
Other Nonconventional Pollutant Parameters			
Ammonia as Nitrogen	NA	8	NA
Chemical Oxygen Demand (COD)	51	3	**Yes**
Chloride	NA	NA	NA
Fluoride	NA	61	NA
Sulfate	NA	NA	NA
Total Dissolved Solids	NA	NA	NA
Total Kjeldahl Nitrogen	NA	NA	NA
Total Phosphorus	92	NA	NA
Total Recoverable Phenolics	NA	NA	NA

Source: MP&M Phase I Sampling Data

NA - Not applicable. Sufficient data not available to calculate BAT percent removal and to assess pass-through.
(a)Calcium, magnesium, and sodium are not presented in this table because these are typical wastewater treatment chemicals at MP&M sites. Additionally, pH and total alkalinity are not presented because these are used as performance parameters for chemical precipitation and sedimentation systems.
(b)Oil and grease is proposed for regulation as an indicator parameter for organic pollutants for pretreatment standards.

8.4 References

1. The 1986 Industrial Technology Division List of Analytes, Revision A, U.S. Environmental Protection Agency, Washington, D.C., April 1986.

2. Natural Resources Defense Council, Inc. vs. Train, 8 ERC 2120 (D.D.C. 1976), modified 12 ERC 1833 (D.D.C. 1979).

3. Fate of Priority Pollutants in Publicly Owned Treatment Works, EPA-440/1-82/303, U.S. Environmental Protection Agency, Washington D.C., September, 1982.

9.0 SOURCE REDUCTION AND RECYCLING

This section presents an overview of source reduction and recycling in the MP&M industry. The applications and descriptions presented in this section are from the following sources: reports prepared by EPA based on visits at MP&M sites; case studies prepared by MP&M sites; and pollution prevention studies conducted by EPA, state and local agencies, and MP&M sites. For a list of current EPA research projects pertaining to source reduction and recycling technologies applicable to the MP&M industry, contact:

Pollution Prevention Research Branch
U.S. Environmental Protection Agency
Risk Reduction Engineering Laboratory
26 W. Martin Luther King Drive (MS-466)
Cincinnati, Ohio 45268
(513) 569-7215
(513) 569-7111 (fax)

Source reduction and recycling techniques have been demonstrated at MP&M sites to both reduce the discharge of pollutants and potentially reduce process and treatment costs. This section has been prepared as a means of transferring information to MP&M site personnel and local regulators concerning source reduction and recycling opportunities available for MP&M wastes. As mentioned above, this section contains information submitted and gathered from sources outside the Agency. EPA has not independently confirmed the information from outside sources and makes no claims as to the validity of the data from outside sources. References have been provided so that the reader can gather more information directly from the sources.

The Agency recognizes that not all of the source reduction and recycling techniques discussed in this section are applicable to all MP&M sites, and therefore may not be applicable for development of national effluent limitations guidelines and standards. Furthermore, specific performance requirements may preclude the implementation of many materials substitution practices. As such, the technologies and practices discussed in this section should be viewed as optional or voluntary practices sites can use to reduce pollutant generation. The source reduction and recycling techniques further considered in development of the MP&M effluent limitations guidelines and standards are discussed in Section 10.0.

Section 9.1 describes the categories of source reduction and recycling techniques and Section 9.2 presents examples of source reduction and recycling techniques used at MP&M sites, including summaries of costs and benefits where available. References are listed at the end of this section.

9.1 Categories of Source Reduction and Recycling Techniques

For the purpose of this section, techniques used in the MP&M industry for source reduction and recycling have been grouped into the following categories.

- Training and Supervision: Ensuring that employees are aware of, understand, and support the company's source reduction and recycling goals; translating these goals into practical information that will enable employees to minimize waste generation through the proper and efficient use of tools, supplies, equipment, and materials.

- Production Planning and Sequencing: Planning and sequencing production to minimize the number of steps and eliminate unnecessary procedures (e.g., plan production to eliminate additional cleaning steps between other operations).

- Process or Equipment Modification: Modifying the process or equipment to minimize the amount of waste generated (e.g., reducing drag-out by slowing the withdrawal speed of parts from electroplating baths, installing electrolytic recovery units to extend the life of electroplating baths, installing oil skimming units on machining sumps to extend coolant life).

- Raw Material and Product Substitution or Elimination: Replacing existing raw materials or products with other materials that produce either less waste and/or less toxic waste (e.g., replacing chromium-bearing solutions with nonchromium-bearing and less toxic solutions, consolidating types of cleaning solutions and machining coolants).

- Loss Prevention and Housekeeping: Performing preventive maintenance and managing equipment and materials to minimize leaks, spills, evaporative losses, and other releases (e.g., installing drip pans to capture process solution for reuse; inspecting the integrity of tanks on a regular basis; using chemical analyses instead of elapsed time or number of parts processed as the basis for disposal of a solution).

- Waste Segregation and Separation: Avoiding mixing different types of wastes and avoiding mixing hazardous wastes with nonhazardous wastes; avoiding mixing recyclable materials with noncompatible materials or wastes (e.g., segregating scrap metal by metal type, separating cyanide-bearing wastewaters for preliminary treatment, separating different types of coolants for treatment and recycle).

- Closed-Loop Recycling: Separating recoverable materials in process streams for recycling for on-site production processes (e.g., using ion exchange to recover metal from electroplating rinse water and recycling the deionized water, using centrifugation to recover and reuse machining coolants).

9.2 Source Reduction and Recycling Technologies Used in the MP&M Industry

For the purpose of describing source reduction and recycling technologies, the unit operations performed in the MP&M industry were classified into the following four groups, as shown on Table 9-1: (1) metal shaping operations; (2) surface preparation and treatment operations (chemical treatment and solvent cleaning); (3) metal and organic deposition operations (including surface finishing operations); and (4) assembly operations. This classification scheme was developed for discussing source reduction and recycling technologies rather than for use in subcategorization or data transfer within the MP&M industry.

Tables 9-2 through 9-6 present examples of source reduction and recycling technologies used in the MP&M industry for the four groups of operations. Where available, these tables identify costs, savings, and waste reduction benefits resulting from the implementation of a specific technology. References specific to each technology are cited in the tables under "Waste Reduction and Other Information."

9.2.1 Metal-Shaping Operations

Metal-shaping operations (including heat treatment) are performed in the MP&M industry to alter the physical form of raw materials to make intermediate and final products. Table 9-2 presents examples of source reduction and recycling technologies used in the MP&M industry for metal-shaping operations.

Wastes generated from these operations are typically scrap metal, spent metal-working fluids, and metal-bearing wastewaters. Sites commonly recycle scrap metals that have value and defined recycling markets. Metal-working fluids are usually oil-water emulsions or oil-based lubricants. Metal-working fluids become contaminated with metals, tramp oils, and cleaning materials (e.g., chlorinated solvents), and spoil without proper management and storage. The life of metal-working fluids can be increased at the source through methods and technologies such as oil skimming, centrifugation,

biocide addition, and pasteurization. Metal-bearing wastewaters typically contain metal contaminants in a water-based slurry. These wastewaters are typically filtered and recycled or treated to remove metals and oil and grease and then discharged.

9.2.2 Surface Preparation and Treatment Operations

Surface preparation and treatment operations (chemical treatment and solvent cleaning) are performed in the MP&M industry to remove unwanted surface materials or to alter the chemical or physical characteristics of a surface in preparation for subsequent operations. Tables 9-3 and 9-4 present examples of source reduction technologies used in the MP&M industry for chemical treatment and solvent cleaning operations, respectively.

Wastes generated from these operations are typically metal-bearing cleaning solutions and rinsewaters and spent solvents. Some of the cleaning solutions also contain cyanide as a component of the solution formulation. Spent cleaning solutions and rinsewaters are typically treated to remove metals and are then discharged.

Discharge rates of surface preparation and treatment wastewaters can be reduced at the source through technologies such as:

- On-demand rinsing and flow control (e.g., conductivity sensors, flow restrictors);
- Filtration and reuse of surface treatment solutions;
- Oil skimming to remove contaminants;
- Reuse of rinse waters as make-up for evaporative losses in process baths or reuse in other rinse tanks; and
- Analytical monitoring of cleaning solutions to determine when the solutions require discharge.

Spent solvents are typically recovered and reused either on or off site.

9.2.3 Metal and Organic Deposition Operations

Metal and organic deposition operations (including surface finishing operations) are performed in the MP&M industry to provide either a protective or decorative coating to a part. Table 9-5 presents examples of source reduction and recycling technologies used by the MP&M industry for metal deposition operations.

Wastewaters generated from these operations include concentrated metal-bearing solutions, dilute metal-bearing rinse waters, and solvent-bearing and metal-bearing wastewaters from painting and corrosion preventive coating operations. These wastewaters are typically treated to remove metals and are then discharged.

Discharge rates of metal and organic deposition wastewaters can be reduced at the source through technologies such as:

- On-demand rinsing and flow control (e.g., conductivity sensors, flow restrictors);
- Reuse of rinse waters as makeup for evaporative losses from concentrated solutions;
- Chemical recovery and reuse (e.g., ion exchange, electrowinning, reverse osmosis, electrodialysis);
- Reuse of painting water curtains by filtration or centrifugation;
- Use of high-transfer efficiency spray painting methods; and
- Analytical monitoring of process solutions to determine when the solutions require discharge.

9.2.4 Assembly Operations

Assembly operations are performed in the MP&M industry to provide a finish to a part or to assemble a final product. Wastewaters generated from these operations consist of dilute metal-bearing wastewater from mechanical finishing operations and oily wastes from testing operations. These operations also include general maintenance operations at MP&M sites. Table 9-6 presents examples of source reduction and recycling technologies used in the MP&M industry for finishing operations.

Table 9-1

Typical Metal Products and Machinery Operations

Metal Shaping		Surface Preparation and Treatment	
• Abrasive Jet Machining • Electrical Discharge Machining • Electrochemical Machining • Electron Beam Machining • Grinding • Heat Treating	• Impact Deformation • Machining • Plasma Arc Machining • Pressure Deformation • Thermal Cutting • Ultrasonic Machining	• Abrasive Blasting • Acid Treatment • Alkaline Treatment • Barrel Finishing • Chemical Machining • Electrolytic Cleaning	• Electropolishing • Metallic Coating Stripping • Organic Coating Stripping • Salt Bath Descaling • Solvent Degreasing
Metal and Organic Deposition		**Assembly**	
• Anodizing • Chemical Conversion Coating • Corrosion Preventive Coating • Electroless and Immersion Plating • Electroplating • Hot Dip Coating	• Mechanical Plating • Metal Spraying • Painting • Sputtering • Vacuum Metalizing	• Adhesive Bonding • Assembly • Brazing • Burnishing • Calibration • Disassembly	• Laminating • Polishing • Soldering • Testing • Thermal Infusion • Welding

Source: MP&M DCPs, MP&M site visits, technical literature.

Table 9-2

Examples of Source Reduction and Recycling Technologies for Metal-Shaping Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Production Planning and Sequencing	Improve scheduling of processes that require use of varying oil types to reduce the number of cleanouts.(b)	NA	[Reference #81](b)
Process or Equipment Modification	Standardize the fluid types used for machining to reduce the number of equipment cleanouts and the amount of residual oils and mixed wastes. This simplifies the management, processing, and recycle of these fluids.(b)	NA	[Reference #81](b)
	Use specific lines for each set of processes that require a specific fluid to reduce the number of cleanouts.(b)	NA	[Reference #81](b)
	Reduce coolant costs by extending machine coolant life through the use of a centrifuge and the addition of biocides.(b)	NA	Waste Reduction: 25% in plant-wide waste coolant generation. Based on handling 20,600 gpy of coolant. [Reference #81](b)
	Monitor coolants (e.g., specific gravity, conductivity, pH, biological activity, visual/odor observations) to better control coolant quality.(b)	Capital Investment: $5,000 Payback Period: 0.7 years(b)	Based on handling 20,600 gpy of coolant. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 9.3 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b; the reference cited with footnote b denotes the reference originally cited in the Bibliographic Report. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by MP&M sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-2 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal-Shaping Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Use disk or belt skimmers or coalescing plate separators to remove waste oil from machine coolants and prolong coolant life. Also, design sumps for ease of cleaning.(b)	NA	Coolant disposal reduced from 3 to 6 times per year to once per year. [Reference #6](b)
	Use distilled or deionized water for adjusting coolant concentrations and maintain coolant concentration through daily analysis. Use disinfectant when cleaning machinery.	NA	[Reference #89]
	Use vapor-phase lubrication for metal forging and shaping operations.	NA	Waste Reduction: 85% lubricant volume reduction. [Reference #92]
	Use the same metal-working fluid throughout the site and use a central fluid reconditioning process to reuse the metal-working fluid.	Capital Investment: $0 Annual Savings: $4,000	Waste Reduction: 24,000 gpy of waste metal working fluid. [Reference #153].
	Use a synthetic oil in metal cutting and forming equipment to lengthen the time between oil changes.	Capital Investment: $2,800 Annual Savings: $800 Payback Period: 3.3 years	Waste Reduction: 700 gpy of waste oil. [Reference #171].
	Install conductivity meters in chemical machining rinses to decrease water use.	NA	[Site 17309](c)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 9.3 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b; the reference cited with footnote b denotes the reference originally cited in the Bibliographic Report. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by MP&M sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-2 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal-Shaping Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Replace thermal treatment of metals with condensation of saturated chlorite vapors on the surface to be heated. This process eliminates the need for subsequent pickling.(b)	NA	[Reference #81](b)
Raw Material Substitution	In cold forming or other processes where oil is used only as a lubricant, substitute a hot lime bath or borax soap for oil.(b)	NA	[Reference #81](b)
	Use a stamping lubricant that remains on the piece until the annealing process, where it is burned off. This eliminates the need for hazardous degreasing solvents and alkali cleaners.(b)	Capital Investment: Less than $30,000 Annual Savings: $12,000 (results from reduced disposal, raw material, and labor costs)(b)	Waste Reduction: The amount of waste solvents and cleaners was reduced from 30,000 lbs in 1982 to 13,000 lbs in 1986. Employee working conditions were also improved by removing vapors associated with solvent cleaners. [Reference #7](b)
	Substitute synthetic coolant for sulphurized oil used in honing process and eliminate hot water wash following honing operation.	Reduced raw material costs by 67%.	Waste Reduction: 128 gpy of waste oil. [Reference #88]
Waste Segregation and Separation	Segregate metal scrap by type to facilitate resale of the metal (e.g., sell previously disposed metallic dust to a smelter).(b)	Capital Investment: $0 Annual Savings: $130,000 Payback Period: Immediate(b)	Waste Reduction: 2,700 tons of scrap metal per year. [Reference #19](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 9.3 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b; the reference cited with footnote b denotes the reference originally cited in the Bibliographic Report. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by MP&M sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-2 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal-Shaping Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Waste Segregation and Separation (Continued)	Improve housekeeping techniques and segregate waste streams (e.g., segregate used oils, when cleaning cutting equipment prevent mixing cutting oil and cleaning solvent).(b)	Capital Investment: $0 Annual Savings: $3,000 (in disposal costs)(b)	Waste Reduction: 30 tons reduced to 10 tons. [Reference #81](b)
Recycling	Recycle metal-working fluids from cutting and machining operations. Oils may not need treatment before recycling.(b)	Capital Investment: $1,900,000 Annual Savings: $156,000(b)	Based on recycling 2 million gpy of oil. [Reference #19](b)
	Install a second high-speed centrifuge on a system already operating with a single centrifuge to improve recovery efficiency.(b)	Capital Investment: $126,000 Payback Period: 3.1 years(b)	Based on handling 20,600 gpy of coolant. [Reference #81](b)
	Install a coolant recovery system and collection vehicle for machines not on a central coolant sump.(b)	Capital Investment: $104,000 Payback Period: 1.9 years(b)	Based on handling 20,600 gpy of coolant. [Reference #81](b)
	Use a settling tank (to remove solids) and a coalescing unit (to remove tramp oils) to recover metal-working fluids.(b)	Capital Investment: Less than $30,000 Annual Savings: $26,800 (resulting from reduced material, labor, and disposal costs)(b)	Includes settling tank to remove solids. [Reference #20](b)
	Use a coalescing plate separator to recycle machining coolant.	67% reduction in coolant costs	Waste Reduction: 52,500 gpy of waste oil. [Reference #90]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 9.3 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b; the reference cited with footnote b denotes the reference originally cited in the Bibliographic Report. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by MP&M sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-2 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal-Shaping Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Install an oil condensing system to reclaim evaporating oil.	Capital Investment: $7,400 Annual Savings: $56,250 Payback Period: 0.1 years	Waste Reduction: 18,750 gpy of oil. [Reference #84]
	Install collection/drip pans under machinery and lubrication operations to recover oils.(b)	NA	[Reference #81](b)
	Centrifuge oil and scrap metal mixtures or install a chip wringer to recover excess coolant for reuse.(b)	Capital Investment: $233,500 Payback Period: 0.9 years(b)	Based on handling 20,600 gpy of coolant. [Reference #81](b)
		Capital Investment: $11,000 to $23,000 (chip wringer and centrifuge system)(b)	[Reference #81](b)
	Use a centrifuge to recycle metal-working fluids from machining chips.	Capital Investment: $23,525 Annual Savings: $21,291 Payback Period: 1.1 years	[Reference #9]
	Install ultrafiltration to recycle metal-working fluids.	Capital Investment: $42,000 Annual Savings: $33,800(b)	[Reference #81](b)
		Annual Savings: $200,000 (in disposal costs)(b)	Based on a wastewater flow rate of 860 to 1,800 gpd. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 9.3 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b; the reference cited with footnote b denotes the reference originally cited in the Bibliographic Report. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by MP&M sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-2 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal-Shaping Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Perform on-site purification of hydraulic oils using cartridge filter system.(b)	Capital Investment: $28,000 Annual Savings: $17,800 (based on operating costs, reduced oil purchase, and lost resale revenues) Payback Period: Less than 2 years(b)	Based on 12,300 gpy of waste hydraulic oil. [Reference #81](b)
	Recycle metal-working fluids on site by filtering, and treat spent fluids with acid to reduce volume of waste to be shipped off site.	Capital Investment: $7,050 Annual Savings: $3,120 Payback Period: 2.3 years	Waste Reduction: 425 gpy of cutting fluid. [Reference #83]
		Capital Investment: $11,750 Annual Savings: $6,140 Payback Period: 1.9 years	Waste Reduction: 2,075 gpy of cutting fluid. [Reference #87]
	Filter and recycle aqueous cutting fluids.	Capital Investment: $22,400 Annual Savings: $17,430 Payback Period: 1.3 years	Waste Reduction: 31,340 gpy of oil. [Reference #86]
	Use a portable sump to remove cutting fluid from chip collection bins for filtration and recycle.	Capital Investment: $0 Annual Savings: $3,120	Waste Reduction: 16,480 gpy of fluid. [Reference #86]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 9.3 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b; the reference cited with footnote b denotes the reference originally cited in the Bibliographic Report. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by MP&M sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-2 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal-Shaping Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Add magnesium chloride as a de-emulsifying agent to break oil-water emulsion and recycle oil layer.	Capital Investment: $2,500 Annual Savings: $6,820 Payback Period: 0.4 years	Waste Reduction: 16,230 gpy of oil. [Reference #85]
	Recycle spent blasting abrasives by mixing them into asphaltic concrete.	Savings: $450 per ton of waste	[Reference #190].
	Install a coolant recycling system and reuse coolant in grinding and machining operations.	NA	[Sites 3036, 4133, 5911, 6054, 6233, 9081, 10843, 11286, 11579, 15000, 15632, 15908, 16905, 17309, 17325, 19698, 20813, 20914, 22208, and 24251](c)
	Recycle water used in abrasive jet machining operation using electrolytic recovery, filtration, and ion exchange.	NA	[Site 11286](c)
	Sell metal fines from abrasive blasting and machining operations for reclamation. Reuse hydraulic oil in machining operations.	NA	[Sites 914, 1220, 4208, 6233, 6924, 7175, 9456, 10283, 11286, 11579, 13103, 14043, 15000, 16589, 18802, 19225, and 23653](c)
	Recycle oil quench baths on site by filtering out the metals.(b)	NA	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 9.3 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b; the reference cited with footnote b denotes the reference originally cited in the Bibliographic Report. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by MP&M sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-3

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Production Planning and Sequencing	Discharge acid and alkaline treatment baths based on the results of chemical analysis rather than schedule.	NA	[Sites 3960 and 7972](c)
Process or Equipment Modification	Use countercurrent rinses after each process to reduce wastewater discharge.(b)	Capital Investment: $800 Annual Savings: $4,630 Payback Period: 0.2 year(b)	Waste Reduction: 2,171,520 gpy. [Reference #94](b)
	Increase rinsing efficiency by using air spargers. Reduce wastewater discharge by installing flow control meters.	Annual Savings: $1,800 in water and sewer fees, plus reduced treatment chemical and waste handling costs.	50% reduction in water usage. [Reference #103]
	Reduce rinse contamination via drag-out by slowing removal of parts from process baths, rotating the parts if necessary.(b)	NA	[Reference #81](b)
	Reduce rinse contamination via drag-out by using drainage boards that direct dripping solutions back to process tanks.(b)	NA	[Reference #81](b) [Site 3960](c)
	Reduce rinse contamination via drag-out by installing drag-out recovery tanks.(b)	NA	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-3 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Reduce rinse contamination via drag-out by using a fog spray rinsing technique above process tanks.(b)	NA	[Reference #81](b)
	Reduce rinse contamination via drag-out by using techniques such as air knives or squeegees to wipe bath solutions off of the part.(b)	NA	[Reference #81](b) [Sites 2306 and 17479](c)
	Reduce rinse contamination via drag-out by changing bath temperature or concentration to reduce the solution surface tension.(b)	NA	[Reference #81](b)
	Decant organic coating stripping solution and remove sludge from bath.	NA	Reduce bath discharge from once per month to once per year. [Site 5410](c)
	Use barrel finishing with glass marbles or steel balls instead of pickling in nitric acid. Use an acidic additive with the glass marbles and a slightly basic additive with the steel balls.(b)	Capital Investment: $62,300(b)	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-3 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Use mechanical scraping instead of acid solution to remove oxides of titanium.(b)	Investment: Less than $30,000 Annual Savings: $0 Cost of mechanical stripping equals cost of chemical disposal.(b)	Waste Reduction: 100%. Previously disposed 15 tons of acid per year with metals. [Reference #81](b)
	Replace alkaline etching of nickel and titanium with a mechanical abrasive system.(b)	Capital Investment: $3,250 Annual Savings: $7,500(b)	Waste Reduction: 100%. Previously disposed of 12,000 gpy of etching solution. [Reference #81](b)
	Clean copper sheeting mechanically with a rotating brush machine that scrubs with pumice, instead of cleaning with ammonium persulfate, phosphoric acid, or sulfuric acid (may generate nonhazardous waste sludge).(b)	Capital Investment: $59,000 Annual Savings: $15,000 (in raw materials, disposal, and labor) Payback Period: 4 years(b)	Waste Reduction: 40,000 lb/yr of hazardous copper etching waste liquid. [Reference #81](b)
	Install an acid cleaning bath maintenance system including oil skimming and cartridge filtration.	Capital Investment: $12,220 Annual Savings: $44,190 Payback period: 0.3 years	Expected to extend bath life by one year. [Reference #162]
	Use a mechanical de-scaling system rather than acid treatment to remove scale from wire rod.	NA	Waste Reduction: 355,000 lbs per year of sulfuric acid. [Reference #180].

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-3 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Use conductivity meters to reduce the quantity of wastewater discharged from rinses.	NA	[Sites 3960, 6028, 6233, 7159, 10674, 10843, 13103, 16385, 17309, 19102, 21293, and 24251](c)
	Use on-demand rinsing (i.e., shut off water discharge when rinse is not in use) to reduce the quantity of wastewater discharged from rinses.	NA	[Sites 2100, 2306, 2948, 3793, 3960, 5410, 6306, 6233, 7159, 10674, 11507, 17309, 17325, 17479, 19225, 19698, 20532, 20813, 22734, and 23653](c)
	Use flow restrictors to reduce the quantity of wastewater discharged from rinses.	NA	[Sites 3862, 5410, 6233, 10283, 10565, 17325, 19225, 19698, 20532, and 20813](c)
Raw Material Substitution	Change copper bright-dipping process from a cyanide dip to a sulfuric acid/hydrogen peroxide dip. The new bath is less toxic.(b)	NA	[Reference #81](b)
	Use alcohol instead of sulfuric acid to pickle copper wire. One ton of wire requires 4 liters of alcohol solution, versus 2 kilograms of sulfuric acid.(b)	Capital Investment: $0(b)	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-3 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution (Continued)	Replace caustic wire cleaner with a biodegradable detergent.(b)	NA	[Reference #81](b)
	Replace chromated etching solutions with nonchromated alkaline solutions for etching of wrought aluminum.(b)	Annual Savings: $44,541(b)	Waste Reduction: 50% reduction in sludge disposal costs. [Reference #81](b)
	Replace barium and cyanide salt heat treating with a carbonate and chloride carbon mixture, or with furnace heat treating.(b)	NA	[Reference #81](b)
	Substitute chromic acid cleaner with cleaners such as sulfuric acid and hydrogen peroxide.(b)	Capital Investment: Less than $30,000 Cost Savings: $10,000 in treatment equipment costs and $2.50/lb of chromium in treatment chemical costs.(b)	Based on rinse water flow rate of 2 gpm. [Reference #81](b)
	Substitute nonhazardous cleaners such as trisodium phosphate or ammonia for cyanide cleaners.(b)	Capital Investment: Less than $30,000 Cost Savings: $12,000 in equipment costs and $3.00/lb of cyanide in treatment chemical costs.(b)	Based on rinsewater flow rate of 2 gpm. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-3 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling	Replace cyanide-bearing nickel stripping process with a non-cyanide bearing nickel stripping process.	NA	[Reference #184]
	Sell waste pickling acids as feedstock for fertilizer manufacturer or neutralization and precipitation.(b)	NA	[Reference #81](b)
	Recover metals from solutions using ion exchange and electrolytic recovery.(b)	Annual Savings: $22,000(b)	Company sells copper recovered from a bright-dip bath regeneration process. [Reference #19](b)
	Send used copper pickling baths to a continuous electrolysis process for regeneration and copper recovery.(b)	Capital Investment: $28,500(b)	200 gallons of solution are recovered per ton of copper processed. [Reference #81](b)
	Recover copper from brass bright dipping solutions using ion-exchange system.(b)	Investment: Less than $30,000(b) Annual Savings: $17,047; based on labor savings, copper sulfate elimination, sludge reduction, copper metal savings, and bright dip chemicals savings.(b)	Facility processes approximately 225,000 lb/month brass. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-3 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Filter and reuse acid treatment baths.	NA	Extended bath life by 70%. [Site 6924]
	Extend alkali wash life by skimming the oil layer and reclaiming the skimmed oil.(b)	NA	[Reference #81](b)
	Recover acids from pickling baths using diffusion dialysis.	NA	Waste Reduction: 6,000 m^3/yr of sludge and 3,200 m^3/yr of acids. [Reference #96]
		Capital Investment: $2,200,000 Annual Savings: $603,000 Payback Period: 3.6 years	[Reference #99]
	Use ultrafiltration to recycle spent iron phosphating/degreasing baths.	Capital Investment: $12,000	Waste reduction: 15,000 gpy (99.8%) of spent solution. [Reference #116]
	Use an in-process treatment system to regenerate and reuse solutions for chemical milling of aluminum.(b)	Capital Investment: $465,000 Annual Savings: $342,000 Payback Period: Less than 2 years(b)	Waste Reduction: 90%. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-3 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Regenerate alkaline etching solution for aluminum by using hydrolysis of sodium aluminate to liberate free sodium hydroxide and produce a dry, crystalline hydrate alumina byproduct.(b)	Capital Investment: $260,000 Annual Savings: $169,282 (from reduced alkaline solution use, income from the sale of the byproduct, and a reduction in the cost of solid waste disposal) Payback Period: 1.5 years(b)	Based on an anodizing operation for which the surface area is processed at a rate of 200 m^2/hr. [Reference #81](b)
	Purify and reuse alkaline cleaning wastewater from an automotive parts washer using emulsion breaking, skimming, and cartridge filtration. Reuse 75% of the washwater; add fresh solution as necessary.	Capital Investment: $19,800 Annual Savings: $107,100 Payback Period: 0.18 years	Approximately 29,000 gpy of RCRA characteristic hazardous wastes D007 and D008 were generated at the facility from the parts washer prior to installing the treatment system. [Reference #159]
	Use waste acid detoxification and reclamation (WADR) process (metal precipitation and vacuum distillation) to purify spent acid from acid treatment baths for reuse.	NA	[Reference #172]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-3 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Surface Treatment(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Use in-process precipitation or vacuum distillation to recycle spent acids.	NA	Waste Reduction: 85% recovery of copper, 80% recovery of nitric acid, and 40% reduction in waste volumes. [Reference #100]
	Regenerate ferricyanide etchants by bubbling ozone through spent etchants.	Capital Investment: $100,000 Annual Savings: $250,000	Improved etchant performance has increased process throughput by 50%. [Reference #179]
	Use acid treatment and alkaline treatment operation discharges for treatment chemicals.	NA	[Sites 6306, 6924, 7159, 10843, 16589, 17325, 17479, 19698, 22734, and 24251](c)
	Use rinse water as make-up for process chemicals	NA	[Sites 6054, 6233, 13682, 18802, and 19019](c)
	Use ultrafiltration or nanofiltration to recycle barrel finishing wastewater.	Capital Investment: $5,500 Annual Operating Costs: $2,500 Annual Savings: $6,657	[Reference #152]
	Use ground corn cob dry burnishing process to replace wet tumbling.	Annual Savings: $17,850	[Reference #152]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-4

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Training and Supervision	Improve solvent management by requiring employees to obtain solvent through their shop foreman.(b)	NA	[Reference #23](b)
	Use software packages to assist with decisions concerning solvent replacements.	NA	[Reference #112]
Production Planning and Sequencing	Preclean parts to extend the life of the aqueous or vapor degreasing solvent.(b)	Annual Savings: $40,000 Payback Period: 2 years(b)	Waste Reduction: 48,000 gal of aqueous waste. Aluminum shot was used to preclean parts. [Reference #19](b)
	Reuse "waste" solvents from cleaner upstream operations in downstream, machine shop-type processes.(b)	Capital Investment: $0 Annual Savings: $7,200(b)	Waste Reduction: 51% (310 tons reduced to 152 tons). [Reference #23](b)
	Use countercurrent solvent cleaning (i.e., clean initially in previously used solvent and progress to new, clean solvent).(b)	NA	[Reference #81](b)
	Cold clean with a recycled mineral spirits stream to remove the bulk of oil before final vapor degreasing.(b)	NA	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A. January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-4 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification	Cover the solvent degreasing unit.	Capital Investment: $220 Annual Savings: $17,180 Payback Period: 0.01 years	Waste Reduction: 50% [Reference #93]
		Capital Investment: $1,250 Annual Savings: $4,118 Payback Period: 0.3 years	Waste Reduction: 9,900 lbs per year of solvent. [Reference #170]
	Increase the freeboard height above the vapor level to 100% of tank width.	Operating costs can be reduced by 30 to 50%.	[Reference #102]
	Install refrigerator coils (or additional coils) above the degreaser vapor zone.(b)	NA	[Reference #81](b)
	Add in-line filters to prevent particulate buildup in the degreaser.(b)	NA	[Reference #81](b)
	Reduce grease accumulation by adding automatic oilers to avoid excess oil applications.(b)	Investment: Less than $30,000 (b)	[Reference #81](b)
	Use plastic blast media for paint stripping rather than conventional solvent stripping techniques.(b)	NA	Waste Reduction: volume of waste sludge is reduced by as much as 99% over chemical solvents; wastewater fees are eliminated. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-4 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Use a vacuum furnace to vaporize oil from parts, replacing solvent degreasing.	Capital Investment: $192,000	Parts must be able to withstand temperatures between 210-650°F. [Reference #95]
	Use hermetically sealed vapor degreasing units.	NA	Waste Reduction: Reduces use of 1,1,1-trichloroethane (TCA) by 40,000 lbs/yr. [Reference #97]
	Use carbon dioxide (CO_2) blasting as an alternative to solvent stripping or degreasing.	Savings: for paint stripping from aircraft, cost for CO_2 blasting is $0.51/ft^2 compared to $1.50 to $2.25/ft^2 for stripping using plastic blast media or solvents.	[Reference #6]
	Use carbon dioxide (CO_2) blasting as an alternative to solvent stripping or degreasing.	Cost of stripping reduced from $19/ft^2 to $5/ft^2.	Waste Reduction: 96% reduction in chemical stripping wastes. [Reference #109]
	Use an abrasive deburring system to clean metal parts instead of solvents.	Capital Investment: $9,000 Annual Savings: $36,000 Payback Period: 0.25 years	Waste Reduction: 1,100 gpy of TCA. [Reference #107]
		NA	[Sites 914, 7175, 13103, and 15908](c)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-4 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Use bicarbonate of soda stripping process for paint stripping as an alternative to solvent stripping.	NA	[Reference #110]
	Use high-pressure supercritical carbon dioxide process as an alternative to solvent degreasing for removing machining coolant from parts.	NA	[Reference #111]
	Use machining coolants and lubricants that do not require solvent degreasing after machining.	NA	[Reference #115]
	Reduce the surface area of a methyl ethyl ketone (MEK) tank used for an organic coating stripping operation to reduce loss of MEK to atmosphere.	Capital Investment: $3,000 Annual Savings: $11,240 Payback Period: 0.3 years	Waste Reduction: 37.6% less MEK used each year. [Reference #164]
Raw Material Substitution	Use less hazardous degreasing agents such as petroleum solvents or alkali washes. For example, replace halogenated solvents (e.g., trichloroethylene) with aqueous cleaner. (Note that compatibility of aqueous cleaners with wastewater treatment systems should be considered.)	Capital Investment: $0 Annual Savings: $12,000(b)	Waste Reduction: 30% of 1,1,1-trichloroethane replaced with an aqueous cleaner. [Reference #7](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-4 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution (Continued)	Use less hazardous degreasing agents such as petroleum solvents or alkali washes. For example, replace halogenated solvents (e.g., trichloroethylene) with liquid alkali cleaning compounds. (Note that compatibility of aqueous cleaners with wastewater treatment systems should be considered.) (Continued)	Capital Investment: $438,000 Payback Period: 5.1 years(b)	Replaced trichloroethylene degreaser with aqueous cleaner system. [Reference #26](b)
		NA	[Sites 3862, 4208, 4979, 7159, 9081, 11316, 13103, 14881, 15908, 16589, 17309, 17479, 18802, 19225, and 20813](c)
		Annual Savings: $2,000 Payback Period: 1.6 years(b)	Substituted chlorofluorocarbon solvents with proprietary cleaner. [Reference #81](b)
		Annual Savings: 38% of cost savings and a 62% return on investment. Payback Period: 1.6 years(b)	Substituted chlorofluorocarbon solvents with proprietary cleaner. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-4 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution (Continued)	Use less hazardous degreasing agents such as petroleum solvents or alkali washes. For example, replace halogenated solvents (e.g., trichloroethylene) with liquid alkali cleaning compounds. (Note that compatibility of aqueous cleaners with wastewater treatment systems should be considered.) (Continued)	NA	Waste Reduction: 32 tpy of flammable ethyl alcohol. Replaced methanol with nonflammable aqueous cleaners. [Reference #101]
		Total savings of $106,395 in material, direct costs, and indirect labor and maintenance costs. Resulted in 117% pre-tax rate of return.	Replaced methylene chloride degreaser with an aqueous cleaning system. [Reference #105]
		Capital Investment: $5,000 Annual Savings: $67,200	Waste Reduction: 24,000 lb/yr of CFC-113. Replaced with spray alkaline cleaner. [Reference #108]
		Capital Investment: $50,000 Annual Savings: $20,450 Payback Period: 2.4 years	Waste Reduction: 99% using ultrasonic cleaning with biodegradable detergents. [Reference #93]
		Capital Investment: $18,000 Annual Savings: $96,000	Waste Reduction: 1,000 gallons per month of TCA and freon 113 using ultrasonic cleaning. [Reference #95]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-4 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution (Continued)	Use less hazardous degreasing agents such as petroleum solvents or alkali washes. For example, replace halogenated solvents (e.g., trichloroethylene) with liquid alkali cleaning compounds. (Note that compatibility of aqueous cleaners with wastewater treatment systems should be considered.) (Continued)	Capital Investment: $1,793 Annual Savings: $4,800 Payback Period: 0.38 years	Replaced TCA and methanol degreasing with terpene-based aqueous degreasing. [Reference #113]
		Capital Investment: $3,520 Annual Savings: $1,340 Payback Period: 2.6 years	Waste Reduction: 15,600 gpy of spent TCA. [Reference #168]
		Capital Investment: $159,600 Annual Savings: $56,800 Payback Period: 2.8 years	Replaced CFC cleaning process with an aqueous cleaning process. [Reference #175]
		NA	Ultrasonic cleaning with aqueous detergents replaced solvent degreasing with 1,1,2-trichloro-trifluoroethane, methylchloro-form, and perchloroethylene. [Reference #173]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-4 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution (Continued)	Replace vapor degreasing units with an aqueous washer. Treat aqueous solution with mechanical filtration and oil skimming.	NA	The aqueous washer cleans most parts well enough to by-pass a wet tumbling process, reducing the amount of wastewater discharged from tumbling by 50%. [Reference #174]
Loss Prevention and Housekeeping	Improve performance of the solvent capture system for a vapor degreasing unit.	Capital Investment: $500 Annual Savings: $400 Payback Period: 1.2 years	Waste Reduction: 30% reduction in trichloroethylene loss per year. [Reference #155]
Loss Prevention and Housekeeping (Continued)	Only degrease parts that must be cleaned. Do not routinely degrease all parts.(b)	NA	[Reference #81](b)
	Rotate parts before removal from the vapor degreaser to allow all condensed solvent to return to degreasing unit.(b)	NA	[Reference #81](b)
	Control the speed at which parts are removed from the degreaser to reduce disruption of the vapor line.(b)	NA	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-4 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling	Recycle spent degreasing solvents on site using batch stills.	Capital Investment: $7,500 Annual Savings: $90,000 Payback Period: 0.08 years(b)	Waste Reduction: 10,000 gph of spent solvent by in-house distillation. [Reference #19](b)
		Capital Investment: $2,600-$4,100 and $4,200-$17,000.(b)	Based on 35-60 gph and 0.6-20 gph, respectively. Cost and throughput estimates for distillation units from two vendors. [Reference #81](b)
		Capital Investment: $55,000 Annual Savings: $200,000 Payback Period: Less than 0.33 years	Waste Reduction: 90% of spent solvent recovered. [Reference #114]
		NA	[Site 24521]
		Capital Investment: $3,500 Annual Savings: $50,400(b)	Facility handles 40,450 gpy of TCA. [Reference #81](b)
		Capital Investment: $5,000 Annual Savings: $4,240 Payback Period: 1.2 years	Waste Reduction: 80% reduction in waste TCA per year. [Reference #155]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-4 (Continued)

Examples of Source Reduction and Recycling Technologies for Surface Preparation Operations - Solvent Cleaning(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Use ozonation-membrane process to recover solvents.	NA	Waste Reduction: 99.8% reduction of trichlorophenol. [Reference #104]
	Arrange a cooperative agreement with other small companies to centrally recycle solvent.(b)	Investment: Less than $30,000(b)	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. EPA/560/8-92/001A, January 1992.

Table 9-5

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Training and Supervision	Train plating shop personnel in water conservation and source reduction practices.(b)	NA	[Reference #81](b)
	Improve paint quality and work efficiency and lower vapor emissions by formally training operators.(b)	Capital Investment: $3,000 Annual Savings: $3,390 Payback Period: 0.9 years(b)	Waste Reduction: 66 gpy of paint/primer residue. [Reference #142](b)
Production Planning and Sequencing	Pre-inspect parts to prevent processing of obvious rejects.(b)	NA	[Reference #81](b)
	Use the correct spray gun for particular applications: conventional air spray gun for thin-film-build requirements; airless gun for heavy film application; and air-assisted airless spray gun for a wide range of fluid output.(b)	Capital Investment: $6,000 Annual Savings: $8,470 Payback Period: 0.7 years(b)	Waste Reduction: 65 gpy of paint/primer residue. Use paint atomization spray equipment with adjustable cross-sectional areas for maximum paint transfer efficiency. [Reference #142](b)
	Reduce equipment cleaning by painting with lighter colors before darker ones.(b)	NA	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Production Planning and Sequencing (Continued)	Flush equipment with used solvent before final cleaning with virgin solvent.(b)	NA	Waste Reduction: 98% from 25,000 gal to 400 gal of paint cleanup solvents. Company uses cleanup solvents in formulation of subsequent batches. [References #31](b)
	Use virgin solvents for final equipment cleaning, then as paint thinner.(b)	NA	[Reference #81](b)
Process or Equipment Modification	Add wetting agents to the plating baths to reduce adhesion of solution to the parts.	NA	[References #119, 120, 127, and 128]
	Increase bath temperature to reduce viscosity and improve drainage rate.	NA	[References #119, 120, 127, and 128]
	Increase drain time to allow parts to drain after removal from bath.	Capital Investment: $0 Annual Savings: $3,350	Waste Reduction: Reduces drag-out of copper into rinse water by 9 gpd. [Reference #157]
	Position workpieces on racks to facilitate drainage.	NA	[References #119, 120, 127, and 128]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Place cadmium and zinc anode baskets on removable anode bars that can be lifted from the tank with an overhead hoist.	NA	Eliminates cadmium buildup causing decanting of the solution. [References #125 and 129]
	Install overflow alarms on all process tanks.	NA	[Reference #81](b)
	Mask part areas that should not be plated.	NA	Reduces buildup of dissolved metals and drag-out. [Reference #126]
	Use brush plating for touch-up and repair work.	NA	Reduces waste generation from cleaning, demasking, and rinsing steps. [Reference #130 and 131]
	Use chemical vapor deposition instead of electroless plating.	NA	[Reference #134]
	Use spray rinsing to increase rinsing efficiency.(b)	NA	[Reference #81](b)
	Use air agitation to improve rinsing efficiency.	NA	[Reference #129]
	Reduce bath evaporation by covering the surface with a blanket of polypropylene balls.(b)	NA	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Continuously filter process baths to extend their life.(b)	NA	[Reference #81, Sites 6233, 7159, and 16385[(b,c)
	Work with customers to eliminate unnecessary etching (e.g., etching to shine parts).(b)	NA	[Reference #81](b)
	Use low concentration plating solutions rather than midpoint concentrations to reduce the total mass of chemical drag-out.(b)	Capital Investment: Less than $30,000 Annual Savings: $1,300(b)	Based on a nickel plating operation with 2,500 gpy of drag-out. [Reference #81](b)
	Use double drag-out followed by recycle of the concentrated drag-out solution to minimize rinse water use.(b)	Annual Savings: $17,110 (based on 6,000 gpd) $60,080 (based on 36,000 gpd) $44,095 (based on 184,000 gpd)(b)	[Reference #81](b)
	Use countercurrent rinses and conductivity controls to reduce rinse water flows.(b)	Annual Operating Costs: $10.00/1,000 gal Annual Savings: $170,000(b)	Waste Reduction: Reduced wastewater discharge from 43,000 gpd to 8,000 gpd. [Reference #81](b)
		Annual Savings: $24,000 to $36,000	Five-stage countercurrent rinse for chrome plating. [Reference #133]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. EPA/560/8-92/001A. January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Use countercurrent rinses and conductivity controls to reduce rinse water flows.(b) (Continued)	NA	Conductivity meters used for rinses. [Sites 3960, 6028, 6233, 10843, 13682, 16385, 17309, and 19102](c)
		NA	[References #119, 120, 127, and 128, Sites 914, 1220, 2100, 2306, 2335, 2634, 2948, 2958, 3793, 3862, 3960, 4000, 4979, 5410, 6233, 6306, 7159, 7175, 7361, 8099, 9081, 10283, 10565, 10843, 11286, 11350, 11507, 11579, 13682, 14043, 15000, 15908, 16385, 16589, 16905, 17309, 17325, 18802, 19698, 20532, 20813, 20914, 21142, 22208, 22436, 22734, 23653, and 24521](c)
	Install countercurrent rinses with reuse of the rinse water as make- up for the plating bath (recovery rinsing).	Capital Investment: $3,100 Annual Savings: $1,650 Payback Period: 1.8 years	Waste Reduction: Approximately 5,390,000 gpy of rinse water. [Reference #153]
	Use ion beam enhanced technology for chromium deposition in place of chromium electroplating.	NA	[Reference #181]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Eliminate use of cyanide in cadmium electroplating operations by using acidic cadmium-bearing electroplating solutions.	NA	[Reference #183]
	Use spray-coating process to deposit metal coatings on parts in place of electroplating.	NA	Process attains a 95% conversion efficiency. Overspray can be collected and recycled. [Reference #185]
	Use hard chrome plating process consisting of a two-buss-bar plating tank, conversion, zero discharge rinse, system, plating bath purifier, and scrubber system.	Capital Investment: $140,000	Scrubber and rinse water are used to replace bath solution lost due to evaporation. [Reference #187]
	Use air knives to reduce drag-out from electroplating baths.	NA	[Sites 3960 and 11975](c)
	Use on-demand rinsing (i.e., shut off water discharge when rinse is not in use) to reduce the quantity of rinse water discharged.	NA	[Sites 2306, 2948, 5410, 6306, 10674, 17325, 19225, 19698, 20532, 28653](c)
	Use flow restrictors to reduce the quantity of rinse water discharged.	NA	[Sites 5410, 6233, 17325, 19225, 19698, 20532, and 20813](c)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Use squeegee to reduce drag-out.	NA	[Sites 2306, and 17479](c)
	Replace galvanizing processes requiring high temperature and flux with one that is low temperature and does not require flux.(b)	Capital Investment: $900,000 Annual Savings: 50% (as compared to conventional galvanizing)(b)	Based on 1,000 kg/hr throughput. [Reference #81](b)
	Reduce exhaust-air flow rate to minimize paint mist loss in paint booth.	Capital Investment: $2,100 Annual Savings: $44,910 Payback Period: 0.1 years	Waste Reduction: 1,719 gpy of paint sludge. [References #146]
	Install an electrostatic powder coating system to replace water curtain spray paint booth.	Capital Investment: $78,440 Annual Savings: $10,230 Payback Period: 7.7 years	Waste Reduction: 7,392 lbs/yr of paint solids and 8,840 lbs/yr paint liquids. [Reference #143]
	Replace water curtain spray paint booth with dry paint booth using dry filtration of overspray.	NA	[References #160 and 191, Sites 3862, 4884, 13103, 15632, 16385, 19019, and 19102](c)
		Annual Savings: $1,500(b)	Waste Reduction: $3,000 gpy. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Use transfer methods that reduce material loss such as dip and flow coating, electrostatic spraying, and electrodeposition.(b)	Capital Investment: Less than $30,000 Annual Savings: $15,000 Payback Period: 2 years(b)	[Reference #81](b)
		Capital Investment: $4,400 Annual Savings: $25,410	Waste Reduction: 495 gpy of paint/primer residue. [Reference #142]
		Capital Investment: $58,320 Annual Savings: $11,080 Payback Period: 5.3 years	Waste Reduction: 580 gpy of paint and primary 85 gpy of solvents. [Reference #165]
		NA	[Sites 4979 and 17325](c)
	Change from conventional air spray to high-volume low-pressure (HVLP) spray.	Capital costs comparable to conventional air spray equipment Annual Savings: $42,000	Waste Reduction: 38% reduction in lacquer paint usage. [Reference #148]
		Capital Investment: $1,500 Annual Savings: $240 Payback Period: 7 years	Waste Reduction: 12 gpy paint. [Reference #156]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Process or Equipment Modification (Continued)	Change from conventional air spray to high-volume low-pressure (HVLP) spray. (Continued)	Capital Investment: $5,000 Annual Savings: $8,500 Payback Period: 0.6 years	Waste Reduction: 50% less filters needed per year to capture paint overspray. Paint transfer efficiency improved by approximately 20%. [Reference #158]
		Capital Investment: $800 Annual Savings: $6,060 Payback Period: 0.2 years	Waste Reduction: 1,750 lbs per year of paint overspray. [Reference #169]
		NA	[Sites 10843 and 13103](c)
	Install conductivity meters to reduce corrosion preventive coating rinse water discharge.	NA	[Site 3960](c)
	Use ion vapor deposition of aluminum rather than a cadmium coating for corrosion prevention.	NA	The aluminum coatings perform better than cadmium coatings in acidic and/or high temperature environments. [Reference #189]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution	Substitute zinc for cadmium in alkali/saline environments.(b)	NA	Can eliminate use of cadmium in a given shop. [Reference #118](b)
	Replace plated parts with brushed aluminum or stainless steel parts (i.e., stainless steel in place of chromium-plated parts).	NA	Eliminates plating processes and associated wastes. May change product appearance. [Reference #117]
	Substitute solutions that don't contain cyanide for cyanide-bearing electroplating solutions. This substitution, however, may not apply to all types of cyanide-bearing electroplating solutions.(b)	NA	Some non-cyanide solutions such as cadmium plating cannot meet all production requirements. [Reference #119](b)
		NA	Waste Reduction: 1.67 gpd of cyanide-bearing wastes. [Reference #136]
		Capital Investment: $10,000 Annual Savings: $50,000	Replaced cyanide-based solution with noncyanide alkaline zinc solution. [Reference #140]
	Substitute zinc chloride for zinc cyanide.(b)	NA	[Reference #81](b)
	Substitute a nonchlorinated stripper for methylene chloride.(b)	NA	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution (Continued)	Replace hexavalent chromium baths with trivalent chromium baths.	NA	Reduces treatment needs and effluent toxicity. Lower tank temperature reduces energy requirements. [References #120 and 192, Site 10674](c)
	Use boric/sulfuric acid anodizing instead of chromic acid anodizing.	NA	Applicability varies for specific alloys and end uses of product. [Reference #121, Site 10674](c)
	Use nonchromium electroplating to replace chromium electroplating.	NA	Substitutes include electroless nickel, hard alloys, and molybdenum. [References #117, 122, 123, and 124]
	Use deionized water for bath makeup and for closed-loop recycling.	NA	Extends useful life of plating baths. [Reference #119]
	Use pure anodes to reduce bath contamination.	NA	Reduces sludge generated by less pure anodes. [References #125 and 126]
	Use iron phosphate coating instead of zinc phosphate.	NA	Waste Reduction: 30,000 lbs/yr of sludge reduced to 6,000 lbs/yr of sludge. [Reference #138]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution (Continued)	Use hot deionized water rather than nickel acetate as an aluminum oxide sealant following sulfuric acid anodizing.	Capital Investment: $1,020 Annual Savings: $3,094 Payback Period: 0.3 years	Waste Reduction: 2,275 gpy of spent nickel acetate sealant solutions. [Reference #167]
	Replace cadmium electroplating with nickel/zinc electroplating.	NA	[Site 20813](c)
	Use alternative coatings for solvent-based paints to reduce volatile organic materials use and emissions.(b)	30% net savings in applied costs per square foot.(b)	[Reference #151](b)
	Replace organic solvent-based paints with high-solids coatings (this may require modifying the painting process, including high-speed/high-pressure equipment, a paint distribution system, and paint heaters).(b)	NA	Waste Reduction: 41% in VOC emissions. The VOC from the paint decreased from 5.5 lb/gal to 3 lb/gal. [Reference #81](b)
	Replace organic solvent-based paints with water-based coatings.(b)	NA	Waste Reduction: 87% reduction in solvent emissions and decreased hazardous waste production. [References #81 and #154](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution (Continued)	Replace organic solvent-based paints with water-based coatings.(b)	Capital Investment: $2,500 Annual Savings: $11,670 Payback Period: 0.2 years	Waste Reduction: 72 gpy of waste paint and sludge and 66 gpy of spent thinner. [Reference #83]
		NA	Waste Reduction: 75% in total drummed hazardous waste. [Reference #147]
	Replace organic solvent-based paints with powder coatings.(b)	Capital Investment: $1.5 million Payback Period: 2 years(b)	Example is for a large, wrought iron patio furniture company. [Reference #81](b)
		Capital Investment: $20,600 Annual Savings: $14,970 (includes installation of a batch spray booth for powder coating) Payback Period: 1.4 years	Waste Reduction: 72 gpy of waste paint and sludge and 66 gpy of spent thinner. [Reference #83]
		NA	[Site 6054](c)
		NA	[Sites 3862, 4884, 7972, 13103, 16632, 16385, 19019, and 19102](c)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution (Continued)	Replace solvent-based paints containing chromium with water-based paints that do not contain chromium.	Capital Investment: $1,000 Annual Savings: $4,180 Payback Period: 0.2 years	Waste Reduction: 1,390 lbs/year waste solvent-based paint containing chromium. [Reference #166]
Loss Prevention and Housekeeping	To prevent spray gun leakage, submerge only the front end (or fluid control) of the gun into the cleaning solvent.(b)	NA	[Reference #81](b)
Waste Segregation and Separation	Segregate wastewaters containing recoverable metals from other wastewater streams.(b)	NA	[Reference #81](b)
	Segregate nonhazardous paint solids from hazardous paint solvents and thinner.(b)	NA	[Reference #81](b)
Recycling	Use electrolytic cells to recover metals from waste plating solutions; applicable to recovery of gold, silver, cobalt, nickel, cadmium, copper, and zinc from solutions with 100 mg/L to 1,000 mg/L of metal.(b)	Capital Investment: $8,750 - $17,500(b)	Metal Recovery: 1-2 tpy. Metal losses reduced by a factor of 100. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Regenerate anodizing and alkaline baths with contemporary recuperation of aluminum salts.(b)	Annual Savings: $0.02/m^2 of aluminum treated Annual Savings: $0.05/m^2 (including sale of recovered dry aluminum sulfate)(b)	Based on a plant that previously disposed of 180,000 L/yr of acid at $0.07/L. [Reference #81](b)
	Use electrodialysis to extend bath life.	NA	Most often used with chromium plating to remove iron, copper, and other cations and convert Cr^{+3} to Cr^{+6}. [Reference #132]
	Sell spent process solutions as make-up to other solutions.(b)	Annual Savings: $16,300(b)	[Reference #81](b)
	Recycle used rinse waters into bath makeup solutions for their respective process baths.(b)	NA	[Sites 914, 2100, 2985, 3793, 3862, 3960, 6233, 6306, 7159, 9456, 16385, 18802, 19102, 19698, 20532, 20813, 23653, and 24521]
	Reduce the quantity and toxicity of final effluent by evaporation and recovery of wastewater.(b)	Annual Savings: Greater than $100,000 Payback Period: Less than 1 year(b)	Reduced chromium consumption from approximately 8,000 lbs/ month to 200 lbs/month by using a closed-loop evaporator on the chromium bearing rinse waters. [Reference #81](b)
		Capital Investment: $1.3 million Annual Savings: $1.2 million(b)	Based on 350,000 m^3/yr of wastewater. [Reference #57](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Reduce the quantity and toxicity of final effluent by evaporation and recovery of wastewater. (Continued)(b)	Capital Investment: $60,000 Annual Savings: $19,350 Payback Period: 3.8 years(b)	Waste Reduction: Reduced chromic acid replacement in chromium plating bath by 4 lbs/hr. [Reference #137](b)
		Capital Investment: $12,200 Annual Operating Costs: $24,741 Annual Savings: $60,964(b)	Evaporative recovery used for nickel plating rinse waters. [Reference #7](b)
		Payback Period: 2-2.5 years(b)	84% reduction of chromium usage, 15-20% sludge reduction. Company installed an evaporative recovery unit for a chromium plating process. [Reference #81](b)
		NA	[Sites 6233](c)
		Capital Investment: $25,000(b)	[Reference #81](b)
		Installed Cost: $35,680 Annual Operating Cost: $9,160 Annual Savings: $21,000(b)	System operates for 5,000 hrs/yr, recovering 9,375 lbs/yr of chromic acid. [Reference #81] (b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Reduce the quantity and toxicity of wastewater by reverse osmosis.(b)	Capital Investment: $16,000 Payback Period: 1.67 years(b)	Waste Reduction: Almost 100% of chemical and 90% of wastewater recovered. Based on 260 L/hr of wastewater. [Reference #81](b)
		Capital Investment: $62,000 ($39,000 for the reverse osmosis unit) Payback Period: Less than 2 years(b)	Company installed reverse osmosis unit and evaporative heaters to recover nickel and rinse water. [Reference #31](b)
		Capital Investment: $8,500(b)	Waste Reduction: Approximately 85% of the nickel drag-out. [Reference #81](b)
		Capital Investment: $200,000 (330 ft^2 membrane) Annual Operating Cost: Large, due to high pressures in system(b)	[Reference #81](b)
		Capital Investment: $21,500 Annual Operation Cost: $9,113 Annual Savings: $8,351 Payback Period: 2.4 years(b)	Economic information for a Watts nickel plating line with drag-out rates greater than 1 gph. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Reduce the quantity and toxicity of wastewater by reverse osmosis. (Continued)(b)	NA	[Site 17309](c)
	Reduce the quantity and toxicity of wastewater by ion exchange.(b)	Capital Investment: $375,000 Payback Period: 2 years(b)	Waste Reduction: 92% recovery of ion exchange-treated wastewater for reuse. [Reference #81](b)
		Payback Period: 5 years(b)	Nickel sulfate wastewater is treated by ion exchange and returned to nickel plating process. [Reference #19](b)
		Capital Investment: $15,000 (1981)(b)	Ion exchange unit installed to recover chromium. [Reference #81](b)
		Capital Investment: $100,000 Annual Savings: $400,000 in recovered silver	Ion exchange resins used to recover silver. [Reference #135]
		Capital Investment: $25,000 Annual Savings: $14,250 Payback Period: 1.75 years	Waste Reduction: 2,000 lbs/yr of hexavalent chromium waste. Used for chromic acid anodizing line. [Reference #139]
		NA	[Reference #163]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Reduce the quantity and toxicity of wastewater by ion exchange. (Continued)(b)	NA	Waste Reduction: 50% reduction in process water use. [Site 22734](c)
		NA	[Sites 2100, 2306, 6028, 6233 and 11316](c)
	Reduce the quantity and toxicity of wastewater by electrolytic recovery.(b)	Capital Investment: $8,500 Annual Savings: $26,060 (in chemical usage and process water)(b)	Company implemented a high-surface area (HSA) electrolytic reactor for cadmium recovery. [Reference #81](b)
		Capital Investment: $43,000 Annual Savings: Treatment costs eliminated; between 5 and 14 kg each of silver, nickel, and copper recovered weekly.(b)	Company used fluidized bed electrolysis to recover metals from electroplating rinse waters. [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Reduce the quantity and toxicity of wastewater by electrolytic recovery. (Continued)(b)	Capital Investment: $2,900 Annual Savings: $2,700	Waste Reduction: 75% reduction in water consumption, 35% reduction in metals discharge. Company installed electrolytic recovery units on its copper, nickel, lead, and tin electroplating lines and counterflow rinses on all plating lines. Majority of water reduction probably due to countercurrent rinses. [Reference #177]
		Capital Investment: $15,000 per unit Annual Savings: $9,700 per unit	Applicable to cadmium/cyanide, silver/cyanide, copper/cyanide, copper/sulfate, and nickel/sulfamate wastewaters. [Reference #186]
		Capital Investment: $6,000 Payback Period: 0.6 years	Waste Reduction: 88% reduction of copper in rinse water. Company converted flowing rinse after electroless copper operation to a drag-out rinse and used electrolytic recovery of copper. [Reference #193]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Reduce the quantity and toxicity of wastewater by electrolytic recovery. (Continued)(b)	Capital Investment: $6,300	Waste Reduction: 69% reduction of copper in rinse water. Used air agitation flow control for drag-out tank and rinses following an electroless copper plating operation. Used electrolytic recovery unit to recover copper. [Reference #194]
		NA	Electrolytic recovery unit used to recovery cadmium from rinse water. [Site 4043](c)
		NA	Electrolytic recovery unit used to recover copper from rinse water. [Sites 2306 and 3862](c)
		NA	[Sites 3960, 7175, and 22734](c)
	Reduce the quantity and toxicity of wastewaters by electrodialysis with ion exchange.(b)	Capital Investment: $21,050 (15-cell-pair unit) Payback Period: 0.75 years(b)	Company recovers gold from plating rinse water using electrodialysis and ion exchange. [Reference #81](b)
		Capital Investment: $109,600 Annual Savings: $26,000(b)	[Reference #87](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Reduce the quantity and toxicity of wastewaters by electrodialysis with ion exchange.(b) (Continued)	Capital Investment: $220,000 Annual Savings: $45,000(b)	Based on a medium-size jewelry plating and manufacturing company; updating the existing water treatment facility would have cost $500,000. [Reference #81](b)
	Reduce the quantity and toxicity of wastewaters by electrodialysis.	Capital Investment: $120,000 Annual Savings: $129,000	Waste Reduction: Recovered 85% of nickel contained in nickel plating rinses. [Reference #141]
		Capital Investment: $30,000	[Reference #188]
		NA	[Sites 4208 and 10565](c)
	Use reactive rinsing in nickel electroplating operations to reduce rinse water use, improve plating efficiency, and conserve process chemicals.(b)	Capital Investment: $250 (for plumbing and installation)(b)	Rinse tanks operated at rate of 4 gpm (reactive rinsing can eliminate 2 out of 3 plating line rinse tanks). [Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Recover phosphate from aluminum bright dipping operations by reacting acidic rinse with soda alkalies to yield a trisodium phosphate solution. Filter and cool the solution to crystallize the trisodium phosphate, and recycle the remaining rinse water.(b)	NA	[Reference #81](b)
	Install a closed-loop system (using electrodialysis) for repurification of process water and reclamation of acid for reuse on electroplating lines.	Capital Investment: $225,000 Annual Savings: $107,000 Payback Period: 2.1 years	Waste Reduction: 96% reduction in acid purchases, 91% reduction in chemical disposal costs, and 98% reduction in water use and sewage fees. [Reference #178]
	Install ion-exchange and electrolytic recovery units on copper electroplating line.	Capital Investment: $15,000	Waste Reduction: 80% less copper discharged from operation. [Reference #128]
		Capital Investment: $320,000 Payback Period: 1 year	Waste Reduction: 69% less copper discharged from operation. [Reference #82]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Use centrifugation to separate paint solids from paint booth water curtain. Recycle water to paint booth.	Disposal costs reduced by 98%	Waste Reduction: Waste volume reduced by 75%. [Reference #145]
		NA	[Sites 6038, 7175, 10674, and 17309](c)
	Use batch distillation to recover xylene from paint equipment cleanup.(b)	Annual Savings: $5,000 Payback Period: 13 months	[Reference #31](b)
	Use a solvent recovery still to recover spent paint thinner from spray gun cleanups and excess paint batches.(b)	Capital Investment: $6,000 (for a 15-gallon capacity still) Annual Savings: $3,600 (in new thinner savings); $5,400 (in disposal savings) Payback Period: Less than 1 year(b)	Waste Reduction: 75% (745 gal of thinner recovered from 1,003 gal). Based on 1,500 gpy of spent thinner processed. [Reference #81](b)
		Capital Investment: $4,360 Annual Savings: $5,400 Payback Period: 0.8 years	Waste Reduction: 510 gpy of spent thinner. [Reference #146]
		Capital Investment: $3,300 Annual Savings: $1,300	[Reference #176]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-5 (Continued)

Examples of Source Reduction and Recycling Technologies for Metal Coating and Deposition Operations(a)

Pollution Prevention Techniques	Pollution Prevention Method	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Use N-methyl pyrrolidone (NMP), tri-propylene glycol monomethyl ether (TPM) and water solution to replace water used for paint booth water curtain.	NA	Paint resin, pigments, and some paint solvents can be recovered from the NMP, TMP, water solutions system uses less energy and results in cleaner paint booth. [Reference #182]
	Treat and reuse paint curtain water.	NA	[Sites 10283, 16905, and 17655]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-6

Examples of Source Reduction and Recycling Technologies for Assembly Operations(a)

Pollution Prevention Techniques	Pollution Prevention Methods	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Training and Supervision	Avoid buying excess finishing material, due to its short shelf-life.(b)	NA	[Reference #81](b)
Process or Equipment Modification	Use pressurized air mixed with a mist of solvent to clean equipment.(b)	NA	[Reference #81](b)
	Use low-flow nozzles for spray cleaning equipment.	Capital Investment: $270 Annual Savings: $13,000	Waste Reduction: 11,000 gpy of cleaning solvents. [Reference #150]
	Use solvent recovery to reduce the emissions of volatile organics from curing ovens.(b)	Annual Savings: $400,000(b)	[Reference #81](b)
	Use mechanical means to attach parts to eliminate the use of adhesives.	Capital Investment: $1,500 Annual Savings: $5,260 Payback Period: 0.3 years	Waste Reduction: 330 gpy of adhesives. [Reference #146]
	Replace solvent-based adhesives with water-based adhesives.	Capital Investment: $31,740 Annual Savings: $25,690 Payback Period: 1.2 years	Waste Reduction: 345 gpy of solvent vapor. Solid waste generated is nonhazardous. [Reference #84]
	Skim contaminants from surface of emulsifier and developer solutions used in a dye penetrant testing operation.	Capital Investment: $330 Annual Savings: $1,390 Payback Period: 0.24 years	[Reference #161]

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

Table 9-6 (Continued)

Examples of Source Reduction and Recycling Technologies for Assembly Operations(a)

Pollution Prevention Techniques	Pollution Prevention Methods	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Raw Material Substitution	Use fluxless soldering to reduce the use of halogenated solvents to remove flux residues.(b)	NA	[Reference #151](b)
Loss Prevention and Housekeeping	Use rags to their full oil-absorbing capacity, and use a laundering system to clean oil-laden rags.(b)	NA	[Reference #81](b)
Waste Segregation and Separation	Segregate solvent waste streams from water streams.(b)	NA	[Reference #81](b)
Recycling	Recycle metal sludges through metal recovery vendors.(b)	NA	[Reference #81](b)
	Use activated carbon to recover solvent vapors, then recover the solvent from the carbon by steam stripping, and distill the resulting water/solvent mixture.(b)	Capital Investment: $817,000(b)	Waste Reduction: Releases of solvent to the atmosphere were reduced from 700 kg/ton of solvent used to 20 kg/ton. [Reference #81](b)
	Use a recovery system to recycle organic solvents contained in air emissions.(b)	Annual Savings: $1,000(b)	[Reference #31](b)
	Use batch distillation to recover isopropyl acetate generated during equipment cleanup.(b)	Payback Period: 2 years(b)	[Reference #31](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

(c) This information was obtained during site visits at the MP&M site(s) indicated in parenthesis.

Table 9-6 (Continued)

Examples of Source Reduction and Recycling Technologies for Assembly Operations(a)

Pollution Prevention Techniques	Pollution Prevention Methods	Examples of Costs and Savings	Waste Reduction and Other Information [References]
Recycling (Continued)	Use a methyl ethyl ketone solvent recovery system to recover and reuse waste solvents.(b)	Annual Savings: $43,000/yr(b)	Waste Reduction: 90% based on a MEK recovery rate of 20 gpd. [Reference #81](b)
	Arrange an agreement with other small companies to jointly recycle cleaning wastes.(b)	NA	[Reference #81](b)

NA - Not available in listed references.

(a) This information was obtained from a report prepared by EPA's Office of Pollution Prevention and Toxics (referred to as the "Bibliographic Report") and from other literature sources. All source references are listed in Section 3.0 and are cited within brackets on this table (e.g., [Reference #1]). Information derived from the Bibliographic Report is denoted by footnote b. Cost, saving, and waste reduction information shown on this table is based on case studies and reflects the successes reported by Metal Products and Machinery sites. Because specific applications are highly variable, this information should be used as an indicator of how a particular pollution prevention technology has performed under specific circumstances.

(b) This information was obtained from Pollution Prevention Options in Metal Fabricated Products Industries, a Bibliographic Report. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics, EPA/560/8-92/001A, January 1992.

9.3 References

1. U.S. Environmental Protection Agency, Office of Research and Development. Guides to Pollution Prevention in the Fabricated Metal Products Industry. EPA/625/7-90/006, Washington, DC, 1990.

2. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. Waste Minimization in Metal Parts Cleaning. EPA/530-SW-89-049, 1989.

3. U.S. Environmental Protection Agency, Center for Environmental Research Information. Meeting Hazardous Waste Requirements for Metal Finishers. EPA/625/4-87/018, 1987.

4. California Alternative Technology Section and U.S. Environmental Protection Agency. Waste Audit Study: Metal Finishing Industry. PIES #005-073-A, 1988.

5. California Alternative Technology Section and U.S. Environmental Protection Agency. Waste Audit Study: Printed Circuit Board Manufacturers. PIES #005-006, 1987.

6. State of Minnesota, State of Oregon, and U.S. Environmental Protection Agency. Case Studies from the Minnesota Technical Assistance Program and the Oregon Hazardous Waste Reduction Program, 1989.

7. North Carolina Pollution Prevention Program. Case Summaries of Waste Reduction by Industries in the Southeast. PIES #112-003-A, 1989.

8. Metropolitan Water District of Southern California and the Environmental Defense Fund. Source Reduction of Chlorinated Solvents - Electronic Products Manufacture and Solvent Cleaning. PIES #609-008-A and #609-005-A, 1990.

9. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Opportunity Assessments Manual, EPA/625/7-88/0033, Cincinnati, Ohio, 1988.

10. Connecticut Hazardous Waste Management Service, State of Connecticut. Waste Minimization and Pollution Prevention: Metal Finishing - A Self Audit Manual, September 1990.

11. Center for Hazardous Materials Research. Hazardous Waste Minimization Manual for Small Quantity Generators in Pennsylvania. PIES #101-004, 1989.

12. Johnson, J.T. A Comprehensive Strategy for an Overall Program of Metal Working Fluid Management. Cincinnati Milacron Products Division, Cincinnati, Ohio, 1985.

13. Schecter, R. and G. Hunt. Case Summaries of Waste Reduction by Industries in the Southeast. North Carolina Pollution Prevention Pays Program. PIES #112-003-A, Raleigh, NC, 1989. p. 40.

14. Traverse, L. Creative Source Reduction Techniques. Third Annual Massachusetts Hazardous Waste Source Reduction Conference Proceedings. PIES #022-012, Massachusetts Office of Safe Waste Management, Boston, MA, October 23, 1986.

15. Schecter, R. and G. Hunt. Case Summaries of Waste Reduction by Industries in the Southeast. North Carolina Pollution Prevention Pays Program. PIES #112-003-A, Raleigh, NC, 1989. p. 39.

16. Fromm, C.H., S. Budaraju, and S.A. Cordery, Jacobs Engineering Group. Minimization of Process Cleaning Waste. In: Proceedings of the Solvent Waste Reduction Alternatives Seminar. PIES #005-012-A-000, Washington, DC, March 1988.

17. Rodzewich, E.A. Source Reduction - Parts Cleaning. In: Proceedings of the Solvent Waste Reduction Alternatives Seminar. PIES #005-012-A-000, Washington, DC, March 1988.

18. Jacobs Engineering Group, Inc. for U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Office of Research and Development. Waste Minimization Audit Report: Case Studies of Solvent Wastes from Parts Cleaning and from Electronic Capacitor Manufacturing Operations. PIES #010-003-A, Cincinnati, Ohio.

19. Institute for Local Self-Reliance. Engine and Plumbing Parts Manufacture, Case Study 60, Proven Profits from Pollution Prevention: Case Studies in Resource Conservation and Waste Reduction, Vol. II. PIES #306-001-A, Washington, DC, 1989.

20. North Carolina Department of Environment, Health, and Natural Resources: Pollution Prevention Program. Managing and Recycling Solvents in the Furniture Industry. PIES #034-018-A, Raleigh, North Carolina, May 1986.

21. Hackney. Pollution Prevention Challenge Grant Program, North Carolina Department of Natural Resources. Pilot Study of Solvent Recovery for Use in Paint Equipment Cleanup. PIES #034-050-A-000, December 1986.

22. Frick, N.H. and G.W. Gruber, PPG Industries, Inc. Solvent Waste Minimization by the Coatings Industry. PIES #800-01, Pittsburgh, Pennsylvania, March 1988.

23. California Department of Health Services, Alternative Technology Section, Toxic Substances Control Division. Waste Audit Study: Automotive Paint Shops. PIES #005-005, January 1987.

24. M. Drabkin and P. Sylvestri. Waste Minimization Audit Report: Case Studies of Minimization of Solvent and Electroplating Wastes at a DOD Installation. PIES #101-036-B, U.S. Environmental Protection Agency Hazardous Waste Engineering Research Laboratory, Office of Research and Development, Cincinnati, Ohio 1989.

25. Patterson, K.B. and D.E. Hunt. The Cyl-Sonic Cleaner: Aqueous Ultrafiltration Cleaning Using Biodegradable Detergents. Process Technology '88: The Key to Hazardous Waste Minimization, Air Force Logistics Command. PIES #100-100-D, U.S. Air Force, AGMC/MAQSE, Newark Air Force Base, Ohio. August 15-18, 1988.

26. Smietana, T., Office of Safe Waste Management. Trichloroethylene Elimination Case Study: Electric Furnace #2 Bright Anneal Line Industrial Metals Department of Texas Instruments, Inc. In: Proceedings of the Third Annual Massachusetts Hazardous Waste Source Reduction Conference. PIES #022-012, October 23, 1986.

27. Massachusetts Department of Environmental Management, Office of Safe Waste Management. Preliminary Report: Phase I Source Reduction Activities, Southeast Platers Project, Case Study B. PIES #022-003-A, July 1988. p. 3.

28. North Carolina Department of Natural Resources and Community Development. Water Conservation for Electroplaters: Counter-Current Rinsing. PIES #034-024A, Raleigh, North Carolina, 1985.

29. North Carolina Department of Natural Resources and Community Development. Water Conservation for Electroplaters: Rinse Tank Design. PIES #034-026A, Raleigh, North Carolina, 1985.

30. Massachusetts Department of Environmental Management, Office of Safe Waste Management. The Robbins Company: Wastewater Treatment and Recovery System, A Case Study. PIES #034-026B, Raleigh, North Carolina, 1985.

31. Hunt, G., Accomplishments of North Carolina Industries - Case Summaries. PIES #034-010, North Carolina Department of Natural Resources and Community Development, Raleigh, North Carolina, January 1986, p. 22.

32. Hazardous Waste Reduction Program of the Oregon Department of Environmental Quality. The Tektonix Payoff. PIES #038-003-A-000, Salem, Oregon, June 1988.

33. United Nations, Economic and Social Council, Economic Commission for Europe. Compendium on Low-and Non-Waste Technology: Elimination of Chlorine by the Use of Fumeless In-line Degreasing in the Aluminum Industry. PIES #400-103, Geneva, Switzerland, 1983.

34. New Jersey Hazardous Waste Facilities Siting Commission, Hazardous Waste Source Reduction and Recycling Task Force. A Study of Hazardous Waste Source Reduction and Recycling in Four Industry Groups in New Jersey. Case Study D4.1, PIES #031-001-A, Newark, New Jersey, April 1987. p. 30.

35. Evanoff, S.P, et. al. Alternatives to Chlorinated Solvent Degreasing - Testing, Evaluation, and Process Design. In: Proceedings of Process Technology '88: The Key to Hazardous Waste Minimization, Air Force Logistics Command. PIES #100-100-D, Sacramento, California. August 15-18, 1988.

36. Hunt, G., et al. North Carolina Department of Natural Resources and Community Development. Accomplishments of North Carolina Industries - Case Summaries. PIES #034-010, Raleigh, North Carolina, January 1986. p. 22.

37. United Nations, Economic and Social Council, Economic Commission for Europe. Compendium on Low- and Non-Waste Technology: A Low-Waste Electroplating Process. PIES #400-125, Geneva, Switzerland, 1985.

38. Huisingh, D., L. Martin, H. Hilger, and N. Seldman. Proven Profit from Pollution Prevention. Case Study 26. PIES #306-001-A. The Institute for Self-Reliance, Washington, D.C., 1985. p. 103.

39. McRae, G.F. In-Process Waste Reduction: Part 1 - Enviroscope, Plating and Surface Finishing, June 1988.

40. Wigglesworth, D., et.al. Alaska Health Project. Waste Reduction Assistance Program (WRAP) On-Site Consultation Audit Report: Electroplating Shop. PIES #002-016-A-001, Anchorage, Alaska, April 7, 1987. p. 17.

41. Saltzberg, E., Ph.D. Science Applications International Corporation. Methods to Minimize Wastes From Electroplating Facilities. In: Proceedings of Process Technology '88: The Key to Hazardous Waste Minimization, Air Force Logistics Command. PIES #100-100-D, Sacramento, California. August 15-18, 1988.

42. Hubbard Enterprises, San Diego County, Department of Health Services. Minimizing Waste from an Electroplating Operation, Pollution Prevention, A Resource Book for Industry. PIES #005-079-A-000, San Diego, California, 1990.

43. Kohl, J., et. al. Reducing Hazardous Waste Generation with Examples from the Electroplating Industry. North Carolina State University, School of Engineering, Raleigh, North Carolina, 1986.

44. Massachusetts Department of Environmental Management, Office of Safe Waste Management. Source Reduction Recommendations for Precious Metal Platers. PIES #002-012, Boston, Massachusetts, April 1988.

45. Achman, D. Reducing Chromium Losses from a Chromium Plating Bath. Minnesota Technical Assistance Program Summer Intern Report. PIES #709-030, Summer 1987.

46. United Nations Economic and Social Counsel. Use of an Evaporator in Chromium Electroplating, Compendium on Low- and Non-Waste Technology. Monograph ENV/Wp.2/5/Add.47. PIES #400-125, Geneva, Switzerland, 1988.

47. Vaaler, L.E., Office of Safe Waste Management. Prospects for Developing Substitutes for Cyanide-Containing Electroplating Baths. In: Proceedings of the Third Annual Massachusetts Hazardous Waste Source Reduction Conference. PIES #022-012, Boston, Massachusetts, October 23, 1986.

48. U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory. Waste Minimization Audit Report: Case Studies of Minimization of Cyanide Waste from Electroplating Operations, Project Summary. PIES #101-023-B, Cincinnati, Ohio, January 1988.

49. Minnesota Technical Assistance Program. Metal Recovery: Metal Finishing Shop. PIES #709-017, Minneapolis, Minnesota, September 1988.

50. Pajunen, P. Eco-Tech Ltd., and E. Schneider, Hewlett Packard, American Electroplaters and Surface Finishing Society and U.S. Environmental Protection Agency. Copper and Nickel Removal in Printed Circuit Board Processing by Ion Exchange and Electroforming. In: Proceedings for the Ninth AESF/EPA Conference on Environmental Control for the Metal Finishing Industry, January 25-29, 1988.

51. Nadeau, T., et. al. Copper, Nickel and Chrome Recovery in a Jobshop to Eliminate Waste Treatment and Sludge Disposal. In: Proceedings of the Third Annual Massachusetts Hazardous Waste Source Reduction Conference, Office of Safe Waste Management. PIES #022-012, Boston, Massachusetts, October 23, 1986.

52. Minnesota Technical Assistance Program. Metal Recovery: Ion Exchange. PIES #709-019, Minneapolis, Minnesota, September 1988.

53. Tran, T.V., et al. Recovery of Nickel Salts by Electrodialysis Reversal Process, Presented at 73rd Annual AESF Technical Conference and Exhibit of Surface Finishing. The American Electroplaters and Surface Finishers Society Bulletin: TP 334-ST. PIES #222-001-A-001, June 23, 1986.

54. North Carolina Pollution Prevention Program. Potential Recovery and Reuse of Cadmium from an Electroplating Bath. Pollution Prevention Challenge Grant Program. PIES #034-050-A-000, Raleigh, North Carolina, December 1987.

55. Hazardous Waste Reduction Program, Oregon Department of Environmental Quality. Guidelines for Waste Reduction and Recycling: Metal Finishing, Electroplating, Printed Circuit Board Manufacturing. PIES #038-010, Eugene, Oregon, July 1989.

56. Nadeau, T., et. al. Copper, Nickel and Chrome Recovery in a Jobshop to Eliminate Waste Treatment and Sludge Disposal. In: Proceedings for the Third Annual Massachusetts Hazardous Waste Source Reduction Conference, Office of Safe Waste Management. PIES #022-012, Boston, Massachusetts, October 23, 1986.

57. United Nations, Economic and Social Council, Economic Commission for Europe. Compendium on Low- and Non-Waste Technology: Continuous Hardening and Zinc-Coating. PIES #400-103, Geneva, Switzerland, 1981.

58. United Nations, Economic and Social Council, Economic Commission for Europe Compendium on Low- and Non-Waste Technology: Continuous Hardening and Zinc-Coating. PIES #400-103, Geneva, Switzerland, 1981.

59. Institute for Local Self-Reliance. Engine and Plumbing Parts Manufacture, Case Study 60, Proven Profits from Pollution Prevention: Case Studies in Resource Conservation and Waste Reduction, Vol. II. PIES #306-001-A, Washington, DC, 1989.

60. Minnesota Technical Assistance Program, University of Minnesota. Metal Recovery: Etchant Substitution. PIES #709-014-A-000, Minneapolis, Minnesota, 1989.

61. Boyce, A., Tekronix, Inc. and D. J. Kavanaugh, CH_2M Hill Industrial Design Corporation. Electrolytic Regeneration of Chromic/Sulfuric Acid Etchant, Ninth AESF/EPA Conference on Environmental Control for the Metal Finishing Industry. American Electroplaters and Surface Finishing Society and U.S. Environmental Protection Agency, Washington, D.C., January 25-29, 1988.

62. Sellers, V.R. Waste Management Alternatives for Electroplating and Printed Circuit Board Manufacturing Operations. In: Proceedings for the Third Annual Massachusetts Hazardous Waste Source Reduction Conference, Office of Safe Waste Management. PIES #022-012, Boston, Massachusetts, October 23, 1986.

63. Smietana, T. Trichloroethylene Elimination Case Study: Electric Furnace #2 Bright Anneal Line Industrial Metals Department of Texas Instruments, Inc. In: Proceedings of the Third Annual Massachusetts Hazardous Waste Source Reduction Conference. Office of Safe Waste Management. PIES #022-012, Boston, Massachusetts, October 23, 1986.

64. New Jersey Hazardous Waste Facilities Siting Commission, Hazardous Waste Source Reduction and Recycling Task Force. A Study of Hazardous Waste Source Reduction and Recycling in Four Industry Groups in New Jersey, Case Study D6.1. PIES #031-001-A, Newark, New Jersey, April 1987. p. 33.

65. Weigel, K. Developments in Powder Coating Technology, Metal Finishing. April 1989. pp. 41-44.

66. Tyler, D.S. Volstatic, Inc. Electrostatic Powder Coating: Finishing for the Future, Metal Finishing, January 1985. pp. 23-26.

67. Sutter, H. Umweltbundesamt. Low-Waste Technologies in the Federal Republic of Germany, The Environmental Professional, Vol. II, PIES #458-006-A-001, Berlin, Germany, 1989. pp. 190-198.

68. North Carolina Department of Environment, Health, and Natural Resources: Pollution Prevention Program. Managing and Recycling Solvents in the Furniture Industry. PIES #034-018-A, May 1986.

69. Hazardous Waste Reduction Program of the Oregon Department of Environmental Quality. The Tektonix Payoff. PIES #038-003-A-000, Salem, Oregon, June 1988.

70. Manzione, M. Brown and Caldwell Consulting Engineers. Waste Minimization for Electroplating and Aircraft Paint-Stripping Wastewater Treatment. In: Proceedings of Process Technology '88: The Key to Hazardous Waste Minimization, Air Force Logistics Command. PIES #100-100-A. Sacramento, California, August 15-18, 1988.

71. Hackney, Pollution Prevention Challenge Grant Program, North Carolina Department of Natural Resources. Pilot Study of Solvent Recovery for Use in Paint Equipment Cleanup. PIES #034-050-A-000, Raleigh, North Carolina, December 1986.

72. California Department of Health Services, Alternative Technology Section, Toxic Substances Control Division. Waste Audit Study: Automotive Paint Shops. PIES #005-005, Sacramento, California, January 1987.

73. U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Office of Research and Development. Audit Report: Case Studies of Minimization of Solvent Waste from Parts Cleaning and from Electronic Capacitor Manufacturing Operations. PIES #101-008-A, Cincinnati, Ohio, November 1987.

74. Office of Management and Budget. Handbook of Standard Industrial Classifications. Springfield, Virginia, 1987.

75. U.S. Environmental Protection Agency, Office of Water. Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Forming and Metal Powders Point Source Category. EPA 440/1-86/019, Washington, D.C., September 1986.

76. U.S. Environmental Protection Agency, Office of Research and Development. Guides to Pollution Prevention - The Fabricated Metal Products Industry. EPA/625/7-90/006. Washington, D.C., 1990.

77. Franklin Associates for the U.S. Environmental Protection Agency. Composition and Management of Used Oil Generated in the United States. Mission, Kansas, 1984.

78. U.S. Environmental Protection Agency, Office of Solid Waste. Industrial Resource Recovery Practices: Fabricated Metals Production, Machinery Manufacturing/Non-Electrical, and Manufacturing of Electrical Machinery. McLean, Virginia, 1982.

79. U.S. Environmental Protection Agency, Office of Solid Waste. Waste Minimization in Metal Parts Cleaning. PIES #101-056-A, Washington, D.C., 1989.

80. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Metal Finishing Point Source Category. EPA/440/1-83/091, Washington, D.C., 1983.

81. U.S. Environmental Protection Agency, Office of Solid Waste. Pollution Prevention in Metal Manufacturing: Saving Money Through Pollution Prevention (Draft). EPA/530/SW-81/056, Washington, D.C., October 1989.

82. City of Palo Alto. Regional Water Quality Control Plant. Pollution Prevention Review: Symtrom Corporation. Palo Alto, California, January 5, 1994.

83. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Sheet Metal Cabinets and Precision Metal Parts. Environmental Research Brief. EPA/600/S-92/021, Cincinnati, Ohio, May 1992.

84. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Heating, Ventilating, and Air Conditioning Equipment. Environmental Research Brief. EPA/500/M-91/019, Cincinnati, Ohio, July 1991.

85. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Compressed Air Equipment Components. Environmental Research Brief. EPA/600/M-91/024, Cincinnati, Ohio, July 1991.

86. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization for a Manufacturer of Speed Reduction Equipment. Environmental Research Brief. EPA/600/M-91/046, Cincinnati, Ohio, October 1991.

87. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization for a Manufacturer of Can-Manufacturing Equipment. Environmental Research Brief. EPA/600/S-92/014, Cincinnati, Ohio, April 1992.

88. Massachusetts Office of Technical Assistance. Pollution Prevention Case Study: Coolant Substitution at Presmet Corporation. Executive Office of Environmental Affairs, Commonwealth of Massachusetts. Undated.

89. Hause, T., Spartan Chemical Co., Inc. Get the Most from Today's Cookouts. Cutting Tool Engineering. Vol. 41, No. 5, October 1989.

90. Turbo Conveyor. Recycling Cuts Coolant Costs 67%, In Modern Machine Shops. Gardner Publications, Inc., Cincinnati, OH, 1989.

91. National Screw Machine Products Association. Project Zero. White Paper Number 2. Used Cutting Oil. S&N Bulletin #185, April 7, 1989.

92. U.S. Environmental Protection Agency, Office of Research and Development. Novel Vapor-Deposited Lubricants for Metal-Forming Processes. Project Summary. EPA/600/S2-87/060, Research Triangle Park, North Carolina, December 1987.

93. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Blazed Aluminum Oil Coolers. Environmental Research Brief. EPA/600/M-91/018, Cincinnati, Ohio, July 1991.

94. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Commercial Ice Machines and Ice Storage Bins. Environmental Research Brief. EPA/600/S-92/012, Cincinnati, Ohio, May 1992.

95. U.S. Environmental Protection Agency, Office of Research and Development. Guide to Clean Technology: Cleaning and Degreasing Process Changes. Cincinnati, Ohio, May 12, 1992.

96. Deushlo, A., D.P., Inc. Diffusion Dialysis. An Economical Technology for Recovery of Fluids from Pickling Processes. OSMOTA Membrantechnik GmbH, Germany. Undated.

97. Tham, J. and L. LankFord. Reducing Use of Ozone-Depleting Substances and Chlorinated Solvents at McClellan AFB. In: Proceedings of the 14th AESF/EPA Conference on Environmental Control for the Surface Finishing Industry. Undated.

98. The Hazardous Waste Consultant. CO_2 Blasting for Metal Cleaning Operations. September/October 1991.

99. Byszewski, C., and K. Mani. Allied-Signal, Inc. Aquatech™ Systems - A Technology for Metal Waste Recovery. In: Proceedings of the Metal Waste Management Alternatives: Minimizing, Recycling, and Treating Hazardous Wastes. Symposium Proceedings. California Department of Health Services and U.S. Environmental Protection Agency. Sacramento, California, August 1989.

100. Jones, E. and T. Stewart. Pacific Northwest Laboratories. Recycling and Treatment of Metal-Bearing Spent Acids. In: Proceedings of the Metal Waste Management Alternatives: Minimizing, Recycling, and Treating Hazardous Metal Wastes Symposium. California Department of Health Services and U.S. Environmental Protection Agency, Sacramento, California, August 1989.

101. Wassell, B. American Etching and Manufacturing. Case Studies in Waste Minimization, Government Institutes, Inc. Rockville, Maryland, October 1991.

102. ASM Committee on Acid Cleaning. Acid Cleaning of Iron and Steel. Metals Handbook, Vol. 5, Metals Park, Ohio.

103. California Department of Health Services, Alternative Technology Section. Toxic Substances Control Division. Waste Audit Study: Metal Finishing Industry. Sacramento, California, May 1988.

104. Williams, M., R. Deshmukh, and D. Bhattachargya. Separation of Hazardous Organics by Reverse Osmosis Membranes. Environmental Progress. Vol. 9, No. 2, May 1990.

105. Hill, L., Parker Haunifin Corporation. Replacing Methylene Chloride Degreasing: A Case Study. In FOCUS Waste Minimization, Issue No. 12, North Carolina Department of Environment Health and Natural Resources. Raleigh, North Carolina, Spring/Summer 1992.

106. Connecticut Technical Assistance Program. Case Study: The United Illuminating Company. ConnTAP Quarterly, Vol. 5, No. 2, Hartford, Connecticut, Spring 1992.

107. Minnesota Technical Assistance Program. Deburring Operations Replaces Vapor Degreaser for Cleaning Metal Parts. MnTAP SOURCE, Vol. 7, No. 3, Minneapolis, Minnesota, Summer 1992.

108. U.S. Environmental Protection Agency, Office of Air and Radiation. Alternatives for CFC-113 and Chloroform in Metal Cleaning. Washington, D.C., June 1991.

109. Schmitz, W. McDonnell Aircraft Company. CO_2 Pellet Blasting for Paint Stripping/Coatings Removal. In: Proceedings/Compendium of Papers: Solvent Substitution. U.S. Department of Energy and U.S. Air Force. Phoenix, Arizona, December 4-7, 1990.

110. Wasson, N. and M. Haas, U.S. Air Force. Sodium Bicarbonate Blasting for Paint Stripping. In: Proceedings/Compendium of Papers: Solvent Substitution. U.S. Department of Energy and U.S. Air Force. Phoenix, Arizona, December 4-7, 1990.

111. Salerro, R. High Pressure Supercritical Carbon Dioxide Efficiency in Removing Hydrocarbon Machine Coolants from Metal Coupons and Component Parts. In: Proceedings/Compendium of Papers: Solvent Substitution. U.S. Department of Energy and U.S. Air Force, Phoenix, Arizona, December 4-7, 1990.

112. Hermansen, R., Hughes Aircraft Company. Development of a Solvent Database Software Program. In: Proceedings/Compendium of Papers: Solvent Substitution. U.S. Department of Energy and U.S. Air Force, Phoenix, Arizona, December 4-7, 1990.

113. Bower, M., APS Materials, Inc. and L. Brown and J. Springer, U.S. Environmental Protection Agency. Chemical Substitution for 1,1,1-Trichloroethane and Methanol In: Proceedings/Compendium of Papers: Solvent Substitution. U.S. Department of Energy and U.S. Air Force, Phoenix, Arizona, December 4-7, 1990.

114. Burrell, M., Waste Minimization Company. The Successful Implementation of a Solvent Recovery Program. In: Proceedings/Compendium of Papers: Solvent Substitution. U.S. Department of Energy and U.S. Air Force. Phoenix, Arizona, December 4-7, 1990.

115. Suolen, M., Oakite Products, Inc. Replacing Petroleum-Based Oils in Metal Forming Operations. Chlorinated Solvent (CFC) Replacement Seminar. Rochester, New York, October 30, 1991.

116. Miller, G., T. Lindsey, A. Ocker, and M. Miller, U.S. Environmental Protection Agency, Risk Reduction Engineering Laboratory. Evaluation of Ultrafiltration to Recovery Aqueous Iron Phosphating/Degreasing Bath. Cincinnati, Ohio, May 1993.

117. U.S. Environmental Protection Agency. Guide to Clean Technology: Alternative Metal Finishes (Draft). July 1992.

118. Grahm, G. and M. Patry. Oklahoma City Air Logistics Center - Propulsion Directorate. Hazardous Waste Minimization Report. Undated.

119. Metal Finishing Guidebook and Directory Issue, 1992. 60th Guidebook Directory Issue, Hackensack, New Jersey, 1992.

120. U.S. Environmental Protection Agency. Guides to Pollution Prevention, the Printed Circuit Board Manufacturing Industry.

121. Koop, R. and Y. Moji. Boric/Sulfuric Acid Anodize-Alternative to Chronic Acid Anodize. In: Proceedings of the 28th Annual Aerospace/Airline Plating and Metal Finishing Forum and Exposition. April 20-23, 1992.

122. Jeannenne, R.A. EN for Hard Chromium. Products Finishing, January 1990.

123. Kusher, B. Coating Alternatives to Chrome Plating. In: Proceedings of the 28th Annual Aerospace/Airline Plating and Metal Finishing Forum and Exposition. April 20-23, 1992.

124. Langan, J. Alternative for Tank Chromium Using Brush Plating. AESF SURFIN Conference. June 1992.

125. American Society of Metals. Metals Handbook. Surface Cleaning, Finishing, and Coating. Vol. 5. Metals Park, Ohio.

126. ICF Technology, Incorporated. New York State Waste Reduction Guidance Manual. Prepared for: New York State Department of Environmental Conservation. Albany, New York, March 1989.

127. Cushnie, G.C. Electroplating Wastewater Pollution Control Technology. Noyes Publications, Park Ridge, New Jersey, 1985.

128. City of Palo Alto. Regional Water Quality Control Plant. Pollution Prevention Review: Mantex Circuits, Inc. Palo Alto, California, January 5, 1994.

129. CH_2M Hill. Engineering Evaluation of Plating Shop Renovation for the 243-G Bay Electroplating Facility (McClellan AFB). Contract No. F0469900035, Task No. 5008, July 1991.

130. Rubinstein, M. Electrochemical Metabolizing - Principals and Practices. Van Nostrand Reinhold, New York, New York 1987.

131. Norris, J. Brush Anodizing in the Aircraft/Aerospace Industries, Plating and Surface Finishing, August 1992.

132. Cushnie, G. and W. Anderson. Removal of Metal Cations from Chromium Plating Solutions. In: Proceedings of the 10th AESF/EPA Conference on Environmental Control for the Metal Finishing Industry, January 1989.

133. Foss, L. Foss Plating Company. Closed Loop Plating System for Waste Minimization. Metal Waste Management Alternatives, 1989 Symposium Proceedings, California Department of Health Services, Pasadena, California, August 1989.

134. Jacobs Engineering Group, Inc. for California Department of Health Services, Toxic Substances Control Division. Reducing California's Metal-Bearing Waste Streams. Pasadena, California, August 1989.

135. Abbott, D. A Systems Approach to Electroplating Waste Minimization. Case Studies in Waste Minimization. Government Institutes, Inc., Rockville, Maryland, October 1991.

136. U.S. Environmental Protection Agency, Office of Research and Development. Plant C. Waste Minimization Opportunity Assessment. Case Studies in Waste Minimization. Government Institute, Inc., Rockville, Maryland, October 1991.

137. U.S. Environmental Protection Agency, Office of Research and Development. Environmental Regulations and Technology: The Electroplating Industry. EPA/625/10-85/001, September 1985.

138. Connecticut Technical Assistance Program. Iron Phosphate Coating Can Eliminate Zinc from Waste Stream. ConnTAP Quarterly, Vol. 3, No. 3, Hartford, Connecticut, Summer 1993.

139. Connecticut Technical Assistance Program. Manufacturer Produces Savings Using Closed-Looped System. ConnTAPP Quarterly, Vol. 3, No. 3, Hartford, Connecticut, Summer 1990.

140. Minnesota Technical Assistance Program. Peerless Chain Company Eliminates Use of Cyanide-Based Plating Solution. MnTAP Source, Vol. 6, No. 4, Minneapolis, Minnesota, Fall 1991.

141. Connecticut Technical Assistance Program. Waste Minimization System Saves Bridgepoint Company $129,000 Annually. ConnTAP Quarterly, Vol. 2, No. 3, Hartford, Connecticut, Summer 1989.

142. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Outdoor Illuminated Signs. Environmental Research Brief. EPA/600/M-91/016, Cincinnati, Ohio, July 1991.

143. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Permanent-Magnet. D.C. Electric Motors. Environmental Research Brief.

144. Park, G. RI Department of Environmental Management. Viteratary Solution Recycling: A Case Study in Pollution Prevention. In: Proceedings of the 1992 Rhode Island Pollution Prevention Conference and Exposition, Providence, Rhode Island, September 30 - October 1, 1992.

145. Centrifuge Reduced Paint Solid Waste. Cut Disposal Fees. Pollution Engineering. October 15, 1992. pp. 16-17.

146. Young, S., Minnesota Technical Assistance Program. Reducing Overspray in a Conventional Air-Atomizing Paint System. Minnesota Waste Management Board. Minneapolis, Minnesota, 1987.

147. U.S. Environmental Protection Agency, Office of Research and Development. Plant A Waste Minimization Opportunity Assessment. In: Case Studies in Waste Minimization. Government Institute, Inc., Rockville, Maryland, October 1991.

148. Frady, M., Lilly Industries, Inc. HVLP Spray Gun Applications. Focus Waste Minimization, Issue No. 12, North Carolina Department of Environmental Health, and Natural Resources. Raleigh, North Carolina, Spring/Summer 1992.

149. Connecticut Technical Assistance Program. Case Study Bead Industries Bridgeport. ConnTAP Quarterly, Vol. 4, No. 3, Hartford, Connecticut, Summer 1991.

150. Minnesota Technical Assistance Program. Case Study: Spray Nozzle Selection Reduces Solvent Waste. MnTAP SOURCE, Vol. 6, No. 3, Minneapolis, Minnesota, Summer 1991.

151. Hoskins, M., Sandia National Laboratories. Reduction of Solvent Use Through Fluxless Soldering. In: Proceedings/Compendium of Papers: Solvent Substitution. U.S. Department of Energy and U.S. Air Force. Phoenix, Arizona, December 4-7, 1990.

152. U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. Pollution Prevention Options in Metal Fabricated Products Industries. EPA/560/8-92/001a, January 1992.

153. U.S. Environmental Protection Agency, Office of Research and Development. Waste Reduction Activities and Options for a Manufacturer of Hardened Steel Gears. Environmental Research Brief. EPA/600/S-92/057, Cincinnati, Ohio, October 1992.

154. U.S. Environmental Protection Agency, Office of Research and Development. Waste Reduction Activities and Options for a Remanufacturer of Automobile Radiators. Environmental Research Brief. EPA/600/S-92/051, Cincinnati, Ohio, October 1992.

155. U.S. Environmental Protection Agency, Office of Research and Development. Waste Reduction Activities and Options for a Fabrication and Finisher of Steel Computer Cabinets. Environmental Research Brief. EPA/600/S-92/044, Cincinnati, Ohio, October 1992.

156. U.S. Environmental Protection Agency, Office of Research and Development. Waste Reduction Activities and Options for an Autobody Repair Facility. Environmental Research Brief. EPA/600/S-92/043, Cincinnati, Ohio, October 1992.

157. U.S. Environmental Protection Agency, Office of Research and Development. Modifications to Reduce Drag-Out at a Printed Circuit Board Manufacturer. Project Summary. EPA/600/SR-92/114, Cincinnati, Ohio, October 1992.

158. U.S. Environmental Protection Agency, Office of Research and Development. Waste Reduction Activities and Options for Manufacturer of Commercial Dry Cleaning Equipment. Environmental Research Brief. EPA/600/S-92/062, Cincinnati, Ohio, October 1992.

159. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Opportunity Assessment: Fort Riley, Kansas. Project Summary. EPA/600/S2-90/031, Cincinnati, Ohio, August 1990.

160. U.S. Environmental Protection Agency, Office of Research and Development. Users Guide for the Conversion of Navy Paint Spray Booth Particulate Emission Control Systems from Wet to Dry Operation. Project Summary. EPA/600/S2-90/008, Research Triangle Park, North Carolina, May 1990.

161. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Opportunity Assessment: Scott Air Force Base. Project Summary. EPA/600/S2-91/054, Cincinnati, Ohio, December 1991.

162. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Opportunity Assessment: Philadelphia Navy Shipyard. Project Summary. EPA/600/S2-90/046, Cincinnati, Ohio, February 1991.

163. U.S. Environmental Protection Agency, Office of Research and Development. Recovery of Metals from Sludges and Wastewaters. EPA/600/S2-91/041, Cincinnati, Ohio, September 1991.

164. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Metal Parts Coating Plant. Environmental Research Brief. EPA/600/M-91/015, Cincinnati, Ohio, July 1991.

165. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for Manufacturer of Rebuilt Railway Cars and Components. Environmental Research Brief. EPA/600/M-91/017, Cincinnati, Ohio, July 1991.

166. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Cutting and Welding Equipment. Environmental Research Brief. EPA/600/S-92/029, Cincinnati, Ohio, September 1992.

167. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Finished Metal Components. Environmental Research Brief. EPA/600/S-92/030, Cincinnati, Ohio, September 1992.

168. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Machined Parts. Environmental Research Brief. EPA/600/S-92/031, Cincinnati, Ohio, September 1992.

169. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Sheet Metal Components. Environmental Research Brief. EPA/600/S-92/037, Cincinnati, Ohio, September 1992.

170. U.S. Environmental Protection Agency, Office of Research and Development. Waste Minimization Assessment for a Manufacturer of Penny Blanks and Zinc Products. Environmental Brief. EPA/600/S-92/037, Cincinnati, Ohio, September 1992.

171. U.S. Environmental Protection Agency, Office of Research and Development. Waste Reduction Activities and Options for a Manufacturer of Commercial Refrigeration Units. Environmental Research Brief. EPA/600/S-92/047, Cincinnati, Ohio, October 1992.

172. Haimowitz, S. Process Profiles: Recover Metals-Laden. Chemical Engineering. October 1993. p. 31.

173. DOE Tests Hail Ultrasonic Cleaning with Aqueous Detergents. Aero Environmental Report. October 1, 1993. p.8.

174. Connecticut Technical Assistance Program. Process Change Eliminates Waste. Site Visit Team Assists Manufacture's Cost Contaminant Measures. ConnTAP Quarterly, Vol. 1, No. 1, Hartford, Connecticut, Winter 1994.

175. Connecticut Technical Assistance Program. Wallingford Manufacturer Blazes Pollution Prevention Trail, Discovers 2.8 Year Payback for Eliminating CFCs. ConnTAP Quarterly, Vol. 6, No. 4, Hartford, Connecticut, Fall 1993.

176. Minnesota Technical Assistance Program. Reducing Wastes at an Autobody Repair Shop. MnTAP SOURCE, Vol. 8, No. 4, Minneapolis, Minnesota, Fall 1993.

177. Commonwealth of Massachusetts, Office of Technical Assistance. Metals Recovery and Wastewater Reduction at Hi-Tech Gold Plating Corporation. Toxics Use Reduction Case Study. Boston, Massachusetts. Undated.

178. Commonwealth of Massachusetts, Office of Technical Assistance. Chemical and Water Use Reduction at Poly-Plating, Inc. Toxics Use Reduction Case Study. Boston, Massachusetts. Undated.

179. Commonwealth of Massachusetts, Office of Technical Assistance. Immortal Etchants. Boston Massachusetts. Undated.

180. Commonwealth of Massachusetts, Office of Technical Assistance. G.F. Wright Ends H_2SO_4 Use for Wire Pickling, Cuts Use by 95 Percent. Draft Toxics Use Reduction Case Study. Boston, Massachusetts. Undated.

181. Dentchman, A.H., Beamalloy Corporation. Beamalloy Corporation Announces New Non-Toxic, Hand Chrome Coating Process. News Release. Dublin, Ohio, July 10, 1992.

182. Walsh, W.C., BASF Corporation Chemicals Division. Alternative Paint Trapping, Fluid for Use in Recirculating Water Automotive Paint Booths. Parsippany, New Jersey, 1993.

183. U.S. Army Corps of Engineers. Non-Cyanide Electroplating. Installation Restoration and Hazardous Waste Control Technologies, 1992. p. 201.

184. U.S. Army Corps of Engineers. Non-Cyanide Metal Stripper Replacement Program. Installation Restoration and Hazardous Waste Control Technologies, 1992. p. 203.

185. U.S. Army Corps of Engineers. Spray-Casting to Replace Electroplating. Installation Restoration and Hazardous Waste Control Technologies, 1992. p. 207.

186. U.S. Army Corps of Engineers. Electrolytic Recovery of Metal/Cyanide Wastewaters. Installation Restoration and Hazardous Waste Control Technologies, 1992. p. 203.

187. U.S. Army Corps of Engineers. Hard Chrome Plating Installation Restoration and Hazardous Waste Control Technologies, 1992. p. 217.

188. U.S. Army Corps of Engineers. Electrodialysis of Chromic Acid Plating Solutions. Installation Restoration and Hazardous Waste Control Technologies, 1992. p. 219.

189. U.S. Army Corps of Engineers. Ion Vapor Deposition (IVD) Substitution of Aluminum for Cadmium. Installation Restoration and Hazardous Waste Control Technologies, 1992. p. 223.

190. U.S. Army Corps of Engineers. Recycle of Spent Abrasive Into Asphaltic Concrete. Installation Restoration and Hazardous Waste Control Technologies, 1992. p. 225.

191. U.S. Army Corps of Engineers. Conversion of Paint Booth Filtration from Wet to Dry. Installation Restoration and Hazardous Waste Control Technologies, 1992. p. 247.

192. General Services Administration, Region 6. Briefing Package for an Alternative Coatings Workshop. Kansas City, Missouri, December 3, 1993.

193 City of Palo Alto. Regional Water Quality Control Plant. Pollution Prevention Review: Technitron, Inc. Palo Alto, California, January 5, 1994.

194. City of Palo Alto. Regional Water Quality Control Plant. Pollution Prevention Review: Davila International Circuits, Inc. Palo Alto, California, January 5, 1994.

NOTE: Information on pollution prevention is available through EPA's EnviroSense clearinghouse. The EnviroSense clearinghouse contains technical, policy, programmatic, legislative, and financial information on pollution prevention efforts in the United States and abroad. The EnviroSense clearinghouse may be accessed by mail, telephone, or the EnviroSense Bulletin Board System, a free 24-hour computer bulletin board. Technical support information on the use on the EnviroSense BBS may be obtained by calling (703) 908-2007.

10.0 TECHNOLOGY OPTIONS

This section describes the five technology options which were used in developing the Metal Products and Machinery (MP&M) Phase I effluent limitations guidelines and standards. Section 10.1 identifies the technologies considered for the MP&M Phase I technology options, including a brief description of each technology, a summary of the demonstration status of each technology, and a summary of the technologies included in the technology options. Section 10.2 summarizes the methodology EPA used to select the technologies included in the options, and describes each technology option. Section 10.3 presents a detailed description of each technology included in the options. **The technologies included in each option were selected for development of the MP&M Phase I effluent limitations guidelines and standards. These technologies are not required for compliance with the MP&M Phase I effluent guidelines; sites can install any technology as long as the site achieves the final effluent limitations.** These technology options were used to estimate compliance costs (see Section 12.0) and pollutant loadings and reductions (Section 13.0) for the MP&M Phase I effluent guidelines.

The MP&M Phase I technology options consist of groups of source reduction, recycling, and wastewater treatment technologies identified to reduce or eliminate the creation or discharge of pollutants from MP&M sites. The technologies considered for the technology options were identified from responses to the MP&M data collection portfolios (DCPs), MP&M site visits and sampling episodes, and technical literature (including case studies and development documents for previously promulgated metals industry regulations).

10.1 Technologies Considered

As discussed in Section 6.0, MP&M Phase I sites generate wastewaters containing oils (including organic pollutants), cyanide, and metals. Many different types of technologies are used in the MP&M industry to control and treat these wastewaters, including both in-process source reduction and recycling technologies and end-of-pipe treatment and disposal technologies. These technologies have been classified into one of the four tiers of the Environmental Management Hierarchy (EMH) from the Facility Pollution Prevention Guide (1). This hierarchy attempts to prioritize technologies in order of importance or benefit to the environment from source reduction (highest priority) to disposal (lowest priority). Tables 10-1 through 10-3 present technologies considered for the MP&M Phase I technology options grouped by their EMH classification as follows:

1. Table 10-1: Source reduction technologies - EMH tier 1;

2. Table 10-2: Recycling technologies - EMH tier 2; and

3. Table 10-3: End-of-pipe treatment and disposal technologies - EMH tiers 3 and 4.

The tables present the following for each technology: a brief technology description; the number of sites visited at which the technology was observed; the number of MP&M Phase I model site DCP respondents reporting using the technology; the estimated number of sites in the MP&M Phase I industry using the technology (based on responses to the DCP scaled to the entire industry); and additional comments noting if the technology was included in the MP&M technology options (as discussed in Section 10.2) and, where appropriate, reasons why the technology was not included in the MP&M technology options.

The demonstration status of source reduction and some recycling technologies in the MP&M Phase I industry was not quantifiable from data in the DCPs. Therefore, Tables 10-1 and 10-2 do not always present estimates of the number of MP&M sites performing each of these technologies. However, as shown on these tables, EPA observed these technologies during visits to MP&M sites. The most frequently observed source reduction and recycling technologies were:

- Centrifugation of machining coolants;
- Conductivity probes;
- Countercurrent cascade rinsing;
- Drag-out rinsing;
- Electrolytic recovery;
- Flow restrictors;
- In-tank filtration;
- Ion exchange; and
- Regeneration of process baths.

In addition, many of the sites visited employed plant maintenance and good housekeeping practices that resulted in source reduction.

As shown in Table 10-3, the most common end-of-pipe treatment technologies in the MP&M Phase I industry are:

- Chemical emulsion breaking;
- Chemical precipitation and settling;
- Chemical reduction of hexavalent chromium;
- Cyanide destruction through alkaline chlorination;
- Gravity settling of wastewater (without chemical addition);
- Gravity thickening of sludge;
- Multimedia filtration (including sand filtration);
- Neutralization (without solids removal);

- Oil skimming; and
- Pressure filtration of sludge.

In addition, an estimated 2,826 of the 10,061 water discharging MP&M sites, contract haul some of their wastewater for off-site treatment and disposal. Many sites with treatment technologies in place also contract haul wastewater treatment sludges for off-site disposal.

10.2 Technology Options

EPA developed five technology options for the MP&M Phase I industry, based on the technologies listed in Tables 10-1 through 10-3 and the following general criteria.

- Demonstrated status at MP&M Phase I sites.

- Demonstrated performance for controlling and treating MP&M Phase I wastewater, including an assessment of pollution prevention benefits. This assessment was based on the EMH classification of each technology.

EPA considered a technology to be demonstrated in the MP&M Phase I industry if the technology was observed during at least one MP&M site visit or reported by at least one MP&M Phase I DCP respondent, and was considered by EPA to be applicable to MP&M Phase I wastewaters. EPA evaluated the performance of each technology using available analytical data from MP&M sampling episodes, analytical data from previously promulgated metals industry regulations, and quantitative and qualitative assessments from engineering site visits and literature.

Based on the technologies listed in Tables 10-1 through 10-3, EPA identified the five technology options used to develop the MP&M Phase I effluent guidelines. These options consist of end-of-pipe treatment (Option 1), end-of-pipe treatment and in-process source reduction and recycling (Option 2), tiered option for "low" flow and "high" flow sites (Option 1A), end of pipe treatment and in-process source reduction and recycling for "high" flow sites (Option 2A), and advanced end-of-pipe treatment and recycling (Option 3). The technology trains for the options are presented in Figures 10-1 through 10-3 and discussed in the following paragraphs.

10.2.1 Option 1: End-of-Pipe Treatment

Chemical Precipitation and Sedimentation Treatment. Option 1 comprises the following technologies:

- Chemical precipitation and sedimentation (including sludge dewatering using gravity thickening, and pressure filtration).

- Oil/water separation through chemical emulsion breaking and either skimming or coalescing;
- Cyanide destruction through alkaline chlorination;
- Chemical reduction of hexavalent chromium;
- Chemical reduction of chelated metals; and
- Contract hauling of solvent degreasing wastewaters.

In Option 1, all process wastewaters are treated with end-of-pipe chemical precipitation and sedimentation. Chemical precipitation and sedimentation involves adjusting the pH of the wastewater with alkaline chemicals such as lime (calcium hydroxide) or caustic (sodium hydroxide), or acidic chemicals (such as sulfuric acid) to produce insoluble metal hydroxides. This step is followed by a settling process to remove the metal hydroxides. This treatment train is widely used throughout the metals industry and is well documented as being effective for removing pollutants present in MP&M wastewaters.

Some MP&M Phase I wastewaters require preliminary treatment prior to chemical precipitation and sedimentation. These wastewaters contain pollutants such as oil and grease, cyanide, hexavalent chromium, chelated metals, and organic solvents that can inhibit the performance of chemical precipitation and sedimentation treatment. These preliminary treatment technologies, which are described below, are most effective on segregated wastewaters, prior to commingling with other wastewaters.

Oil-Bearing Wastewater. EPA has determined that some wastewaters, usually alkaline cleaning wastewaters and water-based metal-working fluids (e.g., machining and grinding coolants, deformation lubricants), may contain significant amounts of oil and grease. These wastewaters require preliminary treatment to remove oil and grease and organic pollutants. Chemical emulsion breaking followed by either skimming or coalescing effectively removes these pollutants.

Cyanide-Bearing Wastewater. EPA has identified MP&M wastewaters that may contain significant amounts of cyanide, such as plating and cleaning wastewaters. These wastewaters require preliminary treatment to destroy the cyanide. This is typically performed using alkaline chlorination with sodium hypochlorite or chlorine gas.

Hexavalent Chromium-Bearing Wastewater. EPA has identified hexavalent chromium-bearing wastewaters, usually generated by acid treatment anodizing, conversion coating, and electroplating operations and rinses. Because hexavalent chromium does not form a hydroxide and is not treated by chemical precipitation and sedimentation, these wastewaters require chemical reduction of the hexavalent chromium to trivalent chromium. Trivalent chromium does form a hydroxide and is treated by chemical

precipitation and sedimentation. Sodium metabisulfite or gaseous sulphur dioxide are typically used as reducing agents.

Chelated Metal-Bearing Wastewaters. EPA has identified wastewaters that contain significant amounts of chelated metals, such as electroless plating solutions and rinses. These wastewaters require chemical reduction to break down the metal chelates prior to chemical precipitation and sedimentation. Sodium borohydride, hydrazine, and sodium hydrosulfite can be used as reducing agents.

Organic Solvent-Bearing Wastewaters. Option 1 also includes contract hauling of solvent degreasing wastewaters. Based on data collected in DCPs and site visits, most solvent degreasing operations use organic solvents (e.g., 1,1,1-trichloroethane, trichloroethene) that are contract hauled for off-site recycling. Some MP&M Phase I sites reported the use of organic solvent-water mixtures or rinses following organic solvent degreasing. EPA considers contract hauling of these wastewaters as the most cost-effective disposal method for these sites. It is important to note that solvent degreasing operations are currently in a state of transition due to the phase-out of chlorinated solvents under the Montreal Protocol.

10.2.2 Option 2: End-of-Pipe Treatment and In-Process Source Reduction and Recycling

Option 2 comprises the technologies included in Option 1 plus in-process flow control and pollution prevention technologies which allow for recovery and reuse of materials along with water conservation. The specific Option 2 technologies include:

- The technologies included for Option 1;
- Flow reduction with flow restrictors, conductivity controllers or timed rinses, and countercurrent cascade rinsing for all flowing rinses;
- Flow reduction through manual control of the wastewater discharge rate or through analytical testing and maintenance of bath chemistry for all other process water-discharging operations;
- Centrifugation and 100 percent recycling of painting water curtains;
- Centrifugation and pasteurization to extend the life of water-soluble machining coolants, reducing discharge volume by 80 percent; and
- In-process metals separation and recovery with ion exchange followed by electrolytic recovery of the cation regenerants for selected electroplating rinses. This includes first-stage drag-out

rinsing (when necessary) with electrolytic metal recovery. These technologies were not applied to chromium electroplating rinses because chromium is not amenable to electrolytic recovery.

EPA has observed these pollution prevention and water conservation technologies at MP&M Phase I sites during site visits and sampling episodes.

Technologies such as centrifugation and pasteurization for machining coolants, centrifugation for painting water curtains, or ion exchange for electroplating rinses, prolong the use of raw materials prior to disposal. In some instances, the technologies recover metal or metal treatment solutions. Using these recovery technologies along with flow reduction typically reduces the wastewater flow rate with a corresponding increase in pollutant concentrations in the treatment influent streams.

Within the range of influent concentrations measured for the MP&M industry, the effectiveness of chemical precipitation and sedimentation on metal-bearing wastewaters is independent of influent concentration, since the performance of this technology is limited by the solubility of metal hydroxides in water. For example, a well-operated chemical precipitation and sedimentation treatment system achieves similar long-term average concentrations for metal pollutants, whether the influent stream contains 10 or 100 mg/L of metal pollutants.

Sites reducing their wastewater flow rates and increasing their influent pollutant concentrations will achieve more effective treatment, thereby reducing the mass of pollutants discharged in the treated effluent. For example, if a site generates raw wastewater at 2,600 gallons (10,000 liters) per day containing 10 mg/L of pollutant prior to treatment, and implements water reduction and recovery technologies to reduce the flow to 1,300 gallons (5,000 liters) per day while increasing the pollutant concentration to 20 mg/L prior to treatment, the site will reduce the mass of pollutants discharged by treating to the same discharge concentration at half of the flow rate. If the long-term average effluent concentration of a pollutant was 0.1 mg/L, the site would discharge 1,000 mg/day of pollutant (10,000 L/day times 0.1 mg/L) prior to implementing flow reduction and recovery technologies, and 500 mg/day of pollutant (5,000 L/day times 0.1 mg/L) after implementation of the technologies. Option 2 is the preferred option for direct dischargers.

10.2.3 Option 1A: Tiered Option for "Low" Flow and "High" Flow Sites

Option 1A is a tiered option, based on Options 1 and 2, depending on the annual discharge volume at a given MP&M site. The Agency established this option for indirect discharging sites only in development of Pretreatment Standards for Existing Sources (PSES). For "low" flow sites, defined as sites with a discharge volume of less than 1,000,000 gallons per year (gpy), this option would require that sites comply with concentration-based standards based on Option 1. For a site operating 250 days per

year, 1,000,000 gallons per year translates into an average discharge flow rate of 4,000 gallons per day. For "high" flow sites, defined as sites with a discharge volume of 1,000,000 gpy or greater, this option would require that sites comply with mass-based standards based on Option 2.

10.2.4 Option 2A: End of Pipe Treatment and In-Process Source Reduction and Recycling for "High" Flow Sites (Preferred Option)

The Agency established this option for indirect discharging sites only in development of pretreatment standards. Option 2A requires that existing "high" flow indirect sites, defined as sites with a discharge volume of 1,000,000 gallons per year or greater, comply with mass-based standards based on Option 2. Existing "low" flow indirect sites would be exempt from these standards. New indirect sites would be required to comply with mass-based standards based on Option 2. Option 2A is the preferred option for indirect discharging sites.

10.2.5 Option 3: Advanced End-of-Pipe Treatment and Recycling

Option 3 comprises the technologies included in Option 2 plus end-of-pipe ion exchange with 90% reuse of the treated wastewater. This technology has been observed at MP&M Phase I sites, and reported in DCPs. In this option, sites treat their wastewater for reuse in the process, replacing a portion of the water supply used in the process area. Option 3 technology is expected to sufficiently treat wastewater, such that 90% of the treated wastewater can be reused in the process. The other 10% is discharged as a bleed stream after treatment.

10.3 Technology Descriptions for In-Process Source Reduction and Recycling Technologies

This section describes in detail in-process source reduction and recycling technologies included in the MP&M technology options or considered by the Agency to be equivalent or alternative to a technology included in the MP&M technology options. The technology descriptions contain information on the application and performance of the following technologies:

- Centrifugation and pasteurization of machining coolants;
- Centrifugation and recycling of painting water curtains;
- Countercurrent cascade rinsing;
- Electrodialysis;
- Electrolytic recovery;
- Flow reduction for rinses and baths;
- Ion exchange; and
- Reverse osmosis.

10.3.1 Centrifugation and Pasteurization of Machining Coolants

Most machining coolants consist of water-soluble oil in water. The water-soluble coolant is typically pumped through a coolant sump, over the machining tool and part during machining, and returned to the sump. Coolant becomes spent for one or more of the following reasons:

- The concentration of suspended solids in the coolant begins to inhibit performance;
- Nonemulsified, or "tramp", oil collects on the surface of the coolant;
- The coolant becomes rancid due to microbial growth; or
- Coolant additives are consumed reducing corrosion prevention and lubrication properties.

Centrifugation and pasteurization can be used along with oil skimming and biocide addition to reduce coolant discharge and pollutant generation at the source. Buildup of suspended solids in the machining coolant is removed using the centrifuge. Tramp oil can also be removed if the centrifuge used is capable of liquid-liquid separation. If the centrifuge used is only capable of liquid-solid separation, an oil skimmer can be used for removal of tramp oil. Microbial growth is controlled through pasteurization but can also be controlled by adding biocides. Using these technologies can extend the usable life of a water-soluble coolant considerably and, in many cases, indefinitely. A flow diagram of a typically machining coolant centrifugation and recycling system is shown in Figure 10-4.

These technologies result in sites reducing the amount of coolant and wastewater requiring treatment and disposal, and reducing the amount of fresh coolant purchased.

The coolant recycling technologies are most effective when sites consolidate the types of coolants used, and use a centralized coolant recycling system. However, some sites may not be able to consolidate the types of coolants used, because of product or customer specifications. In this case, sites may need to purchase dedicated coolant recycling systems for each type of coolant used.

The centrifuge is a simple unit that is very reliable and requires only routine maintenance, such as periodic cleaning and removal of accumulated solids. Flow rate is the only operating factor to control. The sludge generated from this technology is commonly classified as a hazardous waste. This determination is based on the metal type processed, and the amount of metal that dissolves into the coolant. The sludge is typically contract hauled for treatment and disposal.

10.3.2 Centrifugation and Recycling of Painting Water Curtains

Water curtains are used to catch paint overspray in spray painting booths. This water is continuously recirculated until the solids content in the wastewater necessitates either in-process treatment and recycling or discharge. Sites may employ in-process filters (e.g., cloth filters) for solids removal. Centrifugation of spent water curtains is used to remove the solids and recycle the water curtain, eliminating the need for discharge. Centrifugation is a physical removal process to remove solids from paint curtain wastewater. In this system, wastewater is pumped to a holding tank, then through the centrifuge. Solids are contract hauled for off-site disposal, while the treated wastewater is returned to the paint booth. Chemical addition may be necessary prior to centrifugation to achieve effective solids removal. A flow diagram of a typical paint curtain centrifugation and recycling system is shown in Figure 10-5.

In the centrifugation process, a holding tank large enough to hold the entire volume of the water curtain is necessary. The wastewater is pumped from the water curtain through the centrifuge, where the rotation of the centrifuge forces the solids to be caught in the bowl of the centrifuge, while the treated wastewater is discharged out the center and returned to the sump.

During operation of the paint curtain, solids will accumulate on the bottom of the water curtain sump. Centrifugation of the paint curtain should proceed until all wastewater is treated and the sludge remains in the sump. The sludge in the water curtain sump must be removed either manually, with a sludge pump, or by a vacuum truck. After the sludge has been removed and the water curtain has been treated through the centrifuge, the wastewater from the holding tank is pumped back into the water curtain sump. Make-up water is added to compensate for evaporation. Using this procedure, the paint curtain water can be continuously recycled.

Wastewater from painting water curtains commonly contains organic pollutants as well as certain metals. Eliminating the discharge of wastewater from painting water curtains may eliminate the need for an end-of-pipe treatment step for organic pollutants at certain sites. Also, if a site only generates painting wastewater, additional wastewater treatment would not be necessary if the paint curtain water was continuously recycled.

The centrifuge is a simple unit that is very reliable and requires only routine maintenance. Flow rate is the only operating factor to control. One disadvantage of this technology is that it may not be economically feasible for sites generating only a small amount of paint curtain wastewater. In cases where sites have multiple sumps, portable centrifuges can be used.

The sludge generated from painting water curtains, is commonly classified as a hazardous waste, based on the type of paint used, and is typically contract hauled for treatment and disposal. Most sites employing painting water curtains currently generate sludge from in-

process solids filtration and sump cleanout. The Agency anticipates that additional sludge will be generated by centrifugation and recycling of the water curtains.

10.3.3 Countercurrent Cascade Rinsing

Rinsing follows many MP&M unit operations to dilute and remove dirt, oil, or chemicals remaining on parts and racks from a previous unit operation. By removing drag-out from the surface of the part, rinsing improves the quality of the surface finishing process and prevents the contamination of subsequent process baths. The quantity of water required for good rinsing depends on the number of rinse tanks and their configuration. Single rinse tanks with a continuous overflow are an inefficient use of water. A common method of improving water use efficiency is to install a multiple rinse tank arrangement, such as countercurrent cascade rinsing.

Countercurrent cascade rinsing is widely used for reducing the discharge rate of rinse water at MP&M Phase I sites. A diagram showing the application of countercurrent cascade rinsing is presented in Figure 10-6. Fresh water flows into the rinse tank located farthest from the process tank and overflows, in turn, to the rinse tanks closer to the process tank. This technique is termed countercurrent rinsing, because the work piece and the rinse water move in opposite directions. Over time, the first rinse becomes contaminated with drag-out and reaches a stable concentration which is lower than the process solution. The second rinse stabilizes at a lower concentration, which enables less rinse water to be used than if only one rinse tank were in place. The more countercurrent cascade rinse tanks (three-stage, four-stage, etc.), the less water needed to adequately remove the process solution.

The rinse rate needed to adequately dilute drag-out depends on the concentration of process chemicals in the drag-out, the concentration of plating chemicals that can be tolerated in the final rinse tank before poor plating results, and the number of countercurrent cascade rinse tanks. These factors are expressed in the following equation(2):

$$V_r = \left[\frac{C_o}{C_f}\right]^{1/n} \times V_D \qquad (10\text{-}1)$$

where:

V_r	=	the flow through each rinse stage, gal/min;
C_o	=	the concentration of the contaminant(s) in the initial process bath, mg/L;
C_f	=	the tolerable concentration of the contaminant(s) in the final rinse to give acceptable product cleanliness, mg/L;
n	=	the number of rinse stages used; and
V_D	=	the drag-out carried into each rinse stage, expressed as a flow, gal/min.

This mathematical rinsing model is based on complete rinsing (i.e., removal of all drag-out from the part/fixture) and complete mixing (i.e., homogeneous rinse water). Under these conditions, each additional rinse stage can reduce rinse water use by 90 percent. These conditions are not achieved unless there is sufficient residence time and agitation in the rinse tank. For less efficient rinse systems, each added rinse stage reduces rinse water use by 50 to 75 percent.

Countercurrent cascade rinsing systems have the following limitations: cost of additional rinse tanks; loss of production space; and an increase in production time and labor. Also, when countercurrent cascade rinsing is used, the low flow rate through the rinse tanks may not provide the needed agitation for drag-out removal. In such cases, air or mechanical agitation is added to increase rinsing efficiency.

10.3.4 Electrolytic Recovery

Electrolytic recovery is an electrochemical process used to recover metals from many types of process solutions, such as electroplating rinse waters and baths. Electrolytic recovery removes metal ions from a waste stream by processing the stream in an electrolytic cell, which consists of a closely spaced anode and cathode. Commercial equipment is comprised of several cells, a transfer pump, and a rectifier. Current is applied across the cell and metal cations are deposited on the cathodes. The waste stream is usually recirculated through the cell from a separate tank, such as a drag-out recovery rinse. Figure 10-7 presents a diagram of a typical electrolytic recovery system.

The capacity of electrolytic recovery equipment depends on the total cathode area and the maximum rated output of the rectifier. Commercial units are available with a cathode area ranging from 1 to 100 ft^2 and more, and an output of 10 to 1,000 amperes or more. Theoretical electrolytic recovery rates are determined by Faraday's law and range from 1.19 grams/amp-hour for divalent copper to 7.35 grams/amp-hour for monovalent gold. Actual rates are usually much lower and depend on the metal concentration in the waste stream. At low concentrations (under 100 mg/L), electrolytic recovery rates may be below 10% of the theoretical maximum.

Various types of cathodes are used in electrolytic recovery units, depending mainly on the concentration of metal in the waste stream. The different cathodes are often classified by their surface area. Flat-plate cathodes have the lowest surface area and are used only for recovering gross quantities of metal from metal-rich waste streams (usually 1 to 20 g/L of metal). Reticulate cathodes, which have a metallized woven fiber design, have a surface area ten times greater than their apparent area. These cathodes can be used over a wide range of metal concentrations but, due to cost factors (reticulate cathodes are disposable), are typically used where the dissolved metal concentration is below 1 g/L. Carbon and graphite cathodes have the highest surface area per unit of apparent area. Their use is usually restricted to metal concentrations below 100 mg/L.

Electrolytic recovery is applied to solutions containing nickel, copper, precious metals, and cadmium. Chromium and aluminum are poor candidates for electrolytic recovery. Drag-out recovery rinses and ion-exchange regenerant are common sources of solutions that are processed using electrolytic recovery. Some solutions require pH adjustment prior to electrolytic recovery. Acidic, metal-rich, cation regenerant is an excellent candidate stream for electrolytic recovery, and is often electrolytically recovered without adjustment. In some cases, when the target concentration is reached, the waste stream is reused as cation regenerant.

Dissolved metals in electrolytes can be recovered to low levels (<5 mg/L) using reticulate or carbon cathodes. In practice, however, the target concentration for most applications is 50 to 250 mg/L or higher. With flat-plate cathodes, the target concentration is usually above 0.5 g/L, because plating efficiency drops as concentration falls. Plating time required to lower the concentration of a pollutant from 100 to 10 mg/L can be several times longer than that required to lower the concentration from 10,000 mg/L to 100 mg/L. Also, unit energy costs (measured in dollars per pound of metal recovered) increase substantially at lower metal concentrations.

Electrolytic recovery is offered by numerous vendors, and is applicable to a wide range of rinse solutions and ion-exchange regenerants due to the number of materials and configurations available for anodes and cathodes. All of the commonly electroplated metals, except chromium, can be recovered using electrolytic recovery.

Electrolytic recovery is not applicable to flowing rinses due to the lower metal concentrations and the extended time required for metal recovery. In most cases, electrolytic recovery cannot cost effectively remove dissolved metals to concentrations required for discharge. Electrolytic recovery is used more for gross metal recovery rather than as a compliance technology.

Labor requirements are relatively low for electrolytic recovery. Units recovering metal from drag-out recovery tanks may only require occasional cleaning and maintenance. Units treating batch discharges from ion-exchange units require more labor due to the higher metal content of that solution and the resultant increase in cathode loading

frequency. Energy costs for this technology can be significant, and, in some cases, exceed the recovery value of the metal. Energy requirements depend on several factors, including required voltage, rectifier efficiency, and current efficiency. More concentrated solutions will generally be recovered in a more energy-efficient manner than dilute solutions. Electrode replacement costs may be significant for units using disposable cathodes, especially when high metal recovery rates are encountered. If the materials of construction are properly selected for a given electrolyte, permanent cathodes and anodes may last more than five years for most applications.

10.3.5 Flow Reduction for Rinses and Baths

Flow reduction for rinses and baths encompasses a set of technologies that can be applied to MP&M rinses and process baths to reduce the wastewater discharge rate. These technologies involve water use reduction and bath maintenance and regeneration. The potential for reducing water use at MP&M sites is evident in the water use and discharge data in the DCP database. These data show large variations in site water use per unit of production. While some variations in water flow per unit of production result from process conditions, on-site observations during site visits indicated that most variations are caused by water use practices, including imprecise control of water use.

Rinse Water Reduction

For a given rinse tank design and configuration, there is a minimal rinse water flow rate that provides adequate rinsing. This minimum flow rate can be achieved by coordinating the amounts of rinse water and drag-out. There are various means to control flow, the selection of which depends on the nature of the production operations and the preference of the MP&M site. Three common flow control methods include flow restrictors, timers, and conductivity rinse controls. These technologies have been observed at many MP&M Phase I sites.

Flow Restrictors. Flow restrictors are commonly installed on a rinse tank's water inlet. These devices contain an elastomer washer which flexes under pressure to maintain a constant water flow regardless of pressure. Flow restrictors can maintain a wide range of flow rates, from less than 0.1 gal/min to more than 10 gal/min.

As a stand-alone device, a flow restrictor provides a constant water flow. As such, for intermittent rinsing operations, a flow restrictor does not coordinate the rinse flow with drag-out introduction. Precise control with intermittent operations typically requires a combination of flow restrictors and rinse timers. However, for continuous rinsing (e.g., continuous electroplating machines), flow restrictors may be adequate for good water control.

Rinse Timers. Rinse timers are electronic devices that control a solenoid valve. The timer usually consists of a button that, when pressed, opens the valve for a

predetermined length of time, usually from 1 to 99 minutes. After the time period has expired, the valve is automatically shut. The timer may be activated either manually by the operator or automatically by the action of racks or hoists.

Most rinse systems that are used intermittently benefit from the installation of a rinse timer, as operator error is eliminated. Rinse timers installed in conjunction with flow restrictors can provide precise control when the incoming water pressure may rise and fall. Rinse timers are less effective in continuous or nearly continuous rinse operations (e.g., continuous electroplating machines).

Conductivity Controllers. Conductivity controllers consist of a controller, a meter with adjustable set points, a probe that is placed in the rinse tank, and a solenoid valve. As parts are rinsed, dissolved solids are added to the water in the rinse tank, raising the conductivity of the water. When conductivity reaches a predetermined set point, the solenoid valve is opened. When the conductivity falls below the set point, the valve is shut.

In theory, conductivity control of rinse flow is a precise method of maintaining optimum rinsing conditions in intermittently used rinse operations. In reality, conductivity controllers work best with deionized rinse water. Incoming water conductivity may vary day-to-day and season-to-season, which forces frequent setpoint adjustments. Suspended solids and nonionic contaminants (e.g., oil) are not detected by the conductivity probe and can cause inadequate rinsing.

Bath Maintenance and Regeneration

Process baths become contaminated with impurities that affect their performance. The sources of contamination include: (1) breakdown of process chemicals; (2) buildup of byproducts (e.g., carbonates); (3) contamination from impurities in make-up water, chemicals, or anodes; (4) corrosion of parts, racks, tanks, heating coils, etc.; (5) drag-in of chemicals; (6) errors in bath additions; and (7) airborne particles entering the tank. If left untreated, process baths eventually become unusable and require disposal. MP&M sites commonly use bath maintenance techniques to extend the useful lives of process solutions and reduce waste generation. Several of the more common techniques include filtration, carbon treatment, electrolysis, carbonate freezing, and chemical precipitation. These methods are discussed below.

There are many production, environmental, and cost advantages to maintaining process baths. When used on a continuous or routine basis, these practices maintain the baths in good operating condition and result in consistent production results. They also lower the total dissolved solids concentration of the bath, which reduces the drag-out rate. Use of these technologies reduces the pollutant loading to the wastewater treatment system resulting in a reduction of wastewater treatment chemical purchases and sludge disposal costs.

Filtration. Filtration is used to remove suspended solids from surface finishing solutions. Suspended solids in surface finishing solutions may cause roughness and burning of deposits. Filtration uses various types of equipment; the most common of which are cartridge filters, precoat diatomaceous earth filters, and sand or multimedia filters. Cartridge filters are available with either in-tank or external configurations. The in-tank units are used mostly for small tanks and the external units for larger tanks. Most cartridges are disposable; however, washable and reusable filters are available, which further reduce waste generation. Precoat, sand, and multimedia filters are used mostly for large tanks. Filter media are selected based on the chemical composition of the bath. All filtration systems are sized based on solids loading and the required flow rate. Typical flow rates for electroplating solution applications are 2 to 3 bath volumes per hour.

Carbon Treatment. Carbon treatment of electroplating baths is a common method of removing organic contaminants. The carbon adsorbs organic impurities that result from the presence of oil or the breakdown of bath constituents, such as wetting agents. It is used on both a continuous and batch basis, depending on the site's preference. Various application methods are available, including carbon filtration cartridges (restricted to use on small applications), carbon canisters (used mostly for moderately sized applications), and precoat filters and bulk application/agitation/filtration (used mostly for larger applications). Carbon treatment is most commonly applied to nickel, copper, zinc, and cadmium electroplating.

Electrolysis. Electrolysis (also referred to as dummy plating) is a bath maintenance process in which metallic contaminants (tramp metals) in a surface finishing solution are either plated out (low-current density electrolysis) or oxidized (high-current density electrolysis). Low-current density (LCD) electrolysis is applied to a range of plating and other surface finishing processes, including nickel, copper, and zinc electroplating baths. The tramp metals that are most frequently removed by electrolysis are copper, zinc, iron, and lead. With LCD electrolysis, the tramp metals are selectively plated out onto a corrugated steel sheet cathode by applying a current density that avoids plating the primary metal constituent in the bath. The normal range is 2 to 8 amperes per square foot (ASF). The duration of treatment is typically 2 to 5 amp-hr/gal. In high current density (HCD) electrolysis, trivalent chromium is oxidized to hexavalent chromium in chromic acid baths (e.g., chromium electroplating and chromic acid anodizing). Lead or lead alloy anodes are typically used in the process. A lead peroxide film is formed on the anode which functions as the oxidation agent. Current densities of 100 to 300 ASF are used.

Carbonate Freezing. Carbonate freezing is a method of removing excessive carbonate buildup by forming carbonate salt crystals at a low temperature. This process is most often applied to electroplating baths formulated with sodium cyanide. Carbonates are formed by the breakdown of cyanide (especially at high temperatures), excessive anode current densities, and the adsorption of carbon dioxide from the air. An excessive

carbonate concentration reduces the quality of the product. Carbonate freezing takes advantage of the low solubility of carbonate salts in the sodium cyanide bath. The method involves lowering the bath temperature to approximately 26°F (-3°C) at which point hydrated salt (Na_2CO_3-$10H_2O$) crystallizes out of solution.

Chemical Precipitation. Chemical precipitation is a batch process in which certain inorganic contaminants are removed from electroplating baths. Precipitation is an alternative method to carbonate freezing for cyanide baths and is especially applicable to potassium cyanide baths. Chemicals used for this purpose include barium cyanide, barium hydroxide, calcium hydroxide, or calcium sulfate. The least expensive of these chemicals, calcium sulfate, forms a bulky precipitate that is more difficult to remove. Other common uses of precipitation include sodium sulfide treatment of cyanide baths for zinc and lead removal, nickel carbonate or nickel hydrate treatment of nickel plating baths to remove miscellaneous metal contaminants (e.g., iron, aluminum, silicon), and potassium permanganate treatment of zinc baths to remove iron. Frequently, the process is performed in a spare tank where the solution is chemically treated, filtered, and returned to service.

10.3.6 Ion Exchange (in-process)

Ion exchange is a reversible chemical reaction which exchanges ions in a feed stream for ions of like charge on the surface of an ion-exchange resin. Resins are broadly divided into cationic or anionic types. Typical cation resins exchange H^+ for other cations, while anion resins exchange OH^- for other anions. Figure 10-8 presents a typical ion-exchange column configuration.

In practice, a feed stream is passed through a vessel, referred to as a column, which holds the resin. The feed stream is usually either dilute rinse water (in-process ion-exchange) or treated wastewater (end-of-pipe ion exchange). Often, prior to ion-exchange treatment, the feed stream passes through a cartridge filter and a carbon filter to remove suspended solids and organics that foul the resin bed. The exchange process proceeds until the capacity of the resin is reached (i.e., an exchange has occurred at all the resin sites). A regenerant solution is then passed through the column. For cation resins, the regenerant is an acid, and the H^+ ions replace the cations captured from the feed stream. For anion resins, the regenerant is a base, and OH^- ions replace the anions captured from the feed stream. The concentration of feed stream ions is much higher in the regenerant than in the feed stream; therefore, the ion-exchange process accomplishes both separation and concentration.

Ion exchange is used for water recycling and/or metal recovery. For water recycling, cation and anion columns are placed in series. The feed stream is deionized and the product water is reused for rinsing. Often, closed-loop rinsing is achieved. The regenerant from the cation column typically contains the metal species, which can be recovered in elemental form via recovery. The anion regenerant is typically discharged

to wastewater treatment. When metal recovery is the only objective, a single or double cation column unit containing selective resin is used. These resins attract divalent cations while allowing monovalent cations to pass, a process usually referred to as metal scavenging. Water cannot be recycled because contaminants other than the target cations remain in the stream exiting the column.

Ion-exchange equipment ranges from small, manual, single-column units to multicolumn, highly automated units. For continuous service, two sets of columns are necessary. One set handles the service flow, and the other set is regenerated. Thus, two-column metal scavenging and four-column deionizing systems are common. Automatic systems direct the wastewater flow and initiate regeneration with little or no operator interaction.

Equipment size is based on flow volume and concentration. Resin capacity varies but often ranges from 1 to 2 lbs/ft^3. Flow rates may range from 1 to 20 or more gpm. Columns are typically sized to handle wastewater flow for at least a period of time equal to the time required for regeneration. Automatic systems are sized to provide continuous service. Regeneration volume typically ranges from 2 to 4 resin bed volumes of dilute acid or caustic. Concentrations of feed stream contaminants generally range from 10 to 20 g/L.

The labor requirements for ion exchange depend on the automation level of the equipment. Manual systems can incur significant labor costs associated with preparing, transporting, and disposing of regenerants. Automatic systems require far less labor. Resins, usually lasting for years, eventually need to be replaced due to organic contamination, resin oxidation, and fouling from suspended solids. This process can be hastened by misuse, accidents, or poor engineering. Resin replacement costs can be 10 to 20% of the original capital investment.

Ion exchange is applied in two basic configurations (see Figure 10-8): water recycling and/or metal scavenging (recovery). Deionizing removes all cations and anions from a relatively dilute rinse stream and recycles the deionized water back to the rinsing process. Generally, the total dissolved solids concentration of such streams must be below 500 mg/L, to maintain an efficient regeneration frequency. In some cases, the cation or anion regenerant is compatible with the bath chemistry and can be directly reused in the bath. Usually, however, the regenerant is too dilute or incompatible with the process chemistry and it cannot be reused. In these cases, the metal ions in the regenerant can be recovered using electrolytic recovery or waste treatment. Drag-out reduction, including drag-out tanks, can enhance the efficiency of the recovery process. Effluent total dissolved solids levels of 2 mg/L or less are typical.

Metal scavenging recovers only the metal content of the drag-out. This technology is efficient if the metal ions being scavenged are the primary source of ions in the stream. The metal content of the stream may only be a small fraction of the total dissolved solids (TDS) present in the stream, making scavenging suitable over a wider range of TDS.

Scavenging also provides a highly concentrated regenerant, particularly suitable for electrolytic recovery. Water recycling is not possible since only some of the cations and none of the anions are removed. Effluent metal concentrations of under 0.5 mg/L are typically achieved with standard installations. Scavenging resin systems can also be used to polish discharge from a conventional wastewater treatment system. Ions are selectively captured by the resin, but concentrated salts used for pH neutralization pass through. The regenerant may be sent to an electrolytic recovery device to recover metal, or returned upstream to the conventional wastewater treatment system.

Many process wastewaters are excellent candidates for ion exchange, including the rinse water from plating processes of copper, cadmium, gold, lead, nickel, tin, tin-lead, and zinc. Gold-bearing resins are difficult to regenerate, and frequently require incineration to recover the gold content. Lead is also difficult to recover from ion exchange resins. Methane sulfonic acid (very expensive) and fluoboric acid (usually not suitable for electrolytic recovery) are effective regenerants; these resins may be replaced when exhausted rather than regenerated. Cyanide rinse waters are amenable to ion exchange; cation resins are capable of breaking the metal-cyanide complex and the cyanide is removed in the anion column. The cation regenerant can be electrolytically recovered and the cyanide present in the anion regenerant can be returned to the process or discharged to treatment.

Ion exchange is a commonly used technology within the MP&M industry. In addition to water recycle and chemical recovery applications, ion exchange is used to soften or deionize raw water for process solutions.

10.3.7 Reverse Osmosis (both in-process and end-of-pipe)

Reverse osmosis is a membrane separation technology used by the MP&M industry for chemical recovery. The feed stream, usually relatively dilute rinse water or wastewater, is pumped to the surface of the reverse osmosis membrane at pressures of 400 to 1,000 psig. The membrane separates the feed stream into a reject stream and a permeate. The reject stream, containing most of the dissolved solids in the feed stream, is deflected from the membrane while the permeate passes through. Reverse osmosis membranes reject more than 99% of multivalent ions and 90 to 96% of monovalent ions, in addition to organics and nonionic dissolved solids. The permeate stream is usually of sufficient quality to be recycled as rinse water, despite the small percentage of monovalent ions (commonly potassium, sodium and chloride) that pass through the membrane.

A sufficiently concentrated reject stream can be returned directly to the process bath. The reject stream concentration can be increased if the stream is recycled through the unit more than once or by increasing the feed pressure. In multiple-stage units containing more than one membrane chamber, the reject stream from the first chamber is routed to the second, and so on. The combined reject streams from multistage units

may, in some cases, have high enough concentrations to be returned directly to the bath. A flow diagram of a common configuration for a reverse osmosis recovery system is shown in Figure 10-9.

The capacity of reverse osmosis equipment is generally measured in flow volume, and is determined by the membrane surface area and operating pressure. Generally, capacity is increased by increasing the surface area of the membrane. Operating at higher pressures will increase the permeate flow volume per unit membrane area (also called the flux). Reject stream concentration increases with pressure and decreases as flow volume increases.

Prefiltering and pretreating the feed stream may be necessary to lengthen membrane life or reduce the frequency of fouling. Filtration to remove suspended solids is usually necessary. Adjustment of pH may prevent precipitation from occurring as the feed stream is concentrated, but it may make the concentrate unfit to return to the process bath.

Reverse osmosis is most applicable to electroplating rinse waters, including Watts nickel, bright nickel, brass cyanide, copper cyanide, and zinc cyanide. Total dissolved solids (TDS) concentrations of 1,000 mg/L or more can be tolerated. Permeate TDS concentrations of 250 mg/L or less are typical, and the dissolved solids are mostly common monovalent ions, allowing the permeate stream to be reused in most rinsing operations.

The reject stream concentration limit for basic reverse osmosis equipment is approximately 20 g/L TDS. Multipass and multistage units achieve higher concentrations, approaching 30 g/L TDS or higher. If the reject stream is acceptable to return directly to the process bath and the permeate is recycled as rinse water, a closed loop is created. However, returning the reject stream directly to the bath is, in practice, uncommon, because the concentration is too low. Reject streams can be electrolytically recovered, treated conventionally, or reconcentrated by evaporation and returned to the process.

During the operation of reverse osmosis, energy is consumed only by pumps. In most cases, water recycling is achieved; in some cases, a closed loop is possible. Compared to ion exchange, reverse osmosis has the advantage of tolerating somewhat higher feed stream concentrations. The concentration of reverse osmosis reject streams are near or higher than that of ion exchange regenerants. Both are less effective in handling oxidizing chemistries or feed streams high in organics and total suspended solids (TSS). Ion exchange effluent generally has a lower TDS concentration than reverse osmosis permeate and is appropriate to recycle in all rinses. For most applications, membrane life is measured in years, although membranes are susceptible to fouling from organics, suspended solids, or misuse. Reverse osmosis units may have instrumentation that indicates the condition of the membrane by measuring the flux. If the membrane fouls

or clogs, the flux rate drops, and the membrane should be cleaned. Pressure and other flow gauges are common.

In cases where the reject stream concentration is not high enough to warrant return to the bath, the reject stream can be concentrated with an evaporator, electrolytically recovered, or treated conventionally. When used with evaporators, reverse osmosis loses its low-energy advantage over other in-process reuse and recovery technologies. When both technologies are configured with an electrolytic recovery unit, reverse osmosis often has a higher capital cost than ion exchange. As an end-of-pipe treatment, reverse osmosis and ion exchange are competitive in terms of metals removal; reverse osmosis may result in greater opportunity for water recycling.

Labor needs to operate reverse osmosis equipment are associated with periodic membrane cleaning. Membrane and pump replacement are the primary maintenance items. Membranes generally last 1 to 5 years, depending on the application, but misuse, or changes in feed stream characterization, can have a significant negative impact.

10.4 Technology Descriptions for Preliminary Treatment of Segregated Wastewater Streams

This section describes in detail technologies used for the preliminary treatment of segregated wastewater streams and included in the MP&M technology options. Technology descriptions contain information on the application and performance of the following technologies:

- Chemical reduction of chelated metals;
- Chemical reduction of hexavalent chromium;
- Cyanide destruction through alkaline chlorination; and
- Oil/water separation.

10.4.1 Chemical Reduction of Chelated Metals

Certain MP&M wastewaters contain chelating agents which interfere with conventional chemical precipitation processes. These wastewaters are often associated with electroless plating, and require specific treatment for the chelated metals. In general, there are three methods of treating these wastewaters:

- Reduction to elemental metal;
- Precipitation as an insoluble compound; and
- Physical separation.

Reduction to elemental metal involves the use of either electrical current or reducing agents to reduce the metal ion to its elemental form (i.e., Ni^{2+} to Ni^{o}). The metal is

recovered either in the form of a metal film on a sacrificial anode or as a metal precipitate.

Precipitation as an insoluble compound involves either precipitation methods that are not affected by chelation, or methods that involve breaking the chelate prior to traditional forms of precipitation.

Separation of bath constituents is performed by membrane filtration or ion exchange. These technologies usually generate both a dilute and a concentrated waste stream, both of which may be reused or hauled off-site for treatment and disposal.

Reduction to Elemental Metal

Reduction to elemental metal can be performed using one of two methods. One method is electrolytic recovery in which the dissolved metal is deposited on the cathode for reclamation or disposal. The electric current provides the electrons to reduce the metal ion to its elemental form. The reaction rate, and achievable concentration for this technology, are dependent on the volume of wastewater per unit surface area of cathode. This method typically does not achieve metals concentrations sufficiently low enough for wastewater discharge.

The second method uses a reducing agent to provide the electrons to reduce the metal. Possible reducing agents for use in chelated wastewater streams include:

- Sodium borohydride.
- Hydrazine.
- Sodium hydrosulfite.

Upon reduction, the metal forms a particulate in solution which can then be removed by conventional solids removal techniques. These reducing agents sometimes require the use of other chemicals for pH adjustment, to be used effectively. Figure 10-10 presents a process diagram for this method of chemical reduction of chelated metals.

Precipitation as an Insoluble Compound

The presence of chelating agents hinders the formation of hydroxides, making hydroxide precipitation ineffective on chelated wastewaters. Some other precipitation methods that are not affected or less affected by the presence of chelating agents include: sulfide precipitation, dithiocarbamate (DTC) precipitation, and carbonate precipitation. With the exception of DTC precipitation, all of these technologies are discussed under the chemical precipitation portion of this section. DTC is added to solution in stoichiometric ratio to the metals present. DTC is effective in treating chelated wastewater; however, DTC is also used as a pesticide and, if used incorrectly, may cause process upsets in the biological treatment used at a POTW. The use of DTC by direct dischargers can be

especially harmful to the aquatic environment because the direct dischargers' wastewater does not go through the biological treatment at a POTW. DTC precipitation generates large amounts of sludge, but is effective in treating electroless plating wastewaters.

Physical Separation

Metals can be separated from solution by ion exchange and reverse osmosis. These technologies are not affected by chelators in the wastewater, making these techniques effective in treating wastewater from electroless plating. These technologies are discussed in this section separately.

10.4.2 Chemical Reduction of Hexavalent Chromium

Reduction is a chemical reaction in which electrons are transferred from one chemical (the reducing agent) to the chemical being reduced. Sulfur dioxide, sodium bisulfite, sodium metabisulfite, and ferrous sulfate form strong reducing agents in water. They are often used at MP&M sites to reduce hexavalent chromium to the trivalent form, which allows the metal to be removed from solution by chemical precipitation. Chromium reduction is necessary because hexavalent chromium does not form a hydroxide, and therefore is not precipitated by hydroxide precipitation.

Sodium metabisulfite, sodium bisulfite, and sulfur dioxide are the most widely used reducing agents at MP&M sites. The reaction in these processes is illustrated for the following sulfur dioxide reaction (reduction using other reagents is chemically similar):

$$2H_2CrO_4 + 3SO_2 \rightarrow Cr_2(SO_4)_3 + 2H_2O \qquad (10\text{-}2)$$

An operating pH of between 2 and 3 is normal. At pH levels above 5, the reduction rate is slow and oxidizing agents such as dissolved oxygen and ferric iron interfere with the reduction process by consuming the reducing agent.

A typical treatment involves retention in a reaction tank for 45 minutes. The reaction tank is equipped with pH and oxidation-reduction potential (ORP) controls. Sulfuric acid is added to maintain a pH of approximately 2.0, and a reducing agent is metered to the reaction tank to maintain the ORP at 250 to 300 millivolts. The reaction tank is equipped with an impeller designed to provide approximately one bath volume per minute. Figure 10-11 presents a process flow diagram of a continuous chromium reduction system.

Chemical reduction of hexavalent chromium is a proven technology that is widely used at MP&M sites. Operation at ambient conditions requires little energy, and the process is

well suited to automatic control. A limitation to this technology is that, for high concentrations of chromium, treatment chemicals may be prohibitively expensive.

Maintenance of chemical reduction systems consists of sludge removal, the frequency of which is a function of the input concentrations of detrimental constituents. There may be small amounts of sludge collected due to minor shifts in the solubility of the contaminants (e.g., iron hydroxides). This sludge can be processed by the sludge-handling equipment associated with the chemical precipitation system.

10.4.3 Cyanide Destruction through Alkaline Chlorination

Cyanide destruction through alkaline chlorination is widely used in industrial wastewater treatment. Chlorine is typically used as either chlorine gas or sodium hypochlorite. This process can be illustrated by the following two-step chemical reaction:

$$Cl_2 + NaCN + 2NaOH \rightarrow NaCNO + 2NaCl + H_2O \qquad (10\text{-}3)$$

$$3Cl_2 + 4NaOH + 2NaCNO \rightarrow 2CO_2 + N_2 + 6NaCl + 2H_2O \qquad (10\text{-}4)$$

Figure 10-12 presents a process flow diagram for the alkaline chlorination of cyanide.

The alkaline chlorination process oxidizes cyanides to carbon dioxide and nitrogen. The equipment often consists of an equalization tank followed by two reaction ranks, although a batch reaction can be conducted in a single tank. Each tank has an electronic controller to monitor and maintain the required pH and ORP. In the first reaction tank, conditions are adjusted to oxidize cyanides to cyanates. To effect the reaction, chlorine or sodium hypochlorite is metered to the reaction tank as necessary to maintain the ORP at 350 to 400 millivolts, and aqueous sodium hydroxide is added to maintain a pH of 10 to 11. In the second reaction tank, the ORP and the pH level are maintained at 600 millivolts and 8 to 9, respectively, to oxidize cyanate to carbon dioxide and nitrogen. Each reaction tank has a chemical mixer designed to provide approximately one turnover per minute. The batch process is usually accomplished by using two tanks, one to collect water over a specified time period and one to treat an accumulated batch. If concentrated wastes are frequently dumped, another tank may be required to equalize the flow to the treatment tank. When the holding tank is full, the liquid is transferred to the reaction tank for treatment.

Alkaline chlorination can be performed at ambient temperature, can be automatically controlled at relatively low cost, and is capable of achieving effluent levels of free cyanide that are nondetectable. Disadvantages include the need for careful pH control, possible chemical interference in treating mixed wastes, and the potential hazard of

storing and handling chlorine gas (if sodium hypochlorite is not used). If organic compounds are present, toxic chlorinated organics may be generated. Alkaline chlorination is not effective in treating metallocyanide complexes, such as ferrocyanide. Alkaline chlorination is reliable with proper monitoring and control and proper pretreatment to control interfering substances.

10.4.4 Oil/Water Separation

Oil/water separation includes the breaking of oil/water emulsions as well as the gravity separation of oil. When only free oil is present, only oil skimming is necessary for effective treatment. These technologies are discussed below.

Chemical Emulsion Breaking

Chemical emulsion breaking is used to break stable oil/water emulsions (oil dispersed in water, stabilized by electrical charges and emulsifying agents). A stable emulsion will not separate or break down without chemical treatment. Chemical emulsion breaking is applicable to wastewater streams containing emulsified coolants and lubricants such as machining and grinding coolants, and impact and pressure deformation lubricants. This technology is also applicable to cleaning solutions that contain emulsified oils. A flow diagram of a type of chemical emulsion breaking system is shown in Figure 10-13.

Treatment of spent oil/water emulsions involves using chemicals to break the emulsion followed by gravity differential separation. The major equipment required for chemical emulsion breaking includes reaction chambers with agitators, chemical storage tanks, chemical feed systems, pumps, and piping. Factors to be considered for destroying emulsions are type of chemicals, dosage and sequence of addition, pH, mixing, heating requirements, and retention time.

Chemicals (e.g., polymers, alum, ferric chloride, and organic emulsion breakers) destroy emulsions by neutralizing repulsive charges between particles, precipitating or salting out emulsifying agents, or weakening the interfacial film between the oil and water so it is readily broken. Reactive cations (e.g., H^{+1}, Al^{+3}, Fe^{+3}) and cationic polymers are particularly effective in destroying dilute oil/water emulsions. Once the charges have been neutralized or the interfacial film broken, the small oil droplets and suspended solids either adsorb on the surface of the floc that is formed, or break out and float to the top. Different types of emulsion-breaking chemicals are used for different types of oils. If more than one chemical is required, the sequence of addition can affect both breaking efficiency and chemical dosages.

Another important consideration in emulsion breaking is pH, especially if cationic inorganic chemicals, such as alum, are used as coagulants. For example, a pH between 2 and 4 keeps the aluminum ion in its most positive state where it can function most effectively to neutralize charges. After some of the oil is broken free and skimmed,

raising the pH into the 6-to-8 range with lime or caustic causes the aluminum to hydrolyze and precipitate as aluminum hydroxide. This floc entraps or adsorbs destabilized oil droplets, which can then be separated from the water. Cationic polymers can break emulsions over a wider pH range and thus avoid acid corrosion and the additional sludge generated from neutralization; however, an inorganic flocculent is usually required to supplement the polymer emulsion breaker's adsorptive properties.

Mixing is important in effectively breaking oil/water emulsions because it provides proper chemical feed and dispersion. Mixing also causes collisions of droplets which help break the emulsion, and subsequently helps to agglomerate droplets. Heating also improves the performance of chemical emulsion breaking by lowering the viscosity and increasing the apparent specific gravity differential between oil and water. Heating also increases the frequency of droplet collisions, which helps to rupture the interfacial film.

Once an emulsion is broken, the difference in specific gravities between the oil and the water results in the oil floating to the surface of the water. Solids usually form a layer between the oil and water, since some solids become suspended in the oil. The longer the retention time, the more complete the separation between the oil, solids, and water. Oils and solids are typically skimmed from the surface of the water in a subsequent step after chemical emulsion breaking. Often, other methods of separation, such as air flotation or rotational separation (e.g., centrifugation), are used to enhance separation after chemical emulsion breaking.

The advantages of chemical emulsion breaking are the high removal efficiency potential and the possibility of reclaiming the oily waste. Disadvantages include corrosion problems associated with acid-alum systems, skilled operator requirements for batch treatment, chemical sludges produced, and poor cost-effectiveness for low oil concentrations.

Chemical emulsion breaking is a very reliable process. The main control parameters are pH and temperature. Maintenance is required on pumps, mixers, instrumentation and valves, as well as periodic cleaning of the treatment tank to remove any accumulated solids. Energy use is typically limited to mixers and pumps, but can also include heating.

Solid wastes generated by chemical emulsion breaking include surface oil and oily sludge, which are usually contract hauled for disposal by a licensed contractor. If the recovered oil has a sufficiently low percentage of water, the oil may be burned for its fuel value or processed and reused.

Oil Skimming

Oil skimming is a physical separation technology that uses the difference in specific gravity between oils and water to remove free or floating oil from wastewater. Common separation devices include belt, rotating drum, disk, and weir oil skimmers and coalesces.

These devices are not suited to remove emulsified oil, which requires chemical treatment, membrane filtration, or other technologies. Flow diagrams of several types of oil skimming are shown in Figure 10-14.

To separate oil process solutions, these devices are typically mounted onto the side of a tank and are operated on a continuous basis. The disk skimmer consists of a vertically rotating disk that is partially submerged in the solution. The disk continuously revolves between spring loaded wiper blades that are located above the liquid surface. Its adhesive characteristics cause the floating oil to remain on the disk. As the disk's surface passes under the wiper blades, the oil is scraped off and diverted to a run-off spout for collection. Belt and drum skimmers operate in a similar manner, with either a continuous belt or drum rotating partially submerged in a tank. As the surface of the belt or drum emerges from the liquid, the oil that adheres to the surface is scraped off (drum) or squeezed off (belt) and diverted to a collection vessel. The oil is typically contract hauled for disposal.

Gravity separators use overflow and underflow baffles to skim a floating oil layer from the surface of the wastewater. An underflow baffle allows the oil layer to flow over into a trough for disposal or reuse while most of the water flows underneath the baffle. This is followed by an overflow baffle, which is set at a height relative to the first baffle such that only the oil-bearing portion will flow over the first baffle during normal plant operation. A diffusion device, such as a vertical slot baffle, aids in creating a uniform flow through the system and in increasing oil removal efficiency.

The removal efficiency of a skimmer is partly a function of the retention time of the water in the tank. Larger, more buoyant particles require less retention time than smaller particles. Thus, the efficiency also depends on the composition of the waste stream. The retention time required to allow phase separation and subsequent skimming varies from 1 to 15 minutes, depending on the wastewater characteristics.

Gravity-type separators tend to be more effective for wastewater streams with consistently large amounts of surface oil. Drum and belt type skimmers are more applicable to waste streams containing smaller amounts of floating oil. Using a gravity separator system in conjunction with a drum-type skimmer is an effective method of removing floating contaminants from nonemulsified oily waste streams.

Coalescers are used to remove oil droplets too finely dispersed for conventional gravity separation-skimming technology. Coalescing also reduces the residence times (and therefore separator volumes) required for separation of oil from some wastes. The basic principle of coalescence involves the attraction of oil droplets to the coalescing medium. The oil droplets accumulate on the medium and then rise to the surface of the solution as they combine to form larger particles. The most important requirements for coalescing media are attraction for oil and large surface area. Coalescing media include polypropylene, ceramic, or glass.

Coalescing stages may be integrated with a wide variety of gravity oil separators, and some systems may incorporate several coalescing stages. In general, a preliminary oil skimming step is desirable to avoid overloading the coalescer.

Skimming which removes oil may also remove organic pollutants. Sampling data show that many organic compounds are removed in standard wastewater treatment equipment. Oil separation not only removes oil but also organics that are more soluble in oil than in water. Subsequent clarification removes organic solids directly and probably removes dissolved organics by adsorption on inorganic solids. Sources of these organic pollutants are not always known with certainty, although in MP&M operations they are mainly process coolants and lubricants, additives to formulations of cleaners, paint formulations, or leaching from plastic lines and other materials.

A review of organic compounds commonly found in MP&M waste streams indicated that these compounds are often removed as a result of oil removal and subsequent clarification processes. When all organics analyses from sampled sites are considered, removal of organic compounds appears to be marginal in many cases. However, when only raw waste concentrations of 0.05 mg/L or greater are considered, incidental organics removal becomes much more apparent. Lower values (those less than 0.05 mg/L), are much more subject to analytical variation, while higher values indicate a significant presence of a given compound. When these factors are taken into account, analytical data indicate that most oil removal and subsequent clarification systems can remove priority organic compounds present in the raw waste.

Data from four sampling days at one site demonstrate removal of organics by the combined chemical emulsion breaking and oil skimming operations performed at MP&M sites. Days were selected where treatment system influent and effluent analyses provided paired data points for oil and grease and the organics present. All organics found at quantifiable levels on those days were included. Further, only those days were chosen where oil and grease raw wastewater concentrations exceeded 10 mg/L and where there was reduction in oil and grease going through the treatment system. All site sampling days which met the above criteria were included. The average percent removal for organic pollutants with sufficient data to assess treatment effectiveness was 64%, while the average percent removal for oil and grease was 89 percent. These data indicate that when oil and grease are removed, organics also are removed.

10.5 Technology descriptions for End-of-Pipe Treatment Technologies

This section describes in detail end-of-pipe technologies included in the MP&M technology options or believed to be equivalent or alternative to a technology included in

the MP&M technology options. Technology descriptions contain information on the application and performance of the following technologies:

- Chemical precipitation and sedimentation;
- Reverse osmosis; and
- Ion exchange.

10.5.1 Chemical Precipitation and Sedimentation

Chemical precipitation and sedimentation is a common process used to remove dissolved metals from wastewater. The dissolved metals are converted to an insoluble form and separated from the wastewater. The process is usually performed on a continuous basis in a series of two or three tanks, but can be performed on a batch basis in a single tank. There are several basic methods of performing this process and many variations of each method. The four most common methods are described below. A general flow diagram of a chemical precipitation system is shown in Figure 10-15.

Hydroxide Precipitation. Hydroxide precipitation is the most common method of metals removal from MP&M wastewater. This process was used to develop the MP&M technology effectiveness concentrations (see Section 11.0) and compliance cost estimates (see Section 12.0). This process is typically performed in several stages. In an initial tank, which is mechanically agitated, alkaline treatment reagents such as lime (calcium hydroxide or hydrated lime), sodium hydroxide, or magnesium hydroxide are added to the wastewater to precipitate metal ions as metal hydroxides. The reaction is illustrated by the following equation for precipitation of a divalent metal using lime:

$$M^{2+} + Ca(OH)_2 \rightarrow M(OH)_2 + CA^{2+} \qquad (10\text{-}5)$$

The precipitation process is usually operated at a pH of between 8.5 and 10.0, depending on the types of metals in the wastewater. The pH set-point should be selected based on testing to choose a value at which metals are most effectively removed. The effect of pH on hydroxide precipitation is shown in Figure 10-16.

As shown in this figure, most metal hydroxides have an optimum pH at which the metal is most effectively removed. After precipitation, the metal hydroxide particles are very fine and are resistant to settling. To foster particle growth and improve the settling characteristics of the metal hydroxides, coagulating and flocculating agents are added, usually in a second tank, and slowly mixed. Coagulating and flocculating agents include inorganic chemicals such as alum and ferrous sulfate, and a highly diverse range of organic polyelectrolytes with varying characteristics suitable for different wastewaters. The particles are then settled in a separate tank (e.g., clarifier), under quiescent conditions, due to the difference in density between the solid particles and the

wastewater. The solids are removed from the settling tank by drawing them from the bottom of the tank, and then transferred to a thickener or other dewatering process.

Sulfide Precipitation. The sulfide precipitation process uses similar equipment as that used for hydroxide precipitation. The major difference between the two processes is the treatment reagents used. Sulfide precipitation uses either soluble sulfides (e.g., hydrogen sulfide or sodium sulfide) or insoluble sulfides (e.g., ferrous sulfide) in place of alkali reagents used for hydroxide precipitation. The sulfide reagents precipitate dissolved metals as metal sulfides, which have lower solubility limits than metal hydroxides. Therefore, the sulfide precipitation process can achieve lower levels of residual dissolved metal in the treated effluent (see Figure 10-16). The reaction is illustrated by the following equation for sulfide precipitation of a divalent metal:

$$M^{2+} + FeS \rightarrow MS + Fe^{2+} \qquad (10\text{-}6)$$

Sulfide can precipitate most chelated metals and can be used to remove hexavalent chromium without first reducing the chromium to its trivalent state.

The major disadvantages of sulfide precipitation as compared with hydroxide precipitation are higher capital and operating costs and larger sludge generation rates due to the liberation and subsequent precipitation of ferrous ions. Additional disadvantages of sulfide precipitation are the potential for toxic hydrogen sulfide gas generation, the potential for release of excessive sulfide in the effluent, and the generation of sulfide odors. These can be controlled through proper operation and maintenance of the sulfide precipitation system.

Carbonate Precipitation. Carbonate precipitation typically uses sodium carbonate (soda ash), sodium bicarbonate, or calcium carbonate to form insoluble metal carbonates. The reaction is illustrated by the following equation for sodium carbonate precipitation of a divalent metal:

$$M^{2+} + Na_2CO_3 \rightarrow MCO_3 + 2Na^{+} \qquad (10\text{-}7)$$

Carbonate precipitation is similar in operation to hydroxide precipitation, and is typically performed to remove metals such as cadmium or lead. For these metals, carbonate precipitation can achieve effluent concentrations similar to those achieved by hydroxide precipitation, but typically at a lower operating pH. Carbonate precipitation and hydroxide precipitation are sometimes performed in conjunction, which may improve the overall performance of certain systems.

Carbonate precipitation is less popular than hydroxide precipitation due to the higher cost of treatment reagents and certain operational problems, such as the release of carbon dioxide gas, which can result in foaming and/or floating sludge. This process is not effective for all metals.

Sodium Borohydride Precipitation. Sodium borohydride precipitation uses sodium borohydride as a reducing agent to precipitate metals from solution as insoluble elemental metals. This reaction is illustrated by the following equations for precipitation of a divalent metal:

$$4M^{2+} + NaBH_4 + 2H_2O \rightarrow NaBO_2 + 4M + 8H^+ \qquad (10\text{-}8)$$

$$4M^{2+} + NaBH_4 + 8OH^- \rightarrow NaBO_2 + 4M + 6H_2O \qquad (10\text{-}9)$$

This process is similar in operation to hydroxide precipitation. Borohydride precipitation is usually performed in a pH range of 8 to 11 to ensure efficient utilization of borohydride. The optimum pH is determined by testing borohydride usage, reaction time, and effluent quality.

Sodium borohydride precipitation is effective for removing lead, mercury, nickel, copper, cadmium, and precious metals such as gold, silver, and platinum from wastewaters. This process has also been reported to reduce sludge generation by 50% over lime precipitation.

Chemical precipitation and sedimentation is a highly reliable technology when proper monitoring and control are used. The effectiveness of metal precipitation and sedimentation processes depends on the types of equipment used and numerous operating factors, such as the characteristics of the raw wastewater, types of treatment reagents used, and operating pH. In some cases, it is necessary to vary operational factors to achieve sufficiently low effluent concentrations. Often, subtle changes such as varying the operating pH or extending the reaction time of the process may sufficiently improve its efficiency. In other cases, modifications to the treatment system are necessary. For example, some raw wastewaters contain chemicals that may interfere with the precipitation of metals, in which cases, additional treatment reagents such as ferrous sulfate, sodium hydrosulfate, aluminum sulfate, or calcium chloride may be required. These chemicals may be added prior to or during the precipitation process to affect substances causing the interference.

The types of equipment used for chemical precipitation and sedimentation vary widely. Small batch operations can be performed in a single tank, usually having a conical bottom that permits removal of settled solids. Continuous processes are usually

performed in a series of tanks, including a rapid mix tank for mixing the precipitating chemicals, a slow mix tank for addition of coagulants and flocculants and floc formation, and a settling tank or clarifier for separation of the solids from the wastewater. An alternative method of separating precipitated solids from wastewater is filtration, during which the entire wastewater flow is passed through a filter press (only applicable to very low wastewater flows) or a membrane filter (e.g., ultrafiltration). When membrane filters are used, the coagulation and flocculation step is omitted because these chemicals can plug the small pores of the membrane.

Chemical precipitation and sedimentation systems require routine maintenance to assure proper operation. Routine maintenance includes calibration of instrumentation and cleaning of probes; transfer and chemical pumps and mixers (inspection, cleaning, lubrication, replacing seals and packing, replacing check valves, cleaning strainers); and tank and sump maintenance (inspection, cleaning, corrosion prevention).

10.5.2 Reverse Osmosis (End-of-Pipe)

Reverse osmosis is a membrane separation technology used by the MP&M industry as an in-process step or as an end-of-pipe treatment. In-process reverse osmosis is discussed in Section 10.3.

In an end-of-pipe application, reverse osmosis is typically performed to recycle water and reduce discharge volume rather than recover chemicals. The effluent from a conventional treatment system generally has a TDS concentration unacceptable for most rinsing operations, and cannot be recycled. These TDS concentrations can be tolerated by reverse osmosis membranes with or without some pretreatment, and the effluent stream is acceptable for most rinsing operations.

10.5.3 Ion Exchange (end-of-pipe)

Ion exchange is used for both in-process and end-of-pipe applications. In-process ion exchange is discussed in Section 10.3.6. End-of-pipe ion exchange is typically used as a final polishing step, or to recycle water. End-of-pipe ion exchange usually employs cation resins to remove metals but sometimes both cation and anion columns are used. The regenerant from end-of-pipe ion exchange is not usually amenable to metal recovery as it is usually more dilute and is not specific to a metal type.

10.6 Technology Descriptions for Sludge Handling and Disposal Technologies

This section describes in detail sludge handling and disposal technologies included in the MP&M technology options or believed by the agency to be equivalent or alternative to a

technology included in the MP&M technology options. Technology descriptions contain information on the application of the following technologies:

- Gravity thickening;
- Pressure filtration;
- Sludge drying; or
- Vacuum filtration.

10.6.1 Gravity Thickening

Gravity thickening is a physical liquid-solid separation technology used to dewater wastewater treatment sludge. Sludge is fed from a primary settling tank or clarifier to a thickening tank, where gravity separates the supernatant from the sludge, increasing the sludge density. The supernatant is returned to the primary settling tank. The thickened sludge that collects on the bottom of the tank is pumped to additional dewatering equipment or contract hauled for disposal. Figure 10-17 shows the diagram of a gravity thickener.

Gravity thickeners are generally used in facilities where the sludge is to be further dewatered by a mechanical device, such as a filter press. Increasing the solids content in the thickener substantially reduces capital and operating costs of the subsequent dewatering device and also reduces the hauling cost. The process is potentially applicable to any MP&M site that generates sludge.

10.6.2 Pressure Filtration

The filter press is the most common type of pressure filtration used in the MP&M industry for dewatering wastewater treatment sludges. A filter press consists of a series of parallel plates pressed together by a hydraulic ram (older models may have a hand crank), with cavities between the plates. Figure 10-18 presents a diagram of a plate-and-frame filter press. The filter press plates are concave on each side to form cavities and are covered with a filter cloth. At the start of a cycle, a hydraulic pump clamps the plates tightly together and a feed pump forces a sludge slurry into the cavities of the plates. The liquid (filtrate) escapes through the filter cloth and grooves molded into the plates and is transported by the pressure of the feed pump (typically around 100 psi) to a discharge port. The solids are retained by the cloth and remain in the cavities. This process continues until the cavities are packed with sludge solids. An air blow-down manifold is used on some units at the end of the filtration cycle to drain remaining liquid from the system, thereby improving sludge dryness and aiding in the release of the cake. The pressure is then released and the plates are separated.

The sludge solids or cake is loosened from the cavities and falls into a hopper or drum. A plate filter press can produce a sludge cake with a dryness of approximately 25 to 40 percent solids for metal hydroxides precipitated with sodium hydroxide, and 35 to

60 percent solids for metal hydroxides precipitated with calcium hydroxide. The solids content attained depends on the length of the drying cycle. Filter presses are available in a very wide range of capacities (0.6 ft^3 to 20 ft^3). A typical operating cycle is from 4 to 8 hours, depending on the dewatering characteristics of the sludge. Units are usually sized based on one or two cycles per day.

10.6.3 Sludge Drying

Wastewater treatment sludges are often hauled long distances to disposal sites. The transportation and disposal costs depend mostly on the volume of sludge. Therefore, many MP&M sites use sludge dehydration equipment following dewatering to further reduce the volume of the sludge.

The solids content of the sludge dewatered on a filter press is usually in the range of 25 to 60 percent. Dehydration equipment can produce a waste material with a solids content of approximately 90 percent.

There are several design variations for sludge dehydration equipment. A commonly used type is a sludge drying unit that uses an auger or conveyor system to move a thin layer of sludge through a drying region and discharge it into a hopper. Various heat sources are used for sludge drying, including electric, electric infrared, steam, and gas. Some continuous units are designed such that the sludge cake discharge from a filter press drops into the feed hopper of the dehydration unit, making the overall dewatering process more automated. System capacities range from less than 1 ft^3/hr to more than 20 ft^3/hr of feed. Sludge dehydration equipment requires an air exhaust system due to the fumes generated during drying.

Energy requirements depend mostly on the water content of the feed stock and the efficiency of a given unit. Sludge drying was not included in the preferred technology options for MP&M due to space constraints, energy requirements, and possible cross-media impacts.

10.6.4 Vacuum Filtration

Vacuum filtration is performed at some MP&M sites to reduce the water content of sludge, increasing the solids content from approximately 5 percent to between 20 and 30 percent. At these MP&M sites, sludge dewatering by vacuum filtration generally uses cylindrical drum filters. The filters on these drums are typically either cloth made of natural or synthetic fibers or a wire-mesh fabric. The drum is dipped into a vat of sludge and rotates slowly, creating an internal vacuum that draws sludge to the filter. Water is drawn through the porous filter cake through the filter to a discharge port, and the dewatered sludge is scraped from the filter. Because dewatering sludges using vacuum filters is relatively expensive per kilogram of water removed, the liquid sludge is

frequently gravity thickened prior to vacuum filtration. Figure 10-19 shows a typical vacuum filter.

Vacuum filters are frequently used both in municipal treatment plants and in a wide variety of industries. They are most commonly used in larger facilities, which may have a thickener to double the solids content of clarifier sludge before vacuum filtering. Often a precoat is used to inhibit filter binding.

Maintenance of vacuum filters involves cleaning or replacing the filter media, drainage grids, drainage piping, filter parts, and other parts. Maintenance time may be as high as 20% of total operating time; therefore, it is desirable to maintain one or more spare units. If intermittent operation is used, the filter equipment should be drained and washed each time it is taken out of service, and an allowance for this wash time made in filtering schedules.

Vacuum filtration was not included in the preferred technology options for MP&M because it was estimated that pressure filtration could achieve a greater solids percentage.

MP&M Source Reduction Technologies

Technology	Technology Description	Demonstration Status: Number of Site Visits[1]	Comments
Conductivity Probes	Conductivity probes measure the conductivity of water in a rinse tank to regulate the flow of fresh rinse water into the rinse system. A solenoid valve on the rinse system fresh water supply is connected to the controller, which opens the valve when a preset conductivity level is exceeded and closes the valve when conductivity is below that level.	20	Included in the technology options. Reduces excessive rinsing.
Countercurrent Cascade Rinsing	Countercurrent cascade rinsing refers to a series of consecutive rinse tanks which are plumbed to cause water to flow from one tank to another in the direction opposite of the work flow. Water is introduced into the last tank of the series, making it the cleanest, and is discharged from the first tank, which will have the highest concentration of contaminants.	48	Included in the technology options. This technology reduces the amount of water necessary for rinsing by up to 90% per stage.
Drag-Out Rinsing	A drag-out rinse is a stagnant rinse, initially filled with fresh water, positioned immediately after process tanks. The drag-out rinse collects the majority of the drag-out from the process tank, preventing it from entering the subsequent flowing rinses. Drag-out can be recovered by returning the contents of these tanks to the process tank. Electrolytic recovery of dissolved metals from drag-out tanks is also common.	21	This technology is included in the technology options as part of the ion-exchange/electrolytic recovery system.
Flow Restrictors	A flow restrictor prevents the flow in a pipe from exceeding a predetermined volume. Flow restrictors can be used to limit the flow into a rinse system. For continuously flowing rinses, a flow restrictor controls the flow into the system, ensuring a consistent, optimum flow rate.	17	Part of technology options. Reduces excessive rinsing.

[1]Indicates the number of MP&M Phase I sites visited by EPA at which the technology was used. The Site Visit Report Database contains data from 80 Phase I sites.

Table 10-1 (Continued)

MP&M Source Reduction Technologies

Technology	Technology Description	Demonstration Status: Number of Site Visits[1]	Comments
Plant Maintenance and Good Housekeeping	Plant maintenance and good housekeeping include in-plant practices such as immediate repair of leaks, maintenance of process lines, training of equipment operators, etc.	45	The benefits of these practices are not quantifiable. These practices are not included in the technology options.
Regeneration of Chemical Baths	Regeneration, rather than treatment and disposal, can be accomplished by various technologies. These include filtration, precipitation, and membrane-based purification technologies.	24	These technologies are not applicable at all sites and are not included in the technology options.
Spray Rinsing Over Process Bath	The installation of low-flow spray rinses over a process bath greatly reduces drag-out into subsequent rinses. The flow rate of the rinse should equal the evaporation rate of the process tank.	3	This technology is not applicable at all sites because of part and process configurations, and is not included in the technology options.
Spray Rinsing with Discharge	For certain part configurations, spray rinsing uses considerably less water than immersion. This technology can be performed as countercurrent cascade rinsing with spray rinses instead of overflow immersion rinses.	46	This technology is not applicable at all sites because of part and process configurations, and is not included in the technology options.
Activated Carbon Adsorption of Painting Water Curtains	Activated carbon adsorption can remove dissolved organics from paint overspray. Pretreatment for solids removal may be necessary. Closed loop reuse of water curtains can be achieved with this technology.	1	This technology requires pretreatment for solids removal and periodic regeneration of activated carbon. A centrifugation is included in technology options to achieve zero discharge of painting water curtains; therefore, this technology is not included in the technology options.

[1]Indicates the number of MP&M Phase I sites visited by EPA at which the technology was used. The Site Visit Report Database contains data from 80 Phase I sites.

MP&M Source Reduction Technologies

Technology	Technology Description	Demonstration Status: Number of Site Visits[1]	Comments
Centrifugation of Painting Water Curtains	Centrifugation removes the heavier solids from the water curtain allowing reuse. The solids are collected as a cake in the basket of the centrifuge. Closed loop reuse of water curtains may be achieved with this technology.	3	This technology requires little maintenance, and has been demonstrated to achieve complete recycle with periodic removal of sludge. This technology is included in the technology options.
Filtration of Painting Water Curtains	Removal of solids by filtration (cloth, sand, diatomaceous earth, etc.) followed by reuse. Closed loop reuse of water curtains may be achieved with this technology.	1	Generates more waste than centrifugation due to filter medium disposal or sand filter backwash. This technology is not included in the technology options.
Settling of Painting Water Curtains	Settling removes the heavier solids from the water curtains. This technology can be used in conjunction with other removal technologies to lessen the solids loading.	1	Equivalent technology (centrifugation) included as part of the technology options; therefore, this technology is not included in the technology option.
Biocide Addition to Lengthen Coolant Life	Machining coolant is often discarded as it becomes rancid. Addition of a biocide can impede the growth of microorganisms that cause rancidity.	3	Equivalent technology (pasteurization) is included as part of the technology options; therefore, this technology is not included in the technology option.
Centrifugation to Lengthen Coolant Life	Centrifugation removes the solids from the coolant to extend its usable life. Some high-speed centrifuges can also perform liquid-liquid separation for the removal of tramp oils and further extension of coolant life.	11	This technology is a component of the coolant recycling system included in the technology options.

[1]Indicates the number of MP&M Phase I sites visited by EPA at which the technology was used. The Site Visit Report Database contains data from 80 Phase I sites.

Table 10-1 (Continued)

MP&M Source Reduction Technologies

Technology	Technology Description	Demonstration Status: Number of Site Visits[1]	Comments
Filtration to Lengthen Coolant Life	Filtration removes the solids from the coolant. These filters include cloth, sand, carbon, etc.	5	Equivalent technology (liquid-liquid centrifugation) is included as part of the technology options; therefore, this technology is not included in the technology options.
Oil Skimming of Tramp Oils to Lengthen Coolant Life	Tramp oil buildup often causes machining coolant to be no longer usable. Oil skimming with belt skimmers, disk skimmers, etc., extends the coolant life.	3	Equivalent technology (liquid-liquid centrifugation) is included as part of the technology options; therefore, this technology is not included in the technology options.
Pasteurization to Lengthen Coolant Life	Machining coolant is often discarded as it becomes rancid. Pasteurization kills the microorganisms that cause rancidity.	1	This technology is a component of the coolant recycling system included in the technology options.
In-Tank Filtration to Lengthen the Life of Concentrated Baths	Filtration to remove accumulated suspended solids, precipitant, or dissolved contaminants extends the life of some process fluids. Suspended solids are removed with paper, cloth, or plastic filters. Activated carbon removes organics.	12	This technology is not applicable at all sites and is not included in the technology options.
In-Process Ion Exchange	Removes contaminants from concentrated baths or rinse water and creates concentrated regenerant streams that can be reclaimed by electrolytic recovery, reused in the process bath, or discharged. Can achieve significant rinse water use reduction for electroplating.	10	This technology is included in the technology options for certain electroplating rinses.

[1]Indicates the number of MP&M Phase I sites visited by EPA at which the technology was used. The Site Visit Report Database contains data from 80 Phase I sites.

Table 10-1 (Continued)

MP&M Source Reduction Technologies

Technology	Technology Description	Demonstration Status: Number of Site Visits[1]	Comments
In-Process Reverse Osmosis	Reverse osmosis is used to recover drag-out or rinse water. In most cases, the purified water is suitable for reuse. The reject stream is usually less concentrated than process baths, but is suitable for reuse in heated baths that create evaporative headroom. The reject stream can also be reclaimed by electrolytic recovery.	1	This technology is similar in application to in-process ion-exchange but is not applicable to as many unit operation-metal type combinations and is not as well demonstrated. This technology is not included in the technology options.

Source: MP&M site visits, MP&M sampling episodes, MP&M DCPs, technical literature.

[1]Indicates the number of MP&M Phase I sites visited by EPA at which the technology was used. The Site Visit Report Database contains data from 80 Phase I sites.

Table 10-2

MP&M Recycling Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Evaporation with Condensate Recovery	Evaporation of wastewater, leaving a concentrated residue for disposal, and condensing the water vapor for reuse.	1	NA	NA	This unit operation is very energy intensive. This technology is not included in the technology options.
Ion Exchange	Ion exchange can be used at the end-of-pipe as a final polishing step. Ion exchange polishing is done with a cation (scavenger) column only. Anions remain in solution and are discharged. This can be used as a stand alone technique or a polishing technique after metals precipitation. In cases where recycle is desired, both cation and anion columns are necessary.	3	7	34	Permeate contains moderate dissolved solids concentrations and reuse may be limited to non-critical unit operations. This technology is included in the technology options.
Reverse Osmosis	Membrane filtration in which the wastewater is forced through the membrane at high pressure leaving a concentrated stream of pollutants for disposal. Reverse osmosis may provide an effluent clean enough for reuse.	1	0	0	Similar in application to end-of-pipe ion-exchange, but not as well demonstrated. This technology is not included in the technology options.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-2 (Continued)

MP&M Recycling Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Electrolytic Recovery (Electrowinning)	Dissolved metals are recovered from concentrated sources with this technology. For rinses, electrolytic recovery is typically restricted to drag-out rinses. Flowing rinses are generally too dilute for efficient electrolytic recovery. This technology is effective on the concentrated regenerant from ion-exchange.	11	NA	NA	This technology works in conjunction with drag-out rinsing and in-process ion exchange to recovery metals from wastewater. This technology is included in the technology options.

Source: MP&M site visits, MP&M sampling episodes, MP&M DCPs, technical literature.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-3

MP&M End-of-Pipe Treatment and Disposal Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Chemical Emulsion Breaking	Addition of acids (typically sulfuric) to oil-bearing wastewater to break oil/water emulsions for subsequent gravity separation.	6	16	207	This technology is included in the technology options.
Chemical Reduction of Hexavalent Chromium	Reduction of hexavalent chromium to trivalent chromium using a reducing agent such as sulfur dioxide, sodium bisulfite, or sodium metabisulfite.	43	65	753	This technology is included in the technology options.
Cyanide Destruction Through Alkaline Chlorination	Destruction of cyanide by adding chlorine (usually sodium hypochlorite or chlorine gas) to first oxidize cyanide to cyanate, then cyanate to carbon dioxide and nitrogen gas.	27	24	337	This technology is included in the technology options.
Flotation of Oils or Solids	Removal of oils or solids by bubbling gas through the wastewater, bringing solids to the surface for subsequent removal.	3	9	96	Based on analytical data collected for the MP&M sampling program, this technology is not as effective as oil/water separation followed by chemical precipitation and sedimentation. Therefore, this technology is not included in the technology options.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-5 (Continued)

MP&M End-of-Pipe Treatment Technologies and Disposal Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Oil Skimming of Oily Wastewater Streams	Removal of free floating oil by gravity separation and mechanical skimming. This technology does not remove emulsified oils.	23	50	480	This technology is included in the technology options.
Cyanide Oxidation by Ozone	Oxidation of cyanide by ozone. Yields ammonia, carbon dioxide and oxygen.	0	1	4	The generation of ozone requires expensive equipment and safety controls. This technology is not included in the technology options. An equivalent technology (cyanide destruction through alkaline chlorination) was included in the technology options.
Ultrafiltration	Filtration using a membrane of very small pore size. Generally used for the removal of emulsified or free-floating oils. This technology also removes other solids.	2	15	171	Based on analytical data collected for the MP&M sampling program, this technology is not as effective as oil/water separation followed by chemical precipitation and sedimentation. Therefore, this technology is not included in the technology options.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-3 (Continued)

MP&M End-of-Pipe Treatment Technologies and Disposal Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Activated Carbon Adsorption	Removal of dissolved organic pollutants by filtration through activated carbon. The dissolved organics are removed by the process of adsorption. This technology requires preliminary treatment for removal of suspended solids and oil and grease.	2	7	73	Applicable to wastewaters containing high concentrations of organic pollutants. MP&M treatment influent streams typically do not contain high concentrations of organic pollutants. This technology is not included in the technology options.
Aerobic Decomposition	The biochemical decomposition of organic materials in the presence of oxygen. The decomposition is performed by microorganisms.	1	4	76	Applicable to wastewater with high concentrations of organic pollutants. MP&M treatment influent streams typically do not contain high concentrations of organic pollutants. At the site at which technology was observed, the technology was operated to treat nonprocess wastewater (contaminated groundwater). This technology is not included in the technology options.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-3 (Continued)

MP&M End-of-Pipe Treatment Technologies and Disposal Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Air Stripping	Removal of dissolved organic pollutants by contacting the organics in the wastewater with a continuous stream of air bubbles. Volatile organic pollutants are transferred from the wastewater to the air.	0	2	14	Applicable to wastewaters containing high concentrations of organic pollutants. MP&M treatment influent streams typically do not contain high concentrations of organic pollutants. This technology is not included in the technology options.
Neutralization	The neutralization of high or low pH wastewater to within an acceptable range with acidic or alkaline chemicals. Common acids include sulfuric and hydrochloric. Common alkaline chemicals include lime (calcium hydroxide) and sodium hydroxide.	32	100	1,283	This technology adjusts pH, but does not remove suspended solids and dissolved metals. This technology is not included in the technology options.
Chemical Precipitation Sedimentation	Removal of metals by precipitating as insoluble compounds such as hydroxides, sulfides, or carbonates. Precipitation as metal hydroxides using lime (calcium hydroxide) or sodium hydroxide is the most common.	63	130	1,666	This technology is included in the technology options.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-3 (Continued)

MP&M End-of-Pipe Treatment Technologies and Disposal Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Atmospheric Evaporation	Includes both natural solar evaporation and forced atmospheric evaporation by which the evaporation rate is accelerated by increased temperature, air flow, and surface area.	3	8	54	Solar evaporation usually occurs in ponds or lagoons with large space requirements. Also, atmospheric evaporators have significant energy requirements as well as possible cross-media impacts. This technology is not included in the technology options.
Ion Exchange	Ion exchange can be used at the end-of-pipe as a final polishing step. Ion exchange polishing is done with a cation (scavenger) column only. Anions remain in solution and are discharged. This can be used as a stand alone technique or a polishing technique after metals precipitation.	3	7	34	Usually used in conjunction with another end-of-pipe technology (e.g., following chemical precipitation). This technology is included in the technology options.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-3 (Continued)

MP&M End-of-Pipe Treatment Technologies and Disposal Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Multimedia Filtration	Filtration using media of different grain size to remove solids from wastewater. Larger particles are removed by the coarser media and the smaller particles are removed by the finer media. Media include garnet, sand, and anthracite coal. The filter is periodically backwashed to remove solids.	4	10	332	Usually used in conjunction with another end-of-pipe technology (e.g., following chemical precipitation). Based on analytical data collected for the MP&M sampling program, this technology does not provide additional metal removals beyond chemical precipitation and sedimentation. This technology was considered for BCT (see section 15) for TSS removal, but is not included in the technology options.
Sand Filtration	Single media filtration of wastewater using sand. The filter is periodically backwashed to remove solids.	21	19	258	Usually used in conjunction with another end-of-pipe technology (e.g., following chemical precipitation). Based on analytical data collected for the MP&M sampling program, this technology does not provide additional metal removals beyond chemical precipitation and sedimentation. This technology is not included in the technology options.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-3 (Continued)

MP&M End-of-Pipe Treatment Technologies and Disposal Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Gravity Settling	The physical removal of suspended particles by gravity. This process does not include the addition of any chemicals.	6	32	1,094	This technology only settles suspended solids and does not remove dissolved metals. This technology is not included in the technology options.
Centrifugation of Sludge	Use of centrifugal force to separate water from solids. Centrifugation dewaters sludges, reducing the volume and creating a semi-solid cake. Centrifugation of sludge can typically achieve a sludge of 20-35% solids.	3	5	74	This technology is energy intensive, and is therefore not included in the technology options. Equivalent sludge dewatering technologies (gravity thickening and pressure filtration) are included in the technology options.
Gravity Thickening of Sludge	Physical separation of solids and water by gravity. Water separates from the sludge and is decanted from the top of the mixture. Gravity thickening can typically thicken sludge to 5% solids.	26	62	820	This technology is included in the technology options.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-3 (Continued)

MP&M End-of-Pipe Treatment Technologies and Disposal Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Pressure Filtration of Sludge	Physical separation of solids and water by pressure filtration. This technology is most commonly performed in a plate-and-frame filter press where the sludge builds up between the filter plates and water is filtered through a cloth. Pressure filtration can produce a sludge cake with greater than 40% solids.	49	66	1,003	This technology is included in the technology options.
Sludge Drying	Drying of sludge by heating causes the water in the sludge to evaporate.	11	13	140	This technology is very energy intensive, and is therefore not included in the technology options. Equivalent technologies (gravity thickening and pressure filtration) are included in the technology options.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

Table 10-3 (Continued)

MP&M End-of-Pipe Treatment Technologies and Disposal Technologies

Technology	Technology Description	Demonstration Status			Comments
		Number of Site Visits[1]	Number of Model Sites[2]	Estimated Number of MP&M Phase I Sites[3]	
Vacuum Filtration of Sludge	Physical separation of solids and water by drawing the sludge through a cloth filter. The water passes through the filter and the sludge is scraped from the filter. The most common type is the rotary drum vacuum filter in which the sludge is drawn from the outside towards the inside of a rotating filter drum. The filtrate leaves from the center while the sludge is continuously scraped off as the drum rotates.	7	9	132	This technology is very energy intensive and typically does not achieve as high of a percent solids as pressure filtration. This technology is not included in the technology options. Equivalent sludge dewatering technologies (gravity thickening and pressure filtration) are included in the technology options.

Source: MP&M site visits, MP&M sampling episodes, MP&M DCPs, technical literature.

NA - Numerical data are not available.
[1]Indicates the number of visited MP&M Phase I sites at which the technology was used. The Site Visit Report Database contains data from Phase I 80 sites.
[2]Indicates the number of model sites that indicated use of this technology. These data are not available for in-process technologies. Based on the 396 dcp respondents used as model sites.
[3]Indicates the estimated number of MP&M Phase I sites currently performing this technology. EPA estimates that MP&M Phase I includes 10,601 sites. The numbers in this column were calculated using statistical weighting factors for the dcp respondents.

End-of-Pipe Technologies

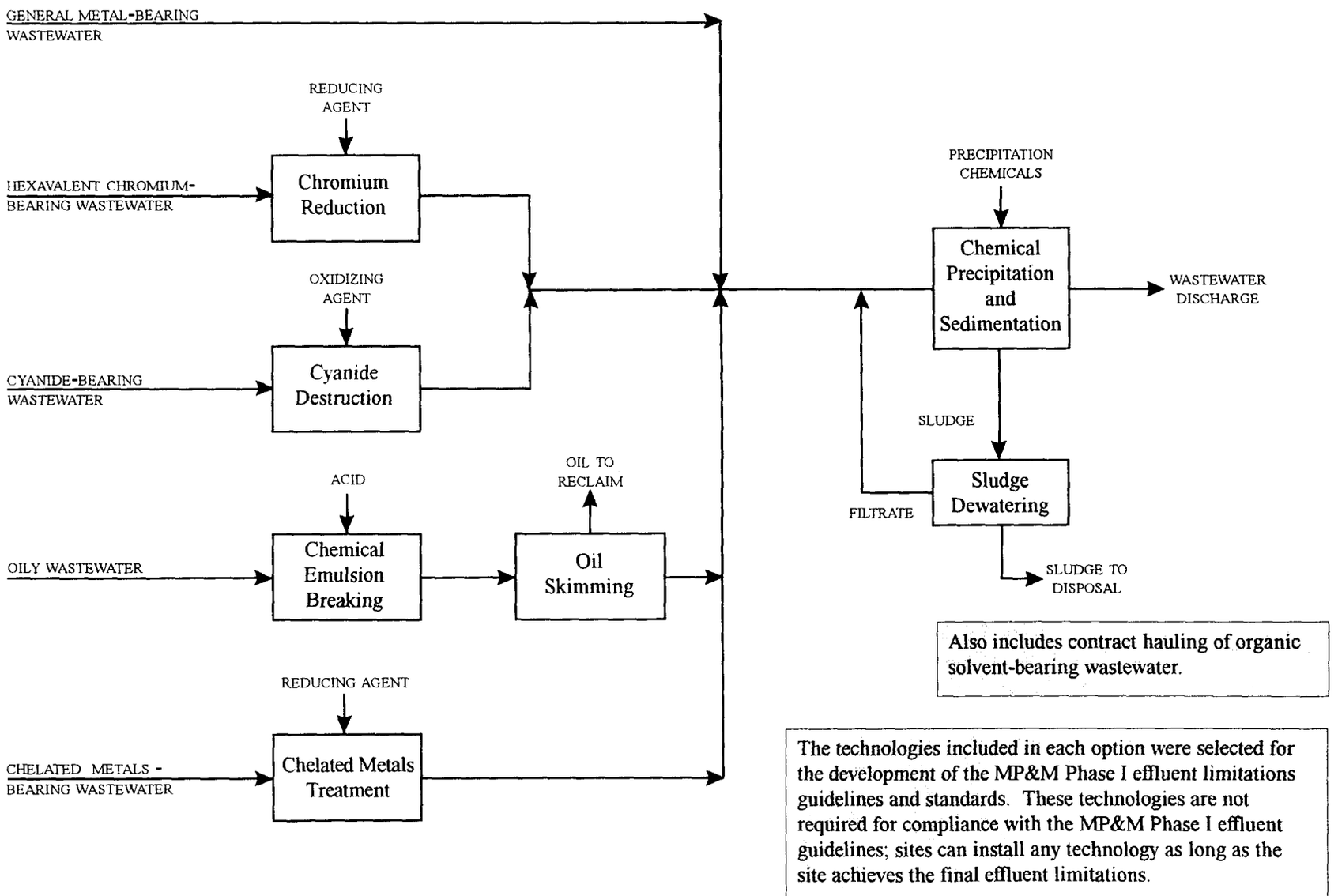


Figure 10-1. End-of-Pipe Technology Trains for MP&M Technology Options 1, 2, 1A, and 2A

In-Process Technologies

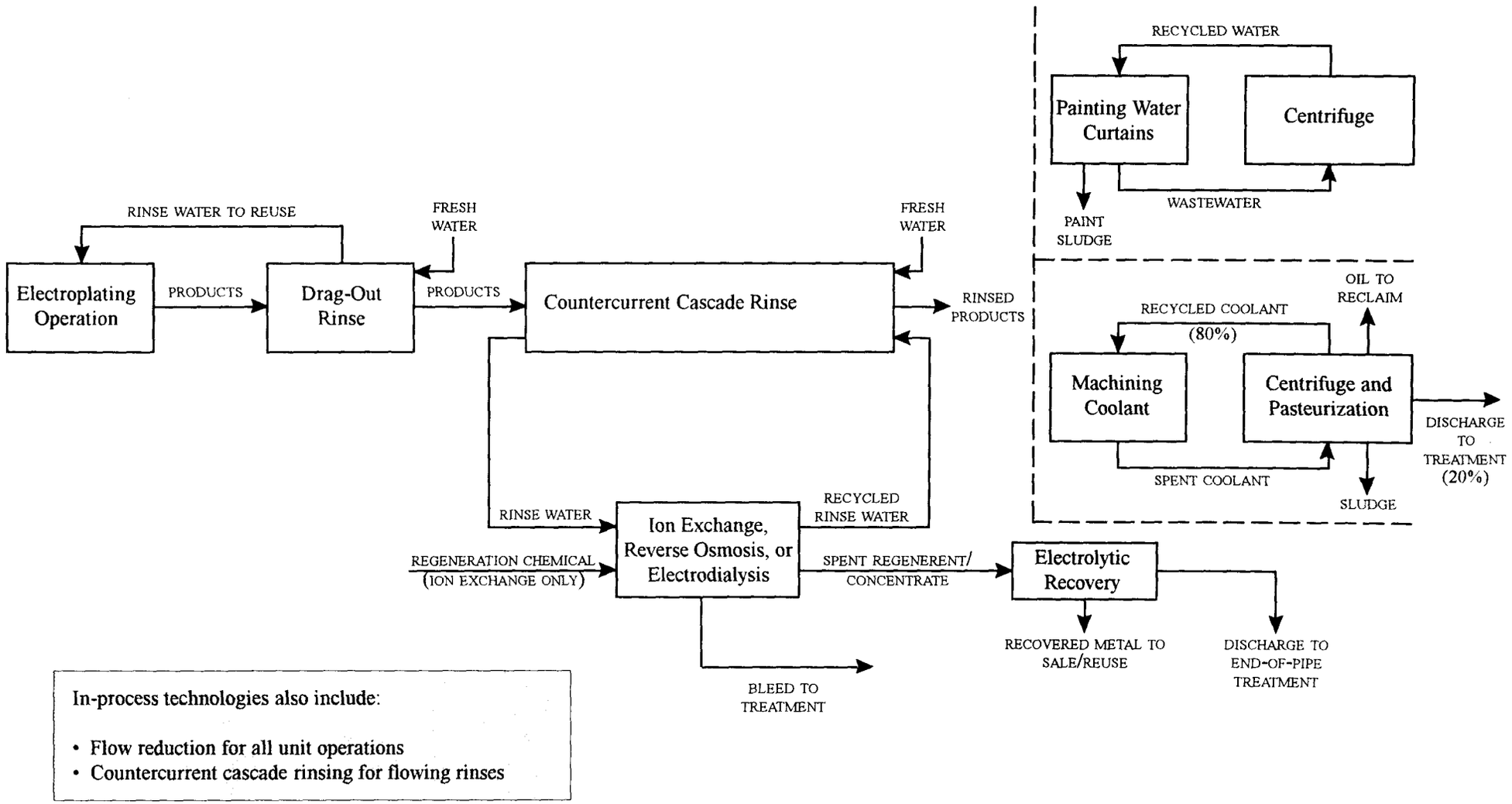


Figure 10-2. In-Process Technology Trains for MP&M Technology Options 1A, 2, 2A, and 3

End-of-Pipe Technologies

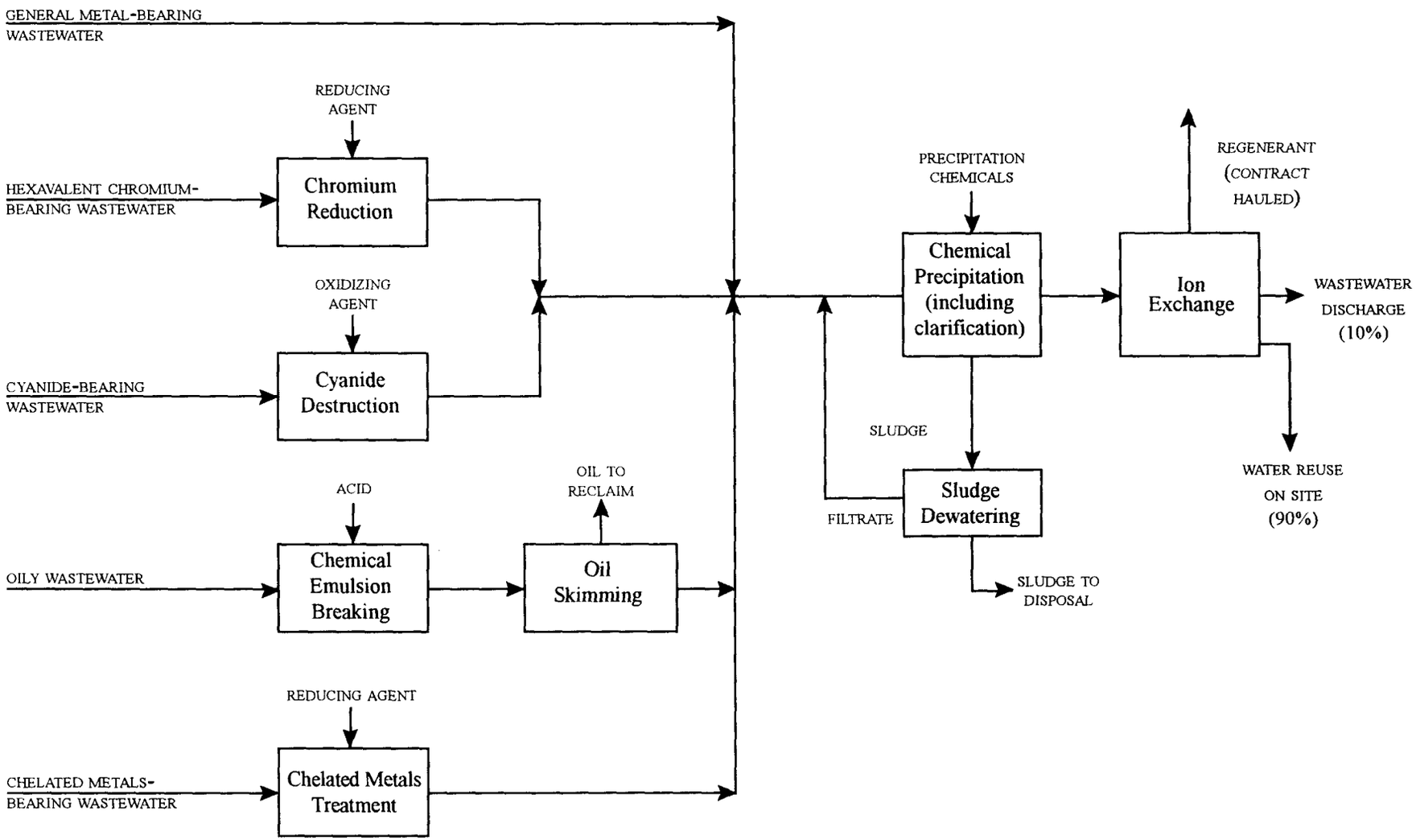
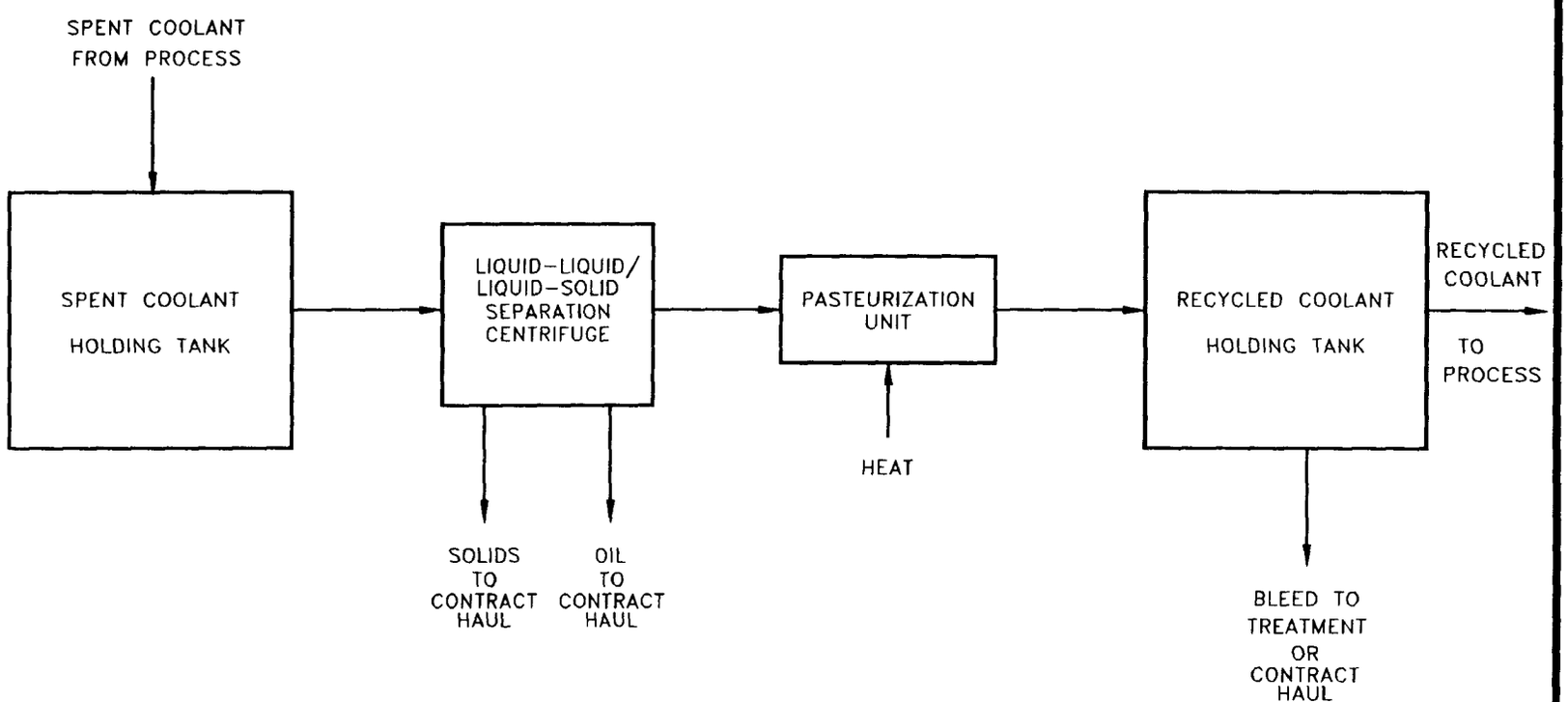
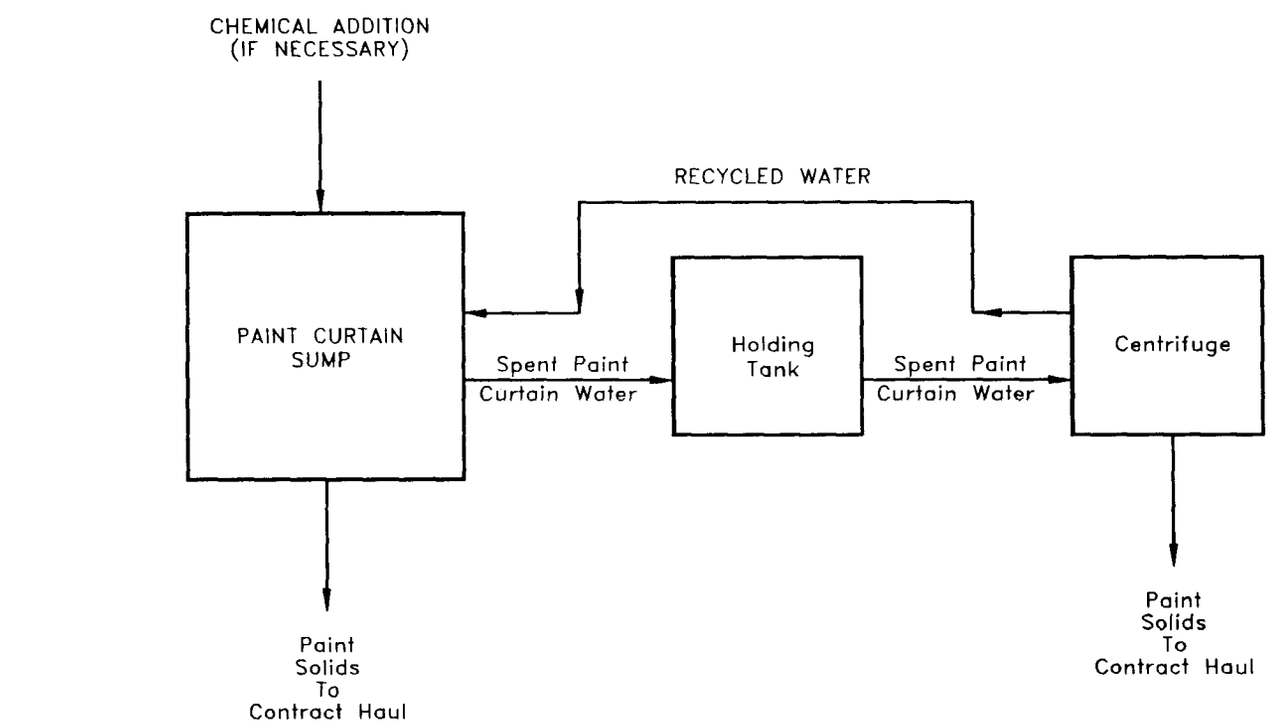


Figure 10-3. End-of-Pipe Technology Train for MP&M Technology Option 3



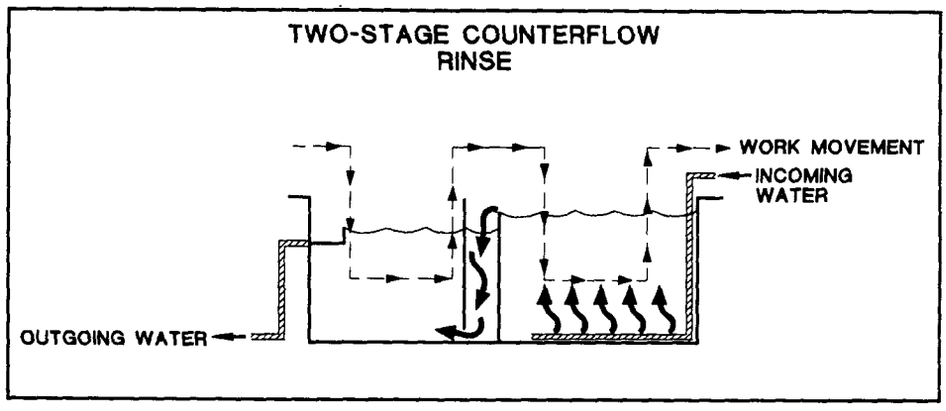
- HOLDING TANKS ARE USED FOR LARGER VOLUME APPLICATIONS. FOR SMALLER VOLUME APPLICATIONS, THE CENTRIFUGE AND PASTEURIZATION UNIT CAN BE MADE PORTABLE AND TREATMENT CAN OCCUR FROM EACH INDIVIDUAL MACHINING COOLANT SUMP.
- AN OIL SKIMMER CAN BE USED ON THE SPENT COOLANT HOLDING TANK IN WHICH CASE A SLOWER, LIQUID-SOLID SEPARATION CENTRIFUGE COULD BE USED.
- BIOCIDE ADDITION CAN BE USED IN LIEU OF PASTEURIZATION.

Figure 10-4. Centrifugation and Pasteurization of Machining Coolants



Many sites also operate solids removal mechanisms on the paint curtain sump such as filtration and skimming

Figure 10-5. Centrifugation and Recycling of Painting Water Curtains



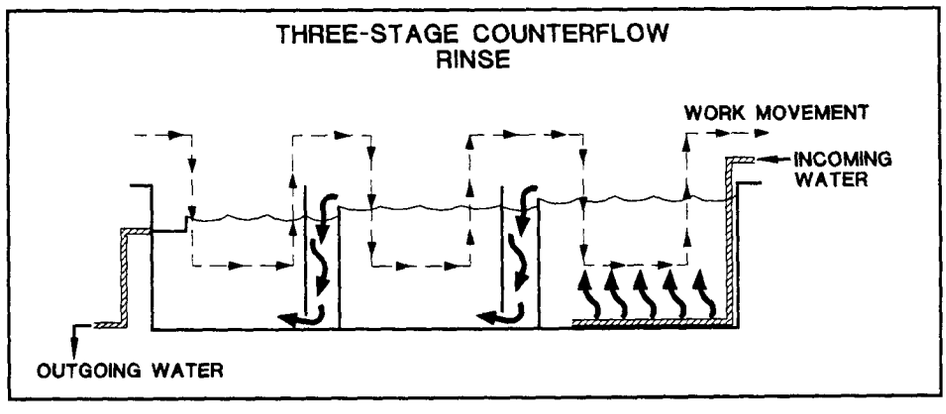


Figure 10-6. Countercurrent Cascade Rinsing

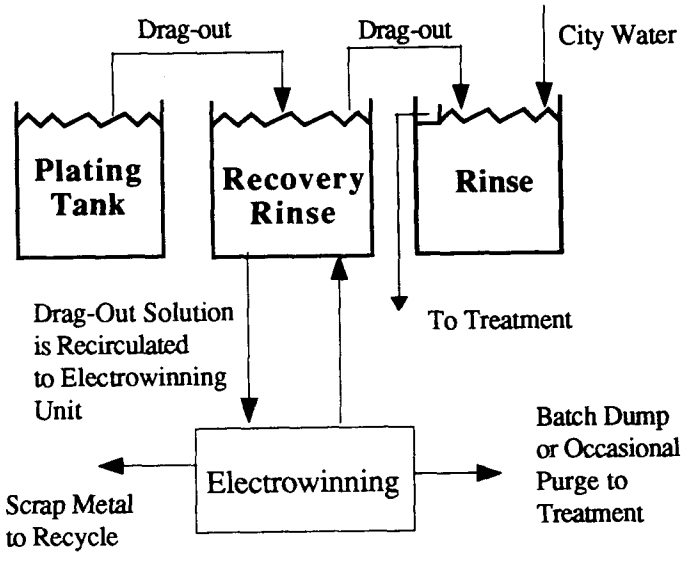
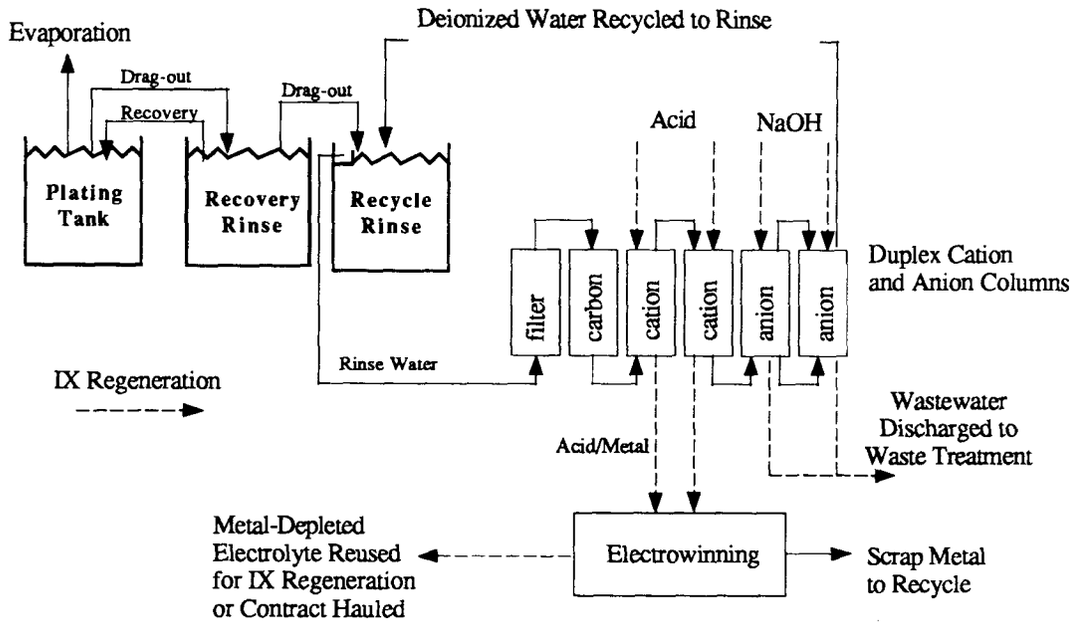
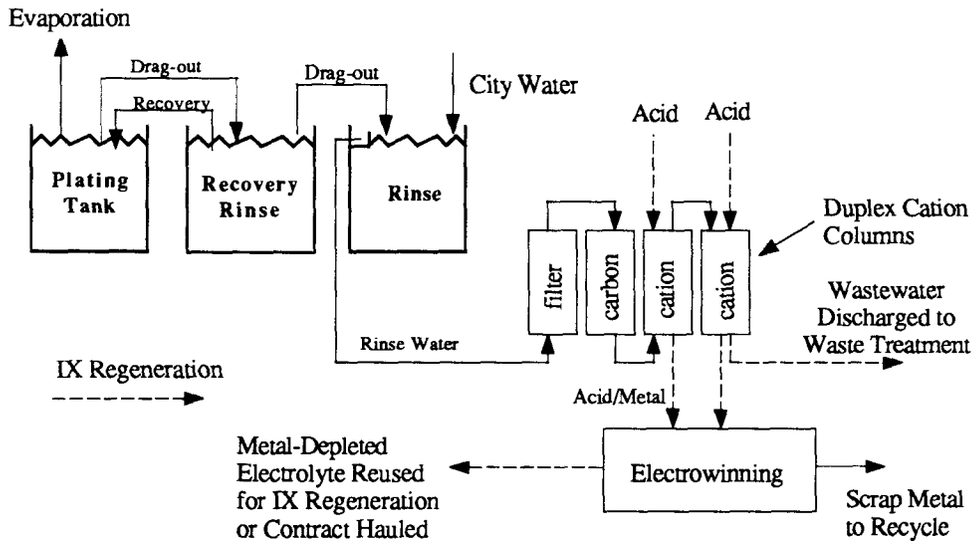


Figure 10-7. Electrolytic Recovery



Ion Exchange Recovery-Metal Recovery/Deionized Water Recycle



Ion Exchange Recovery-Metal Scavenging Configuration

Figure 10-8. Common Configurations for Application of Ion Exchange for Chemical Recovery

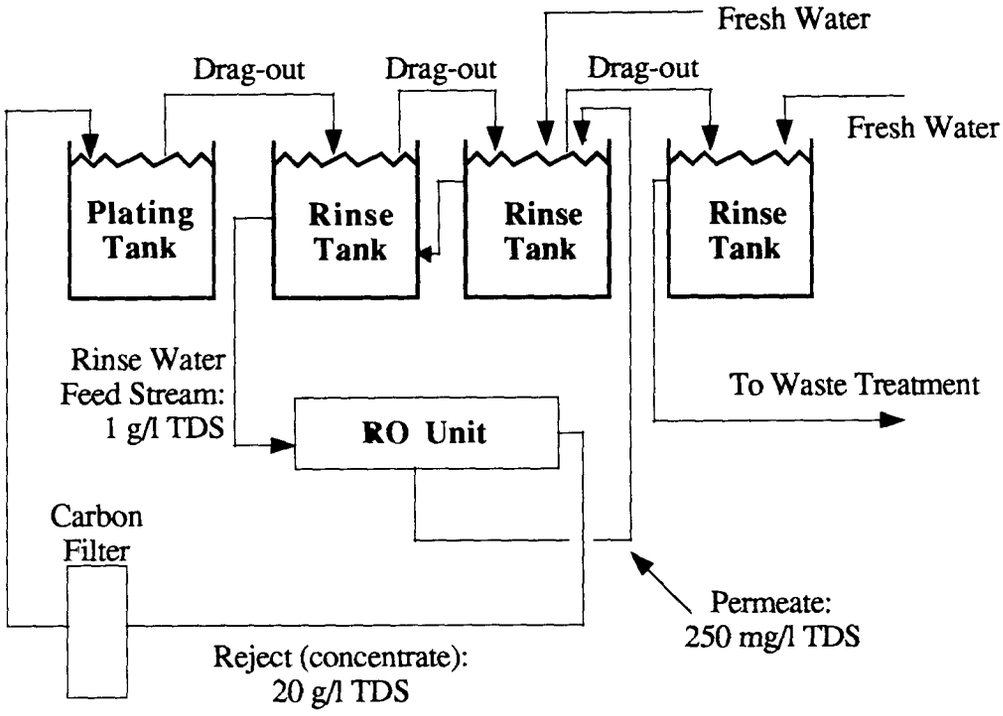


Figure 10-9. In-Process Reverse Osmosis

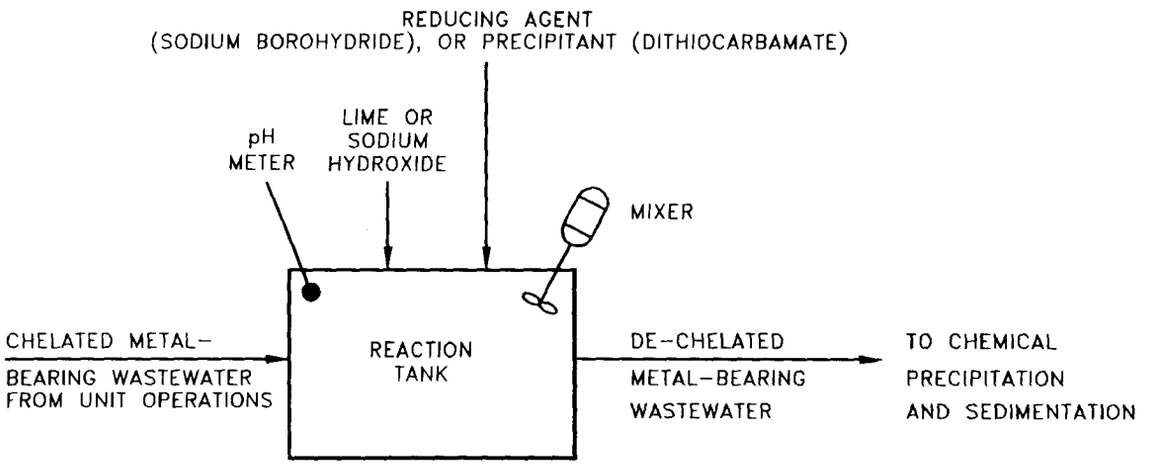


Figure 10-10. Chemical Reduction of Chelated Metals

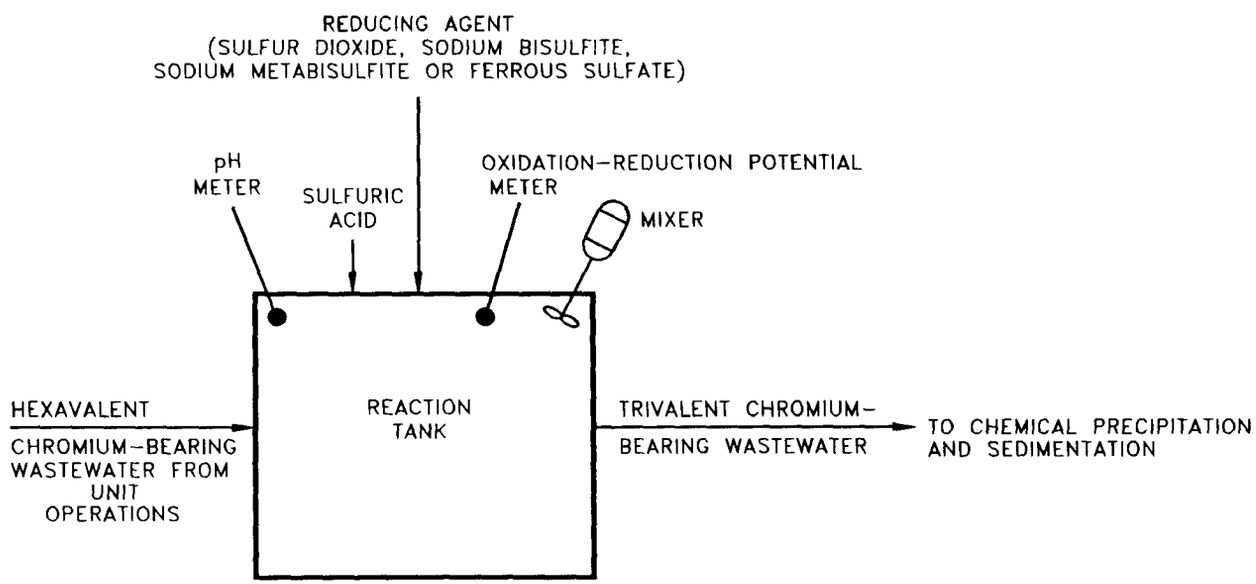
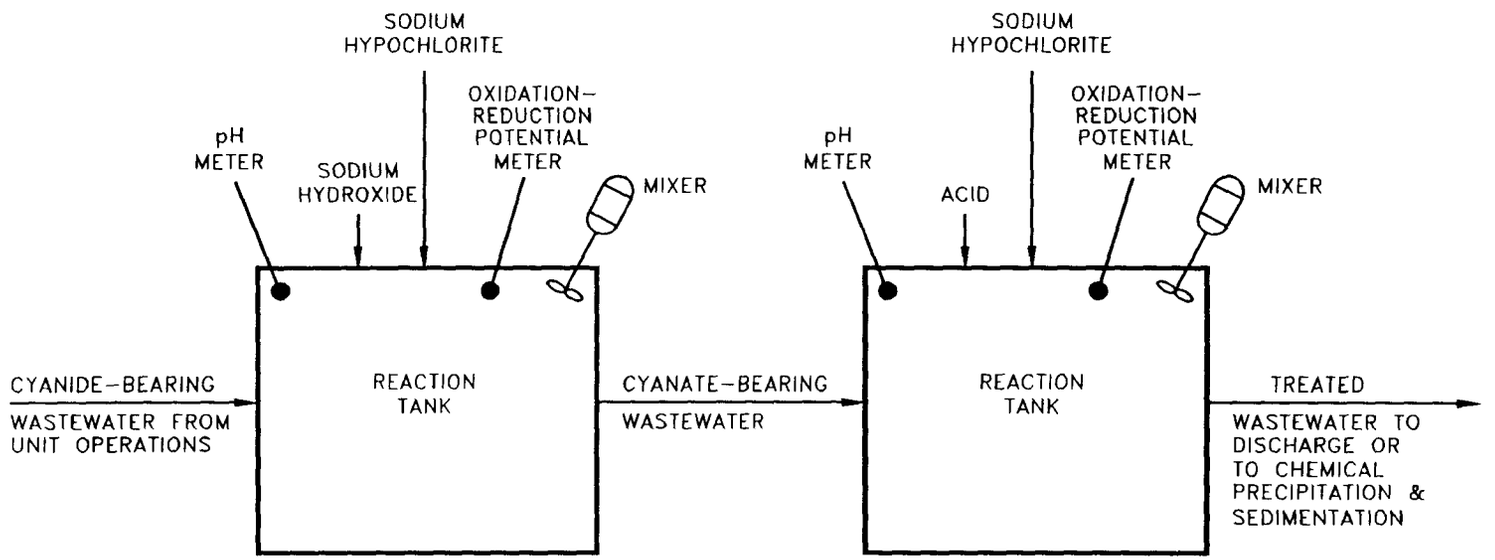


Figure 10-11. Chemical Reduction of Hexavalent Chromium



This technology may also be performed on a batch basis in a single tank.

Figure 10-12. Cyanide Destruction through Alkaline Chlorination

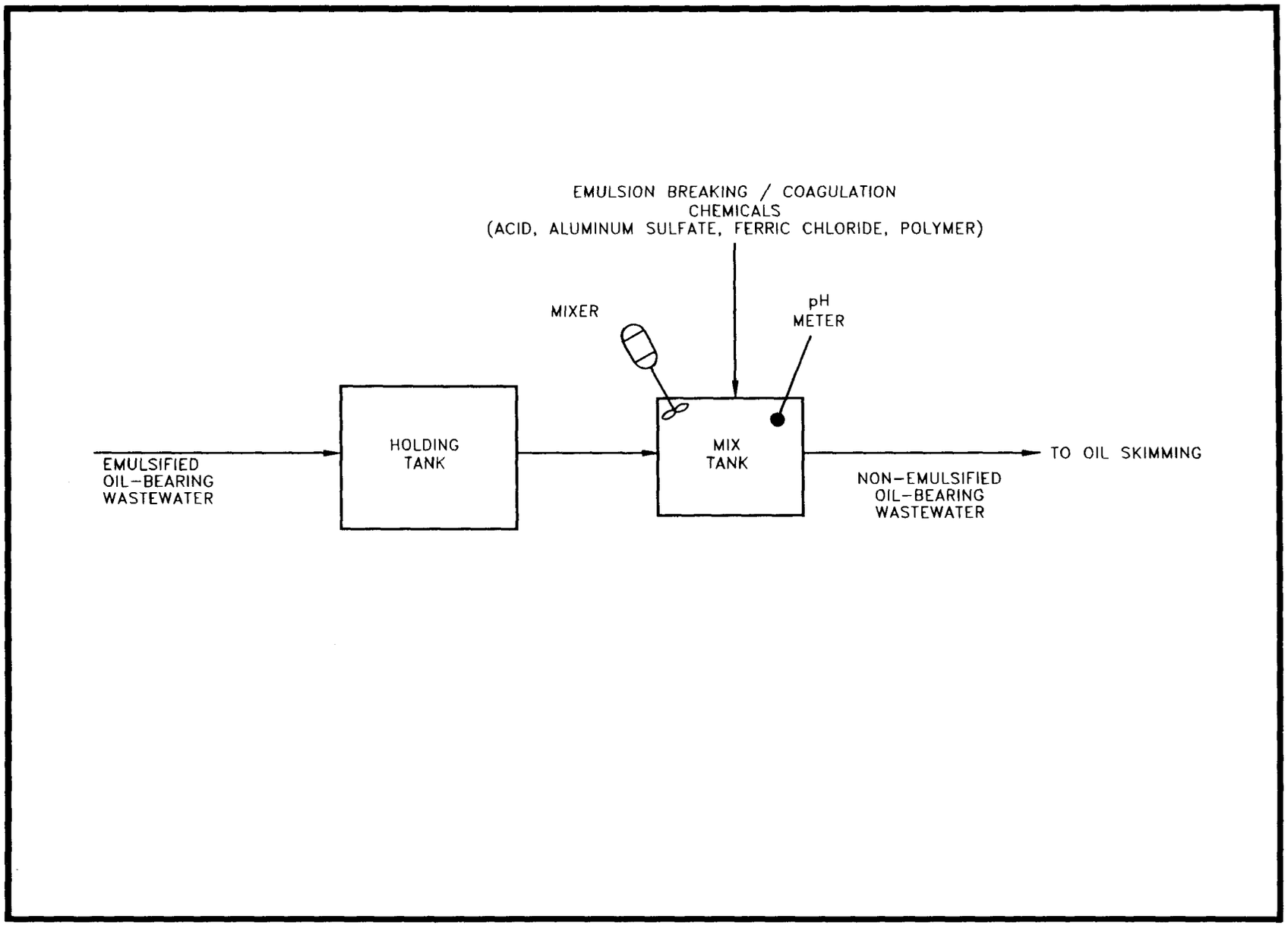


Figure 10-13. Chemical Emulsion Breaking

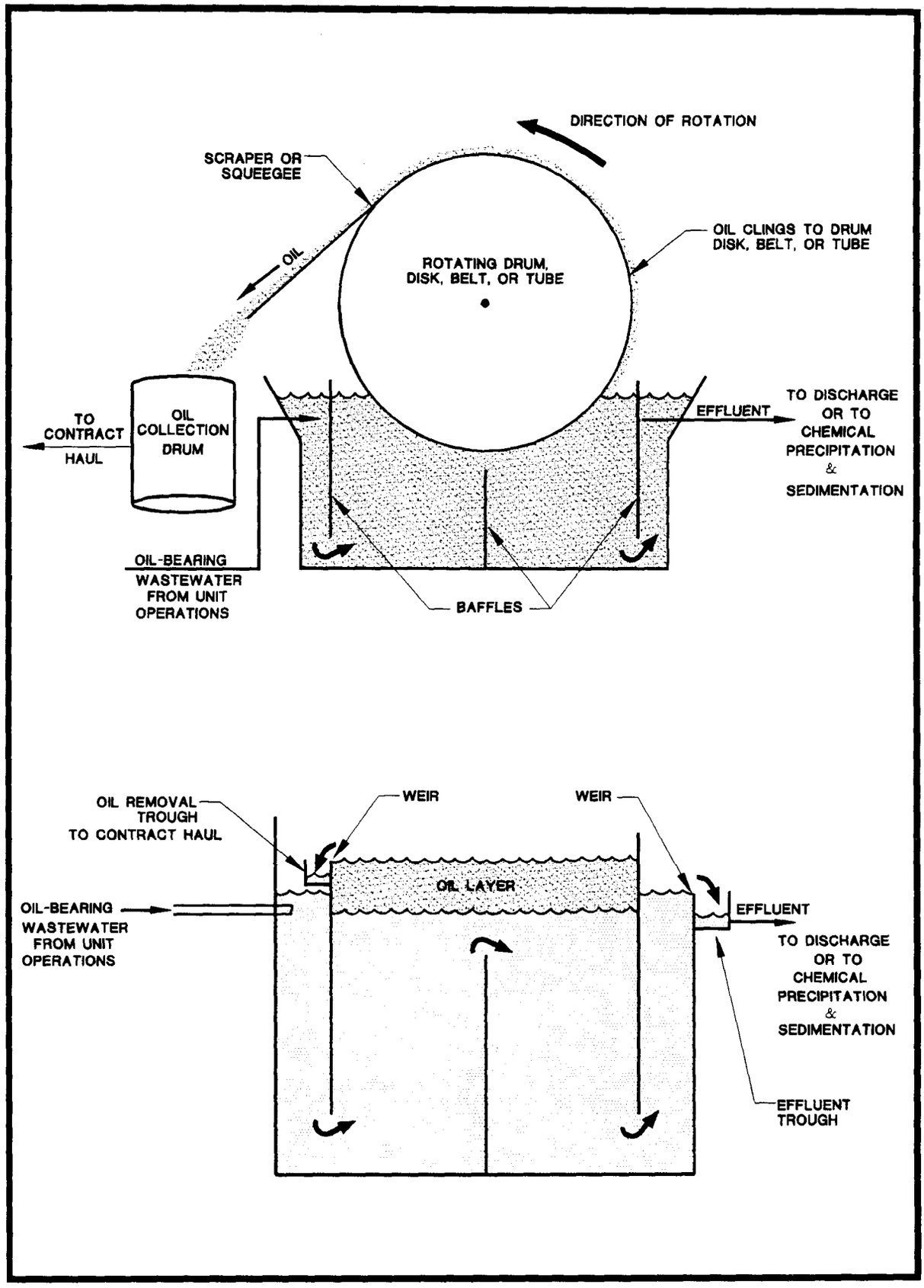
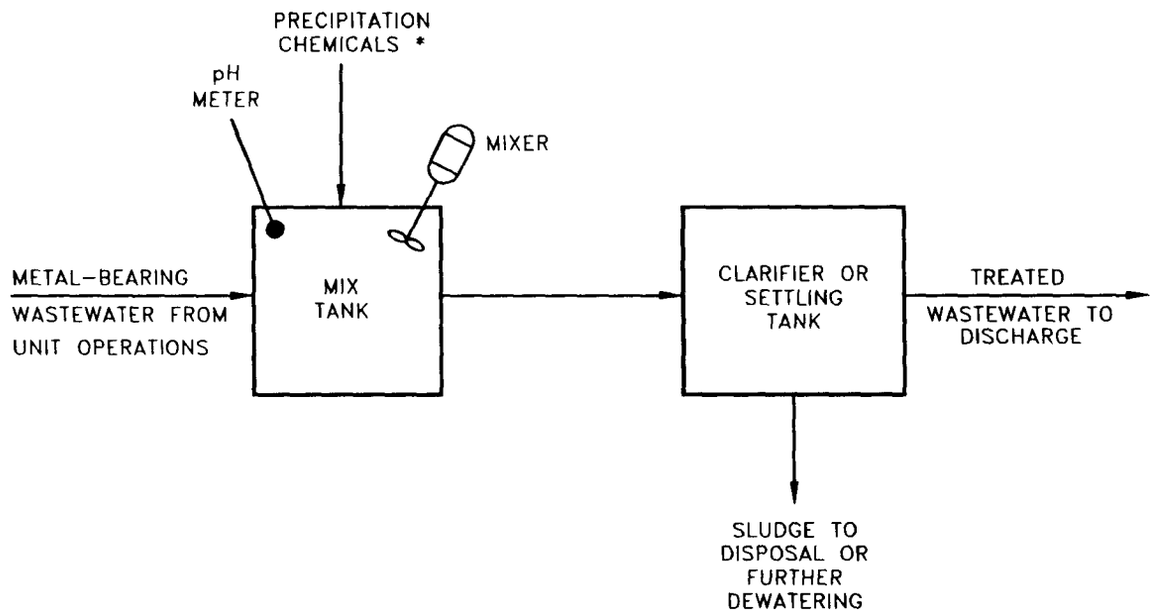


Figure 10-14. Oil Skimming



* PRECIPITATION CHEMICALS FOR HYDROXIDE PRECIPITATION INCLUDE: CALCIUM HYDROXIDE (LIME), SODIUM HYDROXIDE OR MAGNESIUM HYDROXIDE.

PRECIPITATION CHEMICALS FOR SULFIDE PRECIPITATION INCLUDE: HYDROGEN SULFIDE, SODIUM SULFIDE OR FERROUS SULFIDE.

PRECIPITATION CHEMICALS FOR CARBONATE PRECIPITATION INCLUDE: SODIUM CARBONATE (SODA ASH), SODIUM BICARBONATE OR CALCIUM CARBONATE.

Figure 10-15. Chemical Precipitation and Sedimentation

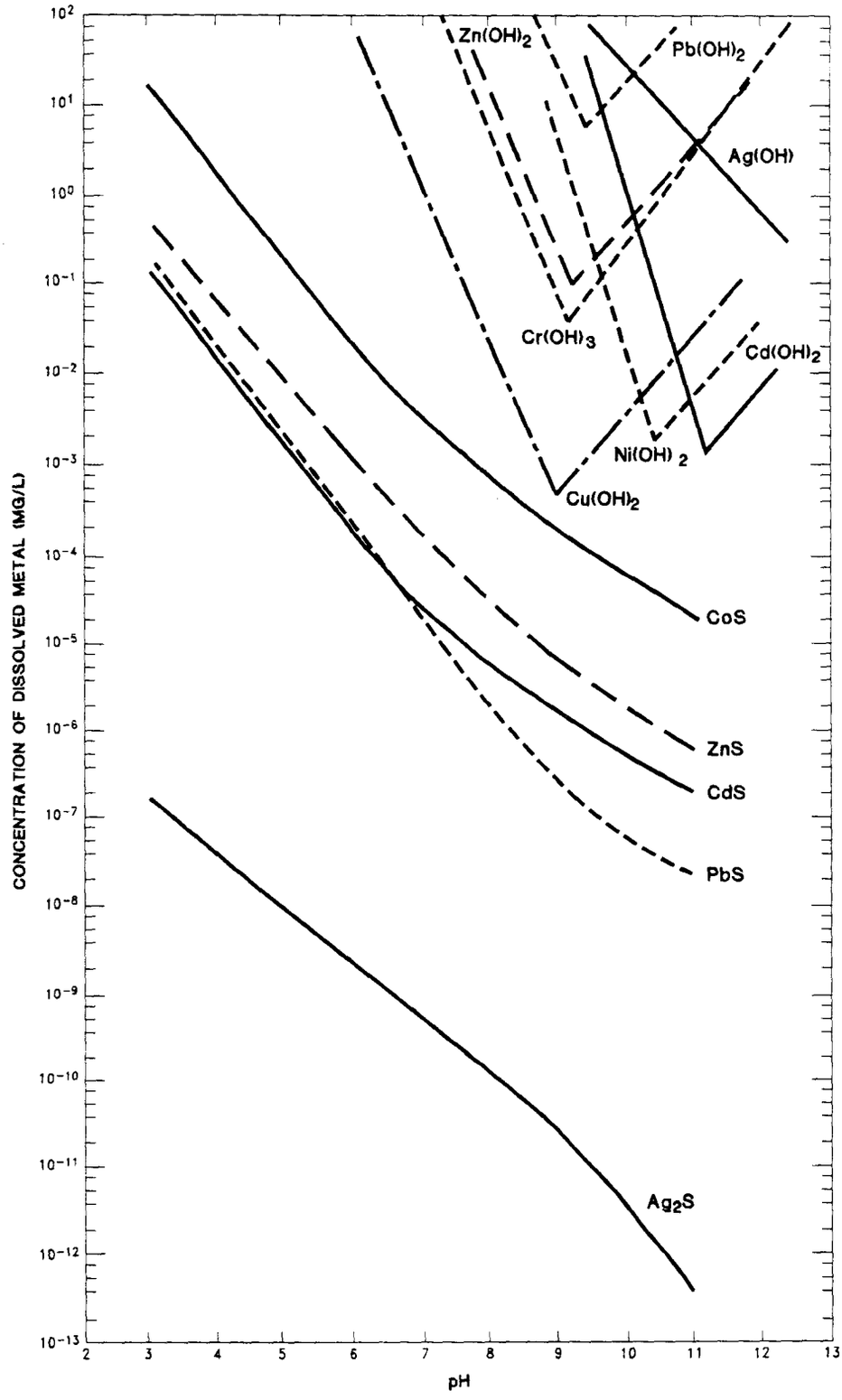


Figure 10-16. Effect of pH on Hydroxide Precipitaion

Source: Technical Development Document for the Organic Chemical, Plastics and Synthetic Fibers Point Source Category, and the Technical Development Document for the Nonferrous Metal Forming and Metal Powders Point Source Category.

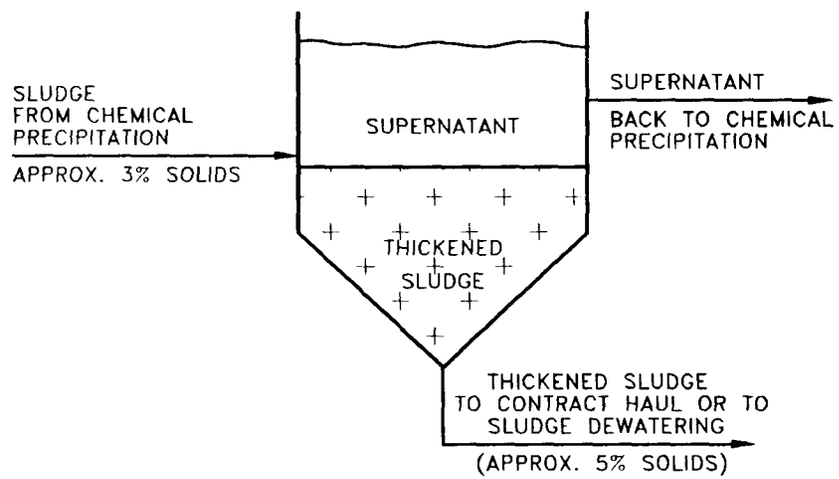


Figure 10-17. Gravity Thickening

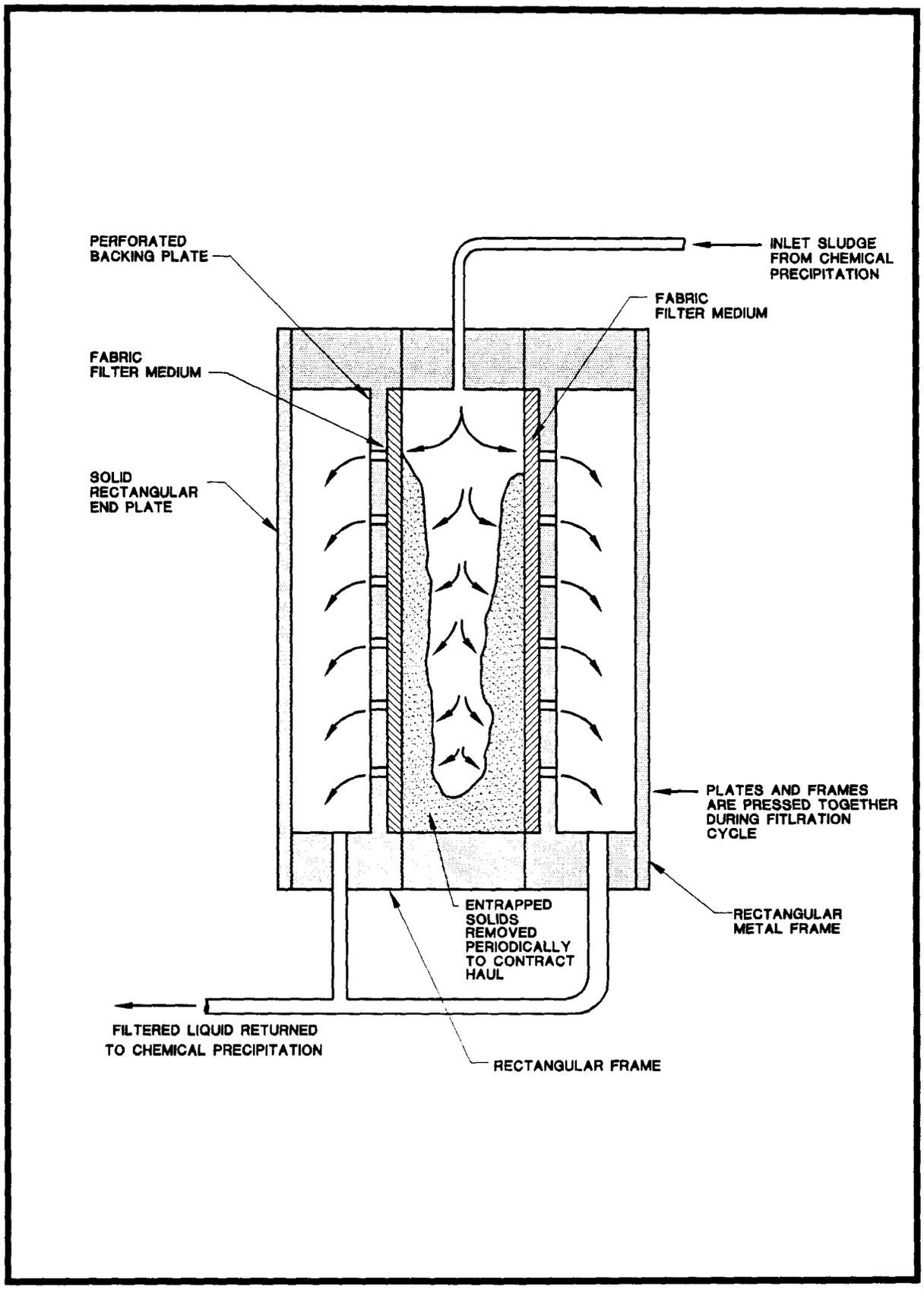


Figure 10-18. Pressure Filtration

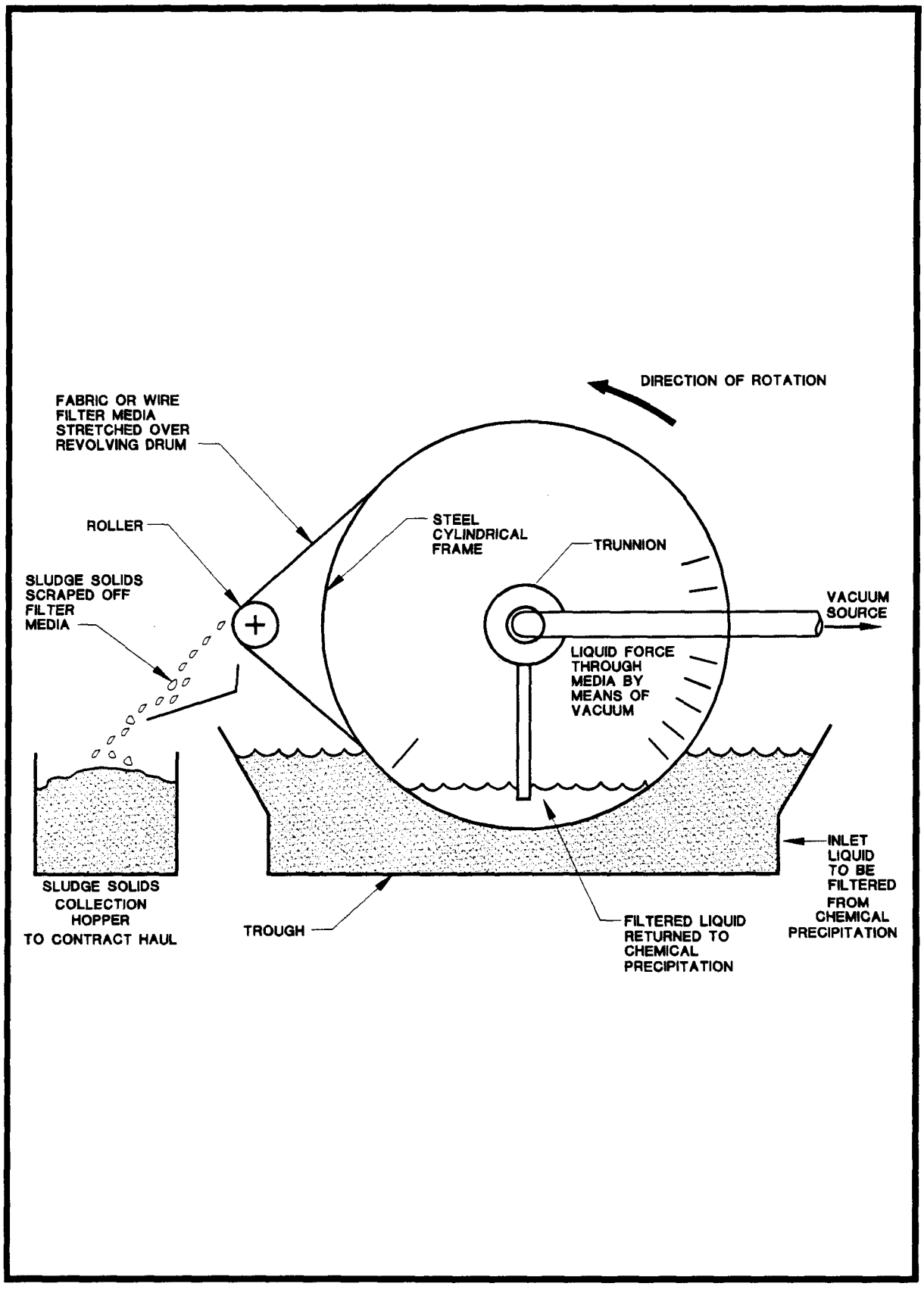


Figure 10-19. Vacuum Filtration

10.7 References

1. Facility Pollution Prevention Guide, EPA/600/R-92/088, U.S. EPA, Washington, DC, 1992.

2. Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Forming and Metal Powders Point Source Category. U.S. Environmental Protection Agency, EPA 440/1-86/019, September 1986.

3. Cherry, K.F Plating Waste Treatment. Ann Arbor Sciences Publishers, Inc., Ann Arbor, Michigan, 1982.

4. Freeman, K.M. Standard Handbook of Hazardous Waste Treatment and Disposal. McGraw Hill Book Company, New York, 1989.

11.0 DEVELOPMENT OF LONG-TERM AVERAGES AND VARIABILITY FACTORS

This section summarizes the results of an assessment of the demonstrated performance and the calculation of long-term average technology effectiveness concentrations for the end-of-pipe wastewater treatment technologies described in Section 10.0. The demonstrated performance for the following technologies is described below:

- Cyanide destruction through alkaline chlorination (for treatment of cyanide);
- Chemical precipitation and sedimentation and preliminary treatment, where appropriate, consisting of chemical emulsion breaking, oil skimming, chromium reduction and chemical reduction of chelated metals (for treatment of all other regulated pollutants).

Section 10.0 contains a detailed description of each of these technologies, as well as the physical and chemical principles underlying their operation. Section 10.0 also identifies the number of Metal Products and Machinery (MP&M) sites visited, DCP respondents, and Phase I sites that use each of these technologies.

Section 11.1 describes the data sources used in assessing the performance of cyanide destruction and chemical precipitation and sedimentation technologies; Section 11.2 describes the data editing procedures used in the assessment; and Section 11.3 describes the long-term average concentrations, variability factors, and limitations calculated from this assessment.

11.1 Sources of Technology Performance Data

EPA collected and compiled analytical data for treatment influent and effluent streams for 23 chemical precipitation and sedimentation systems at 19 MP&M Phase I sites. EPA also collected data for raw wastewater and treated wastewater for seven cyanide destruction systems at seven MP&M Phase I sites. These data, collected using EPA sampling and chemical analysis protocols as described in Section 4.0, are presented in sampling episode reports contained in the administrative record for this rulemaking. Sampling episodes ranged in duration from one to five days.

The database of sampling episode treatment influent and effluent data, termed the Technology Effectiveness Concentration (TEC) database, contains 11,510 data points. A data point is a concentration of a specific constituent in an influent or effluent stream from a given sampling day at a sampled site. The TEC database contains cyanide data for 49 cyanide destruction influent and effluent data points and 11,461 chemical precipitation and sedimentation influent and effluent data points. Of these data points, 4,896 represent treatment of organic pollutants, while 6,565 represent treatment of

priority and nonconventional metal pollutants, and conventional and other nonconventional pollutant parameters.

EPA did not calculate long-term average concentrations for organic pollutants. Although organic pollutants are present in the wastewater generated by several specific MP&M unit operations, they are rarely present in the combined wastewater treatment influent at concentrations sufficient to assess treatment effectiveness. For this reason, the amount of treatment effectiveness data collected during the MP&M sampling program for organic pollutants is limited. As shown in Section 7.0, only 30 of the 233 organic pollutants analyzed for in the MP&M sampling program were detected in wastewater treatment influent streams and most of these were detected in one or two samples. The primary mechanism of organic pollutant removal in the MP&M end-of-pipe technology options is oil/water separation. For the MP&M Phase I regulation, oil and grease will be used as an indicator parameter for the organic pollutants which have the potential to be present and which will remain with the oil layer after oil/water separation. EPA calculated long-term average technology effectiveness concentrations for organic pollutants, for the purpose of estimating pollutant loadings and compliance costs; however, these concentrations were not used in development of variability factors and concentration limitations.

11.2 Data Editing Procedures

EPA reviewed the TEC database to identify data points that were considered appropriate for calculating long-term averages and variability factors for the MP&M industry. EPA identified data from well-designed and well-operated treatment systems, and focused on data for the specific pollutants processed and treated on site. Figure 11-1 summarizes the technology effectiveness data editing procedures discussed below. As shown on this figure, the data editing procedures consisted of four major steps:

(1) Assessment of the performance of the entire treatment system;

(2) Identification of process upsets during sampling that impacted the treatment effectiveness of the system;

(3) Identification of pollutants not present in the raw wastewater at sufficient concentrations to evaluate treatment effectiveness; and

(4) Identification of treatment chemicals used in the treatment system.

These steps are described below. Each data point that failed one or more of the evaluation criteria described below was flagged and excluded from calculation of the long-term average concentrations and variability factors. Only those data points that were not assigned any of the flags described below were used to calculate long-term

averages and variability factors. The number of data points listed as receiving flags for each editing criteria is additive (i.e., the numbers represent the number of data points flagged for specifically that criteria).

11.2.1 Assessment of Treatment System Performance

The first step in the data editing procedures was to assess the performance of the entire treatment system during sampling. For sites that were identified as not being well-designed or well-operated systems, all data were flagged and excluded from use in calculating long-term averages. For this assessment, EPA first identified the metals processed on site, as well as whether the site performed unit operations likely to generate oil and grease and cyanide. EPA focused on these pollutants because the treatment trains described in Section 10.0 are designed to treat and remove these pollutants. In some cases, complete data were not available as to the types of metals processed on site because the EPA toured only a portion of the site during the visit. In these cases, EPA reviewed the concentrations of pollutants in the raw wastewater to identify additional pollutants likely processed on site. EPA then performed the following four technical analyses of the treatment systems:

(1) EPA reviewed the sampled treatment systems to identify any systems that included technologies not included in the technology options listed in Section 10.0. If a sampled system included technologies not in the technology options, the data from that system could not be used to quantify the performance of any of the technology options. EPA identified one system that included biological treatment as part of the chemical precipitation and sedimentation system. Because this technology was not included in the technology options, EPA deleted the data from this system for subsequent analysis by assigning a flag of "O" to all data from this system (224 data points).

(2) Based on the metals processed or treated on site, EPA identified chemical precipitation and sedimentation systems that were not operated at the proper pH for optimal removal of the metals. This analysis was performed on a system-by-system basis. Because the optimum pH for metals removal by a system varies for each combination of metals processed on site, control of pH is essential for proper pollutant removal. EPA also reviewed data for cyanide destruction systems to identify systems not operated at the proper pH for cyanide destruction. EPA identified three chemical precipitation and sedimentation systems that were operated outside pH ranges considered to be optimum for removal of the metals processed on site. EPA also identified one cyanide destruction system that was operated outside the pH range considered optimum

for cyanide destruction. All data for these systems (904 data points) were assigned a flag of "P".

(3) EPA identified chemical precipitation and sedimentation systems that did not have solids removal indicative of effective treatment. As discussed in Section 10.0, metals are removed in chemical precipitation and sedimentation by sedimentation of metal hydroxides in the form of suspended solids. The effectiveness of a system at removing precipitated hydroxides is measured by the removal of total suspended solids (TSS). Poor TSS removal is typically indicative of poor metals removal. In general, EPA identified solids removal systems that did not achieve 90% TSS removal and had effluent TSS concentrations greater than 50 mg/L as having poor solids removal. Site specific exceptions were made to this rule depending on influent concentrations of TSS. Details on these site-specific exceptions are contained in the MP&M public record. EPA identified two systems that were considered to have poor solids removal. All data for these systems (492 data points) were assigned a flag of "T".

(4) EPA identified chemical precipitation and sedimentation systems at which the concentration of most of the metals present in the influent stream did not decrease. A lack of reduction in metal concentrations is indicative of poor treatment. EPA identified two systems for which most of the metals were not treated. All data for these systems (296 data points) were assigned a flag of "A". EPA did not identify any cyanide destruction systems across which the concentration of cyanide did not decrease for most of the days sampled.

11.2.2 Identification of Process Upsets Occurring During Sampling

EPA reviewed the sampling episode reports for each of the sampled sites, and identified any process upsets that resulted in poor treatment during one or more days of the sampling episode. EPA identified one system for which process upsets occurred during sampling. For this system, the site personnel used barrel finishing wastewater (containing iron and aluminum) as a flocculation agent. During two days of sampling, site personnel used a different barrel finishing solution. This solution was not an effective flocculation agent; therefore, the treatment system did not operate effectively during these two days of sampling. The poor treatment is indicated by increased effluent concentrations of metals during those two days as compared to the other days of sampling. During the last day of sampling, site personnel discontinued use of the new solution and used the original barrel finishing solution. All data points for samples

collected during the two days of sampling when the new solution was used (96 data points) were assigned a flag of "V".

11.2.3 Identification of Pollutants Not Present in the Raw Wastewater at Sufficient Concentrations to Evaluate Removal

As discussed above, the first step in assessing treatment performance consisted of identifying the metals processed on site. This step included review of the concentrations of pollutants in the raw wastewater to identify metals present that may not have been identified during the site visit. EPA also identified sites processing oil and grease and cyanide. Based on pollutants processed on site, as well as the treatment influent concentrations of the pollutants analyzed, EPA performed the following data edits to identify pollutants not present in the raw wastewater at sufficient concentrations to evaluate removal.

(1) All data points for a pollutant at a site were assigned a flag of "N" if the pollutant was not detected in any of the raw wastewater samples collected during the sampling episode. EPA assigned this flag to 775 data points.

(2) All data points for a pollutant at a site were assigned a flag of "L" if the pollutant was not detected in the raw wastewater at a concentration greater than 0.1 mg/L in any of the raw wastewater samples collected during the sampling episode. EPA assigned this flag to 900 data points in addition to those previously flagged.

(3) All data points for a pollutant at a site were assigned a flag of "F" if the pollutant was not detected in most of the raw wastewater samples collected during the sampling episode. EPA assigned this flag to 88 data points in addition to those previously flagged.

(4) All data points for a pollutant at a site were assigned a flag of "C" if the pollutant was not detected in the raw wastewater at a concentration greater than 0.1 mg/L in most of the raw wastewater samples collected during the sampling episode. EPA assigned this flag to 142 data points in addition to those previously flagged.

(5) If the raw material associated with a pollutant (metal, oil and grease, or cyanide) was not processed on site, all of the remaining records associated with that pollutant (those without flags) were assigned a flag "1". EPA assigned this flag to 600 data points in addition to those previously flagged.

EPA then reviewed the water use practices for the sampled sites to identify sites that may be diluting the concentration in the raw wastewater of pollutants processed on site. Because the MP&M effluent limitations guidelines and standards include water conservation practices and pollution prevention technologies, EPA reviewed the data to ensure that the technology effectiveness concentrations were based on sites that had these practices and technologies in place. EPA reviewed the site visit reports, sampling episode reports, and additional information obtained from each of the sampled sites to identify unit operations for which sites did not have water conservation and pollution prevention technologies in place, and assigned a flag of "2" to pollutants affected by poor water use practices. EPA did not assign this flag to all pollutants on site because sites could have poor water use practices for unit operation processing a specific pollutant (e.g., a cadmium electroplating line) but could have good water use practices for all other unit operations and pollutants processed on site. EPA assigned this flag to 100 data points in addition to those previously flagged.

11.2.4 Identification of Wastewater Treatment Chemicals

EPA identified wastewater treatment chemicals used in each of the sampled treatment systems to determine if the removal of the metals used as treatment chemicals was consistent with removal of other metals on site, indicating a well-designed and well-operated system. If a metal was used as a treatment chemical, and the site treated the metal to a concentration consistent with other metals removed on site, the treatment chemical metal was not assigned a flag. If the metal was used as a treatment chemical, and the metal was not removed to a concentration consistent with other metals removed on site, but the metals processed on site were removed, the treatment chemical was assigned a flag of "G". EPA assigned this flag to 194 data points in addition to those previously flagged, primarily for calcium, sodium, and magnesium.

11.3 Long-Term Average Concentrations and Variability Factors

EPA used the data editing procedures described above to create the Long-Term Average (LTA) database. EPA used this database to calculate the long-term average concentrations and variability factors that are the basis for setting discharge limits. This database included all data in the TEC database with the addition of the flags assigned during data editing. This database contains 1,775 unflagged data points from 15 chemical precipitation systems, and 28 unflagged data points from four cyanide destruction systems. Table 11-1 presents the unflagged data (i.e., the data from the TEC database which was used to calculate long-term averages) for each of the regulated parameters.

Long-term averages and variability factors were estimated from actual concentrations of constituents measured in MP&M wastewaters treated by cyanide destruction and chemical precipitation and sedimentation systems. The data sets of daily effluent concentrations were obtained from EPA sampling episodes at MP&M facilities. For a

given sampling episode, long-term averages were determined for all analytes that had at least one sample that passed engineering review, while variability factors were only estimated for analytes that had at least four samples, including two detects.

The long-term average for each pollutant for a given sampling episode was estimated by the arithmetic average of the daily concentration values. Observations recorded as below the method detection limit (nondetects) were assigned a numerical value equal to the detection limit. The daily variability factor was estimated for all constituents by fitting a modified delta-lognormal distribution to daily concentration data. This is the same distributional model used by EPA in the final rulemakings for the Organic Chemicals, Plastics and Synthetic Fibers (OCPSF) and Pesticides Manufacturing categories and the proposed rulemaking for the Pulp and Paper category.

The daily variability factor is defined as the estimated 99th percentile of the concentration distribution divided by the expected value of the concentration. The 4-day variability factor is defined similarly except that the 95th percentile of the distribution of 4-day averages is used instead of the 99th percentile of daily measurements. A description of the modified delta-lognormal model is presented below.

11.3.1 Modified Delta-Lognormal Model

The modified delta-lognormal distribution models the effluent concentration data as a mixture of nondetects and measured values. This distribution is appropriate because the data for most constituents consisted of a mixture of measured values and nondetected values. The modified delta-lognormal distribution assumes that each nondetect observation represents an actual concentration equal to the method detection limit, and the detected values are distributed according to a lognormal distribution.

The expected value, 99th percentile, and variability factor for the concentration of each constituent were estimated by fitting the data to a delta-lognormal distribution (1), modified to accommodate a non-zero value of the detection limit (2).

The modified delta-lognormal model is a mixture distribution in which the detected concentrations follow a standard lognormal distribution (i.e., the logarithm of the concentration is assumed to be normally distributed with parameters mean, μ, and standard deviation, σ). All nondetects are assumed to have a concentration value equal to the detection limit.

The cumulative distribution function, which gives the probability that an observed concentration (C) is less than or equal to some specified level (c), can be expressed as a function of the following quantities:

D	=	the detection limit,
δ	=	the probability of a nondetect,

I(c-D)	=	an indicator function which equals 1 for $c \geq D$ and 0 otherwise,
μ	=	the mean of the distribution of log transformed concentrations,
σ	=	the standard deviation of the distribution of log transformed concentrations,
y	=	variable of integration.

The equation of the cumulative distribution function is as follows:

$$F(c) = P(C \leq c) = \delta I(c-D) + (1-\delta)\frac{1}{\sqrt{2\pi\sigma^2}}\int_0^c \frac{1}{y}\exp\left[-\frac{(\ln(y)-\mu)^2}{2\sigma^2}\right]dy. \quad (11\text{-}1)$$

The expected value E(C) of the actual concentration under this distribution function is given by

$$E(C) = \delta D+(1-\delta)\exp\left[\mu+\frac{\sigma^2}{2}\right], \quad (11\text{-}2)$$

and the variance V(C) is given by the following expression:

$$V(C) = (1-\delta)\exp(2\mu+\sigma^2)[\exp(\sigma^2)-(1-\delta)] + \delta(1-\delta)D[D-2\exp(\mu+\frac{\sigma^2}{2})]. \quad (11\text{-}3)$$

The 99th percentile of the distribution can be expressed in terms of μ, σ, and the inverse normal cumulative distribution function (Φ^{-1}), as follows:

$$C_{99} = \max\left[D,\exp\left[\mu+\sigma\Phi^{-1}\left[\frac{0.99-\delta}{1-\delta}\right]\right]\right]. \quad (11\text{-}4)$$

Finally, the daily variability factor VF(1) is the 99th percentile divided by the expected value:

$$VF(1) = \frac{C_{99}}{E(C)} \quad (11\text{-}5)$$

The daily variability factors for each sampling episode-constituent data set were estimated by the following steps (for notational purposes let a typical data set consist of n_1 detects, n_2 nondetects, and have concentrations X_i, $i=1,..,n_1$). The estimate, $\hat{\mu}$, of the log mean was calculated by taking the arithmetic average of the log transformed detects:

$$\hat{\mu} = \frac{1}{n_1}\sum_{i=1}^{n_1} \ln(X_i) \tag{11-6}$$

The estimate, $\hat{\sigma}$, of the log standard deviation was calculated by taking the square root of the sum of the squared differences between the log concentrations and $\hat{\mu}$, divided by the number of detects minus one:

$$\hat{\sigma} = \sqrt{\frac{1}{n_1-1}\sum_{i=1}^{n_1} (\ln(X_i)-\hat{\mu})^2} \tag{11-7}$$

The estimated probability of a nondetect, $\hat{\delta}$, was calculated by dividing the number of nondetects by the number of observations:

$$\hat{\delta} = \frac{n_2}{n_1+n_2} \tag{11-8}$$

These quantities were then substituted into equations 11-2 and 11-4 to give estimates $\hat{E}(C)$ and $\hat{C}_{99}$ of the mean concentration and the 99th percentile, respectively. Finally, the resulting estimated mean and 99th percentile were substituted into equation 11-5 to yield the daily variability factor estimate, $\hat{V}F(1)$.

The average daily variability factor multiplied by the median long-term average yields the value used by EPA as the maximum value that an individual concentration measurement can be expected to attain. An analogous measure of the maximum value attained by the averages of four daily concentration measurements can also be defined and estimated from the data. The definition of the 4-day variability factor, VF(4), is the 95th percentile of the distribution of 4-day averages, divided by the expected value of 4-day averages.

The value of VF(4) can be estimated from the daily concentration data by exploiting the statistical properties of the 4-day averages, C_4, and approximating the distribution of C_4 by the modified delta-lognormal model. This approximation has been shown to provide a good estimate to the actual distribution (3). To develop the estimate of VF(4), first note that the logarithm of C_4 is normally distributed with unknown mean and standard deviation denoted by μ_4 and σ_4, respectively. Also, $E(C_4) = E(C)$ because the expected

value of a sum of random variables divided by a constant is equal to the sum of their expectations divided by that constant. And $V(C_4) = V(C)/4$ because the variance of a sum of independent random variables divided by a constant is equal to the sum of their variances divided by the square of that constant (4). Finally, the probability that C_4 is a nondetect is δ^4, since the average of four independent concentrations is a nondetect only if all four are nondetects, and the probability of this occurring is equal to the product of the component probabilities, or δ^4 if the daily nondetect probability is δ.

The following equations therefore hold:

$$E(C_4) = E(C) = \delta^4 D + (1-\delta^4)\exp\left[\mu_4 + \frac{\sigma_4^2}{2}\right], \tag{11-9}$$

$$V(C_4) = \frac{1}{4}V(C) = (1-\delta^4)\exp(2\mu_4+\sigma_4^2)(\exp(\sigma_4^2)-(1-\delta^4)) + \delta^4(1-\delta^4)D(D-2\exp(\mu_4+\frac{\sigma_4^2}{2})), \tag{11-10}$$

and

$$C_{95}(4) = \max\left[D, \exp\left[\mu_4 + \sigma_4\Phi^{-1}\left[\frac{0.95-\delta^4}{1-\delta^4}\right]\right]\right]. \tag{11-11}$$

Equations 11-9 and 11-10 can be algebraically solved for σ_4 in terms of the average and variance of the daily concentrations, the probability of a nondetect, and the detection limit. This expression is as follows:

$$\sigma_4 = \ln\left[1 + \frac{V(C)}{4(E(C)-\delta^4 D)^2} - \frac{\delta^4(1-\delta^4)D^2}{(E(C)-\delta^4 D)^2} + \frac{2\delta^4 D}{E(C)-\delta^4 D}\right] + \ln(1-\delta^4). \tag{11-12}$$

To derive an estimate, $\hat{\sigma}_4$, of the left-hand side of equation (11-12), each quantity on the right-hand side was replaced by its estimate computed from the daily concentration data (i.e., $E(C)$ was replaced by $\hat{E}(C)$, $V(C)$ by $\hat{V}(C)$, and δ by $\hat{\delta}$). Next, the estimated $\hat{\sigma}_4$ together with $\hat{\delta}$ and $\hat{E}(C)$ were substituted into equation 11-9, which was solved to yield an estimate $\hat{\mu}_4$ of μ_4. Finally, μ_4 and σ_4 in equation 11-11 were replaced by their estimates to yield an estimated value of the 95th percentile of the 4-day average distribution, and this estimate was divided by $\hat{E}(C)$ to give the estimated variability factor $\hat{V}F(4)$.

The EPA sampling episodes provided a single detection limit for all analytes except for oil and grease at one site. Because the modified delta-lognormal distribution is based on a single detection limit, EPA had to select the detection limit to be used for the statistical analyses in this case. EPA used the average oil and grease detection limit for this site to estimate the variability factor. The variability factor results would not have differed if an alternative detection limit was chosen because the two reported detection limits were so close in magnitude, 0.290 mg/l and 0.300 mg/l.

The results of applying the modified delta-lognormal model are shown in Table 11-2, which give the estimated long-term averages and variability factors of constituent concentrations for facilities using chemical precipitation and sedimentation treatment and cyanide treatment. Note that variability factors were not estimated for facility data sets that had fewer than four observations or for those with fewer than two detects.

11.3.2 Option Limitations and Long-Term Average

The previous section described how sampling episode-level variability factors (VFs) were estimated from daily effluent concentration data using the modified delta-lognormal model. This section describes how these episode-level VFs were used to calculate daily and monthly average limitations for the MP&M technology options and regulated pollutants. Because the limitations are based on final end-of-pipe treatment, only one set of limitations are presented. All of the MP&M technology options include end-of-pipe chemical precipitation and sedimentation. Options 1A, 2, 2A, and 3 also include other technologies such as in-process and end-of-pipe recycling; however, these technologies do not affect the treatment performance of chemical precipitation and sedimentation.

The daily limitation and monthly average limitation for a given constituent was estimated according to the following methodology:

- The long-term average (LTA) was estimated for each data set by computing the arithmetic average of the constituent daily concentrations. Observations below the sampling episode detection limit were set equal to the detection limit for the purposes of this calculation.

- The constituent LTA was defined to be the median of the episode-level constituent LTAs.

- For those episode data sets that had at least four observations, including two detected values, the modified delta-lognormal model was used to estimate daily and 4-day average variability factors (VF) as described above.

- The constituent daily VF was defined to be the average of the episode-level daily VFs; the constituent 4-day average VF was defined to be the average of the episode-level 4-day average VFs.

- The daily and monthly average limitations were calculated by multiplying the constituent LTA by the daily and 4-day constituent VFs, respectively.

Table 11-3 shows the results of applying this methodology to estimate long-term averages, daily limitations, and monthly average limitations for chemical precipitation and sedimentation and cyanide destruction, respectively.

Table 11-1

MP&M Technology Effectiveness Data*

Episode	Influent Concentration (mg/L)	Effluent Concentration (mg/L)
	ALUMINUM	
1197A	5.040 2.040 0.571	0.270 0.286 0.247
4011	20.600 10.700 13.100	2.450 5.520 2.770
4278	6.750 6.280 4.610 3.915	0.068 0.044 0.030 0.054
4279	59.832 27.345 26.395 18.021 17.129	2.814 1.076 1.979 2.306 2.225
4310	11.350 4.280 2.870	0.373 0.373 0.451
4330	11.306 6.601 6.248 4.107 2.831	0.084 0.089 0.080 0.079 0.087
4415	31.762 28.953 22.635	2.040 0.120 0.195
4417	85.000 42.100 30.800 29.100 9.500	4.710 4.890 6.540 8.250 3.840
4417A	571.000	1.950

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

Table 11-1 (Continued)

MP&M Technology Effectiveness Data*

Episode	Influent Concentration (mg/L)	Effluent Concentration (mg/L)
	CADMIUM	
4277	18.900 5.270 3.420 2.930 0.903	0.230 0.219 0.202 0.140 0.078
4279	7.730 7.639 2.636 2.437 1.431	0.190 0.086 0.176 0.211 0.022
	CHROMIUM	
1197A	28.700 1.400 0.027	1.230 0.656 0.027
4011	7.040 2.720 1.890	0.726 0.756 1.130
4079	5.540 4.400 0.200	1.820 0.456 0.635
4278	17.000 13.600 13.100 10.850	0.020 0.007 0.007 0.033
4279	22.559 11.269 10.352 9.668 7.609	0.364 0.508 0.834 0.576 0.180
4310	1,350.000 89.300 88.400	1.770 4.650 0.395

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

Table 11-1 (Continued)

MP&M Technology Effectiveness Data*

Episode	Influent Concentration (mg/L)	Effluent Concentration (mg/L)
CHROMIUM (Continued)		
4330	34.721	0.066
	34.568	0.131
	8.533	0.043
	6.651	0.050
	5.762	0.043
4384	20.300	0.786
	9.460	0.603
	5.410	0.593
	3.480	0.532
	1.350	0.411
4415	5.304	0.015
	1.476	0.020
	0.973	0.112
4417	5.100	0.020
	3.560	0.029
	3.310	0.013
	2.770	0.010
	1.570	0.022
4417A	16.100	0.021
4438	28.100	0.099
	19.300	0.088
	17.400	0.091
4470	12.102	0.083
	7.792	0.108
	7.568	0.069
	6.136	0.055
	5.177	0.072
COPPER		
4277	29.500	0.638
	14.600	0.385
	13.100	0.462
	7.735	0.701
	5.160	0.610

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

Table 11-1 (Continued)

MP&M Technology Effectiveness Data*

Episode	Influent Concentration (mg/L)	Effluent Concentration (mg/L)
COPPER (Continued)		
4278	125.000 101.500 67.100 57.400	0.061 0.329 0.087 0.036
4279	3.663 2.193 1.812 1.163 0.930	0.099 0.093 0.124 0.175 0.034
4417A	37.000	21.600
CYANIDE		
4274	119.000 108.000 65.500	0.010 0.010 0.010
4279	50.000 48.000 11.000 9.900 7.600	0.010 0.010 0.010 0.010 0.010
4384	25.100 23.850 5.860 4.570 0.366	0.758 0.694 0.945 0.992 0.463
4460A	21.100	0.020
IRON		
4079	67.300 26.900 3.350	1.040 1.520 1.740
4277	4.050 1.240 0.493 0.393 0.148	0.017 0.042 0.037 0.028 0.055

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

Table 11-1 (Continued)

MP&M Technology Effectiveness Data*

Episode	Influent Concentration (mg/L)	Effluent Concentration (mg/L)
	IRON (Continued)	
4278	3880.000 3630.000 3400.000 2950.000	4.380 1.060 1.430 10.300
4279	44.601 39.440 21.875 18.324 13.301	1.198 0.629 0.337 1.325 0.774
4310	40.050 19.000 1.700	2.220 8.890 3.100
4384	25.800 20.200 18.300 10.200 3.260	1.730 1.600 1.170 1.420 1.320
4415	39.697 36.902 34.694	1.410 0.069 0.154
4417	7.690 3.270 2.260 1.960 0.633	0.022 0.039 0.032 0.023 0.030
4417A	222.000	0.225
4438	29.300 9.700 7.350	0.450 0.380 0.448
4470	486.040 219.910 184.210 175.830 171.510	3.281 3.167 3.259 3.076 4.116

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

Table 11-1 (Continued)

MP&M Technology Effectiveness Data*

Episode	Influent Concentration (mg/L)	Effluent Concentration (mg/L)
NICKEL		
4277	27.400 6.380 3.540 2.705 1.050	0.173 0.197 0.180 0.180 0.161
4278	608.000 594.000 502.500 481.000	0.318 0.317 1.570 0.596
4279	13.153 7.141 3.847 3.537 2.619	0.527 0.477 0.481 0.058 0.363
4417A	9.330	0.014
4438	34.200 32.400 31.700	0.378 0.518 0.348
4470	2.664 2.293 2.052 1.880 1.830	0.222 0.224 0.229 0.339 0.143
ZINC		
4277	3.480 2.640 1.335 0.925 0.801	0.022 0.015 0.047 0.042 0.013
4278	13.700 12.600 11.100 10.400	0.011 0.022 0.011 0.027

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

Table 11-1 (Continued)

MP&M Technology Effectiveness Data*

Episode	Influent Concentration (mg/L)	Effluent Concentration (mg/L)
	ZINC (Continued)	
4279	100.470	2.866
	93.671	1.229
	44.988	0.263
	40.330	3.528
	34.259	2.059
4415	3.012	0.541
	2.303	0.070
	1.923	0.058
4417	142.000	0.150
	66.100	0.213
	45.900	0.173
	19.900	0.212
	4.550	0.078
4417A	1,540.000	1.620
4470	66.404	1.351
	53.126	1.793
	51.031	1.181
	50.732	0.986
	44.231	1.593
	OIL AND GREASE	
4384	47.200	49.000
	30.000	10.000
	18.000	5.000
	10.000	12.000
	6.000	8.200
4470	52.000	18.000
	23.500	8.000
	23.000	11.500
	22.000	8.000
	18.000	7.000
4471	114.000	8.000
	78.000	7.000
	61.000	13.000
	60.000	5.000

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

Table 11-1 (Continued)

MP&M Technology Effectiveness Data*

Episode	Influent Concentration (mg/L)	Effluent Concentration (mg/L)
TOTAL SUSPENDED SOLIDS		
1197A	260.000 54.000 12.000	32.000 20.000 28.000
4011	230.000 230.000 130.000	22.000 30.000 28.000
4079	240.000 74.000 67.000	9.000 5.000 5.000
4277	320.000 20.000 16.000 13.000 11.000	14.000 14.000 17.000 10.000 17.000
4278	4,650.000 2,300.000 1,900.000 420.000	18.000 34.000 11.000 120.000
4279	1,600.000 1,400.000 960.000 850.000 695.000	57.000 60.000 25.000 94.000 52.000
4330	78.000 30.000 23.000 19.000 10.000	4.000 5.000 3.000 11.000 10.000
4384	610.000 586.000 565.000 394.000 380.000	23.000 68.000 50.000 32.000 55.000

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

Table 11-1 (Continued)

MP&M Technology Effectiveness Data*

Episode	Influent Concentration (mg/L)	Effluent Concentration (mg/L)
TOTAL SUSPENDED SOLIDS (Continued)		
4415	130.607 119.036 77.141	1.000 1.000 1.000
4417	430.000 70.000 32.000 22.000 4.000	12.000 10.000 7.000 4.000 2.000
4417A	72.000	27.000
4438	410.000 11.000 10.000	7.000 5.000 8.000
4470	1,300.000 640.000 530.000 445.000 320.000	22.000 14.500 10.000 32.000 10.000
4471	100.000 40.000 36.000 6.000	11.000 18.000 48.000 36.000

Source: MP&M Technology Effectiveness Concentration Database.

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

Table 11-2

Variability Factors and Long-Term Averages for Chemical Precipitation and Sedimentation Treatment*

Pollutant	EPA Sampling Episode	Long-Term Average (mg/L)	Daily Variability Factor	4-Day Variability Factor
Aluminum	1197A	0.27	NC	NC
	4011	3.58	NC	NC
	4278	0.05	1.79	1.27
	4279	2.08	2.19	1.34
	4310	0.40	NC	NC
	4330	0.08	1.13	1.04
	4415	0.79	NC	NC
	4417	5.65	1.92	1.27
	4417A	1.95	NC	NC
Cadmium	4277	0.17	2.58	1.43
	4279	0.14	5.78	2.14
Chromium	1197A	0.64	NC	NC
	4011	0.87	NC	NC
	4079	0.97	NC	NC
	4278	0.02	5.11	1.99
	4279	0.49	3.25	1.58
	4310	2.27	NC	NC
	4330	0.07	2.66	1.45
	4384	0.59	1.68	1.21
	4415	0.05	NC	NC
	4417	0.02	2.46	1.40
	4417A	0.02	NC	NC
	4438	0.09	NC	NC
	4470	0.08	1.73	1.22

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.
NC = Not calculated due to insufficient data.

Table 11-2 (Continued)

Variability Factors and Long-Term Averages for Chemical Precipitation and Sedimentation Treatment*

Pollutant	EPA Sampling Episode	Long-Term Average (mg/L)	Daily Variability Factor	4-Day Variability Factor
Copper	4277	0.56	1.73	1.22
	4278	0.13	5.76	2.13
	4279	0.11	3.44	1.63
	4417A	21.60	NC	NC
Iron	4079	1.43	NC	NC
	4277	0.04	2.56	1.43
	4278	4.29	6.60	2.33
	4279	0.85	3.09	1.55
	4310	4.74	NC	NC
	4384	1.45	1.42	1.13
	4415	0.54	NC	NC
	4417	0.03	1.69	1.21
	4417A	0.23	NC	NC
	4438	0.43	NC	NC
	4470	3.38	1.30	1.10
Nickel	4277	0.18	1.18	1.06
	4278	0.70	4.36	1.83
	4279	0.38	5.68	2.12
	4417A	0.01	NC	NC
	4438	0.41	NC	NC
	4470	0.23	1.94	1.28

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.
NC = Not calculated due to insufficient data.

Table 11-2 (Continued)

Variability Factors and Long-Term Averages for Chemical Precipitation and Sedimentation Treatment*

Pollutant	EPA Sampling Episode	Long-Term Average (mg/L)	Daily Variability Factor	4-Day Variability Factor
Zinc	4277	0.03	3.29	1.59
	4278	0.02	1.84	1.35
	4279	1.99	6.54	2.31
	4415	0.22	NC	NC
	4417	0.17	2.40	1.39
	4417A	1.62	NC	NC
	4470	1.38	1.69	1.21
Oil and Grease	4384	16.84	5.23	2.02
	4470	10.50	2.27	1.36
	4471	8.25	2.32	1.37
TSS	1197A	26.67	NC	NC
	4011	26.67	NC	NC
	4079	6.33	NC	NC
	4277	14.40	1.62	1.19
	4278	45.75	6.49	2.30
	4279	57.60	2.71	1.46
	4330	6.60	3.20	1.57
	4384	45.60	2.52	1.42
	4415	1.00	NC	NC
	4417	7.00	3.11	1.60
	4417A	27.00	NC	NC
	4438	6.67	NC	NC
	4470	17.70	2.87	1.50
	4471	28.25	3.78	1.70

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.
NC = Not calculated due to insufficient data.

Table 11-2 (Continued)

Variability Factors and Long-Term Averages for Chemical Precipitation and Sedimentation Treatment*

Pollutant	EPA Sampling Episode	Long-Term Average (mg/L)	Daily Variability Factor	4-Day Variability Factor
Cyanide	4274	0.01	NC	NC
	4279	0.01	NC	NC
	4384	0.77	1.94	1.27
	4460A	0.02	NC	NC

*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.
NC = Not calculated due to insufficient data.

Table 11-3

Long-Term Averages and Limitations for Chemical Precipitation and Sedimentation (Cyanide Destruction for Cyanide)*

Pollutant	Number of Sites (LTA)	Number of Sites (VF)	Median LTA (mg/l)	1-Day Variability Factor	4-Day Variability Factor	Daily Limitation (mg/l)	Monthly Limitation (mg/l)
Aluminum	9	4	0.785	1.756	1.231	1.4	1.0
Cadmium	2	2	0.155	4.183	1.785	0.7	0.3
Chromium	13	6	0.093	2.814	1.474	0.3	0.2
Copper	4	3	0.344	3.644	1.660	1.3	0.6
Iron	11	6	0.853	2.778	1.457	2.4	1.3
Nickel	6	4	0.306	3.290	1.570	1.1	0.5
Zinc	7	5	0.223	3.151	1.569	0.8	0.4
Oil and Grease	3	3	10.500	3.276	1.583	35.0	17.0
TSS	14	8	22.183	3.288	1.592	73.0	36.0
Cyanide	4	1	0.015	1.937	1.275	0.03	0.02

Source: MP&M Technology Effectiveness Database.

LTA = Long Term Average.
VF = Variability factor.
*Not-detected pollutants are reported at the detection limit. In these cases, the detection limits were used to calculate LTAs, variability factors, and limitations.

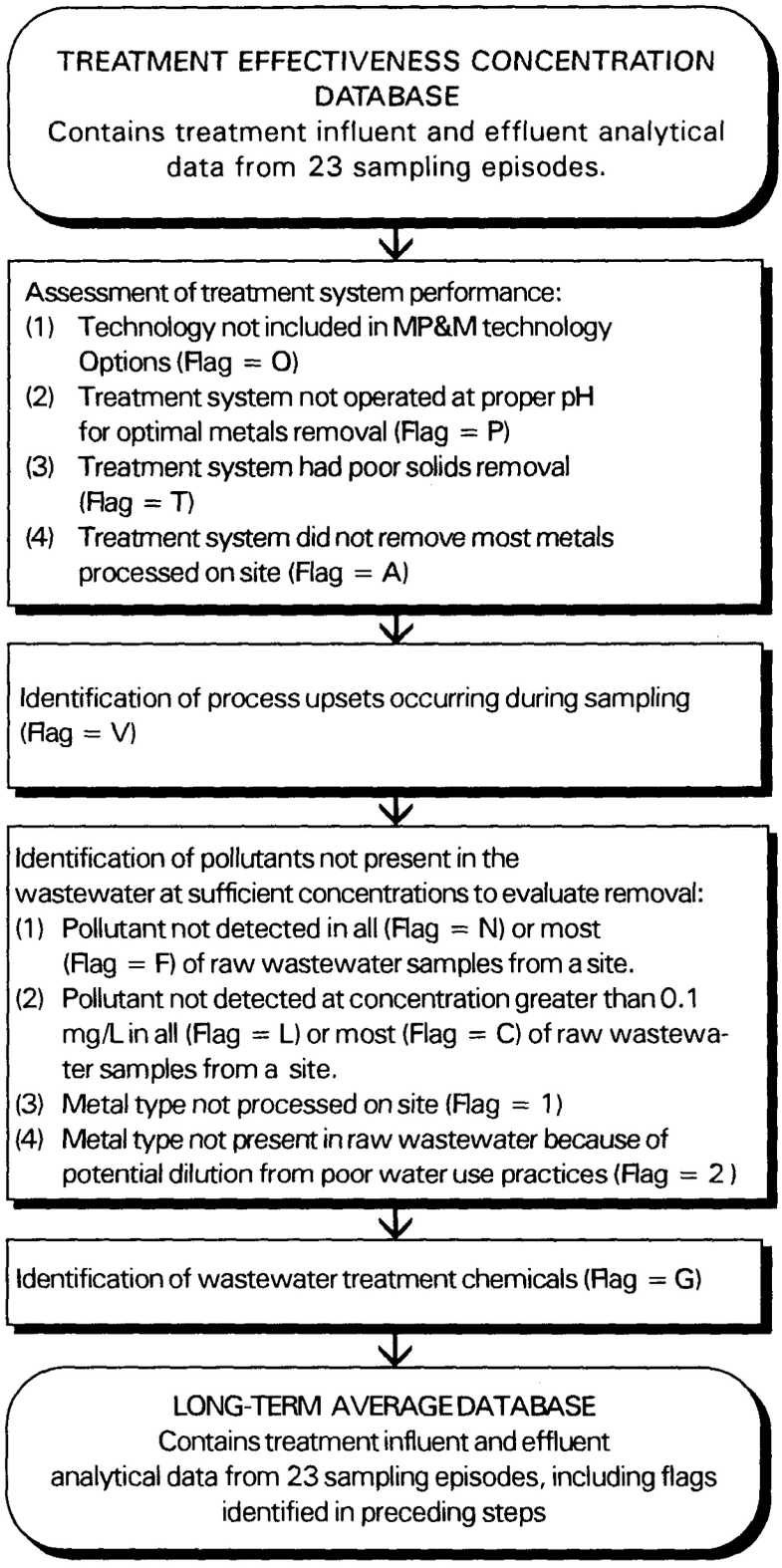


Figure 11-1. Summary of Technology Performance Data Editing Procedures

11.4 References

1. Aitchison, J, and JAC Brown. 1957. *The Lognormal Distribution.* London: Cambridge University Press, pp. 95-96.

2. This modification of the delta-lognormal distribution was used by EPA in establishing limitations guidelines for the Organic Chemicals, Plastics, and Synthetic Fibers point source category. The approach is therefore sometimes called the "Organics method."

3. Barakat, R. 1976. Sums of Independent Lognormally Distributed Random Variables. *Journal of the Optical Society of America.* 66:211-16.

4. Cramer, H. 1963. *Mathematical Methods of Statistics.* Princeton University Press. pp. 173-180.

12.0 COSTS OF TECHNOLOGY BASES FOR REGULATIONS

This section describes the methodology used to estimate the costs for implementing each of the technology options under consideration for the Metal Products and Machinery (MP&M) Phase I Category. The technologies considered for MP&M Phase I are described in Section 10.0. Section 10.0 also describes the combination of these technologies into options for in-process source reduction and recycling and end-of-pipe wastewater treatment. The cost estimates, together with the pollutant reduction estimates described in Section 13.0, provide a basis for evaluating the options. The cost estimates also provide a basis for determining the economic impact of regulation on the industry at different pollutant discharge levels. The results from assessing the economic impact of regulation are found in the Economic Impact Analysis (EIA) for the MP&M Phase I Rulemaking. The EIA is included in the administrative record for this rulemaking.

EPA used the following approach for estimating compliance costs for the MP&M Phase I industry.

- A probability sample of MP&M Phase I industry sites received data collection portfolios (see Section 4.0). The data collection portfolio (DCP) responses from these sites were the bases for the model sites developed for costing.

- Field sampling data were analyzed to determine the pollutant concentrations of untreated wastewater in the industry (see Section 13.0).

- Candidate in-process source reduction and recycling and end-of-pipe wastewater treatment technologies were identified, and appropriate groups of technologies were compiled into technology options. The technology options serve as the bases of compliance cost and pollutant loading calculations (see Section 10.0).

- Field sampling data were analyzed to determine pollutant removal performance of the selected technologies (see Section 11.0).

- Cost equations for capital and operating and maintenance (O&M) costs were developed for each of the technologies (see Section 12.3).

- A computerized design and cost model (the MP&M Design and Cost Model) was developed and used to calculate compliance costs (presented in Section 12.1) and pollutant loadings (presented in Section 13.0) for each option.

- Output from the design and cost model was used to calculate total annualized costs, cost effectiveness values, and the economic impact to the industry (presented in the EIA).

EPA estimated industry-wide costs for five technology options by estimating compliance costs for technology trains at 396 model sites and then using statistically calculated industry weighting factors to scale the results to the 10,601 water-discharging MP&M Phase I sites. Section 12.1 presents a summary of the results of the costing effort. Section 12.2 presents the methodology used to select and develop model sites. Section 12.3 presents the methodology for estimating costs, including descriptions of the components that define capital and annual costs, sources of cost data, standardization of cost data, an overview of the design and cost model, and general assumptions used for costing. Section 12.4 presents detailed descriptions of the design and costing methodology for each in-process and end-of-pipe technology used in the options. Tables 12-1 through 12-4 and Figures 12-1 through 12-3 are located at the end of this section.

12.1 Summary of Costs

As discussed in Section 10.0, EPA identified several in-process and end-of-pipe technologies applicable to MP&M wastewaters. The individual technologies were combined into technology options. Figure 12-1 provides a graphical representation of how the various technologies are combined into technology options. Based on the technologies included in each option and the wastewaters generated at the MP&M model sites, EPA used the MP&M Design and Cost Model to estimate compliance costs for each of the options.

Table 12-1 presents capital and annual costs for both direct and indirect dischargers for all five options. The total capital investment presented in Table 12-1 represents the direct capital costs calculated by the design and cost model, plus the indirect capital costs discussed in Section 12.3.1. The annual cost presented in Table 12-1 represents the direct annual costs calculated by the model, plus the system annual cost of monitoring discussed in Section 12.3.1. Discussion regarding other system annual costs (taxes, insurance, and amortization) are included in the EIA.

12.2 Model Site Development

The Agency used a model site approach to estimate costs for the water-discharging sites in the MP&M Phase I Category (10,601 sites) based on cost estimates for a statistically selected subset of sites. EPA developed a model site from each DCP respondent that met the criteria described below to account for the variability in processes and treatment systems in place within the MP&M Phase I Category.

12.2.1 Site Selection

EPA selected a site as a model if the site met the following criteria:

- Generated revenue from an MP&M Phase I sector;
- Discharged wastewater (treated or untreated) to either a surface water or publicly owned treatment works (POTW); and
- Supplied sufficient economic and technical DCP data required to estimate compliance costs and assess cost effectiveness of the MP&M Phase I technology options.

Based on these criteria, 396 DCP respondents were selected for model site development. EPA used the data from each of these sites to develop 396 model sites. Survey weights were used to project estimates from the model sites to the MP&M Phase I industry population of 10,601 sites. Development of the survey weights and the statistical methodology used to characterize the industry are presented in the "Database Summary Report for the Metal Products and Machinery Mini Data Collection Portfolio" (MDCP Database Report) and the "Database Summary Report for the Metal Products and Machinery Data Collection Portfolio" (DCP Database Report), located in the administrative record for this rulemaking.

12.2.2 Wastewater Stream Parameters

Based on the information provided by the sites in their DCP responses, follow-up letters, and phone calls, EPA classified each process wastewater stream at each site by the type of unit operation (e.g., machining, electroplating, acid treatment), base metal type (e.g., iron, aluminum, copper), and where appropriate, metal type applied. The following additional DCP data were used to characterize process wastewater streams.

- **Wastewater discharge flow rate.** For each process wastewater stream, the rate of process wastewater discharge, the rate of wastewater generated during equipment cleanups, and the rate of wastewater generated during tank cleanouts were summed to obtain the total wastewater discharge flow rate from the unit operation. For sites that did not report wastewater discharge data, wastewater flow rates were modeled statistically using other data provided in the site's DCP or by using data for similar unit operations reported in other DCPs. The approach for this modeling is presented in the DCP Database Report.
- **Production rate.** Depending on the unit operation production-normalizing parameter (see Table 5-4), DCP responses for surface

area processed, mass of metal removed, or air flow rate were used to determine the production rate through a unit operation. For sites that did not report production data, production rates were modeled statistically using other data provided in the site's DCP or by using data for similar unit operations reported in other DCPs. The approach for this modeling is presented in the DCP Database Report.

- **Operating schedule.** DCP responses for the hours per day (hpd) and days per year (dpy) of each unit operation were used when supplied by sites. For blank responses, the following procedure was used:

  - The maximum hpd and dpy reported by the site for other unit operations were used;

  - If all hpd and dpy responses at the unit operation level were blank, the DCP response for wastewater treatment system operating schedule was used; and

  - If all hpd and dpy responses at the unit operation level were blank, and if the wastewater treatment system operating schedule was blank, 8 hpd and 250 dpy were used.

- **Discharge destination.** DCP responses were used to determine whether each unit operation discharged process wastewater, and if so, whether the wastewater was discharged to a surface water or POTW. EPA also determined from the DCP responses whether the wastewater was treated on site prior to discharge. Wastewaters that were contract hauled off site, deep-well injected, or discharged to septic systems were not included in the model. For sites that did not report a discharge destination for some or all operations, the destination was modeled based on other technical information provided in the DCP (e.g., types of discharge permits, discharge destination of other unit operations, process flow diagrams).

- **Tank volume.** Tank volume, which is a design parameter for countercurrent cascade rinsing and drag-out recovery rinsing, was not specifically requested in the DCP. Therefore, for rinses that were reported as being discharged in batches, a linear relationship between volume of batch discharge and annual discharge flow rate was established. Assuming a constant batch volume to tank volume ratio, this relationship was used to estimate tank volumes for all rinsing operations.

12.2.3 Pollutant Concentrations

The concentration of each pollutant in each model site process wastewater stream was estimated using field sampling data for wastewater discharged from the unit operation/metal type combinations. The field sampling program is discussed in Section 4.0. These data were used with DCP flow and production data to calculate the concentrations. A more detailed description of these calculations is provided in Section 13.0.

12.2.4 Technology in Place

The term "technology in place" refers to those technologies that the Agency considered to be installed and operating at a model site in 1989. Technology in place was accounted for in the costing and pollutant removal efforts to ensure that EPA accurately assessed the baseline (1989) costs and pollutant loadings.

Data required to assess in-process technologies in place were not available in the DCPs. The Agency assumed in-process technologies were in place if the model site process wastewater stream had a production-normalized flow rate (PNF, volume of wastewater per unit of production) below the PNF established by the Agency for that technology. The median PNFs for each unit operation are presented in Section 5.0. For example, if a machining wastewater stream had a PNF below the PNF established by the Agency for centrifugation and pasteurization of machining coolant, then the Agency assumed that the model site had a machining coolant regeneration system in place. The specific production-normalized flow rates established by the Agency for each technology are discussed under the descriptions of each technology in Section 12.4.

EPA reviewed DCP data for each model site to assess the types of end-of-pipe technologies in place at each site (e.g., chemical reduction of chromium, sludge pressure filtration). Based on the DCP database, the number of sites having each of these end-of-pipe technologies in place is presented in Table 12-2. EPA identified end-of-pipe technologies on site that, based on technical considerations, were considered equivalent to technologies included in the MP&M Phase I technology options. For example, vacuum filtration was considered equivalent to pressure filtration for sludge dewatering. EPA also identified technologies that were not considered equivalent, and for which no credit for technology in place was given. For example, oil skimming not preceded by chemical emulsion breaking was not considered equivalent to the oil/water separation included in the technology options. Site-specific assumptions regarding treatment technologies in place at model sites are included in the administrative record for this rulemaking.

EPA used the following additional DCP data to assess the capacity of the end-of-pipe technologies in place at the model sites.

- **Operating schedule.** DCP responses for the hours per day (hpd) and days per year (dpy) of operation of each treatment unit were used when supplied by sites. For blank responses, the schedule was determined using the following procedure:

  - The maximum hpd and dpy reported by the site for other treatment units were used;

  - If all hpd and dpy responses for treatment units were blank, the maximum hpd and dpy reported for the unit operations were used; and

  - If the operating schedules for all treatment units and unit operations were blank, 8 hpd and 250 dpy were used.

- **Wastewater streams treated.** The unit operation wastewater streams treated by each end-of-pipe technology in place were determined using the following procedure:

  - DCP process flow diagrams or responses to DCP questions regarding the destination of individual process wastewater streams were used; and

  - If information provided in the DCP was insufficient, then the logic used by the model for assigning streams to technologies was used (e.g., cyanide-bearing streams were directed to cyanide destruction). This logic is described in Section 12.3.

EPA assumed that each model site operated the end-of-pipe technologies in place at full capacity at baseline. Therefore, EPA used the operating schedule of the technology and the wastewater streams treated by the technology to define the maximum operating capacity for each technology. Assumptions regarding how the model accounted for end-of-pipe technologies with insufficient capacity are presented in Section 12.3.4.

12.3 Methodology for Estimating Costs

This section presents a detailed discussion of the methodology for estimating costs, and includes discussions of the components of cost, the sources of cost data, the standardization of cost data, the design and cost model used, and the general assumptions made during the costing effort.

12.3.1 Components of Cost

The components of the capital and annual costs and the terminology used in developing these costs are presented below.

Capital Costs

The capital costs consist of two major components: direct capital costs and indirect capital costs. The direct capital costs include:

- Purchased equipment cost;
- Delivery cost (based on shipping distance of 500 miles); and
- Installation cost (including labor, excavation, site work, and materials).

The direct components of the total capital cost are derived separately for each treatment unit, or technology. Each treatment unit cost includes individual equipment costs (e.g., pumps, tanks, feed systems). The correlation equations used to generate the individual equipment costs are presented in Table 12-3.

Indirect capital costs consist of secondary containment, engineering, contingency, and contractor fees. When combined with the direct capital costs, these form the total capital investment. The indirect costs are derived from factored estimates (i.e., they are estimated as percentages of the total direct capital cost), as shown in Table 12-4.

Annual Costs

The annual costs also consist of both a direct and an indirect component. The equations used to calculate individual equipment direct annual costs are presented in Table 12-3 and include the following.

- **Raw materials.** These costs are for chemicals and other materials used in the treatment processes (e.g., calcium hydroxide, sulfuric acid, sodium hypochlorite, ion-exchange resins).

- **Operating labor and materials.** These costs account for the labor and materials directly associated with operation of the process equipment.

- **Maintenance labor and materials.** These costs account for the labor and materials required for repair and routine maintenance of the equipment.

- **Energy.** These costs are calculated based on total energy requirements (in kW-hrs).

Indirect annual costs include monitoring, taxes, insurance, and amortization. Monitoring refers to the periodic analysis of wastewater effluent samples to ensure that discharge limitations are being met. Assumptions regarding monitoring frequency are presented in Section 12.3.4. Discussions regarding taxes, insurance, and amortization are presented in the EIA.

12.3.2 Sources and Standardization of Cost Data

Capital and annual cost data for the selected technologies were obtained from equipment vendors, literature, and from existing MP&M sites. Specific data from the DCPs were used whenever possible; however, the required types of data were often either not collected or not supplied by the sites. The major sources of equipment cost data were equipment vendors, while the majority of annual cost information was obtained from the literature.

Capital and annual cost data were standardized to 1989 dollars (the year for which all DCP data were collected) based on the following:

- **Capital investment.** Investment costs were adjusted using the Chemical Engineering Plant Cost Index as published in Chemical Engineering Magazine. The value of this index for 1989 was 359.4.

- **Chemicals.** The Chemical Marketing Reporter from July 24, 1989 was used to obtain chemical prices.

- **Water.** Water prices were based on the 1992 Rate Survey of Water and Wastewater conducted by Ernst and Young. Data for 1989 were not available from this source; therefore, the water rate was adjusted to 1989 using the capital investment index from above. The cost for water used was $2.88 per 1,000 gallons of water.

- **Energy.** Monthly electricity prices for 1989 were averaged from the U.S. Department of Energy's Monthly Energy Review. The averaged values were the retail electricity prices charged for industrial service by selected Class A privately-owned utilities. The 1989 monthly average value was $0.047 per kW-hr.

- **Labor.** A labor rate of $24 per hour was used to convert the labor requirements of each technology into annual costs. The base labor rate was obtained from the Monthly Labor Review, which is published by the U.S. Bureau of Labor Statistics of the U.S.

Department of Labor. Monthly values for 1989 for production labor in the fabricated metals industry were averaged to obtain a base labor rate of $10.50 per hour. Fifteen percent of the base labor rate was added for supervision and 100 percent was added for overhead to obtain the labor rate value of $24 per hour.

- **Monitoring.** The annual cost of monitoring was based on 1989 records for wastewater analyses kept by EPA's Engineering and Analysis Division. These costs were as follows: metal pollutants, $232; total cyanide, $35; oil and grease, $45; and total suspended solids, $10.

- **Contract hauling.** Contract hauling costs were based on vendor data obtained during 1993 or from data obtained during engineering site visits performed from 1990 through 1992. The capital cost index discussed above was applied to adjust the data to 1989 dollars. The cost to contract haul metal-bearing sludge was averaged from data obtained from four engineering site visits and two vendor quotes to equal $2.90 per gallon. For waste oil, data from two engineering site visits and two vendor quotes were averaged to equal $2.06 per gallon. For paint sludge, data from two engineering site visits and two vendor quotes were averaged to equal $3.72 per gallon. A vendor quote for hexavalent chromium-bearing, cyanide-bearing, and metal-bearing wastewater was used at prices of $0.49, $0.74, and $0.49 per gallon, respectively. For wastewater bearing oil and grease and organic pollutants, data obtained from EPA's Centralized Waste Treaters project was used for a price of $1.05 per gallon.

12.3.3 Design and Cost Model

EPA developed a computerized design and cost model to estimate compliance costs and pollutant loadings for the MP&M technology options, taking into account each site's treatment in place. The model was programmed with modules which allowed the user to specify various combinations of technologies and practices to be costed as required by the technology options and each model site's wastewater stream characteristics. In the context of the MP&M cost program, "model" refers to the overall computer program and "module" refers to a computer subroutine which generates costs and pollutant loadings for a specific in-process or end-of-pipe technology or practice (e.g., chemical precipitation and sedimentation, contract hauling). Some modules were adapted from cost models used for previous EPA rulemaking efforts for the metals industry, while others were developed specifically for this rulemaking effort.

The Agency developed cost modules for the in-process source reduction and recycling, and end-of-pipe wastewater treatment technologies and practices included in the MP&M Phase I technology options. These technologies and practices are shown below.

Technologies and Practices for Which Cost Modules Were Developed

In-Process Technologies and Practices	End-Of-Pipe Technologies and Practices
Flow reduction for rinses Flow reduction for other operations Countercurrent cascade rinsing Centrifugation and pasteurization of machining coolants Centrifugation of painting water curtains In-process ion exchange and electrolytic recovery	Oil/water separation Chemical reduction of hexavalent chromium Cyanide destruction Chemical reduction of chelated metals Contract hauling of solvent degreasing wastewaters Chemical precipitation and sedimentation Sludge thickening Sludge pressure filtration End-of-pipe ion exchange

Source: MP&M DCPs, MP&M site visits, technical literature.

As described in Section 10.0 and shown in Figure 12-1, Option 1 consists of the end-of-pipe technologies and practices shown above except end-of-pipe ion exchange. Option 2 includes all of the technologies and practices in Option 1 plus all of the in-process technologies and practices. Option 3 includes all of the technologies and practices listed above. Option 1A, considered only for indirect dischargers, consists of Option 1 technologies and practices for sites with discharge flow rates below one million gallons per year and Option 2 technologies and practices for the remaining sites. Option 2A, also considered only for indirect dischargers, exempts sites with discharge flow rates below one million gallons per year and includes Option 2 technologies and practices for the remaining sites. Each technology is discussed in Section 10.0, and specific details regarding the design and costing of each technology and practice are described in Section 12.4.

The logic used by the design and cost model to apply the in-process technologies and practices (Options 1A, 2A, 2, and 3) to a model site is shown in Figure 12-2. As described in Section 12.2.4, the technology-specific PNFs established by the Agency and the unit operation-specific PNFs were used to determine if an in-process technology was in place at a model site. Technology-specific PNFs were expressed in terms of the median PNF. For example, a technology or practice may have been assumed to achieve the median PNF, ten times the median PNF, or 10% of the median PNF, based on data

from the DCPs, site visits, and technical literature. The unit operation-specific PNFs are based on data reported in the DCPs. Technology-specific PNFs are summarized below:

- Flow reduction for rinses (e.g., flow restrictors, conductivity sensors, timed rinsing) was assumed to reduce flow to ten times the median PNF for a unit operation.

- Countercurrent cascade rinsing was assumed to reduce flow to the median PNF.

- Flow reduction for other operations (e.g., manual control of wastewater discharge rate or analytical testing and maintenance of bath chemistry) was assumed to reduce flow to the median PNF.

- Centrifugation and pasteurization of machining coolants were assumed to reduce flow to 20% of the median PNF, since these recycling steps allow the coolant to be used for a longer period of time.

- In-process ion exchange was assumed to reduce flow to 10% of the median PNF. The rinse water recirculates through the ion-exchange column for metals removal, and back to the rinse. The discharge represents a rinse water bleed stream and a column regeneration stream.

- Centrifugation of painting water curtains was assumed to achieve zero discharge of wastewater (with contract hauling of sludge removed from the centrifuge) through 100% reuse of the treated wastewater in the painting booth.

The Agency assumed that sites with PNFs below the target PNFs mentioned above had these technologies in place. These technology-specific PNFs are consistent with data obtained from equipment vendors, literature, DCPs, and engineering site visits.

For flow reduction of rinses, flow reduction of other operations, countercurrent cascade rinsing, and in-process ion exchange, EPA estimated costs for individual units for each process wastewater stream at a site (e.g., five separate countercurrent cascade rinsing systems were costed for five separate acid treatment rinses at the same model site). For centrifugation and pasteurization of machining coolants and centrifugation of painting water curtains, the process wastewater streams were modeled as being combined prior to application of the technology.

Figure 12-3 presents the logic used by the design and cost model to apply the end-of-pipe treatment technologies and practices (all options). Wastewater streams from the unit

operations and the in-process technologies (when applicable) were segregated based on pollutant characteristics (chromium, cyanide, chelated metals, oil, and solvent). Solvent-bearing wastewater streams were contract hauled for off-site disposal, while the other segregated wastewater streams received preliminary treatment.

Effluent from the preliminary treatment technologies was combined with other wastewater streams not requiring preliminary treatment, then treated by chemical precipitation and sedimentation. Sludge from the clarifier of the chemical precipitation and sedimentation system underwent sludge thickening and pressure filtration prior to contract hauling for off-site disposal. For Option 3, effluent from the chemical precipitation and sedimentation system was polished using end-of-pipe ion exchange. Ninety percent of the effluent was reused on site; the remaining 10% was discharged to a surface water or POTW. For Options 1, 1A, 2A, and 2, the effluent from the chemical precipitation and sedimentation system was discharged to either a surface water or POTW.

The model provided the following types of information, as applicable, for each technology designed for a model site:

- Total direct capital costs;
- Total direct annual costs;
- Electricity used and associated cost;
- Sludge generation and associated disposal costs;
- Waste oil generation and associated disposal costs;
- Water use reduction and associated cost credit;
- Metal reclaimed and associated cost credit;
- Chemical usage reduction and associated cost credit;
- Effluent flow rate; and
- Effluent pollutant concentrations.

Specific information calculated by each technology module is presented in Section 12.4.

12.3.4 General Assumptions

This section presents general assumptions that were applied throughout the design and cost model. Technology-specific assumptions regarding the design and costing of the technologies are presented under the appropriate technologies in Section 12.4.

Calculation of Baseline Parameters

As discussed in Section 12.2.4, EPA determined the technologies already in place, including the operating schedules of these systems and the wastewater streams treated by

these systems. Before running the cost model for any of the technology options, a baseline run of the model was performed to determine the following:

- Baseline (1989) operating and maintenance costs incurred by sites;
- Baseline nonwater quality impacts such as electricity usage, sludge generation, and waste oil generation;
- Baseline pollutant loadings; and
- Capacity flow rate of each technology in place.

Use of the capacity flow rate is discussed below. The baseline values for operating and maintenance costs, nonwater quality impacts, and pollutant loadings were subtracted from the values calculated from each technology option to determine the incremental impact over the baseline for each technology option.

End-of-Pipe Technology in Place

As discussed in Section 12.2.4, the model was designed to account for in-process and end-of-pipe operating equipment already in place at the model sites. The assessment of in-process technologies in place is discussed in Section 12.3.3. For end-of-pipe treatment technologies, EPA reviewed information in the DCPs to assess the level of treatment in place at MP&M Phase I sites. EPA identified which of the technologies included in each of the options were in place at the sites. Some sites had no technologies in place, some had a portion of the options in place, and others had complete treatment in place. EPA also assessed the design capacity flow for each treatment unit in place to determine whether each site had sufficient capacity to treat all MP&M process wastewater. In some cases, the technology options required a model site to treat additional wastewater streams with a technology in place at baseline. In these situations, the treatment capacity of the technology may have been insufficient. The following assumptions were used regarding end-of-pipe technology capacities:

- If the technology did not exist at the model site, then a treatment unit of sufficient capacity was designed;
- If the technology existed at the model site with sufficient capacity to treat all of the wastewater, then no treatment unit was designed; and
- If the technology existed at the model site but with insufficient capacity to treat all of the wastewater, then the existing system was assumed to operate at full capacity and an additional treatment unit

was designed to operate in parallel with the existing unit to treat the additional flow.

Precious Metal Reclamation in Place

Based on observations on engineering site visits, EPA assumed that sites generating wastewaters with high concentrations of gold or silver were reclaiming these metals at baseline, either on site or off site. Silver was the only precious metal that was an MP&M pollutant of concern. For the purposes of calculating costs and pollutant loadings, it was assumed that at baseline, all silver electroplating baths and silver electroplating rinses were segregated and that silver was recovered prior to discharge.

Contract Hauling in Lieu of Treatment

EPA assessed the cost of contract hauling wastewater for off-site treatment compared to on-site treatment. The equipment used for the MP&M Phase I technology options has minimum sizes. Because many MP&M sites have low flow rates, it was often found to be less expensive for a model site to have wastewater contract hauled for off-site disposal rather than to treat the wastewater on site. To assess contract hauling in lieu of treatment, EPA compared the costs of contract hauling the wastewater to be treated in a specific treatment unit with the costs of the treatment unit. If contract hauling was less expensive than treating on site, the site was modeled as contract hauling the wastewater. This determination was based on individual technologies and their influent characteristics (flow rate, pollutant concentrations) rather than on the total site wastewater treatment system. For example, cyanide-bearing wastewater could be contract hauled in lieu of treatment while all other wastewater streams were treated on site. The calculation for determining whether treatment on site was less expensive included an equipment life expectancy of 15 years and an annual interest rate of 7 percent.

The following technologies were considered for contract hauling in lieu of treatment:

- Centrifugation and pasteurization of machining coolants;
- Centrifugation of painting water curtains;
- In-process ion exchange;
- Oil/water separation;
- Chemical reduction of hexavalent chromium;
- Cyanide destruction;
- Chemical reduction of chelated metals;
- Chemical precipitation and sedimentation;
- Sludge pressure filtration; and
- End-of-pipe ion exchange.

In the case of end-of-pipe ion exchange, the assessment of treating versus contract hauling was made by comparing the costs of contract hauling the untreated end-of-pipe wastewater to the cost of the entire end-of-pipe wastewater treatment system.

Equipment Size Ranges

As shown in Table 12-3, equipment cost equations were developed for each component of the technologies. The validity ranges presented in the table represent the minimum and maximum sizes (e.g., flow rates, volume capacities) for which the equations were developed. For wastewater streams requiring equipment with a capacity below the minimum range of validity, the equipment was designed at the minimum size. For wastewater streams requiring equipment with a capacity above the maximum range of validity, multiple units of equal capacity were designed to operate in parallel such that the equipment sizes were within the range of validity.

Batch Schedules

For many of the end-of-pipe technologies, EPA designed either batch or continuous systems, depending on the site operating schedule and discharge flow rate. For batch systems, the batch volume and operating schedule were established to minimize cost. If the volume of wastewater to be treated in a single day was below the minimum batch system size, then the operating schedule was altered such that a minimum system would be operated at capacity. For example, if the minimum cyanide destruction system was 60 gallons per batch, and a site generated 10 gallons of cyanide-bearing wastewater per day, then a cyanide destruction system was designed to treat a 60-gallon batch once every six days.

Monitoring

Monitoring costs are presented in Section 12.3.2. The following assumptions were made regarding the frequency of monitoring required by site discharge permits and the monitoring costs currently incurred by sites at baseline.

- Metals and cyanide analyses were assumed to be required four times per month for both direct and indirect dischargers;

- Total suspended solids and oil and grease analyses were assumed to be required four times per month for direct dischargers; and

- Sites reporting in their DCP as currently having a National Pollutant Discharge Elimination System (NPDES) permit or to be currently regulated by categorical effluent limitations guidelines and standards were assumed to have a monitoring program in place. The in-place programs were assumed to have all of the above parameters

monitored once per year for direct dischargers and twice per year for indirect dischargers.

Dilute Influent Concentrations

High wastewater flow rates combined with low production rates caused pollutant concentrations at some sites to be modeled below the long-term average technology effectiveness concentrations (discussed in Section 11.0). This primarily occurred at Option 1, which does not include any flow reduction technologies. In these cases, the model did not design a technology for that wastewater stream. When this situation occurred during the baseline run of the model, the technologies were designed based on hydraulic load to calculate capacity flow rates and baseline operating and maintenance costs for equipment modeled as in place.

Discharge Status

Some model sites have both direct and indirect discharging wastewater streams at baseline. Because the technology options combine all wastewater streams prior to chemical precipitation and sedimentation, a single discharge destination was assigned to each model site. The following assumptions were used to assign discharge destinations to model sites with both direct and indirect baseline discharges:

- If the model site had a wastewater treatment system at baseline with the effluent discharged to one destination, while other wastewater streams on site by-passed the treatment system and discharged to a different destination, the destination of the wastewater treatment system effluent was assigned to the site for the technology options; and

- If the model site did not have technologies in place, the discharge destination with the greatest baseline hydraulic load from the model site was assigned for the technology options.

12.4 Design and Costs of Individual Technologies

The following are detailed discussions regarding the design and costing of the individual technologies that comprise the technology options. Additional documentation is included in the administrative record for this rulemaking. Capital and annual cost equations for the specific equipment mentioned in each section are presented in Table 12-3.

12.4.1 Flow Reduction for Rinses

The Agency applied flow reduction for rinses to those rinses identified through the DCPs and site visits as typically being flowing rinses (e.g., not stagnant rinses). Rinsing operations that did not receive this technology received flow reduction for other operations (discussed below). The rinsing operations that did not receive flow reduction for rinses are as follows:

- Abrasive blasting rinse;
- Abrasive jet machining rinse;
- Burnishing rinse;
- Calibration rinse;
- Disassembly rinse;
- Electrical discharge machining rinse;
- Floor cleaning rinse;
- Grinding rinse;
- Hot dip coating rinse;
- Impact deformation rinse;
- Machining rinse;
- Painting rinse (excluding electrophorectic);
- Polishing rinse;
- Pressure deformation rinse;
- Soldering rinse; and
- Sputtering rinse.

All other rinsing operations received flow reduction for rinses. EPA identified several different technologies capable of reducing the discharge from a flowing rinse. EPA investigated the following three flow reduction technologies: rinse timers to shut off the discharge after a part has been rinsed and rinse water is no longer needed; flow restrictors to provide a maximum flow rate into a rinsing operation; and conductivity sensors to indicate pollutant contamination in the rinse and control the rinse discharge based on contamination. Although sites may use any of these three technologies (as well as others), the Agency based the annual and capital cost on automatic rinse timers (including solenoid valves and electronic timers with associated switches and wiring), which were estimated to be the most expensive of these technologies.

The direct annual costs for this module included operating and maintenance labor and materials and a credit for water use reduction. Labor costs associated with this module include one hour per year for maintenance. EPA calculated the water use reduction achieved by this module using the unit operation-specific PNF reported by the site. For the purpose of estimating compliance costs for the MP&M technology options, the Agency assumed that flow reduction technologies could be used to reduce the discharge from flowing rinses to ten times the median PNF reported in the DCPs for the unit operations. If the PNF was below ten times the median PNF reported for the unit

operation in the DCPs, EPA assumed that adequate rinse flow reduction technology was in place and the module was not used. EPA made this assumption because information on which sites had flow reduction technologies in place was not obtained in the DCPs. For unit operations for which this module was applied, the wastewater flow rate was reduced such that the PNF was equal to ten times the median PNF reported in the DCPs, and pollutant concentrations were increased accordingly.

12.4.2 Flow Reduction for Other Operations

The Agency applied flow reduction for other operations to all unit operations not considered for the rinse flow reduction module. The technology was based on the assumption that the median PNF reported in the DCPs for each unit operation could be achieved for each model site unit operation through manual control of the wastewater discharge rate or through analytical testing and maintenance of bath chemistry. In cases where the site-specific PNF was less than the median PNF for a unit operation, EPA assumed that the site had flow reduction in place for the unit operation. In this case, the module was not used. The Agency selected the median PNF, based on information from site visits. For operations for which this module was applied, the wastewater flow rate was reduced such that the unit operation-specific PNF was equal to the median PNF reported in the DCPs, and pollutant concentrations were adjusted accordingly.

Capital costs for this module were assumed to be zero, since all equipment necessary for process bath maintenance (e.g., thermometers, pH meters, test kits) are typically in place at MP&M sites. Direct annual costs for this module included operating and maintenance labor and materials and a credit for water use reduction. Labor costs were calculated based on one hour per week of maintenance labor per each individual unit maintained. A cost credit for water use savings was calculated based on the annual flow reduction for each unit operation maintained.

12.4.3 Countercurrent Cascade Rinsing

The Agency applied countercurrent cascade rinsing to the same set of unit operations considered for flow reduction of rinses. The technology was based on the installation of an additional air-agitated rinsing stage to the existing rinse tank(s). Capital and annual costs for the following equipment were included within the countercurrent cascade rinse system:

- A rinse tank with a volume equal to the volume of the existing tank;
- An air-agitation system consisting of perforated polyvinyl chloride (PVC) piping (air diffusers) and a motorized air blower; and
- A pump to transfer rinse water from one stage to the next.

EPA estimated retrofit capital costs for installation of the above equipment as 15% of installed equipments costs. These costs were included to account for costs incurred for installation of an additional tank on an existing process line.

For the purpose of estimating compliance costs for the MP&M technology options, the Agency assumed that countercurrent cascade rinsing could be used to reduce the discharge from flowing rinses to the median PNF reported in the DCPs for the unit operations. Information on which sites had countercurrent cascade rinses in place was not available in the DCPs. EPA selected the median PNF based on information collected during visits to MP&M Phase I sites.

The water use reduction after installation of the additional rinsing stage was calculated based on the unit operation-specific PNF reported by the site. If the unit operation-specific PNF was below the median PNF reported in the DCPs for the unit operation, then the technology was assumed to be in place and the module was not used. For operations for which this module was applied, the wastewater flow rate was reduced such that the PNF was equal to the median PNF reported in the DCPs, and pollutant concentrations were increased accordingly.

Direct annual costs for this module included operating and maintenance labor and materials, energy costs, and a credit for water use reduction. The cost credit for water use savings was based on the annual flow reduction for each countercurrent cascade rinse system.

12.4.4 Centrifugation and Pasteurization of Machining Coolant

Centrifugation and pasteurization of machining coolant was applied to machining operations discharging water-soluble or emulsified coolant. The system considered to develop compliance cost estimates consisted of a liquid-liquid separation centrifuge for removal of solids and tramp oils, and a pasteurization unit to stem microbial growth. Fifty percent excess capacity was included when sizing each site's system to account for fluctuations in production. Capital and annual costs were based on packaged systems of different capacities. The various size systems included the following equipment:

- A high speed, liquid-liquid separation centrifuge;
- A pasteurization unit; and
- One holding tank (two holding tanks for the largest size system).

Direct annual costs included operating and maintenance labor and materials, energy costs, sludge and waste oil disposal costs, and a credit for coolant use reduction. Maintenance labor was estimated as four hours per year. Operating labor was estimated at one hour per shift for all but the smallest unit. The smallest unit required one-half hour per shift to operate because it was portable and did not require time for coolant

collection. Annual costs were calculated as the operating and maintenance costs less the cost savings from decreased coolant and water use.

The discharge reduction achieved by this module was calculated using the site-specific PNF for the combined machining coolant wastewater streams. Based on site visit and vendor information, EPA assumed this technology can achieve an 80% reduction of coolant discharge. This is achieved by the site treating and reusing 80% of the coolant, allowing a 20% bleed stream. Therefore, if the site-specific PNF was below 20% of the median PNF reported in the DCPs, then the technology was assumed to be in place and the module was not used. For operations for which this module was applied, the wastewater flow rate was reduced such that the site-specific PNF was equal to 20% of the median PNF reported in the DCPs.

12.4.5 Centrifugation of Painting Water Curtains

Centrifugation of painting water curtains was applied to all spray painting water curtains. The capital and annual costs were based on a centrifuge and a holding tank. The holding tank was sized to hold one-fourth of the site's annual discharge flow. EPA assumed that this system would operate four times per year.

Direct annual costs included operating and maintenance labor and materials, energy costs, sludge disposal costs, and a credit for water use reduction. Operating and maintenance labor varied with the size of unit. Each unit size had an estimated number of hours per shift as well as an estimated number of hours to empty the sludge basket during operation.

All water discharged from the centrifugation system was assumed to be reused in the spray painting water curtains. Therefore, this module was applied to all sites with spray painting water curtain discharges, independent of PNF. The Agency assumed that sludge from the system was contract hauled as a hazardous waste for off-site disposal.

12.4.6 In-Process Ion Exchange

EPA estimated costs for in-process ion exchange of rinse water streams associated with the following types of electroplating: cadmium, copper, tin, tin/lead, zinc, nickel, and lead. The technology was based on rinse water leaving the final stage of a countercurrent cascade rinse, passing through cation and anion ion-exchange columns, and returning to the first stage of the countercurrent cascade rinse. Based on information from site visits and literature, EPA assumed that this technology can achieve a 90% reduction of rinse water discharge from the specific operation for which it is used. This is achieved by the site recycling 90% of the rinse water, allowing a 10% bleed and regeneration stream.

The ion-exchange columns were designed to be regenerated using centralized (one system per site) sulfuric acid and sodium hydroxide feed systems. All acid regenerant streams were sent to electrolytic recovery units for metal reclamation prior to wastewater discharge. Capital and annual costs for the following equipment were included within the ion-exchange system:

- Two sets of cation and anion ion-exchange columns (one set to be regenerated off line while the other set was in use), cation and anion resin, carbon prefilters, and ancillary equipment;
- An electrolytic recovery unit for acid regenerant;
- An electrolytic recovery tank;
- An ion-exchange effluent pump;
- A centralized sulfuric acid feed system;
- A centralized sodium hydroxide feed system; and
- Two regenerant holding tanks.

For rinse water with countercurrent cascade discharge concentrations of electroplated metals greater than 200 mg/L, a drag-out recovery tank and electrolytic recovery unit were designed for installation prior to the countercurrent cascade rinse. The drag-out recovery tank and electrolytic recovery unit were designed to remove the metal such that the concentration in the countercurrent cascade rinse was equal to 20 mg/L. One tank volume of drag-out solution was discharged to the end-of-pipe treatment system per day. Capital and annual costs for the following additional equipment were included when drag-out recovery rinsing was included:

- An electrolytic recovery unit for drag-out solution;
- An electrolytic recovery tank;
- A drag-out tank; and
- A drag-out solution transfer pump.

The Agency determined the required column volumes and regeneration frequencies based on the larger of either the required ionic loading capacities of the columns or the required column contact times. Electrolytic recovery units were costed based on the cation concentration in the regenerant or drag-out solutions, as well as target effluent concentrations. Regenerant addition requirements were based on column resin volumes.

As discussed above, the Agency assumed that ion exchange can achieve a 90% reduction of rinse water discharge flow. If the site-specific PNF was less than 10% of the median

PNF reported in the DCPs for electroplating rinsing, then the technology was assumed to be in place and the module was not used. For operations for which this module was applied, the wastewater flow rate was reduced such that the unit operation-specific PNF was equal to 10% of the median PNF reported in the DCPs. All pollutant concentrations from the ion-exchange system (except for the metal type reclaimed from the regenerant solution by electrolytic recovery) were increased accordingly. The electrolytic recovery units (those used for regenerant solutions) were assumed to treat only the reclaimed metal. The units were designed to treat to the chemical precipitation and sedimentation long-term average pollutant concentration discussed in Section 11.0. After electrolytic recovery, the regenerant solutions were modeled as discharged to the end-of-pipe treatment system.

Direct annual costs included operating and maintenance labor and materials, energy costs, raw materials (e.g., sulfuric acid, sodium hydroxide, ion-exchange resins), and credits for water use reduction and reclaimed metals.

12.4.7 Contract Hauling

The Agency estimated costs for various types of wastes generated on site to be contract hauled for off-site treatment and disposal. These waste types include:

- Metal-bearing sludge;
- Waste oils;
- Paint sludge;
- Chromium-bearing wastewater;
- Cyanide-bearing wastewater;
- Wastewater containing soil and grease and organic pollutants; and
- Metal-bearing wastewater not included above.

Costs for treatment and disposal of each waste type were estimated in dollars per gallon of waste. Additional costs were estimated for sites generating annual volumes of waste less than that of a typical tanker truck hauling capacity (2,200 gallons). The additional costs represented additional fees charged by the contract hauler for using 55-gallon drums instead of a tanker truck. The following is a brief summary of how these costs were applied throughout the design and cost model. Additional details are provided in the administrative record for this rulemaking.

- EPA assumed a cost of $2.90 per gallon for contract hauling metal-bearing sludge for landfilling as a hazardous waste. The sludge was generated by the sludge pressure filtration system, the machining coolant centrifugation and pasteurization system, and the oil/water separation system.

- EPA assumed a cost of $2.06 per gallon for contract hauling waste oil for off-site disposal. Waste oil was generated by the machining coolant centrifugation and pasteurization system, and the oil/water separation system.

- EPA assumed a cost of $3.72 per gallon for contract hauling paint sludge for landfilling as a hazardous waste. The sludge was generated by the painting water curtain centrifugation system.

- EPA assumed a cost of $0.49 per gallon for contract hauling hexavalent chromium-bearing wastewater for off-site treatment. The wastewater was contract hauled from sites at which contract hauling was determined by the cost model to be less expensive than the chemical reduction of hexavalent chromium system.

- EPA assumed a cost of $0.74 per gallon for contract hauling cyanide-bearing wastewater for off-site treatment. The wastewater was contract hauled from sites at which contract hauling was determined by the cost model to be less expensive than the in-process ion-exchange system for cyanide-bearing rinse water or the cyanide destruction system.

- EPA assumed a cost of $1.05 per gallon for contract hauling wastewater bearing oil and grease or other organic pollutants for off-site treatment. The wastewater was contract hauled whenever generated by solvent degreasing operations or from sites at which contract hauling was determined by the cost model to be less expensive than the machining coolant centrifugation and pasteurization system or the oil/water separation system.

- EPA assumed a cost of $0.49 per gallon for contract hauling metal-bearing wastewater for off-site treatment. The wastewater was contract hauled from sites at which contract hauling was determined by the cost model to be less expensive than the in-process or end-of-pipe ion-exchange systems, the chemical reduction of chelated metals system, the chemical precipitation and sedimentation system, and the sludge pressure filtration system.

12.4.8 Oil/Water Separation

EPA estimated costs for batch and continuous systems to separate and remove oil and grease and organic pollutants prior to chemical precipitation and sedimentation. The

Agency assumed that all oil-bearing wastewater streams at each site were commingled prior to treatment. These wastewater streams are listed below:

- Alkaline treatment and rinse (following an oily waste generating operation such as machining or heat treatment with oil quench);
- Corrosion preventive coating and rinse;
- Floor cleaning and rinse;
- Grinding and rinse;
- Heat treatment rinse (following oil quench);
- Impact deformation and rinse;
- Machining and rinse;
- Pressure deformation and rinse;
- Testing (dye penetrant) and rinse; and
- Testing (magnetic flux) and rinse.

The technology was based on chemical emulsion breaking followed by oil removal. Chemical emulsion breaking was either performed using sulfuric acid in a batch system (for wastewater flow rates less than or equal to 265 gallons per hour), or by using aluminum sulfate and polymer in a continuous system (for wastewater flow rates greater than 265 gallons per hour). Oil removal for all batch systems was performed using a belt skimmer. For continuous systems, oil removal was performed by using either a belt skimmer (for oil removal rates less than or equal to 50 gallons per hour) or a coalescent plate separator (for oil removal rates greater than 50 gallons per hour).

Capital and annual costs for the following equipment were included for batch systems:

- Two batch reaction tanks;
- Two motorized reaction tank agitators;
- A reaction tank effluent pump;
- A sulfuric acid feed system;
- Two belt skimmers;
- A waste oil holding tank; and
- A waste oil discharge pump.

For continuous chemical emulsion breaking systems, capital and annual costs for the following equipment were included:

- A flow equalization tank;
- A reaction tank;
- A motorized reaction tank agitator;
- A flow equalization tank effluent pump;
- A reaction tank effluent pump;
- An aluminum sulfate (alum) feed system; and
- A polymer feed system.

For oil removal using a belt skimmer on a continuous system, capital and annual costs for the following equipment were included:

- A equalization/skimming tank;
- A waste oil holding tank;
- A waste oil tank discharge pump;
- An equalization/skimming tank effluent pump; and
- A belt skimmer.

For oil removal using a coalescent plate separator on a continuous system, capital and annual costs for the following equipment were included:

- A coalescent plate separator; and
- A coalescent plate separator effluent pump.

Direct annual costs included operating and maintenance labor and materials, energy costs, raw materials (e.g., sulfuric acid, aluminum sulfate, polymer), and sludge and waste oil disposal costs. Acid addition requirements for the batch system were based on a target pH of 2.5. Aluminum sulfate and polymer addition rates for the continuous system were based on the influent flow rate to the unit. For belt skimmer and coalescent plate separator (CPS) oil removal systems, the oil removal rate and the oil removal equipment sizes were based on the oil and grease loading to the system. Waste oil and CPS sludges were contract hauled for off-site disposal. The effluent from this system was discharged to the chemical precipitation and sedimentation system. EPA adjusted effluent flow rates and concentrations from this treatment unit using mass balances based on the oil removal rate.

12.4.9 Chemical Reduction of Hexavalent Chromium

EPA estimated costs for batch and continuous systems to reduce hexavalent chromium to trivalent chromium prior to chemical precipitation and sedimentation. The Agency assumed that all chromium-bearing wastewater streams at each site were commingled

prior to treatment and that all chromium in that wastewater was in the hexavalent form. The chromium-bearing wastewater streams are listed below:

- Acid treatment (with chromic acid) and rinse;
- Anodizing (chromic acid) and rinse;
- Anodizing sealant (with chromium) and rinse;
- Chromate conversion coating and rinse;
- Chemical conversion coating sealant (with chromium) and rinse;
- Electroplating (chromium) and rinse; and
- Wet air pollution control for chromium-bearing operations.

For flow rates less than or equal to 625 gallons per hour, the Agency costed batch systems based on manual addition of sodium metabisulfite. For flow rates greater than 625 gallons per hour, continuous systems based on sulfonation (i.e., reduction with gaseous SO_2) were costed. Annual costs for the manual addition of sodium metabisulfite and capital and annual costs for the following equipment were included for batch systems:

- Two batch reaction tanks;
- Two motorized reaction tank agitators;
- A reaction tank effluent pump; and
- A sulfuric acid feed system.

For continuous systems, capital and annual costs for the following equipment were included:

- A flow equalization tank;
- A reaction tank;
- A motorized reaction tank agitator;
- A flow equalization tank effluent pump;
- A reaction tank effluent pump;
- A sulfuric acid feed system;
- A continuous sulfur dioxide feed system; and
- A sulfur dioxide supply pump.

Direct annual costs included operating and maintenance labor and materials, energy costs, and raw materials (e.g., sulfuric acid, sodium metabisulfite, sulfur dioxide). Sulfuric acid addition requirements were based on a target pH of 2.5, and reduction reagent addition rates were calculated based on the chromium loading to the system. The effluent from this system was discharged to the chemical precipitation and sedimentation system. EPA assumed that all hexavalent chromium was converted to the trivalent form. EPA also assumed that flow rates and pollutant concentrations (including total chromium) remained unchanged in this treatment unit.

12.4.10 Cyanide Destruction

EPA estimated costs for batch and continuous alkaline chlorination systems to destroy cyanide prior to chemical precipitation and sedimentation. The Agency assumed that all cyanide-bearing wastewater streams at each site were commingled prior to treatment. These wastewater streams are listed below:

- Alkaline treatment (with cyanide) and rinse;
- Electrolytic cleaning (with cyanide) and rinse;
- Electroplating (with cyanide) and rinse;
- Heat treatment quench (cyaniding) and rinse; and
- Wet air pollution control for cyanide-bearing operations.

For flow rates less than or equal to 625 gallons per hour, the Agency costed a batch system based on manual addition of sodium hypochlorite. For flow rates greater than 625 gallons per hour, systems based on continuous sodium hypochlorite addition were costed. Capital and annual costs for the following equipment were included for batch systems:

- Two batch reaction tanks;
- Two motorized reaction tank agitators;
- A reaction tank effluent pump;
- A sodium hydroxide feed system; and
- A sodium hypochlorite feed system.

For continuous systems, capital and annual costs for the following equipment were included:

- A flow equalization tank;
- A reaction tank;
- A motorized reaction tank agitator;
- A flow equalization tank effluent pump;
- A reaction tank effluent pump;
- A sodium hydroxide feed system; and
- A sodium hypochlorite feed system.

Direct annual costs included operating and maintenance labor and materials, energy costs, and raw materials (e.g., sodium hydroxide, sodium hypochlorite). Sodium hydroxide addition requirements were based on a target pH of 11.5, and oxidation reagent addition rates were calculated based on the cyanide loading to the system. Cyanide concentrations in the effluent from this treatment unit were assumed to be equal to the cyanide destruction long-term average concentration (see Section 11.0). EPA assumed that the flow rate and all other pollutant concentrations remained

unchanged in the effluent. The effluent was discharged to the chemical precipitation and sedimentation system.

12.4.11 Chemical Reduction of Chelated Metals

The Agency estimated costs for preliminary treatment of chelated metals with calcium hydroxide and sodium borohydride prior to chemical precipitation and sedimentation. The Agency costed either low-flow batch systems for flow rates less than or equal to 580 gallons per hour or normal batch systems for flow rates greater than 580 gallons per hour. Annual costs for the manual addition of sodium borohydride and capital and annual costs for the following equipment were included:

- Two reaction tanks;
- Two motorized reaction tank agitators;
- A calcium hydroxide (lime) feed system (manual feed for low-flow batch systems); and
- An effluent pump.

Direct annual costs included operating and maintenance labor and materials, energy costs, and raw materials (e.g., calcium hydroxide, sodium borohydride). The Agency assumed that all wastewater generated by electroless plating and electroless plating rinsing operations were commingled and treated by this module. Calcium hydroxide addition requirements were based on a target pH of 8, and sodium borohydride addition rates were based on a dosage rate of 2.4 pounds per 1,000 gallons of wastewater. The effluent from this system was discharged to the chemical precipitation and sedimentation system. EPA assumed that the flow rate and pollutant concentrations remained unchanged in the effluent.

12.4.12 Chemical Precipitation and Sedimentation

The Agency estimated costs for low-flow batch, normal batch, and continuous chemical precipitation and sedimentation systems. All MP&M wastewaters generated on site were commingled and treated by this technology, including the effluents from the in-process and end-of-pipe preliminary treatment technologies.

Low-flow batch systems were designed for influent flow rates less than or equal to 580 gallons per hour. Annual costs for the manual addition of calcium hydroxide (lime) and polymer, and capital and annual costs for the following equipment, were included:

- Two batch reaction tanks;
- Two motorized reaction tank agitators;

- A reaction tank effluent pump; and
- A reaction tank sludge pump.

Normal batch systems were designed for influent flow rates greater than 580 and less than or equal to 2,800 gallons per hour. For these systems, automated feed systems replace the manual addition of calcium hydroxide and polymer.

Continuous systems were designed for influent flow rates greater than 2,800 gallons per hour. These systems included capital and annual costs for the following equipment:

- A rapid mix reaction tank with a five minute retention time;
- A motorized rapid mix tank agitator;
- A polymer feed system;
- A calcium hydroxide feed system;
- A clarifier (lamella clarifier for flow rates less than or equal to 18,000 gallons per hour, circular clarifier for flow rates greater than 18,000 gallons per hour);
- A clarifier effluent pump; and
- A clarifier sludge pump.

Calcium hydroxide addition requirements were based on the following: a target pH of 9, acidity equal to zero, and the stoichiometric quantity required to convert all dissolved metals to metal hydroxides. Polymer addition requirements were based on a rate of 2 milligrams of polymer for each liter of wastewater treated.

Pollutant concentrations in the effluent from these systems were assumed to be equal to the chemical precipitation and sedimentation long-term average concentrations (see Section 11.0). The amount of sludge generated by this system was calculated using site-specific influent pollutant concentration data for the commingled wastewater. The sludge was assumed to be 3% solids and was discharged to a sludge thickening tank. The effluent from this system was either discharged from the site or further treated by the end-of-pipe ion-exchange system, depending on the technology option. Direct annual costs included operating and maintenance labor and materials (including the manual addition of chemicals for low-flow batch systems), energy costs, and raw materials (e.g., calcium hydroxide, polymer).

12.4.13 Sludge Thickening

The Agency estimated costs for sludge thickening by gravity settling for the sludge discharged from the chemical precipitation and sedimentation system. The sludge thickening system increased the solids content of the sludge from 3% to 5% prior to further dewatering in the sludge pressure filtration system. Capital and annual costs for the following equipment were included:

- One holding/thickening tank;
- An effluent pump (for the supernatant); and
- A sludge pump.

The sludge from this system was discharged to the sludge pressure filtration system. The supernatant was discharged to the chemical precipitation and sedimentation system. Direct annual costs included operating and maintenance labor and materials and energy costs.

12.4.14 Sludge Pressure Filtration

The Agency estimated costs for a plate-and-frame filter press to increase the solids content of the sludge from 5% to 35% prior to contract hauling for off-site disposal. Capital and annual costs for the following equipment were included:

- A plate-and-frame filter press; and
- A sludge pump.

Direct annual costs included operating and maintenance labor and materials, energy costs, and sludge disposal costs. Costs also account for storage of the sludge prior to disposal. The filtrate from this system was discharged to the chemical precipitation and sedimentation system. Maintenance labor is estimated at 2 hours per year. Operating labor varies from one to three hours per shift depending on the various press capacity ranges.

12.4.15 End-of-Pipe Ion Exchange

EPA estimated costs for end-of pipe ion exchange for the chemical precipitation and sedimentation effluent for Option 3 only. This technology was based on a 90% reuse of the treated effluent with the 10% blowdown discharged from the site. The ion-exchange columns were regenerated using sulfuric acid and sodium hydroxide feed systems.

Capital and annual costs for the following equipment were included within the ion-exchange system:

- Two sets of cation and anion ion-exchange columns (one set to be regenerated off line while the other set was in use), cation and anion resin, and ancillary equipment;
- An ion-exchange effluent pump;
- A sulfuric acid feed system;
- A sodium hydroxide feed system; and
- Two fiberglass regenerant holding tanks.

Direct annual costs included operating and maintenance labor and materials, energy costs, raw materials (e.g., sulfuric acid, sodium hydroxide, ion-exchange resins), contract hauling costs for regenerant solutions, and credit for water use reduction. The Agency costed the end-of-pipe ion-exchange columns based on the required column contact times. Regenerant addition requirements were based on column resin volumes. Blowdown pollutant concentrations were modeled at the chemical precipitation and sedimentation long-term average concentrations.

Table 12-1

MP&M Phase I Capital and Annual Costs

Option Number	Indirect Dischargers		Direct Dischargers	
	Total Capital Investment (millions of 1989 dollars)	Operating, Maintenance, and Monitoring (millions of 1989 dollars)	Total Capital Investment (millions of 1989 dollars)	Operating, Maintenance, and Monitoring (millions of 1989 dollars)
1	277	267	45.9	14.8
2	433	241	59.0	13.1
3	1,160	677	148	88.4
1A	434	236	Not applicable	Not applicable
2A	337	145	Not applicable	Not applicable

Source: MP&M design and cost model.

Table 12-2

Summary of End-of-Pipe Technologies In Place at MP&M Phase I Sites

Treatment Technology	Estimated Number of Sites with Technology in Place	Estimated Percent of Sites with Technology in Place
Oil/water separation	406	4
Chemical reduction of hexavalent chromium	709	7
Cyanide destruction	351	3
Chemical reduction of chelated metals	4	< 1
Chemical precipitation and sedimentation	1,650	16
Sludge thickening	649	6
Sludge pressure filtration	1,290	12

Source: MP&M Phase I Model Site Profile Database

Table 12-3

MP&M Phase I Equipment Cost Equations*

Equipment	Equation	Range of Validity
Agitator	$A = 210.4\,(HP)\,(f) + 0.05\,(C)$ $C = 1.14 * (1585.55 + 125.302\,(HP) - 3.27437\,(HP)^2)$	$0.33 < HP < 5$
	$A = 210.4\,(HP)\,(f) + 0.05\,(C)$ $C = 1.14 * (839.1 + 587.5\,(HP))$	$0.25 < HP < 0.33$
Air-agitation system	$A = 265.96 + 0.54121\,(V) - 7.4114 * 10^{-5}\,(V)^2 + 5.2352 * 10^{-9}\,(V)^3$ $C = 1{,}505.8 + .62931(V) - 1.411 * 10^{-5}\,(V)^2$	$50 < V < 10{,}000$
Automatic rinse timer	$A = 24$ $C = 409.86$	NA
Belt skimmer, batch	$A = 2.4\,(DPY) + 576 + (4 * (5.5 * 10^{-4})\,(HPD)\,(DPY))$ $C = 3{,}863$	$OR < 25$
	$A = 2.4\,(DPY) + 576 + (4 * (5.5 * 10^{-4})\,(HPD)\,(DPY))$ $C = 4{,}184$	$25 < OR < 50$
Belt skimmer, continuous	$A = 2.4\,(DPY) + 576 + (0.0175\,(HPD)\,(DPY))$ $C = 3{,}863$	$OR < 25$
	$A = 2.4\,(DPY) + 576 + (0.0175\,(HPD)\,(DPY))$ $C = 4{,}184$	$25 < OR < 50$
Clarifier, circular steel	$A = 1.14\left[\exp\left[8.22809 - 0.224781\,(\ln(Y)\,(0.048)\right] + 0.0563252\,(\ln[(Y)\,(0.048)]^2\right]$ $C = 1.14\left[141{,}197.1 + 72{,}0979\,(4)\,(0.048) + 0.01065452\,[(Y) * 0.048]^2) + 0.0180092\,(\ln(F))^2\right]$	$300 < Y < 2{,}800$
Clarifier, lamella	$A = 0.05\,(C)$ $C = 6{,}039.6 + 3.1356\,(Y) - 4.659 * 10^2\,(Y)^2$	$2 < Y < 300$
Coalescent plate separator	$A = (.01\,(C) + 0.038\,(GPH))$ $C = 6410.4 + 75.560\,(Y) - 3.5688 * 10^{-2}\,(Y)^2$	$600 < GPH < 92{,}000$ $10 < Y < 700$

*All costs are calculated in 1989 dollars. Variable definitions are at the end of the table.

MP&M Phase I Equipment Cost Equations*

Equipment	Equation	Range of Validity
Electrolytic recovery unit	$A = [(LBS)(.2)(24)] + [(PT)(AMPS)(.5)(.012)] + [(LBS)(8.95)/10] + [(PT)(ATF)((AMPS/15) + 1)]$ $C = 7{,}912$ $C = 15{,}824$ $C = 21{,}758$ $C = 29{,}670$	$100 \leq AMPS \leq 750$ 100 Amp Cell 250 Amp Cell 500 Amp Cell 750 Amp Cell
Feed system, aluminum sulfate (alum)	$A = 690\,(f)\,(AW)$ $C = 3{,}062.8 + 1{,}394.7\,(F) - 45.449\,(F)^2$	$0.23 < F < 12.5$ Dry
	$A = 6{,}875.5 + 20.747\,(F) + 1.2319 * 10^{-4}(F)^2$ $C = 3.5423 * 10^4 + 127.17\,(F)$	$10 < F < 5{,}000$ Dry
	$A = 1{,}773.5 + 0.10516\,(F) + 3.8552 * 10^{-4}(F)^2$ $C = 2.9547 * 10^4 + 146.24\,(F) - 1.2645 * 10^{-2}(F)^2$	$5.4 < F < 5{,}400$ Wet
Feed system, calcium hydroxide (lime), batch	$A = [57/2{,}000 * F * HPD * DPY] + [(24 * HPD * DPY)/8 * (0.25 + (0.0025 * F * 8))] + [(24 * DPY)/5]$ $C = 1{,}929 + (22.65 * F) - (0.04608 * F^2)$	$F \leq 100$
	$A = [57/2{,}000 * F * HPD * DPY] + [(24 * HPD * DPY)/8 * (0.25 + (0.0025 * F * 8))] + [(24 * DPY)/5]$ $C = 6{,}359.7 + (6{,}573.2 * \log(F))$	$100 < F \leq 5{,}000$
Feed system, calcium hydroxide (lime), continuous	$A = f[-17{,}140 + (22{,}697 * \log(F))] + [(57/2{,}000) * F * HPD * DPY]$ $C = 19{,}511 + (F * 698.8)$	$F < 50$
	$A = f[-17{,}140 + (22{,}697 * \log(F))] + [(45/2{,}000) * F * HPD * DPY]$ $C = 19{,}511 + (F * 698.8)$	$50 \leq F \leq 100$
	$A = f[-17{,}140 + (22{,}697 * \log(F))] + [(45/2{,}000) * F * HPD * DPY]$ $C = 8.795 * 10^4\,(F * 8.9565)$	$100 < F < 1{,}000$
Feed system, polymer	$A = (2.4 * DPY) + 312 + (0.1)(C) + (2.25)(0.989) * F * HPD * DPY$ $C = 3{,}668 + (20{,}666 * F)$	$F \leq 0.5$

*All costs are calculated in 1989 dollars. Variable definitions are at the end of the table.

Table 12-3 (Continued)

MP&M Phase I Equipment Cost Equations*

Equipment	Equation	Range of Validity
Feed system, sodium hydroxide, batch	$A = 24 * (16 + 0.5(BPY)) + (0.138)(F)(HPY)$ $C = 1.14\left[\exp\left[7.50026 + 0.199364 * \ln(F) + 0.0416602 * (\ln(F))^2\right]\right]$	$27 < GPH < 625$ $1.5 < F < 1{,}500$
	$A = (12)(BPY) + (0.138)(F)(HPY)$ $C = (1.14)(250)$	$27 < GPH$ $1.5 < F < 1{,}500$
Feed system, sodium hydroxide, continuous	$A = 1.14\left[\exp\left[7.9707 - 4.45846 * 10^{-3} * \ln(F) + 0.0225972 * (\ln(F))^2\right]\right](f(6000/8760)) + HPY(F)(1.13)$ $C = 1.14\left[\exp\left[9.63461 + 8.36122 * 10^{-3} * \ln(F) + 0.0241809 * (\ln(F))^2\right]\right]$	$.4 < F < 417$
Feed system, sodium hypochlorite	$A = 3{,}192(f) + (F)(f)(6{,}480)$ $C = 652.71 + 95.931(GPH) - 0.86955(GPH)^2$	$1 < GPH < 42$
Feed system, sulfur dioxide (sulfonator)	$A = 1.0865 * 10^4 + 2{,}779.1(F)$ $C = 1.5807 * 10^4 * 10^{(1.1133 * 10^{-3}(F))}$	$4.1 < F < 417$ $0.42 < F < 416.7$
Feed system, sulfuric acid	$A = \left[2{,}724.6 + 3.8647(F) + 1.4692 * 10^{-5}(F)^2\right](f)(6000/8760) + \left[(6000)(.0442)(F)(f)\right]$ $C = 1.14\left[\exp\left[8.1441 + 0.23345(\ln(F)) + 0.0180092(\ln(F))^2\right]\right]$	$0.01 < F < 3{,}200$
Filter press, plate-and-frame	$A = 48 + 3(DPY)(HPD)$ $A = 48 + 6(DPY)(HPD)$ $A = 48 + 9(DPY)(HPD)$ $C = 4098.5 + 2056.2(FCV) - 35.576(FCV)^2$	$1 < FCV < 6$ $6 < FCV < 15$ $15 < FCV < 20$ $1 < FCV < 20$
Ion-exchange system (excluding regeneration feed systems)	$A = \left[(70)(FT^3)(24)\right] + \left[(134)(FT^3)\right] + \left[(FT^3)(HPD)(DPY)(.047)(1.4)\right] + \left[(FT^3)(7.23)(.5)(RPY)\right] + \left[(FT^3)(2{,}950)(.025)\right]$ $C = (2{,}967)(FT^3)$	$FT^3 \geq 1$, manual regeneration $10 \geq FT^3 \geq 1$
	$A = \left[(.25)(70)(FT^3)(24)\right] + \left[(134)(FT^3)\right] + \left[(3.65)(FT^3)(HPD)(DPY)(.047)(1.4)\right] + \left[(FT^3)(7.23)(.5)(RPY)\right] + \left[(4)(FT^4)(2{,}950)(.025)\right]$ $C = (2{,}373.6)(FT^3)$	$FT^3 \geq 1$, automatic regeneration $FT^3 > 10$

*All costs are calculated in 1989 dollars. Variable definitions are at the end of the table.

MP&M Phase I Equipment Cost Equations*

Equipment	Equation	Range of Validity
Machining coolant regeneration system (including holding tanks)	$A = [32 + (0.5 * SHIFT) * 24] + [0.047 * 18 * 8 * SHIFT]$ $C = 25{,}268$	$GPM < 1$
	$A = [(32 + SHIFT) * 24] + [0.047 * 18 * 8 * SHIFT]$ $C = 67{,}639$	$1 \leq GPM < 2$
	$A = [(32 + SHIFT) * 24] + [0.047 * 18 * 8 * SHIFT]$ $C = 87{,}738$	$2 \leq GPM < 6$
	$A = [(32 + SHIFT) * 24] + [0.047 * 18 * 8 * SHIFT]$ $C = 100{,}783$	$6 \leq GPM < 10$
	$A = [(32 + SHIFT) * 24] + [0.047 * 18 * 8 * SHIFT]$ $C = 117{,}613$	$10 \leq GPM < 14$
Paint curtain centrifuge	$A = [0.25 * (TSS/400{,}000) * ANNFLOW * 3.78 * 24/3] + [0.047 * 0.4 * 4 * 8]$ $C = 3{,}995$	$GPM < 8$ Manual Operation
	$A = [0.25 * (TSS/400{,}000) * ANNFLOW * 3.78 * 24/7.6] + [0.047 * 1.5 * 4 * 8]$ $C = 5{,}950$	$8 \leq GPM < 13$ Manual Operation
	$A = [0.167 * (TSS/400{,}000) * ANNFLOW * 3.78 * 24/7] + [0.047 * 1.5 * 4 * 8]$ $C = 10{,}765$	$13 \leq GPM < 16$ Semiautomatic
	$A = [1 * 4 * 24] + [0.047 * 2.2 * 4 * 8]$ $C = 29{,}990$	$16 \leq GPM < 26$ Automatic
	$A = [1 * 4 * 24] + [0.047 * 3.7 * 4 * 8]$ $C = 40{,}240$	$26 \leq GPM < 53$ Automatic
Pump, sludge	$A = 1{,}155.7 + 19.932(SF) - 7.7145 * 10^{-3}(SF)^2 + (0.01)(C)$ $C = 2{,}582.8 + 23.952(SF) - 4.2469 * 10^{-3}(SF)^2$	$5 < SF < 500$
Pump, wastewater	$A = [(1{,}779.5 + 18.098(Y) - 2.0632 * 10^{-3}(Y)^2)](f) + 0.01(C)$ $C = 3{,}196.3 + 3.2367(Y) + 4.1585 * 10^{-4}(Y)^2$	$Y > 1{,}000$ $27 < Y < 3{,}500$
	$A = [(1779.5 + 18.098(Y) - 2.0632 * 10^{-3}(Y)^2)](f) + 0.01(C)$ $C = 602.93 + 44.824(Y)$	$Y \leq 1{,}000$ $Y \leq 27$

*All costs are calculated in 1989 dollars. Variable definitions are at the end of the table.

Table 12-3 (Continued)

MP&M Phase I Equipment Cost Equations*

Equipment	Equation	Range of Validity
Tank, equalization/reaction, concrete	$A = 0.05\,(C)$ $C = 1.14\,[5{,}800 + 0.8\,(V)]$	$24{,}000 < V < 500{,}000$
Tank, equalization/ reaction/rinse, fiberglass	$A = 0.05\,(C)$ $C = 1.14\,[\exp\,[4.7308 - 0.0628537\,\ln(V) + 0.0754344\,(\ln(V))^2]]$	$57 < V < 1{,}000$
	$A = 0.05\,(C)$ $C = 1.14\,[3100.44 + 1.19041\,(V) - 1.7288 * 10^{-5}(V)^2]$	$1{,}000 \leq V \leq 24{,}000$
Tank, equalization/reaction, steel	$A = 0.05\,(C)$ $C = 1.14\,[692.824 + 6.16706\,(V) - 3.95367 * 10^{-3}(V)^2]$	$100 \leq V < 500$
	$A = 0.05\,(C)$ $C = 1.14\,[3{,}128.83 + 2.37281\,(V) - 7.10689 * 10^{-5}(V)^2]$	$500 \leq V \leq 12{,}000$
	$A = 0.05\,(C)$ $C = 1.14\,[3100.44 + 1.19041\,(V) - 1.7288 * 10^{-5}(V)^2]$	$12{,}000 < V < 24{,}000$
	$A = 0.05\,(C)$ $C = 1.14\,[14{,}759.8 + 0.0170817\,(V) - 8.44271 * 10^{-8}(V)^2]$	$24{,}000 \leq V \leq 500{,}000$
Tank, holding, concrete	$A = 0.02\,(C)$ $C = 1.14\,[5{,}800 + 0.8\,(V)]$	$24{,}000 < V < 500{,}000$
Tank, holding, fiberglass	$A = 0.02\,(C)$ $C = 1.14\,[\exp\,[4.7308 - 0.0628537 * \ln(V) + 0.0754345\,(\ln(V))^2]]$	$57 < V < 1{,}000$
	$A = 0.02\,(C)$ $C = 1.14\,[3{,}100.44 + 1.19041\,(V) - 1.7288 * 10^{-5}(V)^2]$	$1{,}000 < V < 24{,}000$

*All costs are calculated in 1989 dollars. Variable definitions are at the end of the table.

MP&M Phase I Equipment Cost Equations*

Equipment	Equation	Range of Validity
Tank, holding, steel	$A = 0.02(C)$ $C = 1.14[692.824 + 6.16706(V) - 3.95367 * 10^{-3}(V)^2]$	$100 \leq V < 500$
	$A = 0.02(C)$ $C = 1.14[3{,}128.83 + 2.37281(V) - 7.10689 * 10^{-5}(V)^2]$	$500 \leq V \leq 12{,}000$
	$A = 0.02(C)$ $C = 1.14[3{,}100.44 + 1.19041(V) - 1.7288 * 10^{-5}(V)^2]$	$12{,}000 < V < 25{,}000$
	$A = 0.02(C)$ $C = 1.14[14{,}759.8 + 0.0170817(V) - 8.44271 * 10^{-8}(V)^2]$	$25{,}000 \leq V \leq 500{,}000$

Source: MP&M design and cost model.

Variable Definitions:

A = Direct annual costs (1989 dollars per year)
ANNFLOW = Annual flow through equipment (gallons per year)
ATF = Anode type factor (ATF = 0.708 for all metal types except Pb, Sn, and Pb-Sn. ATF = 0.035 for Pb, Sn, and Pb-Sn)
AMPS = Cell amperage (amps)
AW = Weight of aluminum (pounds)
BPY = Number of batches per year
C = Direct capital equipment costs (1989 dollars)
DPY = Days of operation per year
F = Chemical feed rate (pounds per hour)
f = Fraction of time equipment is in operation
FT^3 = Resin volume required (cubic feet)
FCV = Filter cake volume (cubic feet)
G = Sludge disposal rate (gallons per hour)
GPH = Wastewater flow rate (gallons per hour)
GPM = Wastewater flow rate (gallons per minute)
HP = Power requirement (horsepower)
LBS = Pounds of metal reclaimed per year (lbs per yr)
PT = Plate-out time (hours)
HPD = Equipment operational hours per day
HPY = Plant operating hours (hours per year)
LC = Lime cost ($ per lb, March 1982)
NA = Not applicable
NB = Number of batches per day
OR = Oil removal rate (gallons per hour)
RPY = Regenerations per year
S = Clarifier surface area (square feet)
SA = Filter surface area (square feet)
SF = Sludge flow (gallons per minute)
SHIFT = Number of shifts operated per year
TSS = Concentration of total suspended solids (mg per L)
V = Tank volume (gallons)
W = Weight of chemical (pounds)
Y = Wastewater flow rate (gallons per minute)

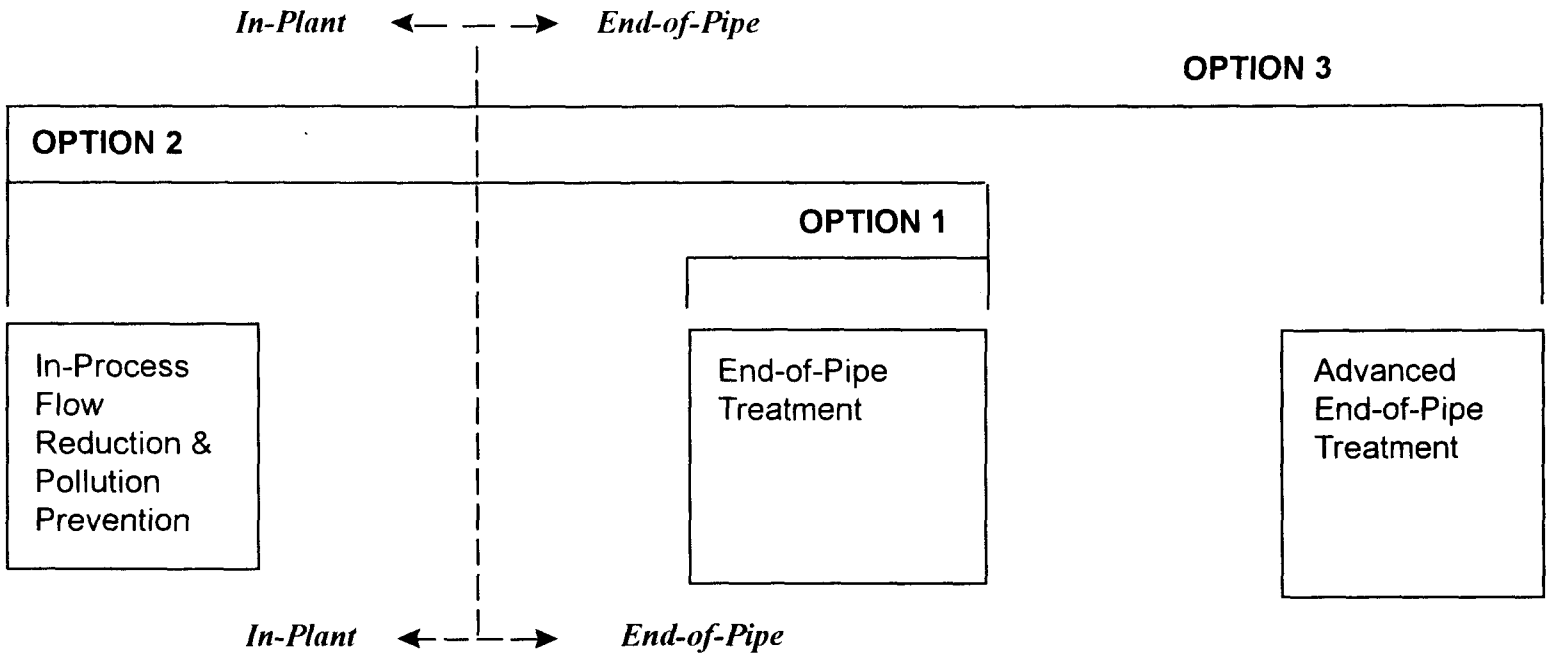
*All costs are calculated in 1989 dollars. Variable definitions are at the end of the table.

Table 12-4

Components of Total Capital Investment

Number	Item	Cost
1	Equipment capital costs including required accessories, installation, delivery, electrical and instrumentation, yard piping, enclosure, pumping, and retrofit allowance	Direct capital cost
2	Engineering/administrative and legal	10% of item 1
3	Secondary containment/land costs	10% of item 1
4	Total plant cost	Sum of items 1 through 3
5	Contingency	15% of 4
6	Contractor's fee	10% of item 4
7	Total capital investment	Sum of items 4 through 6

Source: MP&M design and cost model.



Flow reduction for rinses:
- Flow restrictors
- Conductivity sensors
- Timed rinsing

Counter current cascade rinsing
Flow reduction for other operations:
- Manual control of discharge
- Maintenance of bath chemistry

Centrifugation and pasteurization of machining coolant
Centrifugation of painting water curtains
Ion exchange of certain electroplating rinse waters
Electrolytic metal recovery for drag-out recovery rinsing and ion-exchange regenerant solutions

Oil/water separation
Chemical reduction of hexavalent chromium
Cyanide destruction
Chemical reduction of chelated metals
Contract hauling of solvent degreasing wastewaters
Chemical precipitation and sedimentation
Sludge thickening
Sludge pressure filtration

Advanced End-of-Pipe Treatment:
- Ion Exchange
- Reverse Osmosis

Major reuse of process wastewater

Additional options considered for indirect dischargers:
1A Option 1 for sites with discharge rates below one-millon gallons per year, Option 2 for the remaining sites.
2A Exempt sites with discharge rates below one-million gallons per year, Option 2 for the remaining sites.

Figure 12-1. Relationship Among Options

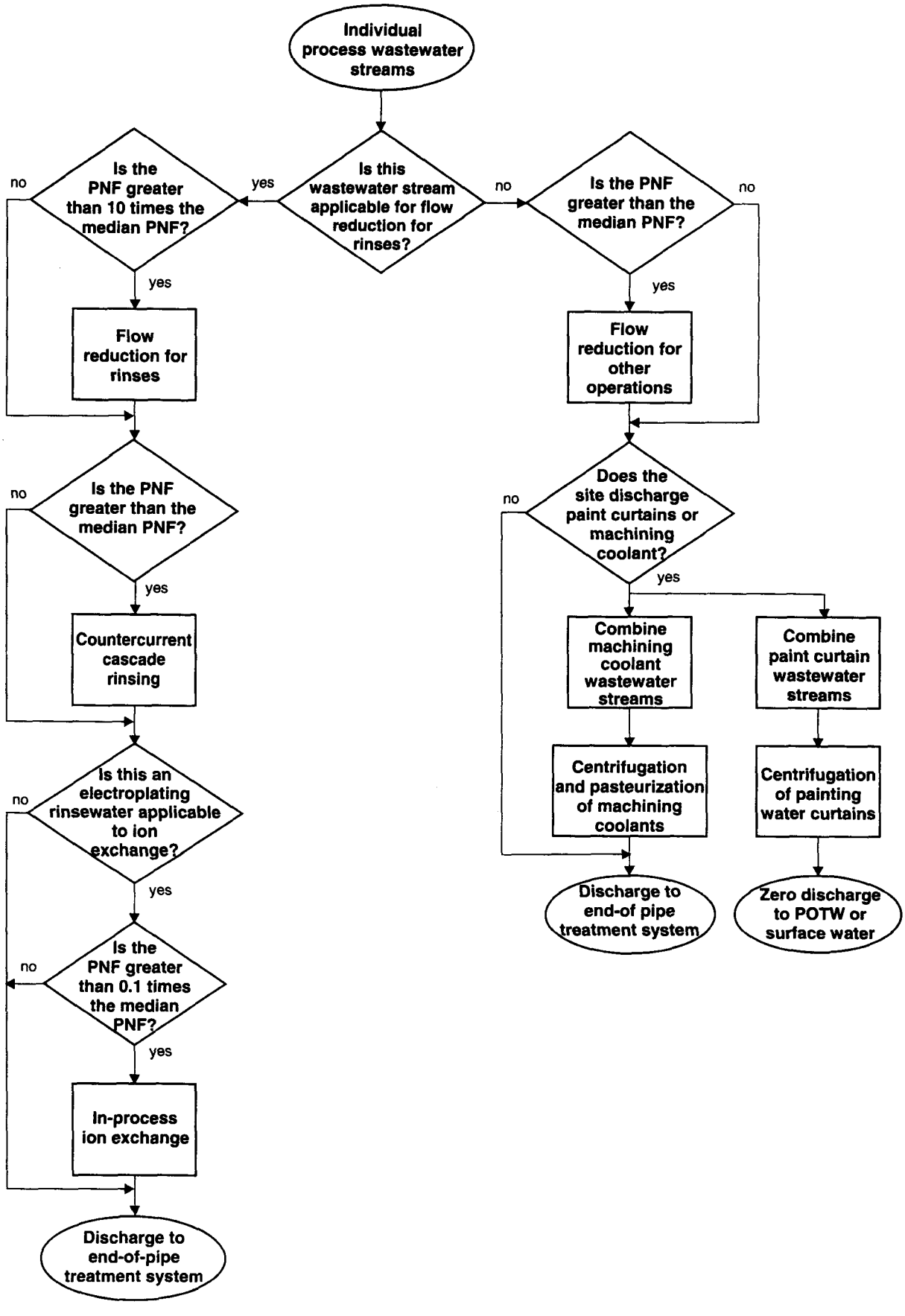


Figure 12-2. Logic Used to Apply In-process Technologies and Practices

graphics\core\mpm395.cdr

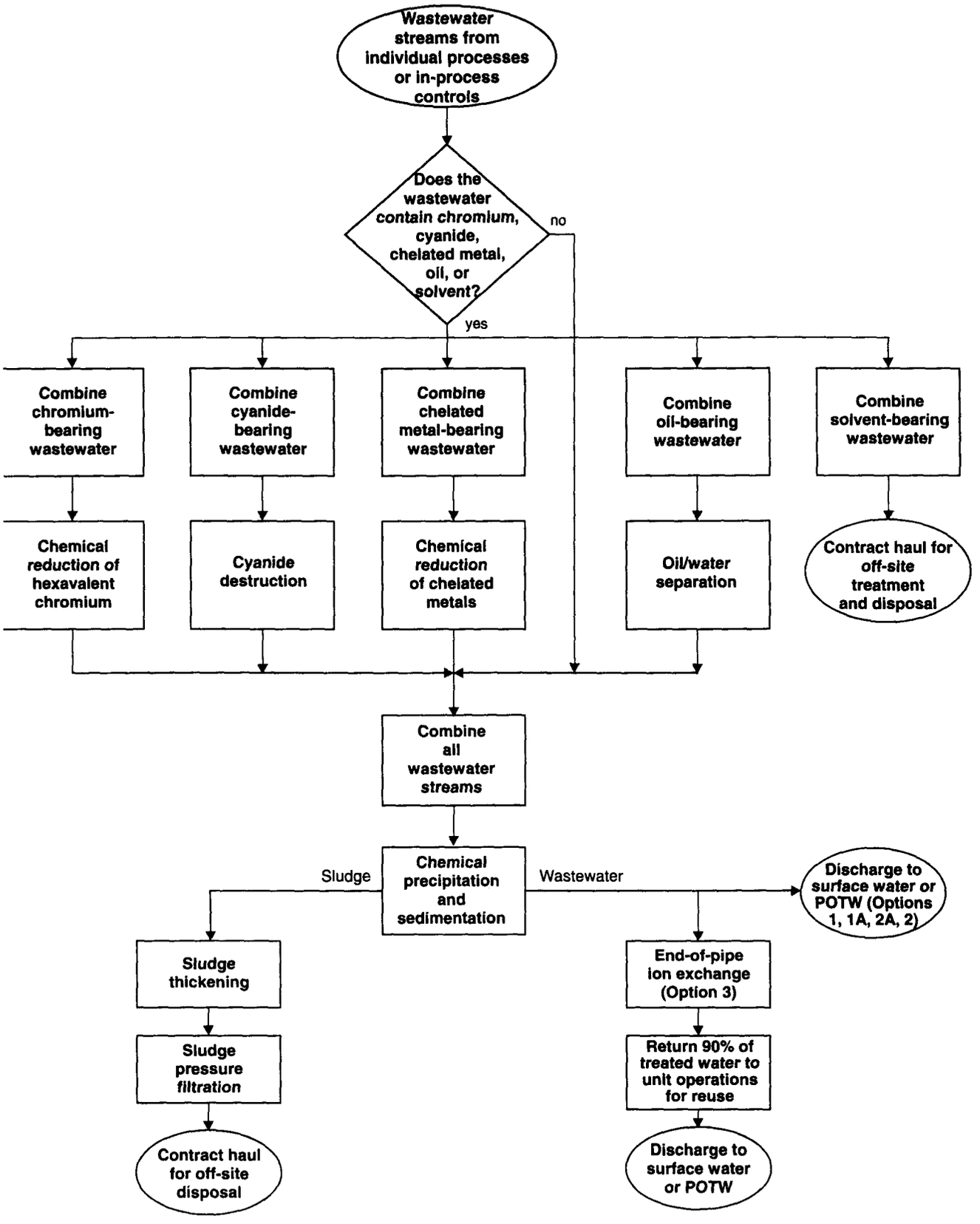


Figure 12-3. Logic Used to Apply End-of-pipe Technologies and Practices

13.0 POLLUTANT LOADING AND REDUCTION ESTIMATES

This section describes EPA's estimation of industry pollutant loadings and pollutant reductions for each of the Metal Products and Machinery (MP&M) technology options described in Section 10.0. The Agency estimated pollutant loadings and reductions from MP&M sites to evaluate loadings to surface waters and publicly-owned treatment works (POTWs) and to assess the cost-effectiveness of each MP&M technology option in reducing these loadings. The results from each of these assessments are presented in separate EPA documents entitled MP&M Phase I Regulatory Impact Analysis and MP&M Phase I Economic Impact Analysis. Pollutant loadings for MP&M direct and indirect dischargers are presented in Tables 13-1 and 13-2, respectively. Pollutant reductions for MP&M direct and indirect dischargers are presented in Tables 13-3 and 13-4, respectively.

Pollutant loadings and pollutant reductions were estimated using the following steps:

1. Field sampling data were analyzed to determine production-normalized pollutant loadings (PNPLs) from sampled operation and metal type combinations.

2. Data were modelled to estimate PNPLs for cases in which particular unit operation and metal type combinations were not sampled but the unit operation performed on a different metal type(s) was sampled.

3. Data were transferred from unit operations with similar wastewater characteristics to estimate PNPLs for unit operations that were not sampled.

4. PNPLs were used in the model site development effort (see Section 12.1) to estimate the concentration of each pollutant of concern in each model site wastewater stream.

5. The model site database was used to calculate industry raw wastewater pollutant loadings from the MP&M Phase I Category.

6. The MP&M Design and Cost Model (see Section 12.2.3) was used to estimate pollutant loadings at baseline and post compliance for each of the MP&M technology options.

7. Pollutant reductions for each technology option were calculated from the Design and Cost Model output by subtracting the baseline loadings from each post-compliance loading.

Figure 13-1 summarizes these steps used to estimate MP&M Phase I pollutant loadings and reductions for each technology option. Section 13.1 describes the data sources and major assumptions used for calculating the PNPLs. Section 13.2 describes the calculation of PNPLs for each unit operation and metal type combination, including cases for which data modelling and data transfers were performed. Section 13.3 presents the results of the raw, baseline, and post-compliance pollutant loading and reduction calculations.

To estimate pollutant loadings, the Agency calculated production-normalized pollutant loadings (PNPLs) for each unit operation and metal type combination based on data collected during the field sampling program and responses to the MP&M data collection portfolios (DCPs). The PNPLs represent the mass of pollutants generated per unit of production (e.g., mg/ft^2 or mg/lb removed). The units of production used to normalize the pollutant loadings for each unit operation are presented in Section 5.0, Table 5-4.

The Agency used production to normalize pollutant loadings to account for the varying amounts of production through unit operations at MP&M sites. As discussed below, the amount of pollutants generated from MP&M unit operations is dependent on the amount of production through an operation. For example, if one operation at an MP&M site has twice as much production as a corresponding operation at another site, the first operation is expected to discharge approximately twice the mass of pollutants as the second operation. By normalizing the discharge of pollutants to production, EPA was able to account for the varying levels of production at MP&M sites.

EPA used a production-based approach to estimate pollutant loadings for each unit operation and metal type combination because pollutant loadings depend primarily on the amount of production through an operation rather than the amount of water used to perform the operation. The sources of pollutants generated while performing MP&M unit operations are the parts processed in the operation, contaminants present on the parts (e.g., oil and grease), and process baths (including materials applied to the parts). Because discharges of pollutants from these sources are directly related to production, the amount of pollution generated by a unit operation is primarily dependent on production and relatively independent of the amount of water used to carry the pollutant. While adding excess process water will reduce the concentrations of pollutants in the discharged stream, the total mass of pollutants discharged will remain constant with constant production. It should be noted that while water use reduction will not reduce the total mass of pollutants discharged from an operation, additional pollution prevention benefits are inherently associated with reduced water use. These benefits include reductions in wastewater treatment chemical usage and sludge generation, and reduced wastewater treatment system capacity requirements.

The Agency developed separate PNPLs for each unit operation and metal type combination identified by DCP respondents to account for variation in pollutant loadings across the variety of unit operations performed and metal types processed at MP&M sites (e.g., EPA expects electroplating operations to have different PNPLs than painting

operations, and grinding of zinc parts to have different PNPLs than grinding of iron parts).

13.1 Data Sources

The Agency used data from the following sources to estimate pollutant loadings for each unit operation:

- Analytical data collected during sampling at Phase I MP&M sites;
- Analytical data collected during sampling at Phase II MP&M sites; and
- Analytical data from previously promulgated metals regulations (non-MP&M sites).

When flow and production data associated with analytical data for a sampled unit operation were not available, the Agency used the median production-normalized flow (PNF, in gallons per unit of production) for the unit operation based on data provided in the DCPs. Table 5-4 lists the production normalizing parameters and median production-normalized flows for each unit operation. Data from MP&M sampling episodes are contained in Sampling Episode Reports (SERs) for each sampled site; these reports, as well as data from MP&M DCPs and previous metals regulations used in this assessment, are included in the administrative record for this rulemaking.

13.1.1 Data Hierarchy

To characterize MP&M unit operations, EPA used the data sources listed above based on the following hierarchy.

1. Analytical data from Phase I MP&M sites were used where available.
2. If analytical data were not available from Phase I MP&M sites, analytical data collected at Phase II MP&M sites and non-MP&M sites were used for each unit operation for which these data were available. The Agency used Phase II or non-MP&M data for unit operation and metal type combinations which were common to Phase I, Phase II, and non-MP&M sites. Because both Phase II and non-MP&M data were considered equally representative of MP&M Phase I unit operations, these data were given equal weight when used.

13.1.2 Use of Data for Nondetected Pollutants

In developing PNPLs, the Agency assumed that all nondetected pollutants of concern were present at the detection limit (Section 8.0 includes a discussion of pollutants of concern). The Agency made this assumption based on process considerations and on analytical data available from the MP&M sampling program. Each pollutant of concern was expected to be present in MP&M wastewater because each pollutant of concern was generated by MP&M processes and was detected at least three times during the MP&M sampling program. As discussed below, EPA made exceptions to this methodology for cyanide and organic pollutants.

The source of cyanide in cyanide-bearing unit operations is soluble cyanide salts added to the process bath rather than the raw material processed. Based on process considerations (e.g., the use of cyanide salts to control electroplating rates for the unit operation), MP&M sampling data, and available technical literature, the Agency developed a list of unit operations expected to contain cyanide. These unit operations are alkaline cyanide treatment, electrolytic cyanide cleaning, cyanide electroplating, cyaniding heat treating (quench), air pollution control for these operations, and associated rinses. For pollutant loadings and reduction estimates, the Agency considered these to be the only MP&M unit operation expected to contain cyanide; therefore, for unit operations not expected to contain cyanide, nondetects for cyanide were assumed to be zero.

The sources of organic pollutants in MP&M unit operations are organic additives added to process solutions, organic materials present on the parts, or external contamination by organic pollutants (e.g., oil or grease). The Agency identified the following as operations expected to generate organic pollutants: alkaline treatment, adhesive bonding, assembly, barrel finishing, chemical machining, corrosion preventive coating, floor cleaning, grinding, heat treating, impact deformation, machining, painting, polishing, pressure deformation, solvent degreasing rinsing, metallic coating stripping, organic coating stripping, dye penetrant testing, hydraulic testing, associated rinses, and non-associated rinsing (see Section 5.0, unit operation number 36 for a description of these rinses). The Agency identified unit operations expected to generate organic pollutant-bearing wastewaters based on the following criteria: (1) based on process considerations, organic pollutants were expected to be present in wastewater from these operations, (2) organic pollutants were detected for these operations during MP&M sampling efforts, or (3) organic pollutants were reported in the DCPs as known or believed to be present in wastewater from these operations. For these operations, nondetected organic pollutants were assumed to be present at the detection limit. For unit operations not expected to contain organic pollutants, nondetects for these pollutants were assumed to be zero.

13.2 Calculation of Unit Operation Production-Normalized Pollutant Loadings

The Agency calculated PNPLs for each MP&M unit operation and metal type combination using the data sources identified in Section 13.1. For most unit operations,

the metal type was defined as the base metal on which the unit operation was performed. For the following unit operations, the Agency used process considerations and available analytical data to determine that the pollutant loadings depend primarily on the metal applied rather than the base metal: electroplating, electroless plating, mechanical plating, and metal spraying. For painting, floor cleaning, and wet air pollution control, the Agency believes that the PNPLs do not vary by base metal type; therefore, PNPLs for these unit operations were not calculated separately for each base metal type processed.

The Agency calculated PNPLs for each unit operation and metal type combination using the following three steps.

1. Unit operation PNPLs were calculated for each metal type for which analytical data were available from the data sources described in Section 13.1.

2. Unit operation PNPLs were modelled for each metal type for which analytical data were not available from the data sources described in Section 13.1. Data modelling was based on data available for the unit operation performed on other metal types.

3. Unit operation PNPLs were transferred to unit operations for which data were not available for any metal type from the data sources described in Section 13.1. Data were transferred from unit operations that were expected to have similar wastewater characteristics based on process considerations.

Sections 13.2.1 through 13.2.3 describes these steps. Documentation for these calculations is contained in the administrative record for this rulemaking.

13.2.1 Production-Normalized Pollutant Loadings for Each Unit Operation and Metal Type Combination With Available Data

The Agency calculated PNPLs for each unit operation and metal type combination for which analytical data were available by multiplying the pollutant concentrations (mg/L) by the production-normalized flow (L/unit of production) associated with the sample. As mentioned above, the Agency used the median production-normalized flow from DCP data when the associated production-normalized flow for a sample was not available.

As described in Section 4.0, for flowing wastewater streams, the Agency collected multiple samples over several days at a single sampling point (i.e., unit operation) to account for the potential variability of wastewater characteristics over time. EPA calculated PNPLs for these sampling points by averaging PNPLs for the samples collected on multiple days at the same sampling point. For example, if three one-day composite samples for acid treatment rinsing of steel parts were collected to characterize

acid treatment rinsing, the PNPLs for each pollutant on each of the three days were averaged to calculate the PNPLs for the sampling point.

The Agency averaged PNPLs for samples collected at the same site for the same unit operation and metal type combination. For example, if samples for acid treatment rinsing of steel parts were collected at two different sampling points at the same site, PNPLs for these two sampling points were averaged to calculate the PNPL for this unit operation and metal type combination at this site. Because the Agency believes that the PNPL variability is greater between sites than between unit operations within a site, equal weight was given to data from each site when calculating PNPLs. EPA then calculated PNPLs for each unit operation and metal type combination by averaging PNPLs for samples collected at different sites for the same unit operation and metal type.

13.2.2 Production-Normalized Pollutant Loadings Modelling Within Unit Operations

The Agency developed a computer algorithm to model PNPLs for unit operations for which analytical data were available for some but not all metal types. This algorithm modelled PNPLs based on the average PNPLs for the same unit operation when performed on other metal types. The algorithm was applicable only when data were available for the unit operation performed on another metal type. In cases where analytical data were not available for a unit operation, PNPLs were transferred from another MP&M unit operation (see Section 13.2.3). Supporting documentation for modelling of PNPLs is contained in the administrative record for this rulemaking.

13.2.3 Production-Normalized Pollutant Loadings Data Transfer Across Unit Operations

The Agency transferred PNPLs to unit operations for which analytical data were not available from Phase I or Phase II MP&M sites or from non-MP&M sites. EPA transferred PNPLs from unit operations expected to have similar wastewater characteristics based on process considerations. Process considerations included the purpose of the unit operation (e.g., metal removal, contaminant removal), the purpose of the process water use (e.g., contact cooling water, cleaning solution), and the wastewater flow per unit of production (i.e., production-normalized flow) as reported by MP&M DCP respondents. Supporting documentation for all data transfers of unit operation PNPLs is contained in the administrative record for this rulemaking.

13.3 Pollutant Loadings and Reductions

The Agency calculated PNPLs for each pollutant of concern (see Section 8.0) for each unit operation and metal type combination contained in the model site profile database (see Section 12.2). The concentration of each pollutant in each model site wastewater

stream was calculated using the following equation (for this example, surface area is used as the production-normalized parameter):

$$\text{CONC mg/L} = \frac{[\text{PNPL(mg pollutant/sq ft processed)}] \times [\text{PROD(sq ft/hr)}]}{[\text{FLOW (gal/hr)}] \times [3.78 \text{ L/gal}]}$$

After pollutant concentrations were added to the model site profile database, industry pollutant loadings for raw wastewater, baseline, and post-compliance at each option were calculated. Industry baseline pollutant loadings were subtracted from the industry post-compliance pollutant loadings to determine pollutant reductions for each option. The results of the pollutant loadings and reductions calculations are presented in the following sections. All pollutant loadings and reductions are presented using 1989 as the basis year.

13.3.1 Calculation of Industry Raw Wastewater Pollutant Loadings

Industry raw wastewater pollutant loadings represent the industry pollutant loadings before accounting for pollutant removal by treatment technologies in place at MP&M sites. EPA estimated site-specific raw wastewater pollutant loadings by summing the pollutant loadings for each wastewater stream at each model site.

The site-specific raw wastewater pollutant loadings were then scaled up to the industry using weighting factors derived statistically for each model site, as discussed in Section 4.0. The scaled-up site-specific pollutant loadings were summed to calculate the industry raw wastewater pollutant loadings. The results of the statistical scale-up for industry raw wastewater annual pollutant loadings for direct and indirect dischargers are presented in Tables 13-1 and 13-2, respectively. Table 13-1 indicates that the industry raw wastewater annual pollutant loadings for MP&M Phase I direct dischargers include approximately 5,460,000 lb/yr of priority metals, 691,000 lb/yr of cyanide, 107,000,000 lb/yr of oil and grease, and 9,220,000 lb/yr of total suspended solids. Table 13-2 indicates that the industry raw wastewater annual pollutant loadings for MP&M Phase I indirect dischargers includes approximately 26,900,000 of priority metals, 9,110,000 lb/yr of cyanide, 691,000,000 lb/yr of oil and grease, and 42,000,000 lb/yr of total suspended solids.

13.2.2 Calculation of Industry Baseline Pollutant Loadings

Industry baseline pollutant loadings represent the industry pollutant loadings after accounting for removal of pollutants by treatment technologies in place at MP&M sites. Section 12.0 describes the assessment of technology in place for each model site. As described above, site-specific raw wastewater pollutant loadings were developed for each model site. A baseline run of the cost model was performed to calculate site-specific

baseline pollutant loadings for each model site. This baseline run used the technologies in place at each site rather than the MP&M technology options. Site-specific baseline pollutant loadings were then calculated as the difference between site-specific raw wastewater pollutant loadings and pollutant removals by technologies in place at each MP&M model site.

Site-specific baseline pollutant loadings were scaled up to industry using weighting factors derived statistically for each model site. The scaled-up site-specific baseline loadings were summed to calculate industry baseline pollutant loadings. The results of the statistical scale-up for industry baseline pollutant loadings are presented in Tables 13-1 and 13-2. Table 13-1 indicates that the industry baseline annual pollutant loadings for MP&M Phase I direct dischargers include approximately 557,000 lb/yr of priority metals, 3,840 lb/yr of cyanide, 18,200,000 lb/yr of oil and grease, and 2,590,000 lb/yr of total suspended solids. Table 13-2 indicates that the industry baseline annual pollutant loadings for MP&M Phase I indirect dischargers includes approximately 6,100,000 lb/yr of priority metals, 170,000 lb/yr of cyanide, 170,000,000 lb/yr of oil and grease, and 17,700,000 lb/yr of total suspended solids.

13.3.3 Calculation of Option-Specific Industry Pollutant Loadings and Pollutant Reductions

Option-specific pollutant loadings (i.e., post-compliance pollutant loadings for each option) represent the total industry pollutant loadings after the application of each MP&M technology option. Option-specific pollutant reductions represent total industry pollutant removal for each technology option. The Agency calculated site-specific raw wastewater pollutant loadings and baseline pollutant loadings as described above. Option-specific pollutant reductions for each model site were calculated as the difference between site-specific baseline pollutant loadings and option-specific pollutant loadings. These calculations were performed using the MP&M Phase I Design and Cost Model (see Section 12.0).

Option-specific pollutant loadings and pollutant reductions were scaled up to industry using weighting factors derived statistically for each model site. The scaled-up site-specific loadings and reductions for each option were summed to calculate the option-specific industry pollutant loadings and reductions. The results of the statistical scale-up for option-specific pollutant loadings are presented in Tables 13-1 (for direct dischargers) and 13-2 (for indirect dischargers). The results of the statistical scale-up for option-specific pollutant reductions are presented in Tables 13-3 (for direct dischargers) and 13-4 (for indirect dischargers). These results were used to select the technology basis for effluent limitations guidelines and standards, as discussed in Section 15.0.

Table 13-1

Summary of Pollutant Loadings by Option for MP&M Phase I Direct Dischargers[1]

Pollutant	Industry Raw Wastewater Pollutant Loading (lbs/yr)	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Loading (lbs/yr)	Option 2, 1A, and 2A Pollutant Loading (lbs/yr)	Option 3 Pollutant Loading (lbs/yr)
ANTIMONY	4,220	4,160	3,630	3,320	330
ARSENIC	1,690	1,660	1,600	1,580	156
CADMIUM	20,600	2,860	2,560	2,060	205
CHROMIUM	3,060,000	357,000	2,860	1,550	154
COPPER	222,000	17,900	9,860	5,590	557
LEAD	18,200	16,100	16,200	15,400	1,530
NICKEL	1,650,000	63,400	8,740	5,070	505
SELENIUM	1,250	1,230	1,030	904	89.6
SILVER	11,100	386	259	168	16.7
THALLIUM	1,240	1,220	1,170	1,150	113
ZINC	467,000	91,000	6,750	3,700	368
TOTAL PRIORITY METALS	**5,460,000**	**557,000**	**54,700**	**40,500**	**4,020**
CYANIDE	691,000	3,840	0.930	0.0500	0.00
TOTAL CYANIDE	**691,000**	**3,840**	**0.926**	**0.0496**	**0.00496**
OIL AND GREASE	107,000,000	18,200,000	249,000	153,000	15,200
TOTAL OIL AND GREASE	**107,000,000**	**18,200,000**	**249,000**	**153,000**	**15,200**
TOTAL SUSPENDED SOLIDS (TSS)	9,220,000	2,590,000	671,000	364,000	36,300
TOTAL TSS	**9,220,000**	**2,590,000**	**671,000**	**364,000**	**36,300**
ALUMINUM	431,000	63,100	16,900	11,400	1,140
BARIUM	56,300	7,610	7,720	5,430	540

[1]Pollutant loadings for calcium, magnesium, and sodium are not presented in this table because these are typical wastewater treatment chemicals at MP&M sites. Pollutant loadings for acidity, pH, and total alkalinity are not presented because they are used as performance parameters for chemical precipitation and settling systems.

Table 13-1 (Continued)

Summary of Pollutant Loadings by Option for MP&M Phase I Direct Dischargers[1]

Pollutant	Industry Raw Wastewater Pollutant Loading (lbs/yr)	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Loading (lbs/yr)	Option 2, 1A, and 2A Pollutant Loading (lbs/yr)	Option 3 Pollutant Loading (lbs/yr)
BORON	85,200	84,500	81,500	79,000	7,710
COBALT	34,200	3,840	879	553	55.0
IRON	13,900,000	398,000	26,300	14,200	1,420
MANGANESE	206,000	50,500	3,230	1,940	193
MOLYDBENUM	289,000	16,800	14,500	14,100	1,400
TIN	46,400	3,630	2,800	2,200	219
TITANIUM	22,500	4,290	4,620	3,100	308
VANADIUM	2,700	1,560	1,450	1,120	111
TOTAL NONCONVENTIONAL METALS	**15,000,000**	**634,000**	**160,000**	**133,000**	**13,100**
AMMONIA AS N	131,000	92,600	53,400	39,600	3,960
CHEMICAL OXYGEN DEMAND (COD)	131,000,000	6,500,000	1,430,000	761,000	76,000
CHLORIDE	80,000,000	14,600,000	5,130,000	4,040,000	402,000
FLUORIDE	666,000	89,200	39,300	24,200	2,410
SULFATE	19,500,000	6,580,000	6,470,000	5,290,000	526,000
TOTAL DISSOLVED SOLIDS	383,000,000	67,900,000	36,800,000	21,300,000	2,120,000
TOTAL KJELDAHL NITROGEN	247,000	155,000	110,000	80,000	7,990
TOTAL RECOVERABLE PHENOLICS	11,100	10,100	4,550	3,550	354
TOTAL PHOSPHORUS	1,850,000	471,000	53,400	29,200	2,910
TOTAL OTHER NONCONVENTIONALS	**615,000,000**	**96,400,000**	**50,100,000**	**31,600,000**	**3,140,000**
1,1,1-TRICHLOROETHANE	431	322	217	161	16.1
1,1-DICHLOROETHANE	189	187	143	81.0	8.06

[1]Pollutant loadings for [illegible]

Table 13-1 (Continued)

Summary of Pollutant Loadings by Option for MP&M Phase I Direct Dischargers[1]

Pollutant	Industry Raw Wastewater Pollutant Loading (lbs/yr)	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Loading (lbs/yr)	Option 2, 1A, and 2A Pollutant Loading (lbs/yr)	Option 3 Pollutant Loading (lbs/yr)
4-CHLORO-3-METHYLPHENOL	2,390	1,330	781	512	51.1
ETHYLBENZENE	329	294	148	96.4	9.62
METHYLENE CHLORIDE	1,120	365	337	215	21.4
NAPHTHALENE	2,030	470	288	154	15.3
2-NITROPHENOL	2,840	483	471	288	28.7
PHENOL	2,890	1,730	873	589	58.7
BIS(2-ETHYLHEXYL)PHTHALATE	2,680	1,700	1,410	978	97.5
DI-N-BUTYL PHTHALATE	2,680	1,040	534	287	28.7
PHENANTHRENE	1,980	465	289	158	15.8
TETRACHLOROETHENE	372	350	327	259	25.8
TOLUENE	209	204	134	83.8	8.34
TOTAL PRIORITY ORGANICS	**20,200**	**8,940**	**5,950**	**3,860**	**385**
2-BUTANONE	38,300	8,650	908	443	44.2
2-METHYLNAPHTHALENE	1,990	635	517	334	33.4
2-PROPANONE	3,750	1,850	1,120	530	52.8
ALPHA-TERPINEOL	10,300	8,910	550	348	34.7
BENZOIC ACID	7,920	954	776	413	41.3
BENZYL ALCOHOL	5,050	3,870	916	548	54.7
HEXANOIC ACID	1,710	633	484	332	33.1
N-DECANE	1,990	492	302	167	16.6
N-DOCOSANE	11,900	1,360	295	153	15.2

[1]Pollutant loadings for calcium, magnesium, and sodium are not presented in this table because these are typical wastewater treatment chemicals at MP&M sites. Pollutant loadings for acidity, pH, and total alkalinity are not presented because they are used as performance parameters for chemical precipitation and settling systems.

Table 13-1 (Continued)

Summary of Pollutant Loadings by Option for MP&M Phase I Direct Dischargers[1]

Pollutant	Industry Raw Wastewater Pollutant Loading (lbs/yr)	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Loading (lbs/yr)	Option 2, 1A, and 2A Pollutant Loading (lbs/yr)	Option 3 Pollutant Loading (lbs/yr)
N-DODECANE	15,600	4,490	1,800	1,000	99.9
N-EICOSANE	4,820	718	470	243	24.2
N-HEXACOSANE	9,100	1,290	495	256	25.6
N-HEXADECANE	9,490	7,890	693	427	42.7
N-OCTACOSANE	7,580	1,180	672	348	34.8
N-OCTADECANE	4,070	1,950	571	362	36.2
N-TETRACOSANE	12,000	1,560	672	348	34.8
N-TETRADECANE	22,700	21,300	672	417	41.6
N-TRIACONTANE	3,600	869	611	347	34.6
TOTAL NONCONVENTIONAL ORGANICS	**172,000**	**68,600**	**12,500**	**7,020**	**700**

Source: MP&M Phase I Pollutant Loadings.

Table 13-2

Summary of Pollutant Loadings by Option for MP&M Phase I Indirect Dischargers[1]

Pollutant	Industry Raw Wastewater Pollutant Loading (lbs/yr)	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Loading (lbs/yr)	Option 2 Pollutant Loading (lbs/yr)	Option 3 Pollutant Loading (lbs/yr)	Option 1A Pollutant Loading (lbs/yr)	Option 2A Pollutant Loading (lbs/yr)
ANTIMONY	13,400	12,300	11,200	9,670	966	9,670	10,100
ARSENIC	5,450	5,300	4,900	4,480	448	4,490	4,610
CADMIUM	48,100	28,100	16,700	11,700	1,170	11,800	15,800
CHROMIUM	15,500,000	2,280,000	14,400	8,900	888	9,010	89,100
COPPER	3,510,000	1,100,000	47,300	31,200	3,110	31,500	59,100
LEAD	127,000	119,000	81,200	61,800	6,170	62,100	76,200
NICKEL	2,100,000	958,000	35,600	23,800	2,380	24,100	82,800
SELENIUM	4,010	3,910	3,490	3,280	328	3,290	3,330
SILVER	748,000	37,900	1,430	979	97.9	988	4,590
THALLIUM	5,090	4,970	4,550	3,760	376	3,760	3,810
ZINC	4,880,000	1,560,000	33,500	21,200	2,120	21,500	147,000
TOTAL PRIORITY METALS	**26,900,000**	**6,100,000**	**254,000**	**181,000**	**18,100**	**182,000**	**497,000**
CYANIDE	9,110,000	170,000	37.9	6.01	0.600	6.27	1,310
TOTAL CYANIDE	**9,110,000**	**170,000**	**37.9**	**6.01**	**0.601**	**6.27**	**1,310**
OIL AND GREASE	691,000,000	170,000,000	1,130,000	793,000	79,200	801,000	22,900,000
TOTAL OIL AND GREASE	**691,000,000**	**170,000,000**	**1,130,000**	**793,000**	**79,200**	**801,000**	**22,900,000**
TOTAL SUSPENDED SOLIDS (TSS)	42,000,000	17,700,000	3,240,000	2,130,000	213,000	2,150,000	5,740,000
TOTAL TSS	**42,000,000**	**17,700,000**	**3,240,000**	**2,130,000**	**213,000**	**2,150,000**	**5,740,000**
ALUMINUM	3,570,000	577,000	100,000	65,500	6,540	66,200	255,000

[1]Pollutant loadings for calcium, magnesium, and sodium are not presented in this table because these are typical wastewater treatment chemicals at MP&M sites. Pollutant loadings for acidity, pH, and total alkalinity are not presented because they are used as performance parameters for chemical precipitation and settling systems.

Table 13-2 (Continued)

Summary of Pollutant Loadings by Option for MP&M Phase I Indirect Dischargers[1]

Pollutant	Industry Raw Wastewater Pollutant Loading (lbs/yr)	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Loading (lbs/yr)	Option 2 Pollutant Loading (lbs/yr)	Option 3 Pollutant Loading (lbs/yr)	Option 1A Pollutant Loading (lbs/yr)	Option 2A Pollutant Loading (lbs/yr)
BARIUM	588,000	382,000	43,900	31,900	3,180	32,000	44,400
BORON	1,500,000	1,500,000	1,440,000	1,200,000	120,000	1,210,000	1,230,000
COBALT	56,500	12,500	4,780	3,340	334	3,370	7,270
IRON	8,720,000	2,850,000	126,000	81,600	8,150	82,700	624,000
MANGANESE	1,560,000	382,000	15,500	10,200	1,020	10,300	87,100
MOLYDBENUM	134,000	91,000	68,900	58,300	5,830	58,700	70,600
TIN	73,200	34,800	16,100	12,200	1,220	12,300	23,900
TITANIUM	269,000	20,700	14,000	10,800	1,070	10,800	16,100
VANADIUM	37,400	9,230	8,250	6,470	646	6,500	6,780
TOTAL NONCONVENTIONAL METALS	**16,500,000**	**5,860,000**	**1,840,000**	**1,480,000**	**148,000**	**1,490,000**	**2,360,000**
AMMONIA AS N	2,210,000	538,000	264,000	174,000	17,400	176,000	253,000
CHEMICAL OXYGEN DEMAND (COD)	1,640,000,000	452,000,000	6,500,000	4,200,000	421,000	4,250,000	53,600,000
CHLORIDE	122,000,000	63,800,000	28,500,000	21,400,000	2,140,000	21,600,000	22,700,000
FLUORIDE	4,240,000	1,460,000	211,000	139,000	13,900	140,000	253,000
SULFATE	86,400,000	71,400,000	45,600,000	34,800,000	3,470,000	35,000,000	37,100,000
TOTAL DISSOLVED SOLIDS	1,670,000,000	562,000,000	181,000,000	121,000,000	12,100,000	122,000,000	171,000,000
TOTAL KJELDAHL NITROGEN	4,110,000	1,470,000	625,000	416,000	41,700	420,000	560,000
TOTAL RECOVERABLE PHENOLICS	134,000	78,000	34,800	25,400	2,530	25,600	51,700
TOTAL PHOSPHORUS	25,100,000	13,600,000	229,000	140,000	14,000	142,000	2,060,000
TOTAL OTHER NONCONVENTIONALS	**3,560,000,000**	**1,170,000,000**	**263,000,000**	**183,000,000**	**18,200,000**	**184,000,000**	**288,000,000**

[1]Pollutant loadings for calcium, magnesium, and sodium are not presented in this table because [illegible] MP&M sites. Pollutant loadings for acidity

Table 13-2 (Continued)

Summary of Pollutant Loadings by Option for MP&M Phase I Indirect Dischargers[1]

Pollutant	Industry Raw Wastewater Pollutant Loading (lbs/yr)	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Loading (lbs/yr)	Option 2 Pollutant Loading (lbs/yr)	Option 3 Pollutant Loading (lbs/yr)	Option 1A Pollutant Loading (lbs/yr)	Option 2A Pollutant Loading (lbs/yr)
1,1,1-TRICHLOROETHANE	125,000	41,800	1,190	1,090	109	1,100	3,300
1,1-DICHLOROETHANE	1,910	1,550	660	574	57.3	581	828
4-CHLORO-3-METHYLPHENOL	70,400	48,900	3,630	2,470	247	2,490	8,300
ETHYLBENZENE	4,080	3,650	890	693	69.1	697	2,690
METHYLENE CHLORIDE	4,160,000	131,000	3,570	2,280	228	2,300	8,430
NAPHTHALENE	41,700	21,900	947	679	67.9	684	4,820
2-NITROPHENOL	47,500	25,700	1,480	1,000	100	1,010	6,640
PHENOL	37,700	24,500	5,060	3,800	380	3,820	7,490
BIS(2-ETHYLHEXYL)PHTHALATE	73,300	51,000	8,960	6,580	657	6,610	13,000
DI-N-BUTYL PHTHALATE	45,800	30,200	2,180	1,510	151	1,520	13,800
PHENANTHRENE	33,700	19,100	892	614	61.4	618	4,410
TETRACHLOROETHENE	4,330	4,230	1,870	1,630	163	1,650	3,650
TOLUENE	3,790	2,430	752	593	59.2	599	1,070
TOTAL PRIORITY ORGANICS	**4,650,000**	**406,000**	**32,100**	**23,500**	**2,350**	**23,700**	**78,400**
2-BUTANONE	1,060,000	791,000	6,490	3,910	390	3,970	146,000
2-METHYLNAPHTHALENE	33,900	19,700	1,730	1,170	117	1,180	5,100
2-PROPANONE	176,000	97,000	7,560	5,000	499	5,070	16,400
ALPHA-TERPINEOL	79,700	54,900	2,020	1,340	134	1,350	5,490
BENZOIC ACID	122,000	63,900	2,680	1,800	180	1,810	15,900
BENZYL ALCOHOL	50,100	34,000	4,680	3,250	325	3,270	7,210

[1]Pollutant loadings for calcium, magnesium, and sodium are not presented in this table because these are typical wastewater treatment chemicals at MP&M sites. Pollutant loadings for acidity, pH, and total alkalinity are not presented because they are used as performance parameters for chemical precipitation and settling systems.

Table 13-2 (Continued)

Summary of Pollutant Loadings by Option for MP&M Phase I Indirect Dischargers[1]

Pollutant	Industry Raw Wastewater Pollutant Loading (lbs/yr)	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Loading (lbs/yr)	Option 2 Pollutant Loading (lbs/yr)	Option 3 Pollutant Loading (lbs/yr)	Option 1A Pollutant Loading (lbs/yr)	Option 2A Pollutant Loading (lbs/yr)
HEXANOIC ACID	34,100	21,000	1,620	1,070	107	1,070	4,890
N-DECANE	33,900	19,300	917	627	62.7	631	4,550
N-DOCOSANE	215,000	121,000	915	594	59.3	598	25,100
N-DODECANE	230,000	127,000	6,030	4,010	401	4,040	29,200
N-EICOSANE	80,300	43,400	1,330	909	90.9	916	10,400
N-HEXACOSANE	165,000	93,200	1,440	974	97.4	981	19,800
N-HEXADECANE	101,000	70,600	2,620	1,710	171	1,720	8,560
N-OCTACOSANE	133,000	74,000	1,870	1,240	124	1,250	16,600
N-OCTADECANE	110,000	76,000	1,850	1,220	122	1,230	12,000
N-TETRACOSANE	213,000	119,000	1,920	1,290	129	1,300	25,800
N-TETRADECANE	155,000	113,000	2,540	1,660	166	1,670	7,110
N-TRIACONTANE	63,500	36,300	1,800	1,200	120	1,200	8,480
TOTAL NONCONVENTIONAL ORGANICS	**3,050,000**	**1,970,000**	**50,000**	**33,000**	**3,300**	**33,300**	**368,000**

Source: MP&M Phase I Pollutant Loadings.

Table 13-3

Summary of Pollutant Reductions by Option for MP&M Phase I Direct Dischargers[1]

Class of Pollutant	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Reduction (lbs/yr)	% Reduction from Baseline	Option 2, 1A, and 2A Pollutant Reduction (lbs/yr)	% Reduction from Baseline	Option 3 Pollutant Reduction lbs/yr	% Reduction from Baseline
PRIORITY METALS	557,000	502,000	90	517,000	93	553,000	99
CYANIDE	3,840	3,840	>99	3,840	>99	3,840	>99
OIL AND GREASE	18,200,000	17,900,000	99	18,000,000	99	18,200,000	>99
TOTAL SUSPENDED SOLIDS	2,590,000	1,920,000	74	2,220,000	86	2,550,000	99
NONCONVENTIONAL METALS	634,000	474,000	75	501,000	79	621,000	98
OTHER NONCONVENTIONALS	96,400,000	46,300,000	48	64,900,000	67	93,300,000	97
PRIORITY ORGANICS	8,940	2,990	33	5,080	57	8,550	96
NONCONVENTIONAL ORGANICS	68,600	56,100	82	61,600	90	67,900	99

Source: MP&M Phase I Pollutant Loadings.

[1]Pollutant loadings for calcium, magnesium, and sodium are not presented in this table because these are typical wastewater treatment chemicals at MP&M sites. Pollutant loadings for acidity, pH, and total alkalinity are not presented because they are used as performance parameters for chemical precipitation and settling systems.

Table 13-4

Summary of Pollutant Reductions by Option for MP&M Phase I Indirect Dischargers[1]

Class of Pollutant	Industry Baseline Pollutant Loading (lbs/yr)	Option 1 Pollutant Reduction (lbs/yr)	% Reduction from Baseline	Option 2 Pollutant Reduction (lbs/yr)	% Reduction from Baseline	Option 3 Pollutant Reduction (lbs/yr)	% Reduction from Baseline	Option 1A Pollutant Reduction (lbs/yr)	% Reduction from Baseline	Option 2A Pollutant Reduction (lbs/yr)	% Reduction from Baseline
PRIORITY METALS	6,100,000	5,850,000	96	5,920,000	97	6,080,000	>99	5,920,000	97	5,610,000	92
CYANIDE	170,000	170,000	>99	170,000	>99	170,000	>99	170,000	>99	169,000	99
OIL AND GREASE	170,000,000	169,000,000	99	170,000,000	>99	170,000,000	>99	170,000,000	>99	147,000,000	87
TOTAL SUSPENDED SOLIDS	17,700,000	14,500,000	82	15,600,000	88	17,500,000	99	15,600,000	88	12,000,000	68
NONCONVENTIONAL METALS	5,860,000	4,020,000	69	4,370,000	75	5,710,000	97	4,370,000	75	3,490,000	60
OTHER NONCONVENTIONALS	1,170,000,000	903,000,000	77	983,000,000	84	1,150,000,000	98	982,000,000	84	878,000,000	75
PRIORITY ORGANICS	406,000	374,000	92	383,000	94	404,000	99	383,000	94	328,000	81
NONCONVENTIONAL ORGANICS	1,970,000	1,920,000	97	1,940,000	98	1,970,000	>99	1,940,000	98	1,610,000	81

Source: MP&M Phase I Pollutant Loadings.

[1]Pollutant loadings for calcium, magnesium, and sodium are not presented in this table because these are typical wastewater treatment chemicals at MP&M sites. Pollutant loadings for acidity, pH, and total alkalinity are not presented because these are used as performance parameters for chemical precipitation and settling systems.

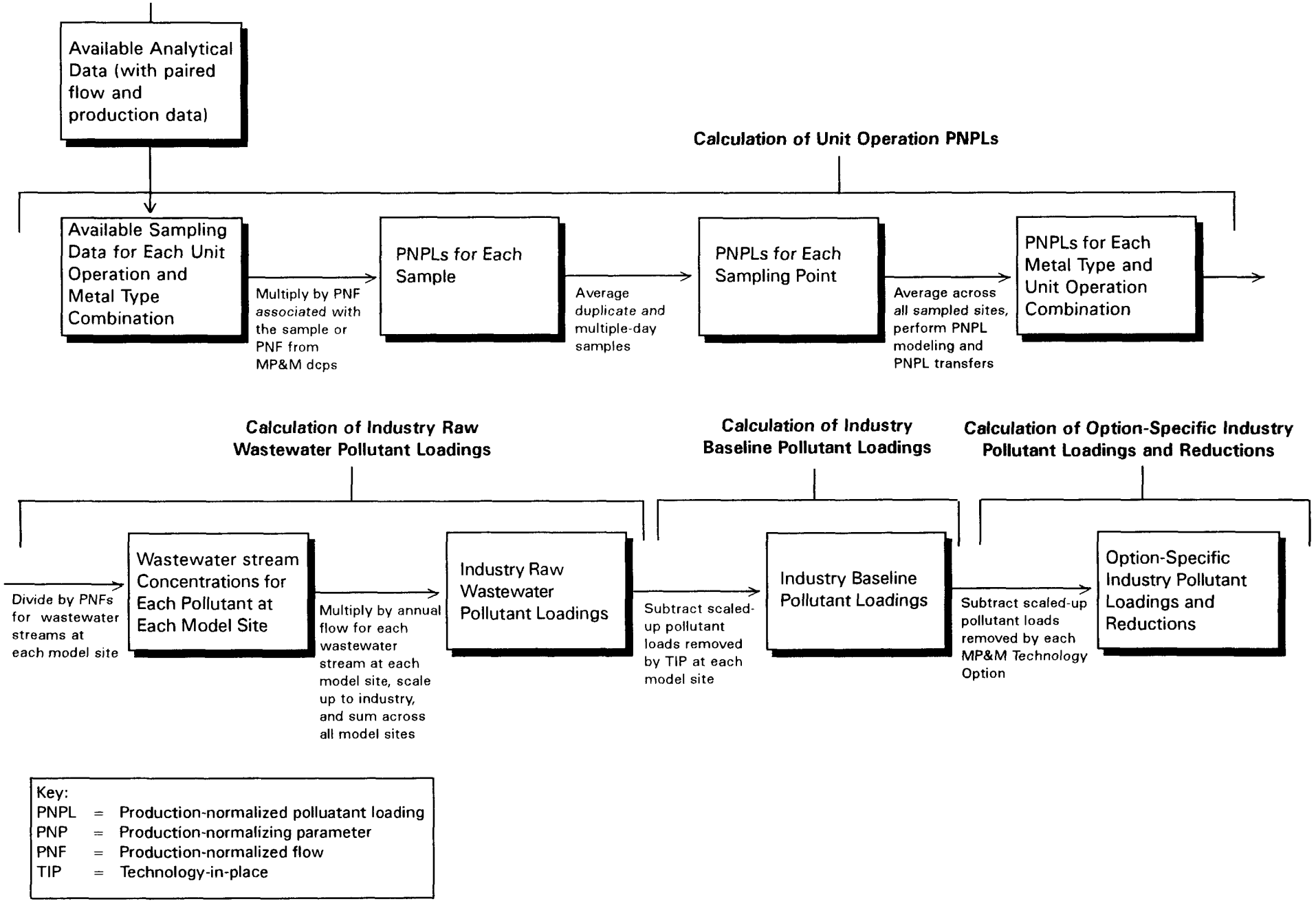


Figure 13-1. Estimation of MP&M Pollutant Loadings and Reductions

14.0 NONWATER QUALITY IMPACTS

Sections 304(b) and 306 of the Act require EPA to consider nonwater quality environmental impacts (including energy requirements) associated with effluent limitations guidelines and standards. In accordance with these requirements, EPA has considered the potential impact of the proposed regulation on energy consumption, air emissions, and solid waste generation. The Agency has also considered the impacts of other ongoing EPA rulemaking efforts on Metal Products and Machinery (MP&M) Phase I sites.

This regulation was reviewed by EPA personnel responsible for nonwater quality environmental programs. To balance environmental impacts across all media and energy use, the Agency has determined that the impacts identified below are justified by the benefits associated with compliance with the limitations and standards.

14.1 Energy Requirements

EPA estimates that compliance with this regulation will result in a net increase in energy consumption at MP&M Phase I sites. Estimates of energy usage by option are presented below.

Option	Energy Required (million kilowatt hrs/yr)
Baseline (1989)	610
Option 1	810
Option 1A	750
Option 2	740
Option 2A	640
Option 3	760

Source: MP&M Phase I Design and Cost Model Output.

Option 1, consisting solely of end-of-pipe treatment, requires the greatest energy usage. Options 1A, 2, and 2A, which include in-process flow control and recycling technologies for some or all sites, require less energy than Option 1. While the flow control and recycling technologies require some energy, net energy consumption is reduced under these options since the lower hydraulic loading reduces the end-of-pipe treatment energy required. The additional end-of-pipe technology included in Option 3 (ion-exchange) increases energy consumption from Option 2 to Option 3.

Approximately 2,805 billion kilowatt hours of electric power were generated in the United States in 1990 (1). Additional energy requirements for Option 1 (which has the greatest energy requirements of the four options) correspond to approximately 0.007% of national requirements. The increase in energy requirements due to the implementation of MP&M technologies will in turn cause an air emissions impact from the electric power generation facilities. The increase in air emissions is expected to be proportional to the increase in energy requirements, or approximately 0.007 percent.

14.2 Air Emissions Impacts

The Agency is developing National Emission Standards for Hazardous Air Pollutants (NESHAPs) under Section 112 of the Clean Air Act (CAA) to address air emissions of the hazardous air pollutants (HAPs) listed in Title III of the CAA Amendments of 1990 (CAAA). Current and upcoming NESHAPs that may potentially affect MP&M sites are listed below.

- Chromium Emissions from Hard and Decorative Chromium Electroplating and Chromium Anodizing Tanks - Proposed December 16, 1993 and promulgated on January 25, 1995.

- Halogenated Solvent Cleaning - Proposed November 29, 1993, and promulgated on December 2, 1994.

- Aerospace Manufacturing - Proposed June 6, 1994, and scheduled for promulgation on July 31, 1995.

- Miscellaneous Metal Parts and Products (Surface Coating), scheduled for promulgation November 15, 2000.

These NESHAPs will define maximum achievable control technology (MACT). Like effluent guidelines, MACT standards are technology-based. The CAAA set maximum control requirements on which MACT can be based for new and existing sources.

The use of chlorinated solvents in the MP&M industry can create a source of hazardous emissions. The Agency believes this regulation will not affect the use of chlorinated solvents in the MP&M industry. This regulation neither requires nor discourages the use of aqueous cleaners in lieu of chlorinated solvents. EPA has recently initiated its Significant New Alternatives Policy (SNAP) program which reviews chlorofluorocarbon (CFC) substitutes stemming from the Montreal Protocol. In this program, EPA reviews available data for CFC substitutes, and assesses the environmental impacts of the substitutes. EPA published a final rulemaking for the SNAP program on March 18, 1994 (59 FR 13044) and plans to publish subsequent notices as determinations are made as to the viability of the substitutes.

EPA is addressing emissions of volatile organic compounds (VOCs) from industrial wastewater through a Control Techniques Guideline (CTG) for industrial wastewater under Section 110 of the CAA (Title I of the 1990 CAAA). The MP&M industry is one of several industries that would be covered by the industrial wastewater CTG. The industrial wastewater CTG will provide guidance to states in recommending reasonably available control technology (RACT) for VOC emissions from industrial wastewater at sites located in areas failing to attain the National Ambient Air Quality Standard for ozone.

The Agency believes that the in-process and end-of-pipe technologies included in the technology options for this regulation do not generate significant air emissions.

14.3 Solid Waste Generation

Solid waste generated at MP&M sites includes hazardous and nonhazardous wastewater treatment sludge as well as waste oil removed in wastewater treatment. EPA estimates that compliance with this regulation will result in a decrease in wastewater treatment sludge and an increase in waste oil generated at MP&M Phase I sites.

EPA estimates that MP&M Phase I sites generated 33 million gallons of wastewater treatment sludge and 8.1 million gallons of waste oil in 1989 from the treatment of wastewater. The amount of wastewater treatment sludge and waste oil expected to be generated in each of the technology options is presented in the table below.

Option	Wastewater Treatment Sludge Generated (gal/yr)	Waste Oil Generated (gal/yr)
Baseline (1989)	33,000,000	8,100,000
Option 1	31,000,000	38,000,000
Option 1A	21,000,000	36,000,000
Option 2	21,000,000	36,000,000
Option 2A	22,000,000	34,000,000
Option 3	21,000,000	36,000,000

Source: MP&M Design and Cost Model Output.

As shown in this table, wastewater treatment sludge generation decreases from baseline to Option 1 (which consists of end-of-pipe treatment without in-process flow control). The net decrease is attributed to the fact that Option 1 includes sludge dewatering, which may result in a significant decrease in sludge generation for sites that have chemical precipitation and sedimentation technologies without sludge dewatering in place

at baseline. Sludge reduction is not expected at sites which already have sludge dewatering in the baseline. An increase of sludge is expected to occur at sites which do not have treatment technology in place but are expected to install treatment under the MP&M options.

The sludge reduction from Option 1 to Options 1A, 2, and 2A is attributed to the water conservation and pollution prevention technologies included in Options 1A, 2, and 2A. EPA expects these technologies to result in sludge reduction for the following reasons:

- In-process metals recovery for electroplating rinses, recycling of coolants, and recycling of paint curtains reduce the mass of metal pollutants in treatment system influent streams, which in turn reduces the amount of sludge generated during metals removal;

- Bath maintenance practices included in Options 1A, 2, and 2A reduce the mass of metal pollutants discharged to treatment, which in turn reduces the amount of sludge generated during metals removal; and

- Water conservation technologies included in Options 1A, 2 and 2A reduces the discharge mass of metals present in the source water to a site (e.g., calcium, sodium), which in turn reduces the amount of sludge generated during metals removal.

EPA does not expect Option 3 to result in additional sludge generation or reduction over Options 1A, 2, and 2A.

Sludges generated at MP&M sites are often determined to be hazardous under the Resource Conservation and Recovery Act (RCRA) as either a listed or characteristic hazardous waste based on the following information:

- If the site performs electroplating operations, and this wastewater is mixed with the other wastewater treated on site, the resulting sludge is a listed hazardous waste F006 (40 CFR 260.11), or

- If the sludge or waste oil from wastewater treatment exceeds the standards for the Toxicity Characteristic Leaching Procedure (i.e. is hazardous), or exhibits other RCRA-defined hazardous characteristics (i.e., reactive, corrosive, or flammable) it is considered a characteristic hazardous waste. (40 CFR 261.24).

Additional federal, state, and local regulations may result in MP&M sludges being classified as hazardous wastes.

EPA is addressing emissions of volatile organic compounds (VOCs) from industrial wastewater through a Control Techniques Guideline (CTG) for industrial wastewater under Section 110 of the CAA (Title I of the 1990 CAAA). The MP&M industry is one of several industries that would be covered by the industrial wastewater CTG. The industrial wastewater CTG will provide guidance to states in recommending reasonably available control technology (RACT) for VOC emissions from industrial wastewater at sites located in areas failing to attain the National Ambient Air Quality Standard for ozone.

The Agency believes that the in-process and end-of-pipe technologies included in the technology options for this regulation do not generate significant air emissions.

14.3 Solid Waste Generation

Solid waste generated at MP&M sites includes hazardous and nonhazardous wastewater treatment sludge as well as waste oil removed in wastewater treatment. EPA estimates that compliance with this regulation will result in a decrease in wastewater treatment sludge and an increase in waste oil generated at MP&M Phase I sites.

EPA estimates that MP&M Phase I sites generated 33 million gallons of wastewater treatment sludge and 8.1 million gallons of waste oil in 1989 from the treatment of wastewater. The amount of wastewater treatment sludge and waste oil expected to be generated in each of the technology options is presented in the table below.

Option	Wastewater Treatment Sludge Generated (gal/yr)	Waste Oil Generated (gal/yr)
Baseline (1989)	33,000,000	8,100,000
Option 1	31,000,000	38,000,000
Option 1A	21,000,000	36,000,000
Option 2	21,000,000	36,000,000
Option 2A	22,000,000	34,000,000
Option 3	21,000,000	36,000,000

Source: MP&M Design and Cost Model Output.

As shown in this table, wastewater treatment sludge generation decreases from baseline to Option 1 (which consists of end-of-pipe treatment without in-process flow control). The net decrease is attributed to the fact that Option 1 includes sludge dewatering, which may result in a significant decrease in sludge generation for sites that have chemical precipitation and sedimentation technologies without sludge dewatering in place

at baseline. Sludge reduction is not expected at sites which already have sludge dewatering in the baseline. An increase of sludge is expected to occur at sites which do not have treatment technology in place but are expected to install treatment under the MP&M options.

The sludge reduction from Option 1 to Options 1A, 2, and 2A is attributed to the water conservation and pollution prevention technologies included in Options 1A, 2, and 2A. EPA expects these technologies to result in sludge reduction for the following reasons:

- In-process metals recovery for electroplating rinses, recycling of coolants, and recycling of paint curtains reduce the mass of metal pollutants in treatment system influent streams, which in turn reduces the amount of sludge generated during metals removal;

- Bath maintenance practices included in Options 1A, 2, and 2A reduce the mass of metal pollutants discharged to treatment, which in turn reduces the amount of sludge generated during metals removal; and

- Water conservation technologies included in Options 1A, 2 and 2A reduces the discharge mass of metals present in the source water to a site (e.g., calcium, sodium), which in turn reduces the amount of sludge generated during metals removal.

EPA does not expect Option 3 to result in additional sludge generation or reduction over Options 1A, 2, and 2A.

Sludges generated at MP&M sites are often determined to be hazardous under the Resource Conservation and Recovery Act (RCRA) as either a listed or characteristic hazardous waste based on the following information:

- If the site performs electroplating operations, and this wastewater is mixed with the other wastewater treated on site, the resulting sludge is a listed hazardous waste F006 (40 CFR 260.11), or

- If the sludge or waste oil from wastewater treatment exceeds the standards for the Toxicity Characteristic Leaching Procedure (i.e. is hazardous), or exhibits other RCRA-defined hazardous characteristics (i.e., reactive, corrosive, or flammable) it is considered a characteristic hazardous waste. (40 CFR 261.24).

Additional federal, state, and local regulations may result in MP&M sludges being classified as hazardous wastes.

Based on information collected during site visits and sampling episodes, the Agency believes that some of the solid waste generated at MP&M sites would not be classified as hazardous. However, for the purpose of compliance cost estimation, the Agency assumed that all solid waste generated as a result of the technology options would be hazardous.

The increase in waste oil generation from baseline to Option 1 is attributed to removal of oil from MP&M wastewaters prior to discharge to POTWs or surface waters. Option 1 includes oil/water separation to remove oil from oil/bearing wastewaters. The waste oil is usually either recycled on site or off site, or contract hauled for disposal as either a hazardous or nonhazardous waste. The increase of waste oil generation reflects a transfer of oil from the wastewater to a more concentrated waste oil, and does not reflect an increase in overall oil generation at MP&M Phase I sites. For the purpose of compliance cost estimation, EPA assumed that all waste oil was contract hauled for disposal; however, EPA expects that some of the waste oil can be recycled either on site or off site.

The decrease in waste oil generation from Option 1 to Options 1A, 2, and 2A is attributed to the 80% reduction of coolant discharge using the recycling technology included in Options 1A, 2, and 2A. This system recovers and recycles oil/bearing machining coolants at the source, reducing the generation of spent coolant. Coolant recycling saves approximately 8.7 million gallons of water-soluble coolant (assumed to be 5% oil in water) at Option 1A, 9.8 million gallons at Option 2 and 8.7 million gallons at Option 2A. EPA does not expect Option 3 to result in additional waste oil generation or reduction over Option 2.

The in-process technologies of ion-exchange and electrolytic recovery provide the pollution prevention benefits of reclaiming on estimated 1.7 million pounds of metal annually at Options 1A, 2, and 2A. This reuse reduces the solid waste generation at the end-of-pipe for the treatment of wastewater from operations using these technologies.

14.4 References

1. Steam, Its Generation and Uses, 4th Ed. (Babcock & Wilcox, Ed Stutz & Kitto, Barberton, Ohio, 1992).

15.0 EFFLUENT LIMITATIONS AND STANDARDS

This section presents the proposed Metal Products and Machinery (MP&M) Phase I effluent limitations guidelines and standards for each regulatory level of control required by the Clean Water Act. These levels of control are discussed in Section 2.0. The proposed limitations and standards are based on the technologies included in Option 2A, as discussed in Section 10.0. The proposed MP&M effluent limitations guidelines and standards consist of mass-based limitations for all direct dischargers, for all new indirect dischargers, and for existing indirect dischargers with greater than or equal to one million gallons per year of process wastewater discharge. Existing indirect dischargers with less than one million gallons per year of process wastewater discharge are exempt from the proposed regulation. Direct dischargers are sites that discharge wastewater to a surface water. Indirect dischargers are sites that discharge wastewater to a publicly-owned treatment works (POTW).

Section 15.1 presents a discussion of the technology option used as a basis for the effluent limitations and standards. Section 15.2 presents the numerical concentration-based limitations and standards upon which the mass-based standards should be based. Sections 15.3 through 15.6 discuss each of the regulatory levels of control.

15.1 Technology Option

The proposed limitations and standards are based on the technologies included in Option 2A. The technology basis for Option 2A is end-of-pipe treatment using chemical precipitation and sedimentation, used in conjunction with flow reduction and pollution prevention technologies. Option 2A also includes the following preliminary treatment steps: oil/water separation through chemical emulsion breaking and either skimming or coalescing; cyanide destruction through alkaline chlorination; chemical reduction of hexavalent chromium; chemical reduction of chelated metals; and contract hauling of organic solvent-bearing wastewaters. These preliminary treatment technologies are applied as necessary based on wastewater characteristics.

Option 2A includes the following in-process pollution prevention and water conservation technologies:

- Flow reduction using flow restrictors, conductivity meters, and/or timed rinses, for all flowing rinses, plus countercurrent cascade rinsing for all flowing rinses;
- Flow reduction using bath maintenance for all other process water-discharging operations;
- Centrifugation and 100% recycling of painting water curtains;

- Centrifugation and pasteurization to extend the life of water-soluble machining coolants, reducing discharge volume by 80 percent; and

- In-process metals recovery with ion exchange followed by electrolytic recovery of the cation regenerants for selected electroplating rinses. This includes first-stage drag-out rinsing with electrolytic metal recovery.

The technologies included in Option 2A are discussed in detail in Section 10.0.

The effluent limitations and standards are based on the technologies discussed above. However, these technologies are not mandated under effluent guidelines and pretreatment standards. Sites regulated by this rule are required to meet the discharge limitations but are not required to use the technologies discussed above.

15.2 Numerical Limitations and Standards

For all direct dischargers, new indirect dischargers, and existing indirect dischargers discharging greater than or equal to one million gallons of process wastewater per year, EPA will require permit writers to develop mass-based limitations based on the proposed concentration-based limitations. Existing indirect dischargers discharging less than one million gallons of process wastewater per year are exempt from the proposed regulation. Table 15-1 presents the proposed concentration-based limitations. These limitations were developed from the MP&M sampling data using the data editing and statistical procedures discussed in Section 11.0.

EPA developed the proposed MP&M Phase I effluent limitations guidelines and standards as concentration-based limitations which must be converted to mass-based limitations. Mass-based limitations should be developed using the MP&M flow guidance presented in Section 16.0. If mass-based limitations have not been developed as required, the source shall achieve discharges not exceeding the concentration limitations listed in the proposed regulation.

To fully implement the mass-based permits, it is important for Control Authorities to issue permits in a timely manner. Dischargers are required under the General Pretreatment Regulations (40 CFR 403) to provide, among other things, Baseline Monitoring Reports. The Agency expects Control Authorities to place a priority on issuing needed mass-based permits, and those permits should be issued within one year after the Baseline Monitoring Report deadline. Control Authorities that do not meet these permitting timelines may not be in compliance with their pretreatment programs under 40 CFR 123.45.

EPA recommends that, for sites with pollution prevention and water conservation technologies in place that are equivalent to those included in Option 2A, permit writers

use historical flow as a basis for converting the proposed concentration-based limitations to mass-based. For sites without these types of technologies in place, EPA recommends that permit writers do not use historical flow, but use other tools listed in Section 16.0 (e.g., measuring production through unit operations, measuring the concentration of total dissolved solids (TDS) in rinse waters) to convert the proposed concentration-based limitations to mass-based. This approach encourages sites to implement good water use practices and investigate and install pollution prevention and water conservation technologies.

15.3 Best Practicable Control Technology Currently Available (BPT)

The proposed MP&M Phase I BPT effluent limitations guidelines are based on the average of the best existing performance by MP&M Phase I sites of various sizes, ages, and unit processes for control of pollutants. The BPT limitations apply to the estimated 1,895 MP&M Phase I sites that discharge process wastewater to a surface water. The following table presents the estimated amount of pollutants discharged annually from direct dischargers.

Annual Pollutant Discharges by Direct Dischargers

Pollutant Parameter	Estimated Mass of Pollutant Discharged Annually (thousands of pounds)
Priority Metal Pollutants	557
Nonconventional Metal Pollutants (a)	634
Priority Organic Pollutants	8.94
Nonconventional Organic Pollutants	68.6
Cyanide	3.84
Oil and Grease	18,200
Total Suspended Solids	2,590

Source: EPA MP&M pollutant loading estimates
a - Nonconventional Metal Pollutants do not include calcium, magnesium, and sodium, which are used as treatment chemicals at MP&M sites.

In establishing the proposed BPT effluent limitations guidelines, EPA considered the category-wide cost of achieving effluent reductions in relation to the effluent reduction benefits. EPA estimates that implementation of Option 2A technologies will require, for direct dischargers, a capital cost of $63.0 million (1994 $), which will require an annualized cost of $18 million. As a result of this regulation, EPA estimates that 18 sites may close with an accompanying job loss of 158 full-time employees. EPA estimates that

compliance activities may generate annual labor requirements which could more than offset these job losses. The proposed BPT limitations will remove annually an estimated 20 million pounds of conventional pollutants (total suspended solids and oil and grease), 1 million pounds of metal pollutants and cyanide, and 66,700 pounds of organic pollutants. The following table presents the estimated amount of pollutant discharges after implementation of BPT.

Estimated Annual Pollutant Discharges by Direct Dischargers after Implementing BPT Technologies

Pollutant Parameter	Estimated Mass of Pollutant Discharged Annually (thousands of pounds)
Priority Metal Pollutants	40.5
Nonconventional Metal Pollutants (a)	133
Priority Organic Pollutants	3.86
Nonconventional Organic Pollutants	7.02
Cyanide	<0.001
Oil and Grease	153
Total Suspended Solids	364

Source: EPA MP&M pollutant loading estimates
a - Nonconventional Metal Pollutants do not include calcium, magnesium, and sodium, which are used as treatment chemicals at MP&M sites.

The proposed BPT limitations apply to all of the pollutants listed in Table 15-1. These include priority metal pollutants, conventional pollutants, and nonconventional metal pollutants. EPA developed the proposed BPT effluent limitations guidelines as concentration-based limitations which must be converted to mass-based limitations. Mass-based limitations should be developed using the MP&M flow guidance presented in Section 16.0. If mass-based limitations have not been developed as required, the source shall achieve discharges not exceeding the concentration limitations listed in the regulation.

EPA identified 24 metal types processed at MP&M Phase I sites. Because EPA did not have sufficient data to set limitations for all of these metal types, EPA is regulating aluminum and iron as indicator metals for removal of nonregulated metals that may be processed at MP&M sites. Aluminum is most effectively removed in chemical precipitation and sedimentation systems at a pH between 7.5 and 8 standard units, while iron is most effectively removed at a pH of approximately 10.5 standard units. Most of the metals present in MP&M wastewaters are effectively removed in this pH range.

Therefore, removal of aluminum and iron will indicate effective removal of other metal types.

EPA is using oil and grease as an indicator for monitoring for organic pollutants that have the potential to be present in MP&M Phase I wastewaters. EPA is using oil and grease as an indicator since most of the organic pollutants detected in MP&M wastewaters during the MP&M Phase I sampling program are more soluble in oil than in water, and as such would partition to the oil layer. Thus, removal of oil and grease will result in significant removal of these pollutants. Data for oil/water separation systems collected during the MP&M Phase I sampling program show removals between 63 and 90 percent for organic pollutants across the oil/water separation systems. These data support the conclusion that the organic pollutants will partition to the oil layer. In addition, most of the organic pollutants detected in MP&M wastewaters are insoluble in water, further supporting that these pollutants will partition to the oil layer.

EPA considered establishing limitations for total toxic organics (TTO), which would reflect the sum of concentrations achieved for several specific organic pollutants identified during the MP&M sampling program. However, because of the diversity in the types of organic-bearing solutions (cleaners, coolants, paints, etc.) used in the MP&M industry, as well as the current industry trends in identifying substitutes for organic solvent degreasing, EPA did not have sufficient analytical data to identify and regulate all organic pollutants in use at MP&M sites. Therefore, EPA did not use TTO as an approach to controlling organic pollutant discharges.

EPA also considered establishing limitations for lead, since lead is known to have several adverse human health effects. Although lead was analyzed for in nearly all samples collected during the development of the MP&M Phase I effluent guidelines, lead was rarely found at concentrations above 0.1 milligrams per liter in raw wastewater prior to treatment. The majority of lead data were nondetects or detects at low concentrations. Therefore, EPA has not proposed a lead limitation.

15.4 Best Conventional Pollutant Control Technology (BCT)

BCT limitations control discharges of conventional pollutants from existing direct dischargers. BCT is not an additional limitation, but replaces BAT for the control of conventional pollutants. EPA evaluates the reasonableness of BCT candidate technologies (those that are technologically feasible) by applying a two-part cost test:

(1) The POTW test; and
(2) The industry cost-effectiveness test.

In the POTW test, EPA calculates the cost per pound of conventional pollutant removed by industrial dischargers in upgrading from BPT to a BCT candidate technology, and then compares this cost to the cost per pound of conventional pollutant removed in

upgrading POTWs from secondary treatment. The upgrade cost to industry must be less than the POTW benchmark of $0.25 per pound (in 1976 dollars).

In the industry cost-effectiveness test, the ratio of the incremental BPT to BCT cost divided by the BPT cost for the industry must be less than 1.29 (i.e., the cost increase must be less than 29 percent).

EPA applied the BCT cost test to the use of multimedia filtration technology as a means to reduce loadings of total suspended solids (TSS). The MP&M Phase I sites were divided into three flow categories for this analysis: low flow (less than 10,000 gallons per year); medium flow (between 10,000 gallons per year and 1,000,000 gallons per year); and high flow (greater than 1,000,000 gallons per year). For each of these three flow categories, a representative site was selected for which EPA had estimated the costs of installing the BPT technologies.

EPA evaluated the costs of installing a multimedia filter to remove an estimated additional 45 percent of the TSS discharged after chemical precipitation and sedimentation. This estimated removal reflects the reduced TSS concentrations achieved when filters are used at MP&M Phase I sites. The cost per pound removed in the high flow case was $28 per pound of TSS (in 1976 dollars); the cost per pound removed in the medium flow case was $131 per pound of TSS (1976 dollars); and, the cost per pound removed in the low flow case was $813 per pound of TSS (1976 dollars). All of these cases exceed the $0.25 per pound (in 1976 dollars) POTW cost test value. Because these costs exceed the POTW benchmark, the first part of the cost test fails; therefore, the second part of the test was not performed. Because multimedia filtration does not pass the cost test, BCT limitations for MP&M Phase I are proposed to be set equal to BPT limitations.

15.5 Best Available Technology Economically Achievable (BAT)

EPA developed the proposed MP&M Phase I BAT effluent limitations guidelines for five priority pollutant metals, cyanide, and two nonconventional pollutant metals. EPA also developed proposed BAT limitations for oil and grease as an indicator for the following organic pollutants: 2-methylnaphthalene, 2-propanone, N-octadecane, and N-tetradecane. Oil and grease is also used as an indicator for additional organic pollutants that may be present in MP&M Phase I wastewaters. The proposed BAT limitations for these pollutants are the same as those for BPT. The pollutant removals, costs, and economic impacts of BAT are expected to be the same as for BPT.

Like BPT, EPA developed the proposed BAT effluent limitations guidelines as concentration-based limitations which must be converted to mass-based limitations. The proposed concentration-based limitations are presented in Table 15-1. Mass-based limitations should be developed using the MP&M flow guidance presented in Section

16.0. If mass-based limitations have not been developed as required, the source shall achieve discharges not exceeding the concentration limitations listed in the regulation.

15.6 Pretreatment Standards for Existing Sources (PSES)

The proposed MP&M Phase I PSES are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of publicly owned treatment works (POTWs). The proposed MP&M Phase I PSES apply to existing indirect dischargers with annual process wastewater discharge rates greater than or equal to one million gallons. Existing indirect dischargers with an annual process wastewater discharge of less than one million gallons are exempt from the proposed regulation. EPA estimates that 1,998 MP&M Phase I sites will be regulated under PSES, while 6,708 will be exempt. Sites regulated under PSES discharge approximately 18 billion gallons of process wastewater per year. The following table presents the estimated amount of pollutant discharges from sites regulated under PSES.

Annual Pollutant Discharges by Sites Regulated Under PSES

Pollutant Parameter	Estimated Mass of Pollutant Discharged Annually (thousands of pounds)
Priority Metal Pollutants	5,780
Nonconventional Metal Pollutants (a)	4,910
Priority Organic Pollutants	351
Nonconventional Organic Pollutants	1,640
Cyanide	169

Source: EPA MP&M pollutant loading estimates
a - Nonconventional Metal Pollutants do not include calcium, magnesium, and sodium, which are used as treatment chemicals at MP&M sites.

EPA estimates that the exempt sites discharge approximately 0.74 billion gallons of process wastewater per year. The following table presents the estimated amount of pollutant discharges from the sites exempted from PSES.

Annual Pollutant Discharges by Sites Exempt From PSES

Pollutant Parameter	Estimated Mass of Pollutant Discharged Annually (thousands of pounds)
Priority Metal Pollutants	325
Nonconventional Metal Pollutants (a)	947
Priority Organic Pollutants	55.7
Nonconventional Organic Pollutants	336
Cyanide	1.30

Source: EPA MP&M pollutant loading estimates
a - Nonconventional Metal Pollutants do not include calcium, magnesium, and sodium, which are used as treatment chemicals at MP&M sites.

The MP&M Phase I sites annually discharging less than one million gallons of process wastewater represent 77% of the number of Phase I indirect dischargers, but only generate 4% of the wastewater and 10% of the baseline pollutant loading from indirect dischargers. Therefore, EPA believes that the costs of regulating existing indirect discharging MP&M Phase I sites annually discharging less than one million gallons of process wastewater do not justify the potential pollutant reduction achieved by regulation.

As discussed in Section 8.0, EPA determined which pollutants to regulate in PSES on the basis of whether or not the pollutants pass through, interfere with, or are incompatible with the operation of POTWs (including interference with sludge practices). The Agency evaluated pollutant pass-through by comparing the percentage of pollutant removed by well-operated POTWs with secondary treatment with the percentage removed by BAT technology applied by direct dischargers. Based on this analysis, EPA developed PSES for five priority pollutant metals, cyanide, and two nonconventional pollutant metals. EPA also developed PSES for oil and grease as an indicator for monitoring for organic pollutants that have the potential to be present in MP&M wastewaters. The proposed PSES for these pollutants are listed in Table 15-1.

EPA estimates that PSES will require a capital cost of $351 million (1994 $), which will require an annualized cost of $185 million. As a result of this regulation, EPA estimates that 7 sites may close with an accompanying job loss of 540 full-time employees. EPA estimates that compliance activities may generate annual labor requirements which could more than offset these losses. The PSES limitations will remove annually an estimated 9 million pounds of metal pollutants and cyanide, and 2 million pounds of organic pollutants. The following table presents the estimated amount of pollutant discharges after implementation of PSES.

Estimated Annual Pollutant Discharges by Indirect Dischargers after Implementing PSES

Pollutant Parameter	Estimated Mass of Pollutant Discharged Annually (thousands of pounds)
Priority Metal Pollutants	497
Nonconventional Metal Pollutants (a)	2,360
Priority Organic Pollutants	78.4
Nonconventional Organic Pollutants	368
Cyanide	1.31

Source: EPA MP&M pollutant loading estimates
a - Nonconventional Metal Pollutants do not include calcium, magnesium, and sodium, which are used as treatment chemicals at MP&M sites.

15.7 New Source Performance Standards (NSPS) and Pretreatment Standards for New Sources (PSNS)

NSPS and PSES are established to control the discharge of pollutants from new sources. The same technologies discussed for BAT and PSES are available as the basis for NSPS and PSNS. Option 2A was the selected option for BAT and for large flow PSES. The only higher technology option identified by EPA was Option 3, which includes end-of-pipe ion exchange with ninety percent process water reuse. Since new sites have the potential to install this technology more cost effectively than existing sources, Option 3 was considered for NSPS and PSNS. EPA did not select Option 3 technology as the basis for NSPS and PSNS because the costs do not justify the removals achieved. Therefore, NSPS and PSNS for MP&M Phase I are based on Option 2A technologies identified above.

EPA developed the proposed NSPS and PSNS as concentration-based limitations which must be converted to mass-based limitations for all new sources. The proposed concentration-based limitations are presented in Table 15-1. Mass-based limitations should be developed using the MP&M flow guidance presented in Section 16.0. If mass-based limitations have not been developed as required, the source shall achieve discharges not exceeding the concentration limitations listed in the regulation.

Table 15-1

MP&M Phase I Concentration-Based Limitations

Pollutant or Pollutant Parameter	Maximum for Any One Day (milligrams/liter)	Monthly Average - Shall Not Exceed (milligrams/liter)
Aluminum (T)(1)	1.4	1.0
Cadmium (T)(1)	0.7	0.3
Chromium (T)(1)	0.3	0.2
Copper (T)(1)	1.3	0.6
Iron (T)(1)	2.4	1.3
Nickel (T)(1)	1.1	0.5
Zinc (T)(1)	0.8	0.4
Cyanide (T)(1)	0.03	0.02
Oil and Grease (2)	35	17
Total Suspended Solids (3)	73	36
pH	(4)	(4)

Source: MP&M Technology Effectiveness Concentration (TEC) database.

(1) These concentrations apply to BPT, BAT, PSES, NSPS, and PSNS.
(2) These concentrations apply to all levels of regulatory control. Oil and grease is proposed as an indicator for organic pollutants.
(3) These concentrations apply to BPT, BCT, and NSPS.
(4) Within 6.0 to 9.0 standard units. This applies to BPT, BCT, and NSPS
(T) Total (e.g., total aluminum, total cadmium, total cyanide).

16.0 PERMITTING GUIDANCE

This section provides guidance to permit writers in implementing the Metal Products and Machinery (MP&M) Phase I effluent guidelines. The MP&M Phase I category covers sites that generate wastewater while processing metal parts, metal products, and machinery, and includes operations performed during manufacturing, assembly, rebuilding, repair, and maintenance. Phase I covers sites processing products in any of the following seven industrial sectors: aerospace, aircraft, electronic equipment, hardware, mobile industrial equipment, ordnance, and stationary industrial equipment. A site is considered to be included in a sector if any of the products processed at the site are used within that sector. Section 3.0 presents examples of the MP&M Phase I applicability.

As discussed in Section 15.0, the MP&M Phase I effluent limitations guidelines and standards consist of mass-based limitations for all direct dischargers, for all new indirect dischargers, and for existing indirect dischargers with greater than or equal to one million gallons per year of process wastewater discharge. Existing indirect dischargers with less than one million gallons process wastewater discharge are exempt from this regulation. Direct dischargers are sites that discharge wastewater to a surface water. Indirect dischargers are sites that discharge wastewater to a publicly-owned treatment works (POTW). EPA requires permit writers to develop mass-based limitations based on the proposed concentration-based limitations. Concentration-based limitations should be converted to mass-based limitations using the flow guidance provided in this section. Table 15-1 presents the concentration-based limitations.

The MP&M Phase I effluent limitations are based on a technology train consisting of in-process pollution prevention and flow reduction technologies followed by end-of-pipe treatment. The in-process technologies include flow reduction for all unit operations; countercurrent cascade rinsing for flowing rinses; ion exchange and electrolytic recovery for certain electroplating rinses; at-the-source machine coolant recycling; and at-the-source paint curtain recycling. The end-of-pipe treatment consists of chromium reduction, cyanide destruction, oil/water separation, chelated metals treatment, and chemical precipitation and settling. Section 10.0 presents a detailed discussion of this technology train. **Sites do not have to install this technology train to comply with the MP&M effluent guidelines; this train was used solely as the basis for developing the limits. Sites can use any technology as long as the limits are achieved.**

Section 16.1 provides basic guidance on implementing the MP&M Phase I effluent guidelines. Sections 16.2 through 16.5 present flow guidance for the following major wastewater-generating unit operations performed at MP&M sites, respectively:

- Surface treatment rinsing operations (e.g., acid and alkaline treatment rinsing, electroplating rinsing, anodizing rinsing, and chemical conversion coating rinsing);
- Machining operations;
- Painting operations; and
- Cleaning operations.

These operations generate approximately 75% of the wastewater generated by MP&M Phase I sites. EPA estimates that 9,075 of the estimated 10,601 MP&M Phase I wastewater-discharging sites perform one or more of these operations. EPA also estimates that most of the remaining 1,526 sites are indirect discharges with less than one million gallons of annual process wastewater discharge, and will be exempt from the regulation. For sites not addressed by this flow guidance, EPA recommends that permit writers use best professional judgment (BPJ) to develop the flow basis for converting the concentration-based limits to mass-based limits.

16.1 Implementing the MP&M Phase I Effluent Guidelines

For all direct dischargers, all new indirect dischargers, and existing indirect dischargers with one million gallons or greater of annual process wastewater discharge, EPA requires permit writers to develop mass-based limitations based on the proposed concentration-based limitations. Existing indirect dischargers with less than one million gallons of annual process wastewater discharge are exempt from this regulation. The flow guidance provided in this document is being provided by EPA to assist permit writers in developing mass-based limits. Figure 16-1 presents a flow chart that summarizes the MP&M Phase I permitting process.

Indirect dischargers are sites discharging process wastewater to a publicly owned treatment works (POTW); direct dischargers are sites discharging process wastewater to a surface water. Process wastewater is defined as any water that, during manufacturing, rebuilding, or maintenance, comes into direct contact with or results from the production or use of any raw materials, intermediate product, finished product, by-product, or waste product. Noncontact cooling water is not considered a process wastewater.

16.1.1 Assessment of Water Use Practices

Permit writers can use the site's historical flow, unit operation-specific production-normalized flows (flow per unit of production), or other tools available to the permit writer to develop a flow basis to convert the concentration-based limitations to mass-based limitations. The Agency recommends that permit writers use historical data only when a site has demonstrated pollution prevention and water conservation practices in place (e.g., on-demand countercurrent cascade rinses, in-process metal recovery, recycling of machining coolants) for unit operations contributing the majority of the flow from the site. Examples of common pollution prevention and water conservation practices applicable to the major wastewater-generating MP&M operations are summarized in Sections 16.2 through 16.5. Additional examples are presented in Section 9.0. Sections 16.2 through 16.5 also provide guidance for assessing the performance of these practices at MP&M Phase I sites. Unit operations typically contributing the majority of the flow from a site are: cleaning solutions and rinses (e.g., alkaline treatment solutions and rinses, acid treatment solutions and rinses); surface finishing rinses (e.g., electroplating rinses, anodizing rinses, chemical conversion coating rinses); machining operations; and painting operations.

16.1.2 Use of Historical Flow in Developing Mass-Based Limitations

For a site with pollution prevention and water conservation practices in place, the Agency recommends that the permit writer use the site's historical flow rate to convert the concentration-based limitations to mass-based limitations. In this case, the permit writer would multiply the site's historical process wastewater discharge flow rate by the concentration-based limitations to calculate mass-based limitations. Estimation of a site's historical process wastewater discharge flow rate is discussed below. Linking the use of historical flow rate data to pollution prevention and water conservation practices reduces the opportunity for dilution to achieve concentration limitations. This approach also encourages sites to evaluate existing and potential pollution prevention and water conservation opportunities.

Historical flow should be calculated as a reasonable estimate of the actual long-term discharge flow rate from a site. For example, the normal daily average process wastewater flow rate during a representative period of time (e.g., one to three years), could be considered a historical flow rate. These average flows could be based on a single year's data; however, if available, multiple years' data are preferable to obtain a representation of annual average flow. Guidance for determining appropriate process wastewater flow rate is presented in several documents published by the EPA Office of Wastewater Enforcement and Compliance, Washington, DC: "Guidance Manual for the Use of Production-Based Pretreatment Standards and the Combined Wastestream Formula," 1985 (NTIS Order No. PB92-114438) and "Training Manual for NPDES Permit Writers," 1993 (EPA 833-B-93-003).

16.1.3 Use of Flow Guidance in Developing Mass-Based Limitations

When sites do not have pollution prevention and water conservation practices in place, the Agency recommends that the permit writer use means other than historical flow for setting the flow basis for the mass-based limitations. The MP&M Phase I flow guidance, including discussions of flow trends and unit operation-specific production-normalized flow rates, is a recommended tool for converting concentration-based limitations into mass-based limitations. This flow guidance is discussed below.

The basis for the MP&M Phase I flow guidance is the production-normalized flow (PNF) for each unit operation. The PNF represents the amount of wastewater discharged from a unit operation per unit of production, as discussed in Section 5.0. Table 16-1 presents descriptive statistics for PNFs obtained from the MP&M data collection portfolios (DCPs). EPA mailed DCPs to over 1,000 MP&M Phase I sites. For most unit operations, the PNFs are based on surface area as the production-normalizing parameter. For six operations (abrasive jet machining, electrical discharge machining, grinding, machining, plasma arc machining, and thermal cutting), the mass of metal removed is the production-normalizing parameter.

Table 16-1 presents the following information for each of the MP&M unit operations:

- Total occurrences in DCP data (the presence of the unit operation was reported, but flow and production data may not have been available to calculate PNFs);
- Number of occurrences for which flow and production data were available to calculate PNFs;
- Minimum PNF reported;
- Maximum PNF reported;
- Median PNF reported;
- Mean PNF reported;
- Upper and lower quartile PNF reported; and
- Tenth and ninetieth percentile PNF reported.

The sites that provided the raw data from which the statistics in Table 16-1 were derived, have implemented pollution prevention and water conservation practices to varying degrees. Some sites exhibited poor water use practices, while other sites effectively

implemented one or more pollution prevention or water conservation practices. As a result, the statistical data in Table 16-1 show a wide variation in production-normalized flow. In some cases, the PNFs vary by several orders of magnitude or more. These results are not surprising, given the drastic effects of pollution prevention and water conservation practices on reducing flow. For example, implementing one practice such as converting a single stage overflow rinse to a three stage countercurrent rinse can reduce water use by a factor of 500 or more. Differences in manufactured parts or processing requirements may also affect PNFs. Some of these production related differences are discussed in Sections 16.2 through 16.5.

For sites that do not have pollution prevention and water conservation practices in place, the permitting authority can use the PNFs in Table 16-1, in conjunction with the appropriate production data for each unit operation at the site, to develop permit flow rates for each unit operation. For example, the permitting authority could multiply the quantity of production through each unit operation by an appropriate PNF for the operation to calculate a permit flow for each operation. Then, the permit flows for each operation could be summed to calculate a permit total flow for the site. The permit total flow would be multiplied by the concentration limitations to calculate mass-based limitations for the site.

When using a PNF for implementation, the permitting authority can select an appropriate PNF from Table 16-1 for each unit operation on site. The Agency recognizes that different part configurations and processing requirements may result in differing water use requirements, even for multiple occurrences of the same operation at a site. For example, a site manufacturing aerospace components may require a higher PNF for rinsing after electroplating internal electronic components than for rinsing after electroplating outer casings. Because of this diversity, while encouraging the use of lower PNFs, the Agency has given the permit writer the flexibility to assess the water use requirements for each site and use appropriate PNFs for the site.

While variations in water flow per unit of production result from variations in the part configurations and processing requirements, on-site observations indicate that they are more frequently the result of imprecise or inadequate control of water use. The permitting authority should be aware of additional factors influencing PNF, and the impact of these factors on the appropriate PNF for an operation at a site. Additional guidance on the factors affecting PNFs and the determination of appropriate PNFs are provided for the following major MP&M Phase I wastewater-generating unit operations in Sections 16.2 through 16.5, respectively:

- Surface treatment rinsing operations (e.g., acid and alkaline treatment rinsing, electroplating rinsing, anodizing rinsing, and chemical conversion coating rinsing);

- Machining operations;

- Painting operations; and
- Cleaning operations.

These operations generate approximately 75% of the wastewater generated by MP&M Phase I sites. EPA estimates that 9,075 of the estimated 10,601 MP&M Phase I wastewater-discharging sites perform one or more of these operations. For sites not addressed by this flow guidance, EPA recommends that permit writers use best professional judgment (BPJ) to develop mass-based limitations.

One approach for developing mass-based limitations is to use as a starting point the 25th percentile PNF (i.e., the PNF value at which 25 percent of the sites were discharging less water per unit of production) for the operations generating most of the process wastewater on site. For sites that, due to process considerations, are unable to achieve the 25th percentile PNF, the permit writer should use the median PNF as a starting point.

16.2 Flow Guidance for Surface Treatment Rinsing Operations

This section provides flow guidance for surface treatment rinses, which are the primary sources of MP&M Phase I process wastewater. Surface treatment rinses include those following acid and alkaline treatment, anodizing, electroplating, electroless plating, and chemical conversion coating. Rinsing is performed to dilute and remove the chemical film of drag-out remaining on parts and racks after processing in a chemical bath. By removing drag-out from the surface of the part, rinsing contributes to the quality of the process and prevents the contamination of subsequent process baths. Available data show that rinse water use rates are a function of production when measured in terms of the surface area of parts processed and water use/conservation practices present at the site.

Section 16.2.1 provides background information to identify pollution prevention and water conservation practices applicable to surface treatment rinses, and evaluation criteria to assess if a particular site has properly implemented these practices. Section 16.2.2 presents guidance for selecting the appropriate flow rate for use in calculating mass-based standards for sites that do not have pollution prevention and water conservation practices in place. The guidance is based on DCP data and information on various factors that impact rinse water requirements such as drag-out rates and the required cleanliness or quality of rinse water.

16.2.1 Identifying Sites With Pollution Prevention and Water Conservation Practices

As discussed in Section 16.1, the Agency recommends that permit writers use historical flow data to calculate mass-based limitations for sites that have implemented pollution

prevention and water conservation practices. This section provides background information and guidance that can be used by the permit writer to determine if a site has implemented pollution prevention and water conservation practices. If the site has implemented pollution prevention and water conservation practices, the permit writer could multiply the site's historical process wastewater discharge flow rate by the concentration-based limitations to calculate mass-based limitations. This will eliminate the requirement of identifying alternate methods to develop mass-based limitations, including tracking production rates through unit operations.

Many MP&M Phase I sites employ some form of water conservation. A portion of sites implement numerous water conservation methods and technologies in combination that result in very low rinse water discharge rates and in some cases eliminate the discharge of rinse water from individual processes. Water conservation is applicable to every flowing rinse; however, process-related factors and site-specific conditions may restrict the use of certain methods. This section identifies pollution prevention and water conservation practices and technologies applicable to surface finishing rinses, presents example configurations of these practices and technologies at MP&M sites, and provides guidance on how to evaluate a site's water use practices.

Pollution Prevention and Water Conservation Practices and Technologies

The Agency has identified four categories of pollution prevention and water conservation practices and technologies that can be applied to reduce rinse water use: drag-out reduction and/or drag-out recovery methods; improved rinse tank design and innovative rinsing configurations; rinse water use control devices; and, metal recovery and rinse water reuse technologies. In addition to conserving water use, some of these methods (especially those that affect drag-out and recover chemicals) also conserve raw materials and reduce treatment reagent requirements and sludge production. Within each of these categories are several specific practices and technologies. Table 16-2 presents several examples of these practices and technologies, as well as their applicability to the MP&M unit operations. Definitions of these practices are provided in Table 16-3.

Drag-Out Reduction and Drag-Out Recovery. The quantity of rinse water needed for good rinsing for a given rinse system is proportional to the quantity of drag-out. Sites can implement various methods that minimize the rate of drag-out (measured as gallons per square foot of part surface area) and/or they can implement direct drag-out recovery. The drag-out rate for an individual process operation (e.g., cleaning or plating) is governed by numerous factors related mainly to the process type, shape of parts processed, production equipment, and processing procedures, which include human factors. Of these factors, the shape of the parts and the type of transport device employed for the parts (e.g., racks, baskets, barrels) usually exhibit the greatest influence on drag-out rates. The following tables present drag-out rate estimations for various shaped parts.

Estimations of Drag-Out Generation Presented in Literature
Average Drag-Out Losses - from Soderberg's Work

Nature of Work Drainage	Drag-Out Rate (gal/1,000 sq ft)
VERTICAL	
Well Drained	0.4
Poorly Drained	2.0
Very Poorly Drained	4.0
HORIZONTAL	
Well Drained	0.8
Very Poorly Drained	10.0
CUP SHAPES	
Well Drained	8.0
Very Poorly Drained	24.0

Source: Reference 1.

Average Drag-Out Losses - from Hogaboom's Work

Electroplating Solution Type	Drag-Out Rate (gal/1,000 sq ft)	
	Flat Surfaces	Contoured Surfaces
Brass	0.95	3.3
Cadmium	1.00	3.1
Chromium (33 oz/gal)	1.18	3.0
Chromium (53 oz/gal) *	4.53	11.9
Copper cyanide	0.91	3.2
Watts nickel	1.00	3.8
Silver	1.20	3.2
Stannate tin	0.83	1.6
Acid zinc	1.30	3.5
Cyanide zinc	1.20	3.8

Source: Reference 1.

*Increased viscosity, caused by an increase in concentration, can increase the drag-out volume approximately three times with less than double the concentration increase.

Soderberg's data indicate that the shape of the part has a significant influence on drag-out rate. Cup shaped parts, including intricately designed parts with internal surfaces, can generate five or more times more drag-out than flat surfaced parts with the same surface area. Hogaboom's data show a similar trend for flat versus contoured surfaces.

These data also show that the type and concentration of the electroplating solution influences the drag-out rate. For example, some solutions, such as stannate tin, drain effectively, while others, such as concentrated chromium electroplating solutions (53 oz/gal) drain poorly. With regard to the type of transport device employed, barrels (used to hold fasteners or other small parts that cannot be practically held by racks) generate more drag-out than racks, because of the surface area of the barrel and its tendency to hold the solution.

The drag-out rate for a given process and part is influenced by several factors other than shape, some of which are interrelated. The following table shows the effect of altering the withdraw rate and drain time.

Effect of Withdrawal Rate and Drain Time on Drag-out Rate

Micro-Etch Results	Withdrawal Rate (ft/min)	Time of Withdrawal (seconds)	Drain Time (seconds)	Total Time (seconds)	Drag-out (gal/1,000 sq ft)
Baseline	100	1.7	3.4	5.1	3.13
Slower Rate of Withdrawal	11	14.9	2.5	17.4	1.73
Intermediate Withdrawal Rate and Longer Drain Time	40	4.3	12.1	16.4	1.83

Electroless Copper Results	Withdrawal Rate (ft/min)	Time of Withdrawal (seconds)	Drain Time (seconds)	Total Time (seconds)	Drag-out (gal/1,000 sq ft)
Baseline	94	1.8	5.2	7.0	1.55
Slower Rate of Withdrawal	12	13.9	3.2	17	0.78
Intermediate Withdrawal Rate and Longer Drain Time	40	4.3	11.9	16.3	0.75

Source: Reference 1.

*The effects of changing the withdrawal rate and drain time were measured at a printed circuit board manufacturing site.

Table 16-4 lists these and other key factors and describes their impact on drag-out rates. Also listed are examples of water conservation practices that reduce the generation of drag-out, and the major restrictions that are associated with these practices. The

following is a summary of additional methods that can be implemented to directly recover drag-out.

1. Rinse over plating tank. Usually spray or fog rinse. Can only be performed when evaporative headroom in plating tank is available.

2. Drip shield or board. An inclined board designed to capture drips and return them to the plating tank as rack is being transported to rinse.

3. Air knife. Device that directs an air stream at parts over the plating tank or drip tank to blow off fluid.

4. Drip tank. An ordinary rinse tank that is initially empty over which racks and barrels are held to drain. The collected drag-out is returned to the plating bath.

5. Drag-out tank. A rinse tank that is initially filled with water but remains stagnant. Parts are rinsed first in this tank. The diluted drag-out can be returned to the process bath (e.g., electroplating solution) if sufficient evaporative headroom exists in the process tank.

6. Drag-in/Drag-out rinse. Two rinse tanks, located on opposite ends of a process tank (e.g., electroplating tank) and hydraulically connected, into which parts are rinsed before and after processing. The drag-out from the first rinse becomes the drag-in to the process tank, causing partial recovery of process solution. A useful arrangement for ambient or low temperature processes where a drag-out tank is not effective due to a low evaporation rate. On manual lines a single rinse tank can perform the same function. Parts are rinsed in the same tank, before and after processing.

Rinse Tank Design and Innovative Configurations. Rinse tank design and rinsing configuration are important factors influencing the PNF for a rinse. The key objectives with regard to optimal rinse tank design are to attain fast removal of drag-out from the part and complete dispersion of the drag-out throughout the rinse tank. When these objectives are achieved, the time necessary for rinsing is reduced and the concentration of contaminants on the part when it leaves the rinse tank are minimized for a given rinse water flow rate. Examples of good design elements include: locating water inlet and discharge points of the tank at opposite positions in the tank to avoid short-circuiting; and use of air agitation for better mixing (2).

Various rinsing configurations are used in the MP&M Phase I industry. The use of single rinse tanks following each process tank is the most inefficient use of rinse water. Multiple rinse tanks connected in series (i.e., countercurrent cascade rinse) reduces the water needs of a given rinsing operation by one or more orders of magnitude (i.e., less water is needed to achieve the same rinsing criterion). Spray rinsing can also be used to reduce water use requirements, but the achievable percent reduction is usually less than for countercurrent cascade rinses. Other configurations that reduce water use include cascade, reactive, and dual purpose rinses.

Rinse Water Use Control. Regardless of the type of rinsing configuration employed, water use reduction can be achieved by coordinating water use and water use requirements (i.e., rinse water is used in direct proportion to drag-out and the rinse criterion is constantly achieved). When water use and water use requirements are matched, the quantity of rinse water used for a given work load and tank arrangement is optimized (2). Sites that have constantly running rinses and no regard for work flow are the most inefficient users of water. A lack of water use control can negate the benefits of using multiple rinse tanks or employing other water conservation practices and result in a high PNF. Many sites employ some form of rinse water control. The four most common methods are flow restrictors (these can be used in conjunction with other methods to regulate the rate at which water is dispensed), manual control (i.e., turning water valves on and off as needed), conductivity controls, and timer rinse controls (see Table 16-3 for definitions).

Metal Recovery and Rinse Water Reuse Technologies. Various technologies are used by MP&M sites to separate surface finishing chemicals from rinse waters or to concentrate the rinse waters, thereby making the chemical and/or rinse water available for reuse. These technologies result in metal recovery and water conservation. The most commonly used technologies are evaporation, ion exchange, electrolytic recovery, reverse osmosis, and electrodialysis (see Table 16-3 for definitions). The following table presents examples of recovery technologies and their primary applications.

Examples of Metal Recovery Methods

Chemistry or Process with which Rinse is Associated	Recovery Method Examples
Brass Electroplating	Electrolytic recovery, evaporation
Cadmium (cyanide) Electroplating	Electrodialysis, electrolytic recovery, evaporation, ion exchange, reverse osmosis
Cadmium (non-cyanide) Electroplating	Electrodialysis, electrolytic recovery, evaporation, ion exchange, reverse osmosis
Chromate Conversion Coating of aluminum	Evaporation
Chromium (hard) Anodizing	Evaporation, mist eliminator
Chromium Electroplating - decorative (Cr^{+6})	Evaporation
Chromium Electroplating - decorative (Cr^{+3})	Evaporation
Copper (cyanide and sulfate) Electroplating	Electrolytic recovery, evaporation, ion exchange, reverse osmosis
Gold Electroplating	Electrolytic recovery, ion exchange
Lead-tin Electroplating	Evaporation, ion exchange
Nickel Electroplating	Electrodialysis, electrolytic recovery, evaporation, ion exchange, reverse osmosis
Nickel Electroless Plating	Evaporation, ion exchange
Nickel Sealant	Reverse osmosis
Silver Electroplating	Electrolytic recovery, evaporation, ion exchange
Zinc (cyanide) Electroplating	Electrolytic recovery, evaporation, reverse osmosis
Zinc (non-cyanide) Electroplating	Electrolytic recovery, evaporation, ion exchange, reverse osmosis
Zincate	Evaporation

Source: Reference 2.

Summary of Water Conservation Methods

Figure 16-2 presents six examples of rinsing configurations with increasingly good levels of water use practices. Each of these rinse systems is described below. These configurations can be operated to provide adequate rinsing and are common at MP&M Phase I sites. However, the quantity of water needed to achieve the same rinsing criteria may vary by as much as two orders of magnitude. The MP&M Phase I effluent limitations guidelines and standards are based on the following rinsing configuration: flow control and countercurrent cascade rinses for all flowing rinses, and ion exchange with electrolytic recovery for all electroplating rinses except chromium electroplating rinses.

Figure 16-2a presents an example of inefficient water use. This configuration involves the employment of a single rinse tank with either continuous water flow or manual use control. To coordinate rinse water needs and use, the water valve must be manually turned on to give the correct flow rate and then turned off when the flow is no longer

needed. The flow rate setting will usually vary from operator to operator and the water valve may be left open during idle production periods. The single rinse tank configuration results in a very high rinse water use rate, even if water use is coordinated with the introduction of drag-out. In the example shown, with a 1 gallon per hour (gph) drag-out rate, the rinse water requirement would be 30 gallons per minute, based on rinsing of Watts nickel plating solution and a rinsing criterion of 50 mg/L nickel. Rinsing criteria are discussed in Section 16.2.2. If coordination of water use and drag-out introduction are not achieved, an even higher rinse water use rate would be needed to meet a given rinse criterion.

Figure 16-2b shows a rinsing configuration where simple rinse water reduction methods have been implemented. The use of water is still inefficient due to the use of a single rinse tank versus the use of multiple rinse tanks shown in subsequent configurations. However, with this configuration, the drag-out rate is reduced by controlling the withdrawal rate of the part and by holding the part over the process tank to permit the drag-out to drip into the tank. The rinse water flow rate is controlled at a constant flow by use of a flow restrictor. The flow restrictor is usually sized to provide adequate rinsing at all times. This type of control is more acceptable for constant production rates, such as that often found with automated plating machines. However, this rinsing configuration is inefficient when there is an intermittent work flow because the rinse water flow rate must be set high enough to provide adequate rinsing during peak production periods. During low or idle production periods a large quantity of rinse water is wasted, unless the water flow is manually stopped.

Figure 16-2c shows a rinsing configuration with a moderately efficient use of water. This is achieved by the employment of a multiple rinse tank arrangement. The arrangement is referred to as parallel rinsing, where each of the two rinse tanks are fed with fresh water and they each discharge to treatment. This arrangement can reduce water use by more than 50% of that used in Figure 16-2a.

Figure 16-2d shows a more efficient rinsing configuration. This configuration is similar to that shown in Figure 16-2c, except that wastewater from the second rinse tank flows back into the first rinse tank to provide more efficient rinsing with less water use. Wastewater from the first rinse tank is then discharged to treatment. In this configuration, known as countercurrent cascade rinsing, the rinse water flows in a direction opposite the part flow. This arrangement can reduce water use by more than 90% of that used in Figure 16-2a.

Figure 16-2e shows a very efficient rinsing configuration. There are three key elements to this rinse system: drag-out reduction/recovery; countercurrent cascade rinses; and water use control. Drag-out reduction/recovery is achieved by controlling the withdrawal rate and dwell time and by installing a drag-out recovery tank. The drag-out recovery tank can reduce the drag-out entering the countercurrent cascade rinses by up to 90%, depending on the surface evaporation rate of the process tank. The feed to the

countercurrent cascade rinses is controlled by a conductivity controller. This type of device coordinates water use with drag-out introduction and reduces the influence of human error found with manually controlled rinses. An alternative device is the timer rinse control, which is as effective as a conductivity controller when there is no variability in drag-out volume between rinsing events.

Figure 16-2f shows a rinse system that employs an ion exchange/electrolytic recovery unit as a chemical recovery and water recycling technology. This rinsing configuration can reduce water use by more than 99% of that used in Figure 16-2a, since some quantity of wastewater would be discharged from the regeneration cycle of the ion-exchange unit.

Evaluating Rinse Water Use at a Site

To identify sites with pollution prevention and water conservation practices in place for rinsing operations, a permit writer should focus on the four categories of these practices discussed in the previous section. Specifically, sites should pass most or all of the following criteria for the majority of flowing rinses on site:

- The site should employ some type of drag-out reduction for the unit operation with which the rinse is associated;
- The site should employ some type of water conserving rinsing configuration;
- The site should have no rinses continuously discharging regardless of production (i.e., the site should implement on-demand rinsing).; and
- For electroplating rinses, the site should also include some type of metal recovery or rinse water reuse technology.

Table 16-2 presents examples of practices and technologies that sites can implement to satisfy these criteria.

Additional Tools for Evaluating Good Water Use Practices

The evaluation discussed above presents qualitative measures of water use practices. Although most sites that implement these practices will achieve moderate to high water conservation, it is possible that excess water use could still exist. If a permit writer suspects that excessive water use is present, additional tools can be used to evaluate water use practices. Two of these tools are discussed in the following paragraphs.

In general, sites that employ a combination of water conservation methods and technologies will have a PNF that is below the median for the MP&M Phase I category. The data presented in Table 16-1 can be used by the permit writer to determine how a

site compares to other sites in the category. If a site has a PNF above the median PNF, the site may be using excessive water for rinsing.

Another tool that can be used by permit writers to assure that good water use is being implemented is to measure the cleanliness or quality of the rinse waters in the final rinse tanks. The measurements can be made using a conductivity meter or by performing an analysis of total dissolved solids (TDS). If the conductivity or TDS of a given rinse is lower than that of an industry accepted criterion (discussed in Section 16.2.2), then excessive water use is most likely present. Conductivity and TDS measurements should be made in the final (cleanest) rinse, not at the point of rinse water discharge.

16.2.2 Flow Guidance for Calculating Mass-Based Limitations

As discussed in Section 16.1, for sites that do not have pollution prevention and water conservation practices in place, the Agency recommends that permit writers do not use historical flow as a flow basis for developing mass-based limitations. This section presents flow guidance to assist permit writers in identifying appropriate PNFs for rinsing operations when developing mass-based limitations based on the production through each unit operation.

Influences on Production-Normalized Flow Rates

Available data show that rinse water use rates are a function of production when measured in terms of the surface area of parts processed. Other factors that affect rinse water use rates include the drag-out rate (gallons per 1,000 square foot of workload), the rinse water purity criteria (mg/L TDS or conductivity), the concentration of TDS in the bath (mg/L TDS), rinse tank design and configuration (e.g., single overflow rinse versus countercurrent cascade rinse), and the type of rinse water flow control (e.g., manual versus conductivity controlled). These factors are discussed below.

Drag-Out Rate. As discussed in Section 16.2.1, the drag-out rate for an individual process operation is governed by numerous factors related mainly to the process type, shape of parts processed, production equipment, and processing procedures, which include human factors. Of these factors, the shape of the parts and the type of transport device employed for the parts (e.g., racks, baskets, barrels) usually exhibit the greatest influence on drag-out rates. However, other factors such as the withdraw rate and the dwell time can have a very significant effect. Cup-shaped parts, including intricately designed parts with internal surfaces, can generate five or more times the drag-out than flat surfaced parts. With regard to the type of transport device employed, barrels (used to hold fasteners or other small parts that cannot be practically held by racks) generate more drag-out than racks, because of the surface area of the barrel and its tendency to hold the solution. Small parts and parts that are not amenable to racking are sometimes held in wire baskets. The spacing of the basket's wire mesh has an effect on the drag-out volume. Due to surface tension, liquid will tend to span closely spaced mesh and

resist draining. Section 16.2.1 presents several examples of practices and technologies that can be implemented to reduce and recover drag-out.

Rinse Water Purity Criteria. Rinse water purity criteria are the levels of tolerable contamination in the rinse water. These levels vary for different processes and types of products. For example, rinse water used after cleaning typically does not have to be as pure as rinse water used following plating, since rinse water that remains on the plated part (essentially the drag-out from the rinse tank) will leave spots after it evaporates if the concentration of dissolved solids in the rinse water is too high. Although preliminary and intermediate processing steps such as cleaning and etching usually do not require as pure a rinse water as final rinsing, some moderate level of purity is needed to stop chemical reactions such as etching and prevent the contamination of subsequent process solutions. Among plating processes, differences also exist in rinse water quality requirements. Parts plated for engineering or functional purposes (e.g., corrosion resistance) can often be rinsed in water that is significantly less pure than decoratively plated parts.

High purity water is needed for various rinsing operations. In some cases, tap water is insufficiently pure to serve as rinse water. For example, some electronics parts require a higher rinse water quality than most municipal systems can supply. To meet these requirements, the source water is purified by reverse osmosis and/or ion exchange to remove dissolved solids and other constituents before use as rinse water. Even for common rinsing operations, source water treatment is sometimes employed, especially when the water supply is high in dissolved solids.

Rinse water quality requirements have been used in the metal finishing industry for decades. They are typically expressed in mg/L of TDS or in conductivity or resistivity units (resistivity is the inverse of conductivity). Some generalized rinse criteria found in the literature (1) are summarized in the following table.

Generalized Rinse Criteria

Type of Rinse	Normal Range for Adequate Rinsing (mg/L TDS)
Alkaline Treatment/Acid Treatment Rinse	400 to 1,000
Functional or Engineering Plating Rinse	100 to 700
Decorative or Bright Plating Rinse	5 to 40

Source: Reference 1.

As discussed in Section 16.2.1, these criteria can be used by permit writers as a tool to assess water use practices at a given site.

Bath Concentration. The concentration of the bath, which can be expressed in mg/L TDS, will affect the quantity of rinse water needed for good rinsing. Baths that are more concentrated (i.e., higher TDS) will require more rinse water to meet the same rinse water purity criteria as a less concentrated bath. The bath concentration is mostly dependent on the type of bath. For example, a typical acid zinc electroplating bath will have a TDS concentration of 166 g/L and a typical copper cyanide electroplating bath will have a TDS concentration of 250 g/L. For equal volumes of drag-out from these two baths, the copper cyanide rinse flow must be 1.5 times greater than the acid zinc rinse flow rate in order to achieve the same rinse quality criteria (i.e., 250/166 = 1.5). This simple calculation does not account for the differences in viscosity which, to a lesser extent than bath concentration, will affect the volume of drag-out. For flat surfaces, the drag-out rate for a 396 g/L chromic acid bath is 3.8 times greater than that of a 247 g/L bath. In some cases, the TDS concentration of the bath is inadvertently increased due to a buildup of bath contaminants (e.g., iron may accumulate in a chromic acid bath due to the attack of the basis metal). The TDS added by the contaminants may affect the drag-out rate in the same manner as its intended bath constituents (e.g., chromic acid). Therefore, a very significant pollution prevention/water conservation benefit can be realized by operating a bath at the lowest concentration necessary to perform the job properly and by maintaining bath contaminants at low levels. The bath concentrations presented in this paragraph were obtained from references 3 and 4.

Rinse Tank Design and Configuration. The rinse tank design and configuration greatly affect the required rinse water flow rate. For example, single overflow rinse tanks can require twenty or more times more water than a two stage countercurrent cascade rinse that provides the same quality of rinsing. For the purpose of evaluating the cost of compliance with the Phase I MP&M regulation, it was assumed that countercurrent cascade rinsing would be implemented. Other information on rinse tank design and configurations is presented in Section 16.2.1.

Rinse Water Flow Control. Rinse water flow control is necessary to coordinate the use of water and the work flow. If this is not done, water can be wasted during idle production periods. Various methods of rinse water use control are employed in the MP&M Phase I industry, as discussed in Section 16.2.1.

Guidance for Production-Normalized Flow (PNF) Selection

The PNF has a significant impact on the calculation of mass-based limitations. Due to the number of product/process variables that influence the PNF, permit writers may select different PNFs for different sites, or different PNFs for different occurrences of the same operation within a site. The purpose of this section is to present available data and information to support the permit writer in determining an appropriate water-conserving PNF for an operation. The data sources are the MP&M DCPs, technical literature, and the MP&M sampling program.

As evidenced by information presented later in this section, most sites should be able to achieve PNFs at the lower end of the ranges presented in Table 16-1 when countercurrent cascade rinsing is implemented. Sites that are unable to implement countercurrent cascade rinsing (e.g., due to space limitations in a plating line), can usually reduce their water use by implementing other flow reduction techniques (e.g., ion-exchange recycling for electroplating rinses, flow restrictors combined with conductivity meters for other rinses). These water-conserving practices were used to evaluate the cost impacts of regulation for sites affected by the MP&M Phase I effluent guidelines. Many other water-conserving practices are also available to sites that can substitute for or complement the use of countercurrent cascade rinsing or ion exchange recycling. These practices are discussed in Section 16.2.1.

Certain specific conditions may affect a site's ability to reduce their water use. Most notably, the drag-out rate (usually expressed in gallons/1,000 square feet) may be higher than average or the rinse water purity criteria (usually expressed in mg/L TDS) may be lower than average. Guidance for identifying such conditions is presented below.

A conservative estimate of an average drag-out rate is 3.2 gallons/1,000 square feet of surface area (1). Higher drag-out rates may require greater rinse water flows to achieve good rinsing. A methodology for measuring drag-out rates is presented at the end of this section. When the drag-out rate for a particular operation exceeds the estimated average rate, the permit writer should take this into account when determining the flow basis for the mass-based limits. The permit writer can use the values in Table 16-1 or other resources to determine appropriate flow rates.

Rinse water purity criteria vary for different processes. Average purity criteria for rinsing following cleaning, functional surface finishing, and decorative surface finishing are 700 mg/L, 400 mg/L, and 22.5 mg/L, respectively. If sites indicate that their surface finishing requirements cause a need for purer rinse water, then the permit writer may choose to use additional resources to select an appropriate flow rate. Often, sites that require purer rinse water can be identified due to their use of softened or deionized water for rinsing. In general, sites using plain tap water or another source of untreated water are inherently less concerned about rinse water purity. A possible exception to this generalization is the case where the available source water is low in TDS (e.g., <100 mg/L) and softening or deionization are not needed. Permit writers may test a site's rinse water to help assess their actual requirements, with the premise that their required water purity criteria is no lower than the existing purity level in the rinse tanks. Testing would involve collecting composite samples from the final rinse tank following each unit operation and analyzing for TDS.

The following are additional informational resources that can be used by the permit writer to select an appropriate flow rate when the drag-out rate is higher than average or purer rinse water is necessary.

Technical Literature. One source of data to use in identifying an appropriate flow rate for an operation is technical literature. Using the rinsing criteria along with the drag-out rates and the typical concentrations of TDS in various process baths, a "literature" flow rate can be calculated. Table 16-5 presents, for several types of rinses, calculated flow rates for a single-stage overflow rinsing configuration and a two-stage countercurrent cascade rinsing configuration. Both rinsing configurations are assumed to have flow control (i.e., water use is coordinated with drag-out introduction using a conductivity control or other device). This table presents the TDS concentration in the associated bath (from literature), the target TDS in the rinse (based on the rinsing criteria), the part type, the assumed drag-out rate (from the tables presented in Section 16.2.1), and two PNF values.

The first value, PNF 100% Control, is a calculated value based on the assumption that a site perfectly coordinates work flow and rinse water use (e.g., using a conductivity controller). In actual operations, perfect coordination is nearly impossible to achieve because the quantity of rinse water needed to meet a given rinse criterion cannot usually be added exactly at the time that drag-out enters and is dispersed in the rinse tank. For example, when a barrel of parts is rinsed, it is usually placed into a rinse tank for 1 to 3 minutes. The rinse water volume needed to meet the rinse criterion may be 50 gallons or more. The flow rate of water into the rinse tank will typically be less than 10 gpm (flow rates into rinse tanks vary depending on the pipe size and water pressure and may be reduced by the installation of a flow restrictor). Therefore, it may take 5 minutes to add the 50 gallons of rinse water. Because it is nearly impossible to exactly coordinate work flow and water use, actual water use rates will be higher than those presented in the column, PNF 100% Control. A reasonable assumption is that good water flow control will result in a PNF twice that of the calculated values that assume 100% control. These flows are shown as PNF 50% Control.

Equations and information that the permit writer can use for calculating other PNFs from literature sources are presented with Table 16-5.

MP&M Field Sampling Data. Additional PNF data are available from the MP&M field sampling program that may be useful to the permit writer in selecting an appropriate PNF for a specific operation. For samples collected for this program, the Agency obtained flow and production data as well as a description of the pollution prevention and water conservation practices in place for several sampled rinses. Table 16-6 presents a summary of these data, collected at two MP&M sites, for countercurrent cascade rinsing operations (the recommended technology on which the MP&M technology options were based). This table also shows the type of process solution, the type of product processed through the rinse, a calculated drag-out rate, an adjusted TDS, and an adjusted PNF. The adjusted TDS values are common rinsing criteria found in the literature. The adjusted PNF values were calculated using the adjusted TDS values and the equations presented with Table 16-5. Therefore, the adjusted PNF values are rinse water flow rates that would be expected for these countercurrent cascade rinsing

operations if they were to provide rinse water quality equal to the adjusted TDS. The purpose of presenting these values is to demonstrate the reasonableness of the PNFs calculated based on literature values in Table 16-5.

Method for Drag-Out Measurement

An accurate method of drag-out measurement is to track the concentration of a metal ion (or other sufficiently concentrated ion) in the rinse tank through a rinsing event. The rise in concentration of the ion in the rinse tank can be used to calculate the volume of process fluid introduced during the event if the concentration of that ion in the process fluid is known.

For example, a sample of a copper sulfate process bath is collected and analyzed for copper concentration along with two rinse samples--one before and one after a rinsing event. The drag-out volume for the rinsing event is:

$$D = \frac{(C_{after} - C_{before})}{C_p} \cdot V_r \qquad (16\text{-}1)$$

where

C_{after}	=	concentration of selected metal ion in rinse tank after rinsing event (g/L)
C_{before}	=	concentration of selected metal ion in rinse tank before rinsing event (g/L)
C_p	=	concentration of selected metal ion in the process tank (g/L)
V_r	=	volume of rinse tank in liters (L)
D	=	volume of drag-out in liters (L)

Several data points should be collected. Once a drag-out rate per unit area is derived, the production-normalized flow (PNF) for the rinse system is:

$$PNF = \frac{(P/D)}{C_{r(ave)}} \cdot C_{p(ave)}$$

where

P	=	the production rate in ft^2
D	=	the drag-out rate in L
$C_{r(ave)}$	=	average target metal ion concentration in the rinse tank (g/L)
$C_{p(ave)}$	=	average target metal ion concentration in the process tank (g/L)
PNF	=	production-normalized flow in L/ft^2

Drag-out also can be measured using only a conductivity meter. This is accomplished by first observing the effect that a controlled amount of process fluid has on the conductivity of a unit volume of rinse water, then applying this data to an actual rinsing event.

For example, measure the conductivity of one liter of fresh rinse water. Then measure the conductivity after adding and thoroughly mixing 1 ml of process fluid. Note the difference between the two measurements. Then measure the conductivity of a rinse tank prior to and after a rinsing event. The flow through the rinse tank must be closed during the test. The drag-out volume, in liters, for the rack or barrel and parts that were rinsed is:

$$D = \frac{(C_{after} - C_{before})}{C_{mix} - C_r} \cdot V_r \qquad (16\text{-}2)$$

where

C_{after}	=	conductivity in rinse tank after rinsing event
C_{before}	=	conductivity in rinse tank before rinsing event
C_{mix}	=	conductivity in mixture of 1 ml of process fluid and 1 liter of fresh rinse water
C_r	=	conductivity of fresh rinse water
V_r	=	volume of rinse tank in liters
D	=	drag-out rate in liters

Several data points should be collected.

16.3 Flow Guidance for Machining Operations

This section provides flow guidance for machining operations, which are significant sources of MP&M Phase I process wastewater. Many machining operations use metal-working fluids to cool and lubricate parts and machining tools during cutting, drilling, milling and other machining operations. During use, these fluids become contaminated

and begin to lose their working characteristics. If neglected, the fluids become unusable and require treatment and disposal. Through proper care, the life span of the fluids can be extended indefinitely. For most machining operations, prolonging metal-working fluid life reduces the cost of treatment and disposal, as well as the cost of fresh coolant.

Section 16.3.1 provides background information to identify pollution prevention and water conservation practices applicable to machining wastewaters, and evaluation criteria to assess if a particular site has properly implemented these practices. Section 16.3.2 presents guidance for selecting the appropriate flow rate for use in calculating mass-based standards for sites that do not have pollution prevention and recycling practices in place. The guidance is based on various factors that impact machining fluid requirements, including type of machining operation, base metal machined, and type of machining system.

16.3.1 Identifying Sites With Pollution Prevention and Water Conservation Practices

As discussed in Section 16.1, the Agency recommends that permit writers use historical flow data to calculate mass-based limitations for sites that have implemented pollution prevention and water conservation practices. This section provides background information and guidance that can be used by the permit writer to determine if a site has implemented pollution prevention and water conservation practices for their machining operations. If the site has implemented pollution prevention and water conservation practices, the permit writer would multiply the site's historical process wastewater discharge flow rate by the concentration-based limitations to calculate mass-based limitations. This will eliminate the requirement of identifying alternate methods to develop mass-based limitations, including tracking production rates through unit operations.

Many MP&M Phase I sites employ some form of pollution prevention and water conservation practices for machining wastewaters. Some sites implement numerous pollution prevention and water conservation methods and technologies that result in very low machining wastewater discharge rates and in some cases eliminate the discharge of machining fluids. Pollution prevention and water conservation practices are applicable to all machining operations; however, process-related factors and site-specific conditions may restrict the utility of certain methods. This section identifies pollution prevention and water conservation practices and technologies applicable to machining operations and provides guidance on how to evaluate a site's water use practices.

Wastewater Generation from Machining Operations

Metal-working fluids, also termed cutting fluids and coolants, are used in machining operations to improve the life and function of machine tools. During machining, these fluids are circulated over working surfaces, reducing friction, cooling the tool and

workpiece, and removing metal chips from the work face. Various types of metal-working fluids are used, the choice of which depends on the type of machining being performed and the preference of the site. The fluids are broadly divided into four groups: straight oil (neat oils), synthetic, semi-synthetic, and soluble oil. The most commonly used metal-working fluids are soluble oil (usually referred to simply as coolant), synthetics, and semi-synthetics.

Soluble oil coolants are prepared by mixing a concentrated coolant with water in a 1:15 to 1:30 ratio to produce a fluid with a 90 to 98 percent water content. Most coolants are suitable for light- and medium-duty operations. Synthetic coolants are designed for high cooling capacity, lubricity, and corrosion prevention. Common chemical agents in synthetics include: amines and nitrites for rust prevention; nitrates for nitrite stabilization; phosphates and borates for water softening; soaps and wetting agents for lubrication; phosphorus, chlorine, and sulfur compounds for chemical lubrication; glycols to act as blending agents; and biocides to control bacteria growth. Semi-synthetics contain small dispersions of oil in an almost otherwise organic water-dilutable system. These fluids are more broadly applicable than soluble oils. Straight oils provide good lubricity, but are less effective for cooling. For this reason, their use is limited mostly to low-speed operations (8).

Metal-working fluids are periodically discarded because of reduced performance or development of a rancid odor. The fluids that contain a large percentage of oil typically are hauled as solid waste for disposal or recovery. Fluids with lower oil content, particularly coolants, typically are sent to a site's wastewater treatment system for treatment and subsequent discharge.

Fluid degradation is caused mainly by contamination with tramp oil and dirt, and by bacterial growth, which can be accelerated by oil contamination. Tramp oil is contributed mostly by the removal of the oil film from the part's surface during machining and by leaks of lubricating and hydraulic oils contained in the machine. Dirt can accumulate in cutting fluid due to airborne dust or poor housekeeping practices. Bacteria are initially contributed to the fluid from the surfaces of the machine and parts and from the air. More than 2,000 known species of bacteria have been reported to affect and eventually destroy the stability of machining fluids (5). Bacteria feed on the fluids' chemicals, causing the fluids to lose lubricity and corrosion inhibition. Under anaerobic conditions, sometimes caused by floating tramp oil in coolant sumps, a hydrogen sulfide odor is generated by bacteria.

In addition to spent fluid, machining operations may generate wastewater from rinsing. Rinsing may be performed to remove fluid, chips and other foreign materials from the machined parts. However, rinsing parts following machining is not typically performed. More frequently, the fluid is permitted to remain on the part to inhibit corrosion, is wiped off using shop towels, or is cleaned in an alkaline cleaning or degreasing operation.

The quantity of wastewater generated by a machining operation depends primarily on the volume of work performed. For machining operations, production volume can be roughly measured in terms of the quantity of metal stock removed by turning, milling, boring, broaching, cutting and other machining operations. For most operations, the removed metal stock are small fragments referred to as chips. Most chips carry a thin film of fluid on their surfaces. The drainage from chips is another source of wastewater from machining.

Pollution Prevention and Water Conservation Practices and Technologies

The Agency has identified two categories of pollution prevention and water conservation practices and technologies that can be applied to reduce metal-working fluid discharge: practices and technologies used to prevent metal-working fluid contamination; and practices and technologies used to extend the life of machining fluids, including practices and technologies used to recover and recycle metal-working fluids. Within each of these categories are several specific practices and technologies. Table 16-7 presents several examples of these practices.

Prevention of Metal-Working Fluid Contamination. Metal-working fluid degradation is primarily caused by contamination of the fluid by tramp oil or dirt. Sites can implement various methods to reduce the amount of fluid contamination. Several of these methods are discussed below.

Reduction of Contamination From Tramp Oil. Tramp oil is a primary contaminant in machining fluids and for many sites the major cause of metal-working fluid degradation. The Agency has identified the following methods to reduce contamination of metal-working fluid with tramp oil.

- Use Coolant in Hydraulic and Other Oil Systems. Some metal working coolants are formulated to be used as hydraulic fluid and/or lubrication in concentrated form, and as a coolant in its dilute form (i.e., diluted with water). When used as a hydraulic fluid or lube, leaks of the fluid will be assimilated into the coolant without causing contamination.

- Replace Hydraulics with Electrical Systems. Hydraulic systems on some machines can be replaced by newer electrical systems that do not contain hydraulic fluid. This could be economically performed during major equipment overhauls.

- Machine Maintenance. The design and age of machines may affect the quantity of hydraulic oil that is contributed to the metal-working fluid during machining operations. There are numerous hydraulic systems used with machines, depending on the type of machine and

its design. These systems will leak variable quantities of oil depending on design, sealing mechanisms, operating pressures, and other factors. Older machines, especially those that are not properly maintained, can have hydraulic seals with excessive leaking. Sites can implement scheduled maintenance of machines to check and repair sealing mechanisms.

Reduction of Contamination from Makeup Water. Makeup water contributes to the dissolved solids content of the metal-working fluid causing reduced fluid life. This problem will occur more rapidly when waters with high total dissolved solids (TDS) are used for evaporative makeup. Certain dissolved solids or minerals contribute more to problems for metal-working fluids than others. For example, chloride salts and sulfates contribute to corrosion at levels greater than 100 parts per million. Sulfates also promote the growth of sulfate-reducing bacteria that cause fluids to become rancid. When minerals become concentrated in the fluid they can cause increased corrosion, gumming and machine wear (8). Consequently, when hard water is used the fluid life can be reduced. Deionized (DI) water can be used in place of hard water. DI units can be either purchased or rented.

Reduction of Contamination from Sumps. The Agency has identified the following methods to reduce contamination from metal working fluid sumps.

- Steam Cleaning of Sumps. Machine coolant sumps harbor bacteria that degrade the fluids. If coolant sumps are not sterilized during clean-outs, the fresh coolant added to cleaned sumps will be subjected to degradation by residual bacteria. The elimination of bacteria from sumps can be accomplished by steam cleaning during clean-out.

- Sump Modification. Many coolant sumps are designed as in-ground concrete tanks. The porous concrete surfaces of the sumps absorb oil and promote bacterial growth. Fluid life may be extended by improving the design of the sumps. Potential design changes include insertion of metal tanks and coating of sump walls with fiberglass or other non-porous material.

Reduction of Miscellaneous Contamination. Metal-working fluid life can be extended by reducing contamination through good housekeeping. Sites can implement housekeeping procedures to prevent the introduction of floor sweepings, solvents, paint chips, soil, rags, paper, and other debris into the coolant sumps.

Extension of Metal-Working Fluid Life. The Agency has identified several methods for extending the life of metal-working fluids. These include raw material substitution, equipment modification, and fluid monitoring. These methods are discussed below.

Raw Material Substitution. As discussed above, four general types of metal-working fluids are used in machining operations. Within a given group of fluids, such as soluble oil, various formulations are used. Within each group, the major difference from one cutting fluid to another is the "additive package." Additives are included in most metal-working fluid formulations to improve fluid performance (e.g., improve lubricity, reduce friction, or increase corrosion protection) and increase life span (e.g., reduce bacterial growth). The range of costs between metal-working fluids varies by 100 percent or more. Metal-working fluids with additive packages that do not meet the lubrication and cooling requirements of the specific machining operation may degrade faster than other metal-working fluids. These fluids will require more frequent replacement and result in higher overall operating costs. These fluids may also effect tool life, further increasing operating costs. Therefore, the use of the proper grade metal-working fluids can increase the life span of the fluid, reducing the generation of waste machining fluids and decreasing the overall operating costs.

Equipment Modification. The Agency has identified the following types of equipment modifications that can extend the life of machining fluids.

- Replacement of Air Agitation With Mechanical Agitation. Some sites use air agitation in central coolant sumps to constantly mix the fluid and prevent phase separation and pooling of tramp oil. Air agitation increases the activity of aerobic bacteria by adding oxygen and results in the bacterial consumption of fluid additives. An alternative method of mixing is mechanical agitation (i.e., pumping). Mechanical agitation provides mixing without increasing the oxygen concentration of the coolant.

- Removal of Tramp Oil. Machining fluid life can be extended by continuous, in-sump removal of tramp oil. Sites can install continuous oil skimming devices directly in the machine sump to remove tramp oil. Tramp oil can also be removed using absorbent blankets, fabrics, or pillows.

Fluid Monitoring. During fluid use, various physical, chemical, and biological changes of the metal-working fluid will occur. If the properties of the fluid are monitored on a regular basis, adjustments can be made before the fluid is degraded. Coolant monitoring measurements include: pH, coolant concentration (using a refractometer or titration kit), total dissolved solids (TDS), tramp oil (visual) and bacteria count (using dip slides or other methods). These data can be used to guide periodic fluid adjustments and/or develop statistical process control (SPC) procedures. The correct pH operating range of most coolants is 8.5 to 9.5. If the pH drops below the operating range, coolants may cause rusting and be prone to increased biological activity. Fluid concentration should be monitored at least weekly, if not daily. Dilute concentration can result in shorter tool life, increased biological activity, and risk of rust. Rich concentrations can lead to

foaming. Tramp oil contributes to biological growth. Biological activity can be monitored using dip slides that are available from coolant suppliers and laboratories (8).

Metal-Working Fluid Recycling. Most metal-working fluids can be recycled on site by removing contaminants contributed during use and storage. Various methods are employed for this purpose, including: settling, straining, skimming, simple filtration, membrane filters, coalescing, centrifugation, cyclone separation, magnetic separation, and pasteurization. Some of these methods can be used in combination to provide nearly 100% recovery of the metal-working fluid. Recycling equipment can be purchased or commercial services are available that perform on-site processing (6, 7). Self-contained recycling units can be purchased that are specifically designed for smaller machine shops. These units provide a complete sump maintenance and fluid recycling system in one unit (8). In most cases, metal-working fluid recycling can be facilitated by consolidating the types of machining fluids used on site to one or two types of fluid.

Additional metal-working fluid recycling can be achieved by chip drainage. Chip drainage can account for up to 50% of annual fluid usage (7). During machining, the metal chips (scraps) become coated with fluid. A portion of the fluid drains from the chips and a portion remains on the chips. In many cases the chips and associated fluid are dropped to the floor and manually collected in storage containers. With some machines, the chips and fluid are directed to a storage container by automated equipment (e.g., belt or pneumatic conveyor). Fluid that drains from chips can be recycled rather than discharged. This may require design changes of chip handling and storage equipment.

Evaluating Metal-Working Fluid Use at a Site

To identify sites with pollution prevention and water conservation practices in place for machining operations, a permit writer should focus on the two categories of practices discussed above. Specifically, sites should pass both of the following criteria for the majority of machining operations on site:

- The site should employ practices and/or technologies to prevent contamination of the metal-working fluid; and
- The site should employ some type of practice or technology to extend the life of the metal-working fluid.

Table 16-7 presents examples of practices and technologies that sites can implement to satisfy these criteria.

16.3.2 Flow Guidance for Calculating Mass-Based Limitations

As discussed in Section 16.1, for sites that do not have pollution prevention and water conservation practices in place, the Agency recommends that permit writers do not use historical flow as a flow basis for developing mass-based limitations. This section presents flow guidance to assist permit writers in identifying appropriate flow rates for machining operations to develop mass-based limitations.

Influences on Flow Rates

Available data show that wastewater discharge rates from machining operations are a function of production when measured in terms of the mass of metal stock removed by the machining operations (see Table 16-1). Wastewater discharge rates are also affected by other factors that will cause production-normalized flow to vary from site to site. The most important of these factors are: the type of metal-working fluid used; the design of the machine fluid system; the machining operations performed; and, the fluid management practices employed. Other factors include: base material being machined, climatic conditions, design and age of machines, and chip storage methods. Several of these factors (type of metal-working fluid, fluid management practices, and chip storage methods) can be controlled by sites by implementing pollution prevention and water conservation practices and technologies, as discussed in Section 16.3.1. The other factors are, to a degree, beyond control of the site and will affect the minimum flow rate achievable by a site. The effects of these factors on flow rates are discussed below.

Design of the Machine Fluid System. Fluids used in machining are stored either in sumps dedicated to individual machines (either internal or external to the machine), or in central sumps that serve multiple machines. The use of the latter design is typically restricted to large machining operations, whereas small machine shops tend to have individual sumps for each machine. With individual sumps the volume of fluid in use per machine is much less than with a central system. Central systems usually contain three to five times greater volumes per machine. The reservoir volumes of most machines with internal sumps are typically 10 to 50 gallons. External sumps serving a single machine will typically have a volume of 1,000 to 2,500 gallons. Central sumps may have volumes that exceed 50,000 gallons.

The amount of make-up fluid in a central system amounts to a smaller percentage of total fluid than in a single machine operation. Consequently, the potential for bacterial degeneration is greater in central systems as the bacteria have a longer time in which to attack the fluid (5). Further, the central sumps are often unlined concrete basins. The porous walls of the sumps hide bacteria and prevent complete disinfecting during clean-outs. This reduces the time needed for the bacteria to become reestablished (7). Additionally, the larger pumps used in central systems keep the tramp oils suspended in the fluid so they do not readily "float out," adding to further bacterial attack. Central

systems may require more maintenance than dedicated sumps to prevent bacterial growth.

Machining Operations Performed. The ratio of scrap metal (e.g., chips) generated to fluid used varies among machining operations. For example, metal cutting may generate large pieces of scrap metal using a small volume of fluid, whereas a milling operation will usually produce a much smaller mass of chips for the same volume of fluid. However, based on the MP&M Phase I DCP database, EPA did not identify any trends in production-normalized flow rate across types of machining operations performed.

Base Material Being Machined. The type of base material being machined affects the quantity of metal-working fluid used. The hardness of base materials varies, which in turn affects the speed at which base metal can be removed. Harder metals will require the use of more fluid than softer metals for the same operation.

Climatic Conditions. The temperature of the shop can affect the life span of metal-working fluid. Warmer temperatures may foster the growth of certain bacteria.

Design and Age of Machines. The design and age of machines may affect the quantity of hydraulic oil that is contributed to the metal-working fluid during machining operations. There are numerous hydraulic systems used with machines, depending on the type of machine and its design. These systems will leak variable quantities of oil depending on design, sealing mechanisms, operating pressures, and other factors. Older machines, especially those that are not properly maintained, can have hydraulic seals with excessive leaking.

Guidance for Production-Normalized Flow (PNF) Selection

The following table presents PNF data from the MP&M DCPs for machining operations. These data are summarized from Table 16-1. Data are in gallons of wastewater (i.e., primarily spent coolant and associated rinse water, if used) discharged per pound of metal removed.

PNFs For Machining Operations

Minimum PNF	10th Percentile	25th Percentile	Median PNF	75th Percentile	90th Percentile	Maximum PNF	Mean PNF
0.0001	0.0040	0.018	0.054	0.23	0.99	510	1.6

Source MP&M Phase I DCP Database.

As shown in this table, the PNFs for machining operations range several orders of magnitude. The DCP data do not include information on the exact types of pollution prevention and water conservation practices in place at the MP&M sites; therefore, the PNFs listed in this table cannot be directly linked to specific practices. Based on data gathered from site visits and technical literature, the Agency believes that the wide range of PNFs is indicative of the variety and extent of pollution prevention practices in use at MP&M sites (e.g., sites with coolant maintenance and recycling practices in place versus sites without these practices in place).

The Agency believes that most sites can reduce their flow rates for machining operations by implementing one or more of the pollution prevention and water conservation practices discussed in Section 16.3.1. Site specific conditions may limit the ability of certain sites to reduce their flow rates.

16.4 Flow Guidance for Painting Operations

This section provides flow guidance for painting operations, which are significant sources of MP&M Phase I process wastewater. Paint is applied to a base material for protective and decorative reasons. It is applied in various forms including dry power, solvent-diluted formulations, and water borne formulations. Various methods of application are used, the most common being immersion and spraying. Water is used in painting operations in paint booth water-wash systems (water curtains), in water-born formulations, in electrophoretic painting solutions and rinses, and in clean-up operations. This discussion is directed at water use in spray painting booths, however, some information on rinsing following electrophoretic painting and water clean-up are also provided.

Section 16.4.1 presents background information to identify pollution prevention and water conservation practices applicable to painting operations. This includes discussions of wastewaters generated from painting operations and practices and technologies that can be implemented to reduce wastewater discharges. Section 16.4.2 presents guidance for selecting appropriate flow rates for use in calculating mass-based standards for sites that do not have pollution prevention and water conservation practices in place. The guidance is based on various factors that impact water use requirements.

16.4.1 Identifying Sites With Pollution Prevention and Water Conservation Practices

As discussed in Section 16.1, the Agency recommends that permit writers use historical flow data to calculate mass-based limitations for sites that have implemented pollution prevention and water conservation practices. This section provides background information and guidance that can be used by the permit writer to determine if a site has implemented pollution prevention and water conservation practices. If the site has implemented pollution prevention and water conservation practices, the permit writer

would multiply the site's historical process wastewater discharge flow rate by the concentration-based limitations to calculate mass-based limitations. This will eliminate the requirement of identifying alternate methods to develop mass-based limitations, including tracking production rates through unit operations.

Wastewater Generation from Painting Operations

This section identifies the types of wastewaters that are generated from painting operations. The focus of this section is on spray painting water-wash systems; however, information on electrophoretic painting is also provided.

Spray painting is performed to apply an organic coating to a product. During manufacturing operations, spray painting is usually performed in a booth to control the introduction of contaminants and the release of solvent and paint to the work place and environment, and to reduce the likelihood of explosions and fires. Paint booths are categorized by the method of collecting the overspray, which is the paint that misses the product during application. The types of paint booths used can be broadly divided into two categories: dry filter and water-wash types. The choice between booth designs depends mainly on production requirements, including part size and configuration, production rate and transfer efficiency, the material being sprayed, and finish quality requirements.

Dry filter booths make use of filter media to screen out the paint solids. This is accomplished by pulling prefiltered air through the booth, past the spraying operation and through the filter media. The air entrains the overspray and is pulled through the filter media which collects the paint. Solvent evaporates from the paint, leaving the paint solids on the filter media. Filters are periodically replaced when they become laden with paint solids and the air flow through them is restricted. Dry filter booths are most often employed when paint usage does not exceed 20 gallons/8 hour shift/10 feet of chamber width (14). At higher usage rates, the frequency of filter changes is too great, causing high operating costs (i.e., filter media, filter media disposal, and labor).

Water use with dry filter units is limited to cleaning painting equipment (e.g., guns and lines) when water-born paints are employed. The operation of dry filter units is essentially dry when solvent-based paints are used.

Water-wash booths employ a "water curtain" to capture paint overspray. This is accomplished by pulling air containing entrained paint overspray through a circulating water stream which "scrubs" the overspray from the air. Although there are numerous design variations among water-wash booths, the two primary categories are termed side-draft and downward-draft. The basic difference between the two types is the way the air movement is directed through the system to draw the paint overspray in for capture (15, 16). Side-draft units are typically used by small painting operations and the downward-draft units are used with large and/or continuous operations.

Water-wash booths use a water stream that recirculates from a sump or tank with a typical capacity of 200 to 5,000 gallons or more. Downward-draft systems normally contain much larger volumes of water than side-draft systems. Water is periodically added to the system as make-up for evaporative losses. The sump water is periodically discharged, usually during general system cleaning or maintenance. The discharge rate is dependent on various factors, including booth design, paint type, overspray rate, and the water treatment methods employed. Water is also used with water-wash booths to clean the painting equipment and the paint booth. Booth cleanup may involve the use of paint stripper to remove dried paint from the walls of the booth and the piping system.

A common strategy employed in water-wash booth operation is to immediately detacify suspended paint solids to reduce maintenance problems and to subsequently separate and remove the solids from the water. The organic resins that make up the bulk of the paint coating are insoluble in water and tend to stay tacky if not treated with some additional material introduced to the water (15, 16). If left untreated, the tacky solids can plug recirculation pipes and pumps and adhere to wetted surfaces of the booth. Dissolved solids are either immediately precipitated and flocculated, removed by water treatment, or discarded when the sump is discharged.

Detacification and the subsequent removal of solids is accomplished in various ways, depending on the type of paint used and the booth design. Detacification chemicals include: sodium hydroxide (caustic); metal salts; clay; and polymers. Depending on the type of paint and the detacification chemical, the paint solids may either disperse or agglomerate. Agglomerated solids may either sink or float. When solids dispersal chemistries are used, the suspended solids build-up in concentration as overspray enters the water. Subsequently, a solids clean-out is performed by introducing another chemical to the water that causes the dispersed solids to agglomerate into a dense floc. The floc is then removed.

Various means are employed to remove the paint solids from the booth water-wash system. These removal mechanisms vary in levels of sophistication, automation, efficiency (removal and separation) and capital and operating costs. The most important factors involved in considering paint removal mechanisms include the booth design, the amount and type of paint overspray, and the availability of capital and operating funds. The most common methods include passive settling, skimming, screening, filtration (bag, roll bed, press) and centrifugal methods (hydrocyclone, centrifuge).

Another common method of painting is electrophoretic painting (also known as electrocoating or electrodeposition), which is the process of coating a workpiece by either making it anodic or cathodic in a bath that is generally an aqueous emulsion of the coating material. The electrophoretic painting bath contains stabilized resin, pigment, surfactants, and sometimes organic solvents in water. Electrophoretic painting is used primarily for primer coats (e.g., bodies for mobile industrial equipment) because it gives a fairly thick, highly uniform, corrosion resistant coating in relatively little time.

During this process, precleaned parts carrying an electrical charge are immersed into the coating tank (paint) and then through a rinsing system. Rinsing is used to remove excess paint (termed drag-out) from the parts. Drag-out volumes can be very significant. For example, it is estimated that a car body may carry one gallon of excess paint into the rinse system. The typical rinsing procedure consists of three stages connected in a counterflow arrangement. Rinsing may include both dip and spray rinsing. Typically, the final rinse is performed with deionized water.

Ultrafiltration is commonly used for separating and recovering paint solids and recycling rinse water. This is achieved by counter-flowing the rinse water into the painting bath and filtering the bath with ultrafiltration. The ultrafilter removes excess water from the bath, recycles the paint solids to the bath, and recycles the water (permeate) to the rinse system. Occasional blowdown of rinse system water is needed to purge the system of contaminants. The volume of wastewater discharged can be reduced by processing the rinse water through a reverse osmosis unit (17).

Pollution Prevention and Water Conservation Practices and Technologies

The Agency has identified three categories of pollution prevention and water conservation practices that can be implemented to reduce or eliminate wastewater discharges from painting operations: practices to reduce the quantity of paint entering the water system; recycling technologies for paint booth water; and conversion of water-wash booths to dry filter booths. These are discussed in this section and summarized in Table 16-8.

Reduce the Quantity of Paint Entering the Water System. Sites can implement various methods to reduce the quantity of paint entering the water system. Several of these methods are discussed below.

Improve Spray Painting Operating Practices. Various practices can be implemented that reduce the quantity of paint and other material entering the water system of a paint booth and thereby reduce the need to discharge wastewater. Generally, implementation of these practices only requires operator training. Potential areas of improvement include: racking and positioning parts to minimize overspray; selecting proper nozzle for efficient spray pattern; scheduling work to reduce color changes and associated clean-outs of guns, lines, and pots; and housekeeping to prevent the introduction of painting wastes and foreign materials into the booth's water system.

Improving Transfer Efficiency. The transfer efficiency (i.e., spray efficiency) is the amount of the coating which is applied to the intended substrate divided by the amount of coating which is sprayed from the gun. It is reported as a percentage. The transfer efficiency is dependent on several factors, including the spraying equipment, part size and configuration, paint type, and operating methods. By improving the transfer efficiency, booth water processing requirements can be reduced.

During the past ten years, improvements to spraying equipment have been made, primarily in response to more stringent air pollution regulations and rising paint costs. One of the key improvements has been the replacement of conventional compressed air spray equipment by more efficient equipment. In terms of transfer efficiency, the various common types of spray equipment are ranked as follows (shown in order of increasing efficiency with relative transfer efficiencies shown in parenthesis): conventional compressed air (25%), airless (35%), air assisted airless (45%), electrostatic, (65%), and high volume-low pressure (HVLP) (80%) (12). The HVLP equipment, although relatively new, has been widely implemented due to the high transfer rates, as well as the low cost of converting from conventional compressed air equipment. The cost is primarily for the spray guns, since the compressors and other equipment are the same as for conventional compressed air painting equipment.

Install Gun Cleaning Station. After use, spray painting equipment must be cleaned to prevent a buildup of paint solids. Spray guns are often cleaned by spraying solvent through the lines and guns and into the booth. This practice increases the quantity of paint entering the booth's water system and increases emissions of volatile organic compounds (VOCs). An alternative practice is to install gun cleaning stations. A commercial gun cleaning unit is designed to sit on top of a 55 gallon drum. The gun is connected to the solvent tank and the drum. The gun is operated and solvent is drawn through the gun and exits into the drum. The solvent in the drum can be recovered by distillation (9).

Booth Water Recycle. Various methods and equipment are used to reduce or eliminate the discharge of the water used in water-wash booths. These methods and equipment prevent the continuous discharge of booth waters by conditioning (i.e., adding detacifiers and paint-dispersing polymers) and removing paint solids. The least efficient paint booth water-wash system, in terms of water use, is one where the paint solids are not conditioned and accumulate until booth water replacement is needed. The clean-out of such systems typically involves draining or pumping the water from the booth reservoir and contract hauling of the entire waste product. Due to high operating costs and downtime, this procedure is usually used only by low production operations With moderate and high production levels, daily, if not continuous, booth water maintenance is needed to conserve water. The most basic form of water maintenance is the removal of paint solids by manual skimming and/or raking. This can be performed without water conditioning since some portion of solvent-based paints usually float and/or sink. With the use of detacifiers and paint-dispersing polymer treatments, more advanced methods of solids removal can be implemented. Some common methods are discussed below.

Wet-Vacuum Filtration. Wet-vacuum filtration units consist of an industrial wet-vacuum head on a steel drum containing a filter bag. The unit is used to vacuum paint sludge from the booth. The solids are filtered by the bag and the water is returned to the booth. Large vacuum units are also commercially available that can be moved from booth to booth by forklift or permanently installed near a large booth.

Tank-Side Weir. A weir can be attached to the side of a side-draft booth tank, allowing floating material to overflow from the booth and be pumped to a filtering tank for dewatering (15, 16).

Consolidator. A consolidator is a separate tank into which booth water is pumped. The water is then conditioned by the introduction of chemicals. Detacified paint floats to the surface of the tank, where it is skimmed by a continuously moving blade. The clean water is recycled to the booth (15, 16).

Filtration. Various types of filtration units are used to remove paint solids from booth water. This is accomplished by pumping the booth water to the unit where the solids are separated and returning the water to the booth. The simplest filtration unit consists of a gravity filter bed utilizing paper or cloth media. Vacuum filters are also employed, some of which require precoating with diatomaceous earth (15, 16).

Centrifuge Methods. Two common types of centrifugal separators are the hydrocyclone and the centrifuge. The hydrocyclone is used to concentrate solids. The paint booth water enters a cone-shaped unit under pressure and spins around the inside surface. The spinning imparts an increased force of gravity which causes most of the solid particles to be pulled outward to the walls of the cone. Treated water exits the top of the unit and the solids exit from the bottom. Some systems have secondary filtration devices to further process the solids. The centrifuge works in a similar manner, except that the booth water enters a spinning drum which imparts the centrifugal force needed for separating the water and solids. Efficient centrifugation requires close control of the booth water chemistry to assure a uniform feed. Also, auxiliary equipment such as booth water agitation equipment may be needed.

Convert Water-Wash Booths to Dry Filter Booths. Water-wash booths can be converted to or replaced by dry filter booths. The dry filter booths have the potential to eliminate the discharge of wastewater, but they create a solid waste stream. The choice between using a water-wash booth or a dry filter booth is primarily based on the quantity of overspray. It is usually cost effective to use a dry filter booth when paint usage does not exceed 20 gallons/8 hour shift/10 feet of chamber width (14).

A 1989 Navy study concluded that conversion from wet to dry booths can be cost effectively performed over a range of operational scenarios. The Navy work included a survey of military and industrial facilities that have successfully made the conversion and an economic analysis based on typical Navy painting operational parameters (19).

Evaluating Water Use for Painting Operations

To identify sites with good painting-related water use practices, a permit writer should focus on the categories of these practices discussed above. Specifically, sites should pass both of the following criteria for the majority of painting operations on site:

(1) The site should employ practices and/or technologies to reduce the amount of paint entering the water system; and

(2) The site should employ some type of practice or technology that minimizes or eliminates the discharge of wastewater by recycling the water used during painting or replacing existing wet systems with dry systems.

Table 16-8 presents examples of practices and technologies that sites can implement to satisfy these criteria.

16.4.2 Flow Guidance for Calculating Mass-Based Limitations

For sites that do not have pollution prevention and water conservation practices in place, the Agency recommends that permit writers do not use historical flow as a flow basis for developing mass-based limitations. This section presents flow guidance to assist permit writers in identifying appropriate flow rates for painting operations to develop mass-based limitations.

Influences on Flow Rates

Available data show that wastewater discharge rates from painting operations are a function of production when measured in terms of the surface area of parts painted (see Table 16-1). Wastewater discharge rates are also affected by other factors that will cause PNFs to vary from site to site. Some sites are able to operate without a wastewater discharge, while others have a wide range of PNFs. The most important of these factors are the paint transfer efficiency, booth type and reservoir size, maintenance requirements of the booth, the booth water chemistry and water recycling methods employed, and the chemical make-up of the paint being applied. Several of these factors (e.g., paint transfer efficiency and the booth water chemistry and water recycling methods employed) can be controlled by sites by implementing the proper pollution prevention and water conservation practices and technologies, as discussed in Section 16.4.1. Some factors are, to a degree, beyond control of the site and will affect the minimum PNF achievable by a site. The effects of these factors on PNF are discussed below.

Solvent, Paint Solids, and Other Components of Paint. The chemical make-up of the paint can impact the PNF. The recirculated water in a water-wash booth contains the various constituents of the paint(s) being applied. With most solvent formulations, the

solvents (e.g., xylene, toluene, methylene chloride) are not water soluble, but can be water miscible. There are some exceptions, such as acetone and methyl ethyl ketone (MEK), which are water soluble. However, in most cases, the solvents are volatile and evaporate over time and exit the booth through the air exhaust system. The organic resins that make up the bulk of the paint coating are insoluble in water and tend to stay tacky if not treated with some additional material introduced to the water (15, 16). If left untreated, the tacky solids can plug recirculation pipes and pumps and adhere to wetted surfaces of the booth. Other paint additives, such as wetting agents, pigments, and heavy metals (e.g., zinc and chromium salts) may be soluble in water. These constituents can be made partly insoluble and removed by adjusting the chemistry of the water.

Water-based paints present two problems with regard to water use. First, these paints disperse in water rather than agglomerate like solvent-based paints. This makes the maintenance of paint booth waters more difficult (15, 16). Second, water is used to clean spraying equipment when water-based paints are applied, and may result in the generation of wastewater. A typical equipment cleaning procedure is to flush with water, then solvent, then water (18).

Paint Booth Maintenance Requirements. Water-wash paint booths are periodically shut down for maintenance, which usually requires that the water in the booth be removed. Various conditions can exist that may create a need to discharge the water, including: odor, bacterial growth, foaming, total dissolved solids (TDS) buildup, and the presence of corrosion and scale constituents.

Booth maintenance typically involves cleaning of the booth surfaces and piping system and incidental repairs. Often this is performed according to a maintenance schedule, but periodic repairs may also necessitate an unplanned shut-down and clean-out. A common procedure for clean-out is to remove the accumulated paint solids from the water, transfer the water to a holding tank, and subsequently return the water after the maintenance has been performed. Alternatively, sites drain the booth water to a sewer or wastewater treatment system or have it hauled to a disposal site.

Water use and discharge may occur during maintenance operations. Systems with accumulated paint solids on the wetted surfaces of the booth and in the piping system can be cleaned by circulating an alkaline cleaner or other chemical for dissolving paint.

Water Reservoir Size. Downward-draft booths generally hold larger volumes of water than side-draft units. Downward-draft sump sizes were identified to be at least 5,000 gallons (19). Effective recycling of the painting water may require an equal holding capacity for sump clean-out.

Guidance for Production-Normalized Flow (PNF) Selection

The following table presents PNF data from the MP&M DCPs for painting operations. These data are summarized from Table 16-1. Data are in gallons of wastewater (i.e., discharged paint booth waters) per square foot of surface area painted.

PNFs for Painting Operations

Minimum PNF	10th Percentile	25th Percentile	Median PNF	75th Percentile	90th Percentile	Maximum PNF	Mean PNF
0.0001	0.0004	0.0023	0.025	0.10	0.36	71	1.3

Source: MP&M Phase I DCP Database.

As shown in this table, the PNFs for painting operations range several orders of magnitude. The DCP data do not include information on the exact types of pollution prevention and water conservation practices in place at the MP&M sites; therefore, the PNFs listed in this table cannot be directly linked to these practices. Based on data gathered during site visits, and from information in technical literature, the Agency believes that the wide range of PNFs is indicative of the degree to which the sites practice pollution prevention and water conservation (e.g., sites with paint booth water recycling practices in place versus sites without these practices in place).

Based on the available data and information, the Agency believes that most sites can achieve zero discharge of painting booth wastewaters. For sites that have a demonstrated need to discharge painting booth wastewater, EPA recommends that permit writers use the PNF data presented above for painting operations in developing mass-based limitations.

16.5 Flow Guidance for Cleaning Operations

This section provides flow guidance for cleaning operations, which are significant sources of MP&M Phase I process wastewater. Cleaning operations include acid treatment, alkaline treatment, and electrolytic cleaning. Depending on the chemicals, equipment, and procedures employed, these processes are commonly referred to as immersion, spray, or electrolytic alkaline cleaning; immersion, spray, or electrolytic acid cleaning or pickling; ultrasonic cleaning; and emulsion cleaning.

This section addresses flow guidance for cleaning solutions or baths. Cleaning solutions become contaminated during use and the constituents of the bath are depleted. When the performance of the baths is reduced, the baths are discharged to treatment or contract hauled for off-site treatment and disposal. Rinse waters are also generated from cleaning operations; flow guidance aspects of rinsing are discussed in Section 16.2.

16.5.1 Identifying Sites With Pollution Prevention and Water Conservation Practices

As discussed in Section 16.1, the Agency recommends that permit writers use historical flow data to calculate mass-based limitations for sites that have implemented pollution prevention and water conservation practices. This section provides background information and guidance that can be used by the permit writer to determine if a site has implemented pollution prevention and water conservation practices for their cleaning operations. If the site has implemented pollution prevention and water conservation practices, the permit writer would multiply the site's historical process wastewater discharge flow rate by the concentration-based limitations to calculate mass-based limitations. This will eliminate the requirement of identifying alternate methods to develop mass-based limitations, including tracking production rates through unit operations.

Many MP&M Phase I sites employ some form of pollution prevention and water conservation practices for cleaning operations. Some sites implement several pollution prevention and water conservation methods and technologies that result in low cleaning wastewater discharge rates and in some cases eliminate the discharge of cleaning solutions. Pollution prevention and water conservation practices are applicable to all cleaning operations; however, process-related factors and site-specific conditions may restrict the utility of certain methods. This section identifies pollution prevention and water conservation practices and technologies applicable to cleaning operations and provides guidance on how to evaluate a site's water use practices.

Wastewater Generation From Cleaning Operations

Cleaning is commonly performed at MP&M Phase I sites as a stand-alone operation or in combination with other MP&M Phase I unit operations such as anodizing, electroplating, conversion coating, and painting. The purpose of cleaning is to remove surface contaminants that affect the appearance of parts or the ability to further process the parts. Various types of acidic and alkaline solutions are used for cleaning.

Cleaning solutions become contaminated during use and the constituents of the bath are depleted. Alkaline cleaners are usually impacted by organic soils such as oil and grease. The effectiveness of most cleaners is reduced when the oil concentration of the bath is in the range of 1 to 5 g/L or more. Oil and grease enter the alkaline cleaning bath on the parts being processed. The rate of oil buildup depends on the production rate (measured in square feet per day) and the quantity and characteristics of the contamination on the parts. Acid treatment solutions and to a lesser extent alkaline treatment solutions accumulate dissolved metals from corrosion of the base metals being processed. The dissolved metal reduces the strength of the cleaning bath. As a buildup of dissolved metal occurs, additional acid or alkaline solution is added, but at certain metal concentrations the bath is no longer usable. The tolerable concentration of

dissolved metal depends mostly on the type of acid or alkaline solution and the function of the bath. The buildup rate of dissolved metal depends primarily on the production rate, type and concentration of acid or alkaline solution, type of base metal, duration of cleaning cycle, and bath temperature.

Pollution Prevention Practices and Technologies

The Agency has identified three categories of pollution prevention and water conservation practices that can be implemented to reduce or eliminate wastewater discharges from cleaning operations: housekeeping and maintenance; oil and suspended solids removal; and dissolved solids removal. These are discussed in this section and summarized in Table 16-9.

Housekeeping and Maintenance. Sites can implement various housekeeping and maintenance practices to reduce the quantity of cleaning solution discharge. Several of these practices are discussed below.

Solution Testing. The chemical make-up of cleaning solutions changes over time due to evaporative losses, additions of water, drag-out of cleaning chemicals, consumption of bath chemistry, chemical reactions, and drag-in of impurities. Because of these factors, cleaning baths lose strength, performance declines, and solutions require disposal. Many sites operate cleaning baths with a schedule consisting of three steps: formulate, use, and discard. This procedure can be expensive and inefficient from a production standpoint, and creates large volumes of waste. For this reason, sites should frequently determine the strength of the cleaning solution and appropriate chemical additions needed to continue solution use. By implementing a program of testing and record keeping, sites can reduce the disposal frequency of cleaning baths.

Most alkaline cleaning solutions are proprietary formulations, and the vendors of these solutions provide test methods for determining the condition of a bath. Also, generic test methods can be employed for which commercial test kits are available. For example, the strength of an alkaline cleaning solution can be tested using a procedure known as the acid-base titration, which measures alkalinity. Also, there is a dual test method that indirectly measures the level of contamination in the cleaner. This process consists of titrating a measured sample of cleaner (e.g., 5 ml) to which is added a color indicator (phenolphthalein or methyl orange) with an acid of precise concentration (e.g., 1*N* solution of sulfuric acid). Phenolphthalein is used as the indicator to measure free alkalinity and methyl orange is used to measure total alkalinity. By performing both tests, the ratio of total alkalinity to free alkalinity can be calculated. A ratio close to one indicates that the cleaner is relatively free of contamination, while a higher ratio indicates that contamination exists. This ratio is sometimes used to determine if a cleaning solution should be discharged. For example, a common guideline used is that the solution is discarded when the ratio exceeds 2.0. The total alkalinity/free alkalinity test method does not work for all cleaners. For example, because of additives used,

some alkaline cleaners do not have any free alkalinity. In such cases, it is necessary to perform more elaborate tests to accurately determine the contaminant concentration (e.g., oil and grease measurement).

Similar test methods exist for acid cleaners. The most common parameters that are included in acid cleaner test programs are acid concentration and dissolved metal concentration. The concentration of sulfuric acid or hydrochloric acid in pickling solutions is usually measured by titrating a sample of the solution with sodium carbonate and using a methyl orange indicator. Iron and other dissolved metals can also be measured by titration or by using laboratory analytical equipment such as an atomic adsorption spectrophotometer.

Recordkeeping. Record keeping is essential for all metal processing solutions, including acid and alkaline cleaners. By maintaining accurate records, a site can identify trends in solution use and focus efforts on extending the lives of those that are frequently discarded. The records of importance are occurrences of chemical additions and solution dumps, production throughput, and analytical data.

Miscellaneous Housekeeping and Maintenance. To obtain consistently good cleaning results and reduce the discharge rate of solution, sites should implement a regular schedule of housekeeping and maintenance. Tasks to be considered include: checking the accuracy of temperature controls; removing sludge build-up from tanks, heating coils, and temperature regulators; retrieving parts, racks, and other foreign materials dropped into the tanks; and checking the integrity of tanks and tank liners.

Oil and Suspended Solids Removal. Cleaning baths accumulate oil and suspended solids during use and eventually reach a contaminant concentration that interferes with the effectiveness of the cleaning process despite the fact that most bath constituents remain usable. Also, contaminated cleaning baths may result in contaminant carry-over to subsequent process solutions. As a result, the cleaning baths are often discarded when they reach a certain concentration of contaminants. The following is a discussion of technologies used to remove oil and suspended solids from cleaning solutions, thereby extending the useful life span of the solutions. These technologies are primarily applicable to alkaline cleaning baths.

Free/Floating Oil Separation Devices. Separation devices for oil/water mixtures take advantage of the difference in specific gravity between oils and water to remove free or floating oil from wastewater. Common separation devices for cleaning solutions include: disk, belt, and rotating drum oil skimmers, and coalescers. These devices are not suited to the removal of emulsified oil, which requires chemical treatment or membrane filtration.

Skimming is a simple method for separating floating oil from cleaning solutions. Skimming devices are typically mounted onto the side of a tank and operate on a

continuous basis. The disk skimmer consists of a vertically rotating disk (typically 12 to 24 inches in diameter) that is partially submerged into the liquid of a tank (typically to a depth of 4 to 12 inches below the liquid surface). The disk continuously revolves between spring loaded wiper blades that are located above the liquid surface. The adhesive characteristics of the floating oil cause the oil to adhere to the disk. The oil is removed from the disk as the disk surface passes through the wiper blades, and diverted to a run-off spout for collection. Maximum skimming rates are typically in the range of 2 to 10 gallons per hour of oil. Belt and drum skimmers operate in a similar manner, with either a continuous belt or drum rotating partially submerged in a tank. As the surface of the belt or drum emerge from the liquid, the oil that adheres to its surface is scraped (drum) or squeezed (belt) off and diverted to a collection vessel.

Coalescers are used to separate liquids with specific gravity differences of 0.09 and greater. Coalescers are typically designed as tanks containing a coalescing media which accelerates phase separation (20). Cleaning solution and oil are removed from the process tank by a suction skimmer and pumped to the coalescer. The media in the coalescers is a material such as polypropylene, ceramic, or glass which attracts oil in preference to water (i.e., oleophilic). The oil/cleaner mixture passes through the unit and the oil adheres to the coalescing media. The oil forms droplets which conglomerate and rise to the surface of the tank where the oil is removed by a skimming device or weir. According to Stoke's Law, the rise/fall velocity of a dispersed phase droplet is exponentially increased with the droplet size. Therefore, the coalescing media causes a far more rapid phase separation than a common gravity settling device.

Common Filtration Methods Filtration is employed to remove suspended solids from cleaning solutions. Common types of filters include cartridge filters, precoat diatomaceous earth filters, and sand or multimedia filters. Cartridge filters are available with either in-tank or external configurations. The in-tank units typically are used for small tanks and the external units for larger tanks. Most cartridges are disposable; however, washable and reusable filters are available which further reduce waste generation. Precoat, sand, and multimedia filters are used mostly for large tank applications. Filter media are selected based on the chemical composition of the bath. All filtration systems are sized based on solids loading and the required flow rate. Typical flow rates for cleaning solution applications are two to three bath turnovers per hour.

Membrane Filtration. Microfiltration and ultrafiltration are membrane-based technologies applied primarily for the removal of emulsified oil and other colloids from aqueous and semi-aqueous cleaning solutions. The feed stream entering a microfiltration or ultrafiltration unit is typically filtered conventionally to remove large particulates. Various units are then employed to trap or skim floating oils and to allow heavier solids to settle. The fluid is then pumped into the membrane compartment of the unit where remaining oils and grease are rejected by the membrane while water, solvent and other cleaning bath constituents pass through. The fluid flows parallel to the membrane with

enough velocity to remove the reject from the membrane surface. Ceramic membranes are available in various pore sizes ranging from several hundred angstroms to over 0.2 microns. The appropriate pore size is determined by the specific cleaner to be filtered. The capacity of a unit is based on the total area and flux rate of the membrane. Commercially available units range in capacity from less than 260 to more than 1,300 gallons per day.

Dissolved Metals Removal

Metals become dissolved in acid and alkaline cleaning solutions as a result of corrosion of the base metal. The dissolved metal forms salts or other compounds that reduce the strength of the cleaning bath. Technologies used for the removal of dissolved metals include acid sorption, diffusion dialysis, and membrane electrolysis.

Acid Sorption. Acid sorption is an acid purification technology that is applicable to various acid treatment solutions, as well as other acidic baths (e.g. anodizing baths). Acid is purified by the removal of dissolved metal. The acid sorption unit resembles an ion-exchange column. The column contains a bed of alkaline anion exchange resin that separates the acid from the metal ions. The acid is taken up by the resin while the metal ions pass through the resin. Water is used to desorb the acid from the resin. The use of water to remove the acid from the resin is the primary difference between this technology and ion exchange, where acidic and alkaline solutions are used for regeneration.

The flow through the resin bed alternates between acid and water. First, spent acid is pumped upward through the resin. A metal-rich, mildly acidic solution passes through the resin and is collected at the top of the bed. Water is then pumped downward through the bed and desorbs the acid from the resin. The purified acid solution is collected at the bottom of the bed. Approximately 80% of the free acid remaining in a spent acid treatment solution can be recovered with this technology. Purification can be performed in a batch mode, but is most effective in a continuous flow mode. Capacity is usually expressed in terms of the mass of metal removed from the acid solution per unit time. Equipment capacities range from 100 grams/hour to several thousand grams/hour. Units are sized to remove metal near or above the rate at which the metal is being introduced. Typically, a target level of metal concentration is determined and the unit is sized to maintain that level.

Diffusion Dialysis. Diffusion dialysis is a membrane process that separates the acid solution from its metal contaminants using an acid concentration gradient between solution compartments. Anion exchange membranes are employed to create the compartments. The membranes are usually assembled in a membrane stack, like that used with electrodialysis. The contaminated acid is passed through one set of compartments and deionized (DI) water through the adjacent compartments. Acid is diffused across the membrane into the DI water whereas metals are blocked due to their

charge and the selectivity of the membrane. Unlike electrodialysis, no electrical potential is used with the diffusion dialysis process. The transport of acid is caused by the difference in acid concentration on either side of the membrane (i.e., material in high concentration moves to an area of low concentration).

Membrane Electrolysis. Membrane electrolysis is a bath maintenance technology used to lower or maintain at an acceptable level the concentration of metallic impurities in cleaning solutions. This technology is also applicable to other metal-bearing solutions (e.g., electroplating, anodizing, and stripping solutions). This technology uses an ion-exchange membrane(s) and an electrical potential applied across the membrane(s). The membranes employed with these technologies are ion-permeable and selective, permitting ions of a given electrical charge to pass through. Cation membranes allow only cations, such as copper, nickel, and aluminum to pass from one electrolyte to another, while anion membranes allow only anions, such as sulfates, chromates, chlorides, or cyanide to pass through. Bath maintenance units can be configured with only cation or anion membranes or both.

A typical application of membrane electrolysis is maintenance of an acid cleaning solution. The cleaning solution is placed into an anode compartment that is separated from a second electrolyte by a cation membrane. The solution in the cathode compartment (i.e., catholyte) is typically a dilute acidic or alkaline solution. When an electrical potential is applied, the dissolved metals in the cleaning solution migrate through the cation membrane, into the catholyte. The catholyte is periodically discarded when it becomes saturated with metals.

Evaluating Cleaning Solution Use at a Site

To identify sites with good solution use practices in place for cleaning operations, a permit writer should focus on the categories of these practices discussed above. Specifically, sites should pass both of the following criteria for the majority of cleaning operations on site:

(1) The site should employ practices to monitor the chemical condition of cleaning solutions and make additions/corrections, as needed; and

(2) The site should employ some type of practice or technology to extend the life of the cleaning solution, including the prevention of contamination and the removal of contaminates.

Table 16-9 presents examples of practices and technologies that sites can implement to satisfy these criteria.

16.5.2 Flow Guidance for Calculating Mass-Based Limitations

For sites that do not have pollution prevention and water conservation practices in place, the Agency recommends that permit writers do not use historical flow as a flow basis for developing mass-based limitations. This section presents flow guidance to assist permit writers in identifying appropriate flow rates for cleaning operations to develop mass-based limitations.

Influences on Flow Rates

Available data show that wastewater discharge rates from cleaning operations are a function of production when measured in terms of the surface area of parts processed (see Table 16-1). Wastewater discharge rates are also affected by other factors that will cause PNFs to vary from site to site. Some sites are able to operate without a wastewater discharge, while other sites have a wide range of PNFs. The most important of these factors are the condition of the surfaces being cleaned, cleaning requirements, type of cleaning process employed, and the methods used for maintaining the cleaning solution in usable condition. The last of these factors can be controlled by sites by implementing the proper pollution prevention and water conservation practices and technologies, as discussed in Section 16.5.1. The other factors are, to a degree, beyond control of the site and will affect the minimum PNF achievable by a site. The affects of these factors on PNF are discussed below.

Condition of the Surfaces Being Cleaned. The condition of the parts being cleaned varies widely, both in terms of the types and quantities of contaminants present and the quantity of soil. For example, some parts may have been wiped clean and have only a light deposit of metal oxide, while other parts may be heavily coated with metal-working fluids. Since the contaminants present on the parts is removed during the cleaning process, the rate of soil introduction per square foot of part cleaned will vary. The type and quantity of soil entering the cleaning solution will therefore affect the cleaner's life-span.

Cleaning Requirements. Some processes such as electroplating require a high degree of cleanliness while others, such as phosphate conversion coating, may have less stringent requirements. The cleaning requirements will therefore vary within a site, as well as from site to site, as will the type of cleaning process selected.

Some cleaning processes are more amenable to pollution prevention practices than others, based on the purpose of the cleaning process. Some cleaning processes are performed to condition the parts as well as to provide cleaning. For example, many electroplating processes require etching of the surface of the part to enhance adhesion of the electroplated metal deposit. Surface etching will cause the introduction of dissolved metal into the cleaning solution and will reduce its life-span.

Type of Cleaning Process and Equipment. The life-span of cleaning solutions depends on the type of cleaning process (i.e., process chemistry and cleaning equipment). Numerous factors affect the selection of a cleaning process, including: type and characteristics of contaminants to be removed; type and condition of base metal; size and configuration of parts; degree of cleanliness required; processing capabilities at the site; subsequent operations to be performed; and financial considerations.

The factors that most affect the selection of process chemistry and equipment are the type of contaminants present on the parts, type of base metal, and the subsequent finishing operation, which in turn dictates the cleaning requirements. Contaminants present on parts can be divided into organic and inorganic contaminants. Examples of organic contaminants are machining fluids, miscellaneous oils, waxes, and buffing compounds. These are typically removed by solvents, detergents, and alkaline solutions. Examples of inorganic contaminants are scale, smut, and grinding residue. These are typically removed by acidic solutions. For both organic and inorganic contaminant removal, various methods are employed. For example, solutions can be applied by spraying or immersing, and can be applied electrolytically (including both anodic and cathodic cleaning). These choices are made primarily based on the concentration and condition of the contaminant and the configuration of the parts.

The base material of the parts is also a consideration when selecting a cleaning process. Some base materials are chemically or physically altered by certain cleaning steps due to mechanisms such as oxidation, etching, activation, and hydrogen embrittlement. Such changes may be either desirable or damaging. The base material must be considered not only in selecting a cleaning chemical but also when considering the operating conditions of the cleaning process (e.g., concentration, temperature, current). Further, the base material contaminates the cleaning solution (e.g., etching during acid treatment), and therefore has an effect on the life span of the solution.

Guidance for Production-Normalized Flow (PNF) Selection

The following table presents PNF data from the MP&M DCPs for cleaning operations. These data are summarized from Table 16-1. Data are in gallons of solution discharged per square foot of surface area processed.

PNFs for Cleaning Operations

Unit Operation	Minimum PNF	10th Percentile	25th Percentile	Median PNF	75th Percentile	90th Percentile	Maximum PNF	Mean PNF
Acid Treatment	0.0000	0.0015	0.0088	0.034	0.14	0.95	140	1.7
Alkaline Treatment	0.0000	0.0027	0.010	0.050	.027	2.8	470	5.7
Electrolytic Cleaning	0.0001	0.0016	0.0032	0.049	0.15	7.6	83	6.2

Source: MP&M Phase I DCP Database.

As shown in this table, the PNFs for cleaning operations range several orders of magnitude. The DCP data do not include information on the types of pollution prevention and water conservation practices in place at the MP&M sites; therefore, the PNFs listed in this table cannot be directly linked to these practices. Based on the data gathered during site visits and from technical literature, the Agency believes that the wide range of PNFs is indicative of the variety of water use practices in place at MP&M sites (e.g., sites with cleaning solution maintenance and recycling practices in place versus sites without these practices in place).

Based on the available data and information, the Agency believes that most sites can reduce their flow rates from cleaning operations by implementing pollution prevention and water conservation practices. Site-specific conditions may limit the ability of certain sites to reduce the flow rates.

Table 16-1

Descriptive Statistics of MP&M Data Collection Portfolio Data for Unit Operations with Square Feet as the Production-Normalizing Parameter

Unit Operation	Total Occurrences	No. PNF Calcs	Minimum PNF (gal/sq ft)	10th Percentile (gal/sq ft)	25th Percentile (gal/sq ft)	Median PNF (gal/sq ft)	75th Percentile (gal/sq ft)	90th Percentile (gal/sq ft)	Maximum PNF (gal/sq ft)	Mean PNF (gal/sq ft)
Abrasive Blasting	33	6	0.0100	0.0100	0.2587	1.0296	1.5893	1.5893	1.5893	0.9177
Abrasive Blasting-Rinse	30	8	0.0089	0.0089	0.4930	2.3642	120.1613	200.0000	200.0000	55.7557
Acid Treatment	732	195	0.0000	0.0015	0.0088	0.0340	0.1358	0.9466	139.7760	1.7012
Acid Treatment-Rinse	605	215	0.0006	0.1000	0.5000	2.4770	16.4571	76.8342	3,756.2500	50.2909
Adhesive Bonding	5	3	0.0017	0.0017	0.0017	0.0223	0.0439	0.0439	0.0439	0.0226
Adhesive Bonding-Rinse	1	0	NA	NA	NA	NA	NA	NA	NA	NA
Alkaline Treatment	952	209	0.0000	0.0027	0.0102	0.0500	0.2711	2.7697	468.7500	5.7399
Alkaline Treatment-Rinse	613	164	0.0007	0.0694	0.2579	1.0573	11.7211	83.1395	3,750.0000	56.8130
Anodizing	129	22	0.0014	0.0026	0.0070	0.0318	0.2563	0.5784	200.0000	9.2690
Anodizing-Rinse	95	18	0.0260	0.0439	0.2500	0.6777	13.4832	240.0000	938.4000	74.4368
Assembly	8	1	0.2520	0.2520	0.2520	0.2520	0.2520	0.2520	0.2520	0.2520
Assembly-Rinse	6	0	NA	NA	NA	NA	NA	NA	NA	NA
Barrel Finishing	299	33	0.0029	0.0694	0.2350	1.1739	9.8684	70.0000	120.0000	15.6880
Barrel Finishing-Rinse	106	12	0.0029	0.0086	0.0825	1.9583	2.9124	5.4000	5.6250	2.0878
Brazing	3	0	NA	NA	NA	NA	NA	NA	NA	NA
Brazing-Rinse	17	2	0.2632	0.2632	0.2632	10.1316	20.0000	20.0000	20.0000	10.1316
Burnishing	23	2	2.8387	2.8387	2.8387	8.0194	13.2000	13.2000	13.2000	8.0194
Burnishing-Rinse	9	0	NA	NA	NA	NA	NA	NA	NA	NA
Calibration	4	0	NA	NA	NA	NA	NA	NA	NA	NA
Chemical Conversion Coating	498	125	0.0000	0.0006	0.0022	0.0188	0.1000	0.6667	9.0000	0.3447

NA - Not available. Insufficient data for calculation.

Table 16-1 (Continued)

Descriptive Statistics of MP&M Data Collection Portfolio Data for Unit Operations with Square Feet as the Production-Normalizing Parameter

Unit Operation	Total Occurrences	No. PNF Calcs	Minimum PNF (gal/sq ft)	10th Percentile (gal/sq ft)	25th Percentile (gal/sq ft)	Median PNF (gal/sq ft)	75th Percentile (gal/sq ft)	90th Percentile (gal/sq ft)	Maximum PNF (gal/sq ft)	Mean PNF (gal/sq ft)
Chemical Conversion Coating-Rinse	352	85	0.0012	0.0125	0.0813	0.2601	1.7200	12.3429	1,329.2308	22.3281
Chemical Machining	24	3	0.0009	0.0009	0.0009	0.0550	12.4424	12.4424	12.4424	4.1661
Chemical Machining-Rinse	16	4	0.5000	0.5000	5.2500	10.4390	13.6676	16.4571	16.4571	9.4588
Corrosion Preventive Coating	105	15	0.0000	0.0008	0.0044	0.0078	0.2572	0.6940	0.9681	0.1547
Corrosion Preventive Coating-Rinse	11	3	0.1976	0.1976	0.1976	0.5580	1.8113	1.8113	1.8112	0.8556
Disassembly-Rinse	6	0	NA	NA	NA	NA	NA	NA	NA	NA
Electrochemical Machining	11	0	NA	NA	NA	NA	NA	NA	NA	NA
Electrochemical Machining-Rinse	8	1	3.8710	3.8710	3.8710	3.8710	3.8710	3.8710	3.8710	3.8710
Electrolytic Cleaning	78	22	0.0001	0.0016	0.0032	0.0488	0.1500	7.6087	83.3333	6.1641
Electrolytic Cleaning-Rinse	68	20	0.0493	0.1233	0.8559	1.5110	32.9461	91.9705	154.9333	25.6060
Electroplating	344	81	0.0003	0.0025	0.0129	0.0602	0.6857	2.9394	11.4289	1.0406
Electroplating-Rinse	301	110	0.0309	0.2638	1.2739	4.9116	37.5000	230.6826	3,750.0000	143.6245
Electropolishing	13	0	NA	NA	NA	NA	NA	NA	NA	NA
Electropolishing-Rinse	7	0	NA	NA	NA	NA	NA	NA	NA	NA
Floor Cleaning	180	47	0.0000	0.0003	0.0007	0.0053	0.0333	0.2500	6.9444	0.2749
Floor Cleaning-Rinse	7	2	0.0769	0.0769	0.0769	0.0948	0.1128	0.1128	0.1128	0.0948
Heat Treating Quench	149	7	0.0104	0.0104	0.0163	1.0008	94.1539	158.9425	158.9425	41.8207
Heat Treating-Rinse	34	2	3.0252	3.0252	3.0252	7.4298	11.8343	11.8343	11.8343	7.4298

NA - Not available. Insufficient data for calculation.

Table 16-1 (Continued)

Descriptive Statistics of MP&M Data Collection Portfolio Data for Unit Operations with Square Feet as the Production-Normalizing Parameter

Unit Operation	Total Occurrences	No. PNF Calcs	Minimum PNF (gal/sq ft)	10th Percentile (gal/sq ft)	25th Percentile (gal/sq ft)	Median PNF (gal/sq ft)	75th Percentile (gal/sq ft)	90th Percentile (gal/sq ft)	Maximum PNF (gal/sq ft)	Mean PNF (gal/sq ft)
Hot Dip Coating	2	0	NA	NA	NA	NA	NA	NA	NA	NA
Hot Dip Coating-Rinse	1	0	NA	NA	NA	NA	NA	NA	NA	NA
Impact Deformation	34	2	0.0784	0.0784	0.0784	0.1743	0.2702	0.2702	0.2702	0.1743
Impact Deformation-Rinse	13	0	NA	NA	NA	NA	NA	NA	NA	NA
Metal Spray (Incl Water Curtains)	17	1	2.2500	2.2500	2.2500	2.2500	2.2500	2.2500	2.2500	2.2500
Painting (Incl Water Curtains)	182	59	0.0001	0.0004	0.0023	0.0250	0.1039	0.3600	70.9036	1.3094
Painting-Rinse	22	8	0.0124	0.0124	0.0510	0.0986	0.8142	0.9598	0.9598	0.3625
Plating-Electroless and Immersion	61	23	0.0009	0.0013	0.0032	0.0302	0.6667	3.4348	24.9600	1.7511
Plating Rinse-Electroless and Immersion	55	22	0.0909	0.8681	2.0870	6.8698	13.8060	86.4000	241.6667	29.0235
Polishing	32	4	0.4542	0.4542	0.5771	1.4375	8.6440	15.1131	15.1131	4.6106
Polishing-Rinse	18	5	2.0571	2.0571	13.8889	13.8889	22.7121	41.7600	41.7600	18.8614
Pressure Deformation	31	1	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106	0.0106
Pressure Deformation-Rinse	5	0	NA	NA	NA	NA	NA	NA	NA	NA
Rinsing	81	16	0.0008	0.0016	0.0478	0.5091	4.4369	20.0000	74.1818	7.6157
Salt Bath Descaling	5	0	NA	NA	NA	NA	NA	NA	NA	NA
Salt Bath Descaling-Rinse	8	1	1.4976	1.4976	1.4976	1.4976	1.4976	1.4976	1.4976	1.4976
Soldering	5	2	0.0031	0.0031	0.0031	27.7909	55.5786	55.5786	55.5786	27.7909
Soldering-Rinse	28	10	0.3175	0.3678	1.3694	3.0301	13.3333	15.8333	17.7778	6.3159

NA - Not available. Insufficient data for calculation.

Table 16-1 (Continued)

Descriptive Statistics of MP&M Data Collection Portfolio Data for Unit Operations with Square Feet as the Production-Normalizing Parameter

Unit Operation	Total Occurrences	No. PNF Calcs	Minimum PNF (gal/sq ft)	10th Percentile (gal/sq ft)	25th Percentile (gal/sq ft)	Median PNF (gal/sq ft)	75th Percentile (gal/sq ft)	90th Percentile (gal/sq ft)	Maximum PNF (gal/sq ft)	Mean PNF (gal/sq ft)
Solvent Degreasing	18	5	0.0276	0.0276	0.0940	0.0940	0.1515	0.8475	0.8475	0.2429
Solvent Degreasing-Rinse	35	8	0.3528	0.3528	1.9017	2.8629	65.6896	4,500.0000	4,500.0000	580.1577
Sputtering-Rinse	1	0	NA	NA	NA	NA	NA	NA	NA	NA
Stripping	141	29	0.0029	0.0056	0.1380	0.3000	0.6000	7.5758	61.0834	3.6535
Stripping-Rinse	125	27	0.0400	0.0722	0.3333	7.8400	29.0323	164.5714	720.0000	55.9570
Testing	247	24	0.0004	0.0026	0.0347	1.3548	13.4574	37.8871	59.5200	10.4011
Testing-Rinse	74	8	0.0440	0.0440	0.3368	0.8747	2.6805	4.6789	4.6789	1.5634
Thermal Cutting	9	2	0.1167	0.1167	0.1167	0.1336	0.1506	0.1506	0.1506	0.1336
Thermal Infusion	1	0	NA	NA	NA	NA	NA	NA	NA	NA
Thermal Infusion-Rinse	1	1	6.0696	6.0696	6.0696	6.0696	6.0696	6.0696	6.0696	6.0696
Ultrasonic Machining	1	1	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
Ultrasonic Machining-Rinse	1	1	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000	0.2000
Welding	17	1	0.0708	0.0708	0.0708	0.0708	0.0708	0.0708	0.0708	0.0708
Welding-Rinse	5	1	30.7251	30.7251	30.7251	30.7251	30.7251	30.7251	30.7251	30.7251

NA - Not available. Insufficient data for calculation.

NA - Not available. Insufficient data for calculation.

Table 16-1 (Continued)

Descriptive Statistics of MP&M Data Collection Portfolio Data for Unit Operations with Pounds of Metal Removed as the Production-Normalizing Parameter

Unit Operation	Total Occurrences	No. PNF Calcs	Minimum PNF (gal/lb met rem)	10th Percentile (gal/lb met rem)	25th Percentile (gal/lb met rem)	Median PNF (gal/lb met rem)	75th Percentile (gal/lb met rem)	90th Percentile (gal/lb met rem)	Maximum PNF (gal/lb met rem)	Mean PNF (gal/lb met rem)
Abrasive Jet Machining	6	2	158.2967	158.2967	158.2967	1,057.7595	1,957.2222	1,957.2222	1,957.2222	1,057.7595
Abrasive Jet Machining-Rinse	1	0	NA	NA	NA	NA	NA	NA	NA	NA
Electrical Discharge Machining	42	6	0.2339	0.2339	0.6667	4.3750	5.1269	23.1200	23.1200	6.3162
Grinding	510	204	0.0003	0.0161	0.0686	0.3691	1.8526	6.0522	193.1818	4.0448
Grinding-Rinse	19	4	0.3064	0.3064	0.9345	1.9879	19.9567	37.5000	37.5000	10.4456
Machining	2,161	974	0.0001	0.0040	0.0180	0.0535	0.2326	0.9920	512.0482	1.6429
Machining-Rinse	66	2	0.1754	0.1754	0.1754	7.7786	15.3818	15.3818	15.3818	7.7786
Plasma Arc Machining	21	0	NA	NA	NA	NA	NA	NA	NA	NA

Source: MP&M Phase I DCPs.

NA - Not available. Insufficient data for calculation.

Table 16-2

Water Conservation Methods for Surface Treatment Rinses

PROCESS Practice (criterion)	Alkaline Clean	Acid Clean	Hex-Chrome	Tri-Chrome	Cadmium Zinc Cyanide	Cadmium Zinc non-Cyanide	Acid Copper	Copper Cyanide	Watts, Woods, other Nickels	Electro-less Nickel	Silver Cyanide	Gold Cyanide	Lead, Lead-Tin	Tin	Chrom-ate	Phos-phate	Chromic-acid anodize	Sulfuric anodize
Drag-out Reduction and Recovery																		
Fog or spray rinsing over tank (110 F or higher)	X	X	X	X				X	X	X				X[2]		X	X	
Controlled slow withdrawal	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Add wetting agent (when compatible)			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Position work piece	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Long drip time	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X
Drip shield	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Air knife	X	X	X	X	X	X					X	X			X	X		X
Drag-out tank (heated)	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Drag in/out tank	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Lowest concentration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Highest temperature	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X

Source: MP&M Site Visits, MP&M DCPs, Technical Literature.

[1]Only common applications of this technology are checked.
[2]Alkaline tin only.
[3]For example: Air or other agitation, minimum size, and inlet, outlet location opposite ends.

Table 16-2 (Continued)

Water Conservation Methods for Surface Treatment Rinses

PROCESS Practice (criterion)	Alkaline Clean	Acid Clean	Hex-Chrome	Tri-Chrome	Cadmium Zinc Cyanide	Cadmium Zinc non-Cyanide	Acid Copper	Copper Cyanide	Watts, Woods, other Nickels	Electro-less Nickel	Silver Cyanide	Gold Cyanide	Lead, Lead-Tin	Tin	Chrom-ate	Phos-phate	Chromic-acid anodize	Sulfuric anodize
Rinse Tank Design and Innovative Configuration																		
Counter-current rinse	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cascading rinse (cleaning)	X	X																
Spray rinse	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Good tank design[3]	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rinse Water Use Control																		
Flow restrictors	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Timer controls	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Conductivity controls	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Metal Recovery and Rinse Water Reuse Technologies																		
Evaporator[1]	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	
Ion exchange[1]					X	X	X	X	X	X	X	X	X	X				
Electrolytic Recovery					X	X	X	X	X	X	X	X						
Electrodialysis[1]		X			X	X			X									
Reverse osmosis[1]					X	X	X	X	X				X	X	X			

Source: MP&M Site Visits, MP&M DCPs, Technical Literature.

[1]Only common applications of this technology are checked.
[2]Alkaline tin only.

Table 16-3

Definitions of Pollution Prevention and Water Conservation Practices and Technologies

Practices or Technology	Definition
Air Knife	Air knives are usually installed over a process tank or drip shield and are designed to remove drag-out by blowing it off the surface of parts and racks. Drag-out is routed back to the process tank. Air knives are more effective with flat parts. Air knives cannot be used to dry surfaces that passivate or stain due to oxidation.
Cascade Rinse	Cascade rinsing is a method of reusing rinse water. Rinse water from one rinsing operation is plumbed to another, less critical one before being discharged to treatment. Some rinse waters acquire chemical properties, such as low pH, that make them desirable for reuse in specific rinse systems. This is generally referred to as reactive rinsing.
Conductivity Controller	Conductivity controllers consist of a controller, a meter with adjustable set points, a probe that is placed in the rinse tank, and a solenoid valve. As parts are rinsed, dissolved solids are added to the water in the rinse tank, raising the conductivity of the water. When conductivity reaches the set point, the solenoid valve is opened to allow make-up water to enter the tank. When the conductivity falls below the set point, the valve is shut to discontinue the make-up water. In theory, conductivity control of rinse flow is a precise method of maintaining optimum rinsing conditions in intermittently used rinse operations. In practice, conductivity controllers work best with deionized rinse water. Incoming water conductivity may vary day-to-day and season-to-season, which forces frequent set point adjustments. Suspended solids and nonionic contaminants (e.g., oil) are not detected by the conductivity probe and can cause inadequate rinsing.
Countercurrent Cascade Rinse	Countercurrent cascade rinsing is widely used for reducing the discharge rate of rinse water. Fresh water flows into the rinse tank located farthest from the process tank and overflows, in turn, to the rinse tanks closer to the process tank. This technique is termed countercurrent rinsing, because the work piece and the rinse water move in opposite directions. Over time, the first rinse becomes contaminated with drag-out and reaches a stable concentration which is lower than the process solution. The second rinse stabilizes at a lower concentration, which enables less rinse water to be used than if only one rinse tank were in place. The more countercurrent cascade rinse tanks (three-stage, four-stage, etc.), the less water needed to adequately remove the process solution.
Drag-in/Drag-out Rinsing	A drag-in/drag-out rinse system may be a single tank or two tanks plumbed together. Parts enter the rinse system before and after dwelling in the process bath. As parts enter the process bath, they drag-in process chemicals present in the drag-in/drag-out rinse rather than plain rinse water. This rinsing configuration is an effective recovery method for process baths that have low evaporation rates.

Table 16-3 (Continued)

Definitions of Pollution Prevention and Water Conservation Practices and Technologies

Practices or Technology	Definition
Drag-out Tank	Drag-out tanks are rinse tanks that are initially filled with water and remain stagnant. Parts are rinsed in drag-out tanks directly after exiting the process bath. Gradually, the concentration of process chemicals in the drag-out tank rises. In the most efficient configuration, a drag-out tank is employed after a heated process tank that has a moderate to high evaporation rate. A portion of the fluid in the drag-out tank is returned to the process tank to replace the evaporative loss. The level of fluid in the drag-out tank is maintained by adding fresh water.
Drip Shields	Drip shields are installed between process tanks and rinse tanks to recover process fluid dripping off racks and barrels that would otherwise fall into rinse tanks or onto the floor. Often, drip shields are an inclined piece of polypropylene or other material which is inert to the process.
Drip Tanks	Drip tanks are similar to drag-out tanks except they are not filled with water. Parts exiting a process bath are held over the drip tank and the process fluid that drips from the parts is collected in the tank. When enough fluid is collected in the drip tank it is returned to the process tank. Drip tanks are generally considered to be a less effective drag-out recovery practice than using drag-out tanks.
Electrodialysis	Electrodialysis is a membrane technology used to remove impurities from and recover process solutions. With this technology, a direct current is applied across a series of alternating anion and cation exchange membranes to remove dissolved metal salts and other ionic constituents from solutions. An electrodialysis unit consists of a rectifier and a membrane stack. The stack consists of alternating anion- and cation-specific membranes which form compartments. As the feed stream enters the unit, each alternating membrane compartment becomes filled with either diluate or concentrate. When the compartments are filled, a direct current is applied across the membrane. Cations in a diluate compartment traverse one cation-specific membrane in the direction of the cathode, and are trapped in that compartment by the next membrane, which is anion-specific. Anions from the neighboring diluate compartment traverse the anion-specific membrane in the direction of the anode, joining the cations, and are likewise trapped in the concentrate compartment by the next cation-specific membrane. In this way, the feed stream is depleted of ions, and anions and cations are trapped in each concentrate compartment. The feed stream is often from the first rinse tank in a countercurrent series, with a concentration of 5 g/L or more of total dissolved solids (TDS). The concentrate, with a TDS concentration of 50 g/L or more, and a volume of less than 10% of the feed stream, is returned to the process. The diluate, representing more than 90% of the feed stream at a TDS concentration of typically 1 g/L or less, is recycled as rinse water or discharged to treatment.

Table 16-3 (Continued)

Definitions of Pollution Prevention and Water Conservation Practices and Technologies

Practices or Technology	Definition
Electrolytic Recovery (Electrowinning)	Electrolytic recovery is an electrochemical process used to recover metals from many types of process solutions, such as electroplating rinse waters and baths. Electrolytic recovery removes metal ions from a waste stream by processing the stream in an electrolytic cell, which consists of a closely spaced anode and cathode. Commercial equipment consists of several cells, a transfer pump, and a rectifier. Current is applied across the cell and metal cations are deposited on the cathodes. The waste stream is usually recirculated through the cell from a separate tank, such as a drag-out recovery rinse. Electrolytic recovery is typically applied to solutions containing nickel, copper, precious metals, and cadmium. Chromium and aluminum are poor candidates for electrolytic recovery. Drag-out recovery rinses and ion-exchange regenerant are common solutions that are processed using electrolytic recovery. Some solutions require pH adjustment prior to electrolytic recovery. Acidic, metal-rich, cation regenerant is an excellent candidate stream for electrolytic recovery, and is often electrolytically recovered without adjustment. In some cases, when the target concentration is reached, the waste stream is reused as cation regenerant.
Evaporation	Evaporation is a common chemical recovery technology. There are two basic types of evaporators: atmospheric and vacuum. Atmospheric evaporators, the more prevalent type, are relatively inexpensive to purchase and easy to operate. Vacuum evaporators are mechanically more sophisticated and are more energy efficient. Vacuum evaporators are typically used when evaporation rates greater than 50 to 70 gallons per hour are required. Additionally, with vacuum evaporators, evaporated water can be recovered as a condensate and reused on site. A disadvantage of evaporation-based recovery is that all drag-out, including unwanted components, are returned and accumulate in the process bath. For this reason, deionized water is preferred as rinse water to prevent the introduction of water contaminants in the process bath.
Flow Restrictor	Flow restrictors are commonly installed on a rinse tank's water inlet. These devices contain an elastomer washer which flexes under pressure to maintain a constant water flow regardless of pressure. Flow restrictors can maintain a wide range of flow rates, from less than 0.1 gal/min to more than 10 gal/min. As a stand-alone device, a flow restrictor provides a constant water flow. As such, for intermittent rinsing operations, a flow restrictor does not coordinate the rinse flow with drag-out introduction. Precise control with intermittent operations typically requires a combination of flow restrictors and rinse timers. However, for continuous rinsing (e.g., continuous electroplating machines), flow restrictors may be adequate for good water control.

Table 16-3 (Continued)

Definitions of Pollution Prevention and Water Conservation Practices and Technologies

Practices or Technology	Definition
Fog or Spray Rinse Over Tank	Fog or spray rinsing is performed over a process bath to recover drag-out. Draining over a process bath can be greatly enhanced by spray or fog rinsing, which dilutes and lowers the viscosity of the film of process fluid clinging to the parts. This method of drag-out recovery is only possible if the evaporation rate of the process fluid is moderate to high.
Good Tank Design	Rinse tanks should be designed to remove the drag-out layer from the part and cause it to rapidly and thoroughly mix with the rinse water. Common elements of good tank design are positioning the inlet and outlet at opposite ends of the tank, using air or other agitation, using a flow distributor, and using the minimum size of tank possible.
Ion Exchange	Ion exchange is a reversible chemical reaction which exchanges ions in a feed stream for ions of like charge on the surface of an ion-exchange resin. Resins are broadly divided into cationic or anionic types. Typical cation resins exchange H^+ for other cations, while anion resins exchange OH^- for other anions. In practice, a feed stream is passed through a vessel, referred to as a column, which holds the resin. The feed stream is typically dilute rinse water. The exchange process proceeds until the capacity of the resin is reached (i.e., an exchange has occurred at all the resin sites). A regenerant solution is then passed through the column. For cation resins, the regenerant is an acid, and the H^+ ions replace the cations captured from the feed stream. For anion resins, the regenerant is a base, and OH^- ions replace the anions captured from the feed stream. The concentration of feed stream ions is much higher in the regenerant than in the feed stream; therefore, the ion-exchange process accomplishes both separation and concentration. Ion exchange is used for water recycling and/or metal recovery. For water recycling, cation and anion columns are placed in series. The feed stream is deionized and the product water is reused for rinsing. Often, closed-loop rinsing is achieved. The regenerant from the cation column typically contains the metal species, which can be recovered in elemental form via recovery. The anion regenerant is typically discharged to wastewater treatment. When metal recovery is the only objective, a single or double cation column unit containing selective resin is used. These resins attract divalent cations while allowing monovalent cations to pass, a process usually referred to as metal scavenging. Water cannot be recycled because contaminants other than the target cations remain in the stream exiting the column.
Long Drip Time	Long drip times over the process tank reduce the volume of drag-out reaching the rinsing system. Automatic lines can be easily programmed to include optimum drip times. On hand lines, racks are commonly hung on bars over process baths and allowed to drip. Barrels can be rotated over the process bath to enhance drainage. Some surfaces cannot tolerate long exposure to air due to oxidation or staining, and would therefore be unsuitable for extended drip times.

Table 16-3 (Continued)

Definitions of Pollution Prevention and Water Conservation Practices and Technologies

Practices or Technology	Definition
Operate at Highest Temperature	Bath temperature and viscosity are inversely related. Operating at the highest possible bath temperature will result in lower viscosity and less drag-out. A second benefit of higher bath temperatures is increased evaporation which facilitates efficient recovery rinsing.
Operate at Lowest Concentration	Operating at the lowest possible concentration reduces the mass of chemicals in a given volume of drag-out. Also, viscosity and concentration are directly related and lower process bath concentration will result in lower viscosity and less drag-out volume. Contaminants and other substances that build in concentration over the life of a process bath should be controlled at a low level, if possible.
Part Position on Rack	Positioning parts on racks to promote rapid draining includes minimizing the profile of the parts emerging from the bath, tilting and inverting cup-shaped parts, and avoiding placement of parts directly atop one another.
Slow Part Withdrawal	The faster a part is removed from a process bath, the thicker the layer of fluid clinging to the part will be. A slower withdrawal rate reduces the thickness of the fluid layer and reduces drag-out. Generally, this method of drag-out reduction can only be practiced on automatic lines where the withdrawal velocity can be programmed.
Reverse Osmosis	Reverse osmosis is a membrane separation technology used for chemical recovery. The feed stream, usually relatively dilute rinse water or wastewater, is pumped to the surface of the reverse osmosis membrane at pressures of 400 to 1,000 psig. The membrane separates the feed stream into a reject stream and a permeate. The reject stream, containing most of the dissolved solids in the feed stream, is deflected from the membrane while the permeate passes through. Reverse osmosis membranes reject more than 99% of multivalent ions and 90 to 96% of monovalent ions, in addition to organic pollutants and nonionic dissolved solids. The permeate stream is usually of sufficient quality to be recycled as rinse water, despite the small percentage of monovalent ions (commonly potassium, sodium and chloride) that pass through the membrane. A sufficiently concentrated reject stream can be returned directly to the process bath. The reject stream concentration can be increased by recycling the stream through the unit more than once or by increasing the feed pressure. In multiple-stage units containing more than one membrane chamber, the reject stream from the first chamber is routed to the second, and so on. The combined reject streams from multistage units may, in some cases, have high enough concentrations to be returned directly to the bath.

Table 16-3 (Continued)

Definitions of Pollution Prevention and Water Conservation Practices and Technologies

Practices or Technology	Definition
Timer Rinse Controller	Rinse timers are electronic devices that control a solenoid valve. The timer usually consists of a button that, when pressed, opens the valve for a predetermined length of time, usually from 1 to 99 minutes. When the valve is open, make-up water is allowed to flow into a given tank. After the time period has expired, the valve is automatically shut. The timer may be activated either manually by the operator or automatically by the action of racks or hoists. Most rinse systems that are used intermittently benefit from the installation of a rinse timer, as operator error is eliminated. Rinse timers installed in conjunction with flow restrictors can provide precise control when the incoming water pressure may rise and fall. Rinse timers are less effective in continuous or nearly continuous rinse operations (e.g., continuous electroplating machines).
Wetting Agents	Wetting agents or surfactants may be added to some process baths to reduce viscosity and surface tension, thereby significantly reducing drag-out.

Source: MP&M Site Visits, MP&M DCPs, Technical Literature.

Table 16-4

Factors Affecting Drag-Out

Factor Affecting Drag-Out	Impact on Drag-out	Potential Pollution Prevention and Water Conservation Practices	Restrictions
Bath Concentration	Concentration and drag-out are directly related.	Operate at lowest concentration possible. Remove all contaminants promptly.	Concentration range limited by process.
Bath Temperature	Higher temperatures lower drag-out by lowering viscosity.	Operate at highest possible temperature.	Temperature range limited by process.
Bath Viscosity	High viscosity raises drag-out by increasing the thickness of the fluid layer clinging to the part.	Operate at highest temperature and lowest concentration possible. Add wetting agent.	Concentration and temperature ranges limited by process. Wetting agent must be compatible.
Part Configuration	Cup shapes result in 8-20 times the drag-out volume of flat shapes.	Drain holes can be added to many cup-shaped parts to improve drainage of drag-out.	Functionality of parts may restrict use of drain holes or other changes to part configuration.
Part Orientation	Orientation on rack can be optimized to minimized drag-out.	Keep records of optimal orientations. Train operators.	None.
Withdrawal Rate	Doubling speed of withdrawal results in a fourfold increase in drag-out volume.	Program automatic equipment for slow withdrawal.	Impossible to consistently practice without automation.
Drain Time	Long drain times and barrel rotations greatly reduce drag-out.	Program automatic equipment for long drain times.	Impossible or difficult to consistently practice without automation. Drain time limited by staining or passivation of some coatings.
Rack versus Barrel	Barrels produce greater drag-out than racks.	(See "Rack/Barrel Design)	Part transport device is dictated by part size.
Rack/Barrel Design	Drag-out volume related to barrel design.	Redesign barrels with largest holes possible.	Barrel design limited by part sizes and configurations.
Rack/Barrel Condition	Loose rack coating cause reservoirs of fluid to be transported with rack.	Maintain a schedule of maintenance and recoating.	None
Operator Awareness	Poor operator awareness greatly increases drag-out or offsets other practices	Require training programs for operators.	None

Source: MP&M Site Visits, MP&M DCPs, Technical Literature.

Table 16-5

Rinse Water Required for Various Plating Processes Based on Literature Values[a]

Process	Rinse Configuration	TDS Concentration	Target TDS Concentration in Rinse	Parts Type	Drag-out Rate	PNF gal/sq.ft. 100% Control	PNF gal/sq.ft. 100% Excess
Acid Zinc	Single overflow	166 g/L	Functional: 100-700 mg/L (used 400 mg/L)	Flat	1.3 gal/1000 sq ft	0.54	1.1
				Contoured	3.5 gal/1000 sq ft	1.5	2.9
	2 stage countercurrent cascade	166 g/L	Functional: 100-700 mg/L (used 400 mg/L)	Flat	1.3 gal/1000 sq ft	0.024	0.048
				Contoured	3.5 gal/1000 sq ft	0.072	0.14
Silver Cyanide	Single overflow	370 g/L	Bright: 5-40 mg/L (used 20 mg/L)	Flat	1.2 gal/1000 sq ft	22	44
				Contoured	3.2 gal/1000 sq ft	58	120
	2 stage countercurrent cascade	370 g/L	Bright: 5-40 mg/L (used 20 mg/L)	Flat	1.2 gal/1000 sq ft	0.16	0.32
				Contoured	3.2 gal/1000 sq ft	0.43	0.87

[a]Notes for this table, including bath formulations assumed and calculations used, are presented below. TDS concentrations are from references 3 and 4, based on bath formulations. Target TDS concentrations are based on criteria presented in Section 3.2.1 (reference 1). Drag-out rates are from references 1 and 2 unless data not available, in which case rates were assumed based on technical knowledge of the operations.

Sources: references 1, 3, and 4.

Table 16-5 (Continued)

Rinse Water Required for Various Plating Processes[a]

Process	Rinse Configuration	TDS Concentration	Target TDS Concentration in Rinse	Parts Type	Drag-out Rate	PNF gal/sq.ft. 100% Control	PNF gal/sq.ft. 100% Excess
Copper Cyanide	Single overflow	250 g/L	Functional: 100-700 mg/L (used 400 mg/L)	Flat	0.91 gal/1000 sq ft	0.57	1.1
				Contoured	3.2 gal/1000 sq ft	2.0	4.0
	2 stage countercurrent cascade	250 g/L	Functional: 100-700 mg/L (used 400 mg/L)	Flat	0.91 gal/1000 sq ft	0.023	0.046
				Contoured	3.2 gal/1000 sq ft	0.081	0.16
Acid Descale	Single Overflow	248 g/L	Clean: 400-1000 mg/L (used 700 mg/L)	Flat	1 gal/1000 sq ft (estimated)	3.5	7.1
				Contoured	3 gal/1000 sq ft (estimated)	11	21
	2 stage countercurrent cascade	248 g/L	Clean: 400-1000 mg/L (used 700 mg/L)	Flat	1 gal/1000 sq ft (estimated)	0.019	0.038
				Contoured	3 gal/1000 sq ft (estimated)	0.056	0.11

[a]Notes for this table, including bath formulations assumed and calculations used, are presented below. TDS concentrations are from references 3 and 4, based on bath formulations. Target TDS concentrations are based on criteria presented in Section 3.2.1 (reference 1). Drag-out rates are from references 1 and 2 unless data not available, in which case rates were assumed based on technical knowledge of the operations.

Sources: references 1, 3, and 4.

Table 16-5 (Continued)

Rinse Water Required for Various Plating Processes[a]

Process	Rinse Configuration	TDS Concentration	Target TDS Concentration in Rinse	Parts Type	Drag-out Rate	PNF gal/sq.ft. 100% Control	PNF gal/sq.ft. 100% Excess
Alkaline Clean (Proprietary Chemistry)	Single overflow	90 g/L	Clean: 400-1000 mg/L (used 700 mg/L)	Flat	1 gal/1000 sq ft (estimated)	0.13	0.26
				Contoured	3 gal/1000 sq ft (estimated)	0.39	0.77
	2 stage countercurrent cascade	90 g/L	Clean: 400-1000 mg/L (used 700 mg/L)	Flat	1 gal/1000 sq ft (estimated)	0.011	0.022
				Contoured	3 gal/1000 sq ft (estimated)	0.033	0.066

[a]Notes for this table, including bath formulations assumed and calculations used, are presented below. TDS concentrations are from references 3 and 4, based on bath formulations. Target TDS concentrations are based on criteria presented in Section 3.2.1 (reference 1). Drag-out rates are from references 1 and 2 unless data not available, in which case rates were assumed based on technical knowledge of the operations.

Sources: references 1, 3, and 4.

Table 16-5: Notes

1. Acid zinc formulation:

$ZnSO_4(7H_2O)$	240 g/L
NH_4Cl	15 g/L
$Al_2(SO_4)_3(18H_2O)$	30 g/L
Licorice	1 g/L

2. Equation used to calculate rinse flow and flow per square foot for single overflow rinse:

$$C_e = \left[\frac{D}{QM + D}\right] C_o$$

Solving for Q:

$$Q = \frac{\left[\frac{DC_o}{C_e}\right] - D}{M}$$

Where:

D	=	Drag-out per ft^2 in gallons	C_e	=	Target concentration of rinse in oz/gal
C_o	=	Concentration of process bath in oz/gal	C_r	=	Target concentration of final rinse in oz/gal
M	=	Interval between drag-out events, in minutes	Q	=	Flow in gal/min

Note: Any interval M can be chosen. Q, when divided by the work rate, ft^2/M, yields the gal/ft^2 in the table and the gal/ft^2 number remains the same for any M.

3. Equation used to calculate 100 % controlled flow and gallons per square foot for countercurrent cascade rinse:

$$Q = \frac{D}{M}\left[\frac{C_o}{C_r}\right]^{1/n}$$

For 50% controlled flow, Q was multiplied by a factor of 2.

Where n = number of rinse stages

With 100% controlled flow, the introduction of drag-out and rinse water into the rinse tank are perfectly coordinated and therefore, the rinse water required to meet the target concentration of the final rinse is equal to Q. With 100% excess flow, the introduction of drag-out and rinse water are not perfectly coordinated and an excess of 100% of Q (or 2Q) is used to meet the target concentration of the final rinse.

4. Silver cyanide formulation (middle of high speed bath range):

AgCN	97.5 g/L
KCN	152.5 g/L
K_2CO_3	52.5 g/L
KNO_3	50 g/L
KOH	17 g/L

5. High efficiency copper cyanide formulation:

CuCN	75 g/L
KCN	133 g/L
KOH	42 g/L

6. Acid descale formulation:

20% H_2NO_3 (by volume)
1.5% HF (by volume)

All bath formulations and equations are from references 1, 3, and 4.

Table 16-6

Adjusted Production-Normalized Flow (PNF) Data for Countercurrent Cascade Rinses MP&M Sampling Program

Measured PNF (gal/sq ft)	Measured TDS (mg/L)	Adjusted TDS (mg/L)[1]	Adjusted PNF (gal/sq ft)[2]	Part Description
CLEANING RINSES WITH FLOW CONTROL (includes timed rinses, conductivity sensors, flow restrictors, and manual shut-off)				
0.031	1,600	700	0.047	Doorknob components
0.037	1,800	700	0.059	Doorknob components
0.054	1,700	700	0.084	Doorknob components
0.26	1,300	700	0.36	Doorknob components
0.26	2,000	700	0.44	Doorknob components
0.26	1,100	700	0.33	Doorknob components
0.30	1,100	700	0.37	Doorknob components
0.38	1,100	700	0.48	Doorknob components
0.49	1,400	700	0.69	Doorknob components
0.49	940	700	0.56	Doorknob components
0.62	1,200	700	0.81	Doorknob components
0.62	860	700	0.68	Doorknob components
PLATING AND CONVERSION COATING RINSES WITH FLOW CONTROL (includes timed rinses, conductivity meters, flow restrictors, and manual shut-off)				
0.017	400	3,900	0.15	Shafts for mobile industrial equipment
0.037	400	4,100	0.350	Shafts for mobile industrial equipment
0.16	400	4,100	1.5	Shafts for mobile industrial equipment
0.83	720	400	0.350	Doorknob Components
1.5	730	400	1.5	Doorknob components

Source: The data presented are from sampling episodes at two MP&M sites.
[1]Adjusted TDS based on rinsing criteria presented in Section 3.1.2 (reference 1).
[2]The adjusted PNFs account for the fact that the TDS was measured from the discharge or first tank in the countercurrent cascade series. The assumption is made that the TDS present in the measured rinse is entirely composed of drag-out and that the water supplied is de-ionized.

Table 16-7

Pollution Prevention and Water Conservation Methods Applicable to Machining Operations

Pollution Prevention/Water Conservation Method	Examples	Applicability
Prevention of Metal-working fluid Contamination		
Reduce Contamination from Tramp Oil	Use coolant in hydraulic and other oil systems	Applicable to most machines. In most cases, requires use of special fluid.
	Replace hydraulics with electrical systems	Limited applicability. Practical only during major equipment overhaul.
	Machine maintenance	Applicable to all machines. Should be performed at regularly scheduled intervals.
Reduce Contamination from Make-up Water	Use deionized water for initial make-up of working fluid and to account for evaporative losses	Applicable to all machining operations using a water soluble fluid. Especially important in areas where the water supply is high in TDS.
Reduce Contamination from Sumps	Sterilize sumps during clean-out using steam.	Applicable to all machining operations. Especially important with large concrete sumps.
	Use metal inserts or coat walls of concrete sumps	Applicable to in-ground concrete sumps.
Extension of Metal-working fluid Life		
Raw Material Substitution	Use high quality fluids with needed "additive package"	Most machining operations can benefit from the use of high quality fluids which can extend fluid life, while reducing bacterial growth, improving lubricity, reducing friction, and providing corrosion protection.

Table 16-7 (Continued)

Pollution Prevention and Water Conservation Methods Applicable to Machining Operations

Pollution Prevention/Water Conservation Method	Examples	Applicability
Equipment Modification	Replace sump's air agitation with mechanical agitation	Applicable to central sumps with air agitation.
	Install tramp oil removal device	Limited mainly to external sumps.
Fluid Monitoring	Make weekly or more frequent measurements of pH, coolant concentration, tramp oil concentration, and bacterial count.	All machining operations. Larger operations can use data for statistical process control.
Metal-working fluid Recycling	Employ methods and technologies for removing fluid contaminants (e.g., filtration, centrifuge, pasteurization)	Simple filtration methods can be employed by all machining operations. More sophisticated equipment is limited to larger operations.
	Recycle chip drainage	Applicable to all machining operations. Requires clean handling and storage methods to prevent contamination.

Source: MP&M Site Visits, MP&M DCPs, Technical Literature.

Table 16-8

Pollution Prevention and Water Conservation Methods Applicable to Painting Operations

Pollution Prevention/Water Conservation Method	Examples	Applicability
Reduce the Quantity of Paint Entering the Water System		
Improve Spray Painting Operating Practices	Provide operator training to: improve racking and positioning of parts to reduce overspray; assure proper selection of nozzle for efficient spray pattern; improve work scheduling and reduce clean-outs; improve housekeeping.	Applicable to all spray painting operations.
Improve Paint Transfer Efficiency	Replace inefficient conventional compressed air spray equipment with high-velocity-low-pressure equipment.	Applicable to most existing spray painting operations using conventional equipment. Will require some retraining of operators.
Install Gun Cleaning Station	Gun cleaning station can be used to clean guns and lines. Can prevent spraying of cleaning fluid/paint into booth.	Applicable to most solvent based painting operations.
Recycle Paint Booth Water		
Recycle Paint Booth Water Through Solids Removal	Employ booth water maintenance system that removes paint solids. Applicable technologies include weirs, filters, and centrifuges.	Applicable to most water-wash booths. Usually requires treatment of booth water with chemicals to produce solids that can be separated from water.
Use Dry Filter Booths		
Use Dry Filter Booths Instead of Water-Wash Booths	Convert existing water-wash booth to a dry filter booth.	Applicable to booths with low to moderate paint usage. In cases of high paint usage, dry filters clog too quickly.

Source: MP&M Site Visits, MP&M DCPs, Technical Literature.

Table 16-9

Pollution Prevention and Water Conservation Methods Applicable to Cleaning Operations

Pollution Prevention/Water Conservation Method	Examples	Applicability
Housekeeping and Maintenance	Checking the accuracy of temperature controls; removing sludge build-up from tanks, heating coils and temperature regulators; retrieving parts, racks, etc. dropped into the tanks; and checking the integrity of tanks and tank liners	Applicable to all cleaning operations.
Oil and Suspended Solids Removal	Technologies used to remove oil and suspended solids from cleaning solutions, thereby extending the useful life span of the solutions (e.g., skimmers, coalescers, cartridge and membrane filters).	Suspended solids removal equipment (e.g., cartridge filters) are applicable to nearly all baths. The other types of equipment are applicable to most to alkaline cleaning baths.
Dissolved Solids Removal	Various technologies and processes that remove dissolved metals from baths, including acid sorption, diffusion dialysis, and membrane electrolysis.	Acid and alkaline solutions that become contaminated with dissolved metal, usually due to etching of the basis metal.

Source: MP&M Site Visits, MP&M DCPs, Technical Literature.

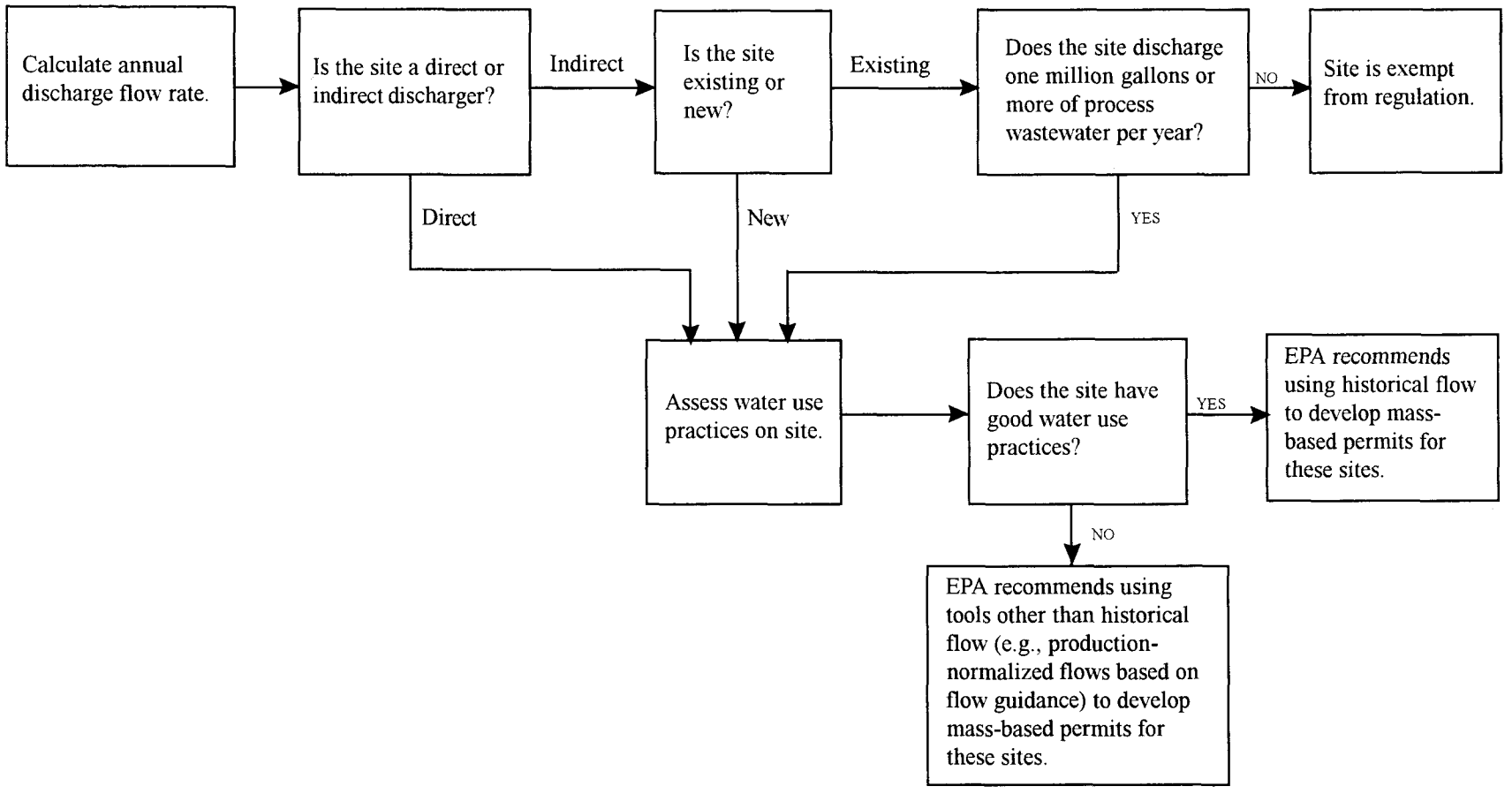


Figure 16-1. MP&M Phase I Permitting Process Flow Chart

Figure 16-2a
Single Rinse Tank

Control Level Zero
(worst case)
- Continuous rinse water flow or dependent on operator
- Short withdraw and dwell times

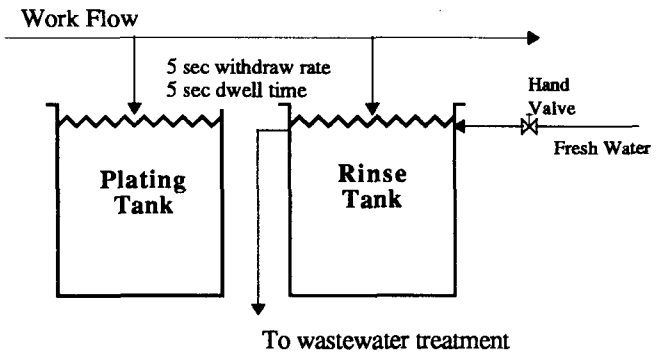


Figure 16-2b
Single Rinse Tank with Flow Reduction

Control Level One
- Flow restrictor limits incoming water flow
- Slower withdraw rate and increased dwell time reduce drag-out formation and loss

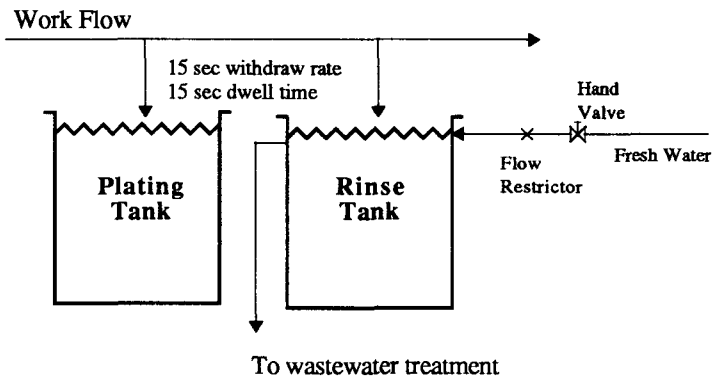


Figure 16-2c
Multiple Rinse Tanks with Flow Reduction

Control Level Two
- Parallel rinse tanks reduce fresh water requirements

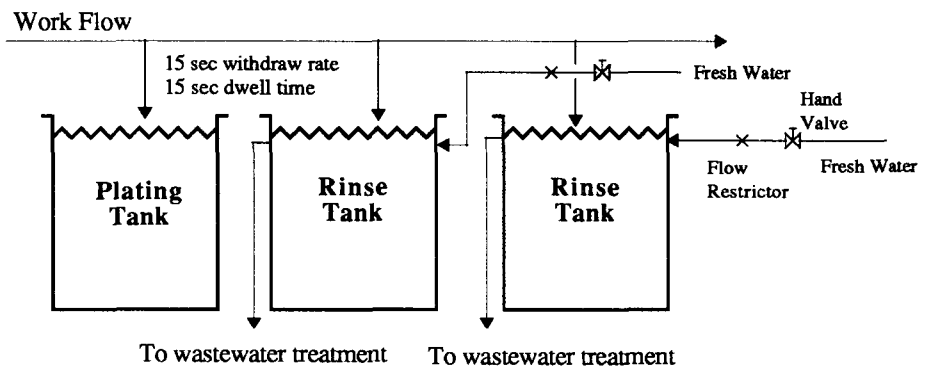


Figure 16-2d
Multiple Rinse Tanks with Flow Reduction

Control Level Three
- Counterflow rinse is more efficient than parallel configuration

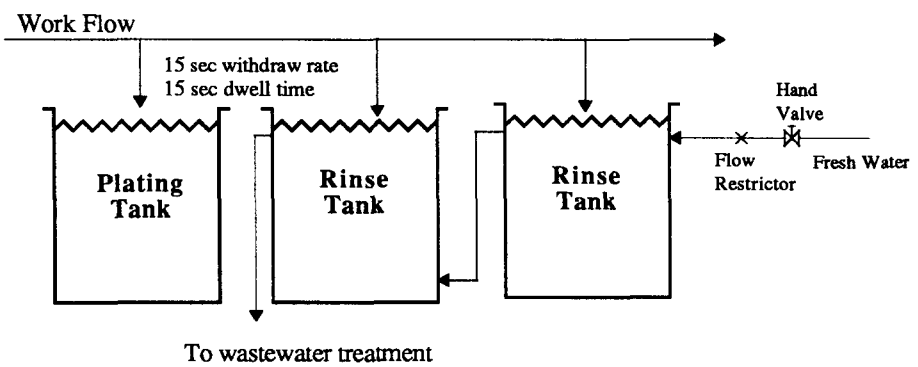


Figure 16-2
Examples of Rinsing Configurations with Increasing Levels of Good Water Use Practices

Figure 16-2e
Multiple Rinse Tanks with Flow Reduction and Drag-Out Recovery

Control Level Four

- Drag-Out recovery tank reduces water needs
- Conductivity controller coordinates rinse water needs and the flow of fresh water

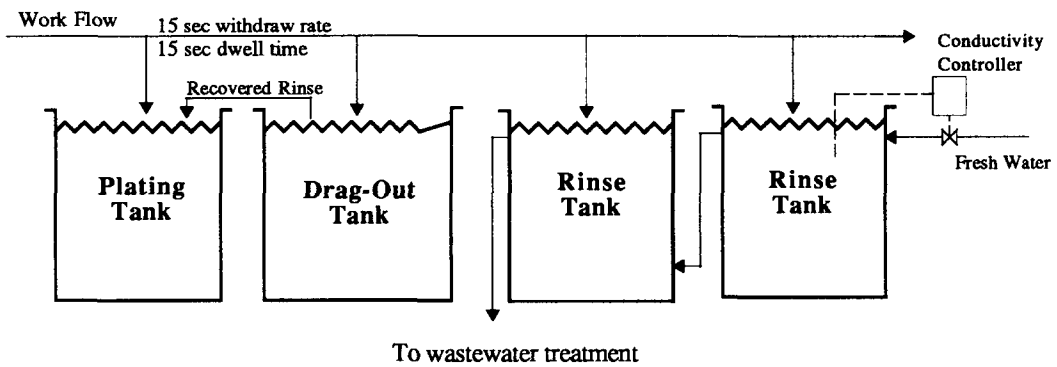


Figure 16-2f
Multiple Rinse Tanks with Water Recycle, Drag-Out Recovery, and Metal Recovery

Control Level Five (best case)

- Recovery system recycles rinse water and recovers metal

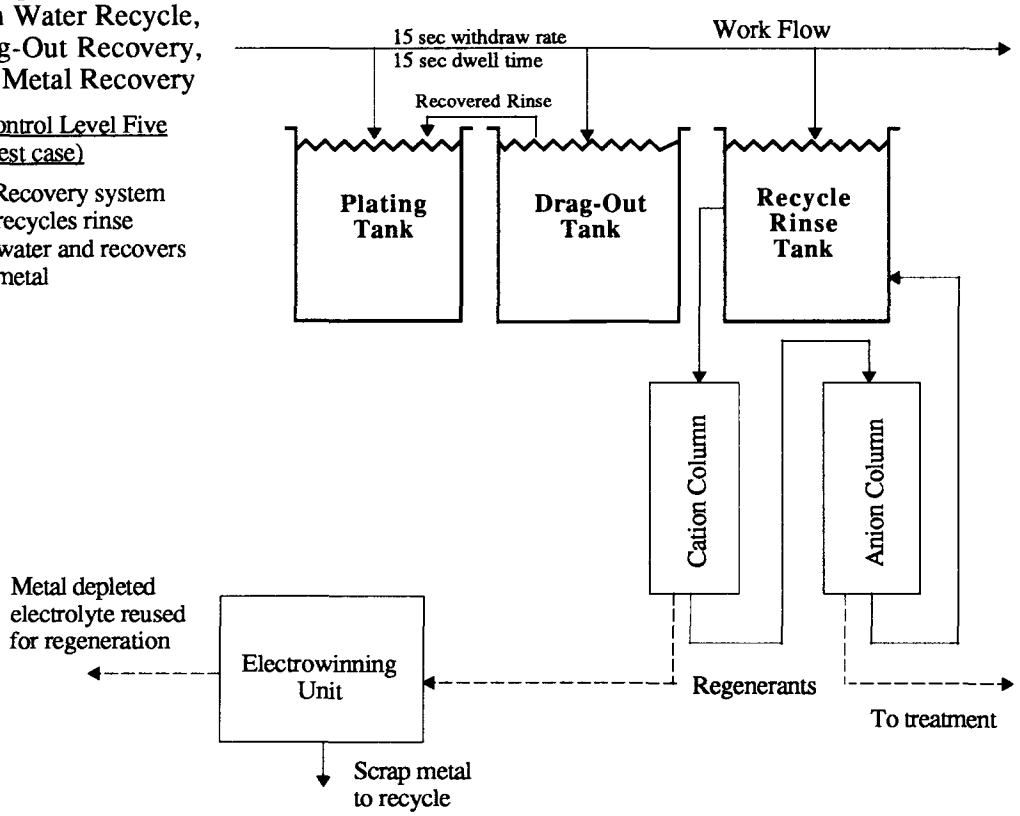


Figure 16-2. (continued)
Examples of Rinsing Configurations with Increasing Levels of Good Water Use Practices

16.6 References

1. Kushner, Joseph B., Water and Waste Control for the Plating Shop, *Gardner Publications, Inc.*, 1976.

2. Cushnie, George C., Pollution Prevention and Control Technology for Plating Operations, National Center for Manufacturing Sciences, 1994.

3. Lownheim, Frederick A., Electroplating Fundamentals of Surface Finishing, McGraw-Hill Book Co., New York, NY, 1978.

4. Murphy, Michael, Ed., Metal Finishing Guidebook and Directory Issue for 1994, Metal Finishing Magazine, Hackensack, NJ, 1994.

5. Master Chemical Corporation, A Guide to Coolant Management.

6. Higgins, Thomas, Hazardous Waste Minimization Handbook, Lewis Publishers, Chelsea, MI, 1989.

7. Ebasco Environmental, Hazardous Waste Minimization Study, Air Force Plant No. 6, Final Report, Norcross, GA, 1992.

8. University of Northern Iowa, Cutting Fluid Management in Small Machine Shop Operations, Iowa Waste Reduction Center, Cedar Falls, Iowa, undated.

9. Lighthall Industries, Lighthall™ SC 70 Gun Cleaner, Lighthall Industries, Santa Cruz, CA.

10. InVireChem, Service Bulletin: First Considerations in Classifying Paint Waste from Spray Booths, InVireChem, Inc., 1989.

11. Nalco, HEC Management Services Program Total Spray Booth Management, Nalco Chemical Company, 1989.

12. Marg, Ken, "HVLP Spray Puts You into Compliance." Metal Finishing, March, 1989.

13. Hund, Jerry, "Spray Application Processes," Metal Finishing Organic Finishing Guidebook and Directory Issue for '94, Metal Finishing, Hackensack, NJ, May, 1994.

14. Thomas, Barry, "Spray Booths," Metal Finishing Organic Finishing Guidebook and Directory Issue for '94, Metal Finishing, Hackensack, NJ, May, 1994.

15. Monken, Alan, "Wastewater Treatment Systems for Finishing Operations," Metal Finishing Organic Finishing Guidebook and Directory Issue for '94, Metal Finishing, Hackensack, NJ, May, 1994.

16. Monken, Alan, "Water Pollution Control for Paint Booths," Metal Finishing Organic Finishing Guidebook and Directory Issue for '94, Metal Finishing, Hackensack, NJ, May, 1994.

17. Brewer, George, "Electrodeposition of Organic Coatings," Metal Finishing Organic Finishing Guidebook and Directory Issue for '94, Metal Finishing, Hackensack, NJ, May, 1994.

18. Joseph, Ron, "Low-VOC Waterborne Coatings," Metal Finishing Organic Finishing Guidebook and Directory Issue for '94, Metal Finishing, Hackensack, NJ, May, 1994.

19. Ayer, Jacqueline and McElligott, Anthony, "Navy Paint Booth Conversion Feasibility Study (CR 89.004)," Naval Civil Engineering Laboratory, January, 1989.

20. Batutis, Edward, F. "Keep Your Cleaners Clean," Products Finishing, October, 1989.

21. Berg, Jack, "Filtered Thoughts--Start at the Cleaning Line," Metal Finishing, November, 1986.

22. Steward, F.A. and McLay, W.J., "Waste Minimization Part IV-Recovery/Regeneration of Process Baths", Metal Finishing, November, 1985.

Based on information collected during site visits and sampling episodes, the Agency believes that some of the solid waste generated at MP&M sites would not be classified as hazardous. However, for the purpose of compliance cost estimation, the Agency assumed that all solid waste generated as a result of the technology options would be hazardous.

The increase in waste oil generation from baseline to Option 1 is attributed to removal of oil from MP&M wastewaters prior to discharge to POTWs or surface waters. Option 1 includes oil/water separation to remove oil from oil/bearing wastewaters. The waste oil is usually either recycled on site or off site, or contract hauled for disposal as either a hazardous or nonhazardous waste. The increase of waste oil generation reflects a transfer of oil from the wastewater to a more concentrated waste oil, and does not reflect an increase in overall oil generation at MP&M Phase I sites. For the purpose of compliance cost estimation, EPA assumed that all waste oil was contract hauled for disposal; however, EPA expects that some of the waste oil can be recycled either on site or off site.

The decrease in waste oil generation from Option 1 to Options 1A, 2, and 2A is attributed to the 80% reduction of coolant discharge using the recycling technology included in Options 1A, 2, and 2A. This system recovers and recycles oil/bearing machining coolants at the source, reducing the generation of spent coolant. Coolant recycling saves approximately 8.7 million gallons of water-soluble coolant (assumed to be 5% oil in water) at Option 1A, 9.8 million gallons at Option 2 and 8.7 million gallons at Option 2A. EPA does not expect Option 3 to result in additional waste oil generation or reduction over Option 2.

The in-process technologies of ion-exchange and electrolytic recovery provide the pollution prevention benefits of reclaiming on estimated 1.7 million pounds of metal annually at Options 1A, 2, and 2A. This reuse reduces the solid waste generation at the end-of-pipe for the treatment of wastewater from operations using these technologies.

14.4 References

1. Steam, Its Generation and Uses, 4th Ed. (Babcock & Wilcox, Ed Stutz & Kitto, Barberton, Ohio, 1992).