PROFILE OF THE METAL FINISHING INDUSTRY

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PREFACE

The following report profiling the metal finishing industry has been developed under contract for the Energy, Environment and Manufacturing project of the Technology Reinvestment Program (EEM-TRP). The report presents factual data obtained through literature research as well as attitudes, perspectives, and opinions gained through interviews with a wide variety of professionals directly involved in or affiliated with the industry.

The purpose of this report is to assist the industry and the EPA Design, for Environment Program in developing a “pollution prevention roadmap” for metal finishing. The report is also expected to be an information resource for the EPA in pursuing strategic regulatory programs such as the Common Sense Initiative.

The report is divided into three chapters. Chapter 1 presents an overview of industry characteristics and markets, identifies key business and competitive issues affecting the evolution of the industry, and analyzes these trends and characteristics to provide insights into its present and future structure. Chapter 2 examines the primary manufacturing processes associated with the metal finishing industry, the environmental issues and concerns stemming from these processes, and discusses the availability and application of technologies which are environmentally and competitively preferable. Finally, Chapter 3 examines the current set of federal, state and local regulations affecting the industry and discusses the implications for the industry now and in the future.

Throughout this report, interpretations and analysis is provided on data and trends in order to provide insight not only on what is happening but why. Much of this analysis was provided by industry professionals interviewed in the generation of this report, although in other circumstances, the authors have drawn conclusions based on the information gathered. Readers should recognize that the analysis and conclusions contained in this report may not be shared by all industry representatives and stakeholders, but instead reflect the authors’ best attempt at synthesizing information from disparate perspectives and sources.

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CHAPTER 1
STRUCTURE OF THE METAL FINISHING INDUSTRY

1.1 Introduction

Metal finishing entails a wide variety of processes which provide the surfaces of manufactured products with a number of desirable physical, chemical, and appearance qualities. Metal finishing is one of the most pervasive services found in the national economy and is intimately connected to industrial and consumer products as well as goods manufactured for the government sector. Every manufactured or fabricated product made of metal or having metal components will feature some type of metal finishing.

This chapter will provide an overview of the economic and competitive structure of the metal finishing industry. A significant amount of metal finishing capacity is found within companies that manufacture products rather than specialize in metal finishing. Thus, this analysis will examine both "captive" operations (establishments that conduct metal finishing within larger manufacturing operations) and "job shops" (independent establishments that contract with manufacturers for their finishing needs.) Also, for purposes of this chapter, "metal finishing" will be broken into two categories. The Electroplating, Plating, Polishing and Anodizing industry is classified under Standard Industrial Code (SIC) 3471 and is comprised of establishments whose primary business is based on these finishing processes. Metal Coating and Allied Services, SIC 3479, is the other major branch of metal finishing and includes establishments involved in the application of liquid paints and powder coatings. Other finishing processes grouped in this category include engraving and etching. In this chapter, the term "metal finishing industry" will be used as a collective descriptor for establishments in both SIC codes.

1.2 Industry Characteristics

The following section provides several types of background information on the metal finishing industry. Unless otherwise noted, the figures listed are for separate metal finishing enterprises or "job shops" -- not captive operations

1.2.1 Industry Volumes

Sales -- According to the U.S. Department of Commerce 1992 Census of Manufacturers, the total value of shipments for the U.S. metal finishing industry (non-captive operations) was approximately $10 billon and was divided roughly equally between plating and coating services. Approximately 95% of this sales volume is revenue directly related to metal finishing contracts and services, with the remaining portion resulting from other secondary revenue generating sources. Approximately 93% of non-captive or "outsourced" metal finishing contractual services are supplied by establishments whose primary SIC code is either 3471 or 3479. This indicates that it is relatively rare to find a company that has metal finishing as a secondary revenue generating operation or a manufacturing company which uses their metal finishing capacity to finish other company's products as well as their own.

Value of Shipments (in millions of dollars)

Year	3471	3479	Total Metal Finishing
1992	4,792	5,240	10,032
1991	4,124	4,634	8,758
1990	4,513	4,929	9,442
1989	4,452	4,756	9,208
1988	4,324	4,867	9,191

Source: 1992 Annual Survey of Manufacturers
Preliminary Industry Reports
U.S. Department of Commerce

Historically, the significance of very small metal finishing operations can be seen in their relative contribution to overall industry sales. In 1992, approximately 13% of the total value of shipments was generated by establishments with five or fewer employees.

Employment - According to the Census of Manufacturers, metal finishing job shops in the United States employ an estimated l09,000 people, 77% of which are production workers. For the period 1988 - 1992, total employment in metal finishing establishments fell by 11.4%, with the greatest decreases in plating related finishing (14.2%). Total metal finishing payroll in 1992 exceeded $3.6 billion. The median number of production workers in a job shop is around 20 which, according to a 1992-1993 Surface Finishing Market Research Board (SFMRB) study, is about the same for captive shops. On a numerical average, however, captive shops shops average 56% more metal finishing employees per facility'.

Metal Finishing Employment Statistics

	All employees			Production workers		
Year	3471	3479	Total	3471	3479	Total
1992	65,400	43,800	109,200	50,400	33,800	84,200
1991	66,600	43,400	110,000	52,500	33,800	86,300
1990	73,200	44,300	117,500	57,900	34,700	92,600
1989	76,600	44,600	121,200	60,800	35,300	96,100
1988	76,300	47,000	123,300	58,200	36,300	94,500

Source: 1992 Annual Survey of Manufacturers
Preliminary Industry Reports
U.S. Department of Commerce

A closer look a! employment statistics for 1991 yields some comparative insights on compensation between production workers in metal finishing and those in other manufacturing industries. Generally speaking, production workers in the metal finishing industry are paid 10% - 20% less

Metal Finishing Labor Statistics

	3471	3479	Avg all Mfg
Wages per hour	$9.01	$10.38	$11.49
Wages per production worker	$18,333	$20,459	$23,139
Hours per production worker	2,034	1,970	2,013

Source: Manufacturing USA. Industry Analysis. Statistics, and Leading Companies, Gale Research Inc.(1994)

The three most common occupations in metal finishing are plating operators (16.6.%). painting operators (8.0%) and laborers/material movers (6.3%)[2].

Profitability -- As the table highlights, in 1993, the average metal finishing facility has a sales volume of approximately $1.1 million with net profits around 5% of sales.

1993 Average Profitability Measures

	3471 (468 establishments)	3479 (312 establishments)
Net Sales	$1,142,147	$1,065,166
Net profit after tax	$47,970 (4.2% of sales)	$60,714 (5.7% sales)
Median return on sales	3.4%	4.5%
Median return on assets	5.8%	8.9%

Source: Dun and Bradstreet, 1993

Finishing capacity does not seem to be positively correlated to greater profitability. In the plating sector, establishments with assets under $250,000 reported better return on assets and profits as a percentage of sales than facilities with assets over $1,000,000 Similar results are found in the painting sector in which the smaller facilities feature some of the best profitability ratios and financial returns. Experts have suggested that the reason for this relationship is that the highly capitalized shops compete in high volume finishing markets which are highly competitive and, as a result, feature lower margins. In turn, lower capitalized shops are more likely to be specialty platers and feature higher margins.

Waste Generation - The contribution of the metal finishing industry to environmental issues of concern can be seen though an examination of Toxic Release Inventory (TRI) data. Organic solvents dominate the list for both the plating and painting sectors.

	3471	3479
Total releases for 1992 (in lbs)	10,037,798	9,467,598
Total transfers for 1992 (lbs.to POTW or off-site location)	35,869,639	75,084,696
Total transfers and releases	45,907,437	84,552,294
Lbs. of TRI Emissions per Dollar of Manufacturing Value Added	.01 lbs/dollar	.03 lbs/dollar

Top ten substances (ranked by volume):

3471	3479
1.1.1 - trichloroethane	Toluene
Trichloroethylene	Xylene
MEK	Glycol ethers
Dichloromethane	MEK
Tetrachloroethylene	1,1,1 - trichloroethane
Toluene	Methyl Isobutyl Ketone
Hydrochloric acid	N-butyl alcohol
Sulfuric acid	1,2,4-trimethylbenzene
Nitric acid	Tricholroethylene
Xylene	Acetone

Source: US EPA Office of Pollution Prevention and Toxics Library

Actual releases and hazardous waste generation rates for the metal finishing sectors will be greater than the figures listed above for two reasons. First, the 320 chemicals and chemical compounds comprising TRI do not overlap completely with substances regulated as hazardous wastes under federal hazardous waste management laws. Second, many metal finishing enterprises may be exempt from reporting requirements because they have fewer than ten employees or use/process TRI materials at levels below reporting thresholds.

A 1993 survey conducted by the National Center for Manufacturing Sciences (NCMS) and the National Association of Metal Finishers (NAMF) noted that the most frequent range of plating discharges from facilities was 1000 - 50,000 gallons per day. 7.5% of survey respondents reported to be "zero discharge" facilities. The survey also noted the top pollutant materials for which compliance difficulty was reported. Nickel, zinc, total chromium, copper, total cyanide, and cadmium all received "compliance difficulty" responses of 10% or more[4].

1.2.2 Industry Distribution

Number and size of companies - As the following tables indicate, the metal finishing industry is a highly fragmented group of relatively small companies. Most companies are comprised of a single facility. The number of metal plating and related facilities decreased 4.3% over a ten year period from 1982 to 1992 while coating and related facilities increased 19.5% over this same period.

U.S. Metal Finishing Facilities

	3471			3479		
	Companies	Facilities	Facilities with < 20 employees	Companies	Facilities	Facilities with < 20 employees
1992	3,165	3,300	71.1%	1,812	1,936	67.0%
1987	3,353	3,451	69.8%	1,702	1,814	66.0%
1982	3,367	3,450	74.0%	1,524	1,620	68.7%

Source: 1992 Annual Survey of Manufacturers Preliminary Industry Reports, U.S. Department of Commerce

Size of U.S. Metal Finishing Facilities (by employees) -- 1987

Number of employees	3471 facilities	3479 faciliti
1-4	943	500
5-9	706	332
10-19	759	366
20-49	719	418
50-99	233	132
100-249	80	57
250-499	8	6
500-999	3	3
	3,451	1,814

Source: **1987 Annual Survey of Manufacturers**
U.S. Department of Commerce

A 1993 Office of Technology Assessment (OTA) report on environment and competitiveness in the metal finishing industry notes that job shops represent only approximately 10-15 percent of the number of companies that perform surface finishing operations. Most metal finishing activity occurs in captive shops within larger manufacturing operations and under different SIC code numbers. Industries such as furniture and fixtures, primary metals industries, machinery, fabricated metal products, electrical and electronic equipment, and transportation equipment are particularly dependent on metal finishing and may have at least a portion of their metal finishing accomplished "in-house." The OTA report also notes that a variety of estimates exist on the number of industrial facilities that use metal finishing processes. The estimates range from a low of 20,000 to a high of 80,000 in the United States[5]. The Surface Finishing Market Research Board estimated that there are over 12,000 job shop and captive metal finishing facilities in North America - a figure which does not include painting and coating operations.

Geographical Distribution - Metal finishing operations are located around the country but, not surprisingly, are concentrated most heavily in manufacturing regions which constitute the customer base. Three areas of notable concentration are the Great Lakes (MI, OH, IL), Northeast (PA, NY, MA, NJ, RI), California, and Texas. In 1987, these ten states accounted for 69% of the plating and related job shop establishments with California (16% of U.S shipments), Michigan (11.2%) and Ohio (9.2%) the top three states in sales volume. Despite this concentration, 35 states had 150 or more employees in plating job shops and 30 states had 150 or more employees in painting job shop[6]. The SFMRB provides the most recent estimates of geographic dispersion. These estimates suggest that changes have occurred as a result of the movement and growth of manufacturing operations in certain areas (e.g. Carolinas) and perhaps environmental regulations. However, traditional industrial regions such as the Great Lakes, East Central, and Mid-Atlantic states still predominate.

1.2.3 Equipment Statistics

Equipment needs in the plating sector of metal finishing can be broken into three primary areas:

- Process equipment -- examples include cleaning systems, tanks, liners, filters, barrels, hoists, valves, process software, etc.

- Chemical Recovery and Recycling Equipment -- examples include ion exchange systems, evaporators, electrolysis systems, reverse osmosis systems, etc.'

- Treatment/Control equipment -- examples include wastewater treatment systems, sludge dryers and filter presses, air scrubbers, etc.

In addition, consumable materials used in process and cleaning baths such as plating chemistries, anodes and salts comprise another significant investment by the plating sector. No reliable information on the relative breakdown of equipment purchases could be found. However, the annual market for equipment and consumable materials in the plating sector has been estimated by the SFMRB to be approximately $1 billion and $ 1.3 billion respectively.

Coating and related sector equipment is broken down similarly into application equipment (guns, booths, ovens, alternative coating systems), recovery equipment (solvent stills) and environmental control devices such as strippers, scrubbers, and sludge dehydrators. Powder coating systems have seen significant growth with average annual sales of 350 installations over the past five years in North America'. As with the plating sector, however, market research information on specific equipment volumes is either scant or proprietary and not readily available.

Equipment use data for plating operations generated by the SFMRB survey showed that 37.4% of respondents used barrel plating; 30.9% were rack only; 27.6% had both types of operations, and 4.1% were reel to reel. The survey also reported that 16.7% of shops used automatic hoist, 40.7% shops used manual hoist, 25.7% were handline operations, 8.7% return type, and 4.1% sidearm.

Equipment use rates in the environmental area were gathered by the NCMS survey of 318 platers-and are presented here for different chemical recovery and solution maintenance technologies (technologies to restore the integrity and life of process solutions). Additional information on the purpose and functions of this equipment is found in Chapter 2.

Recovery Technologies	
Ion exchange	25.0%
Atmospheric evaporators	22.3%
Electrowinning	19.0%
Vacuum evaporators	7.2%
Reverse osmosis	1.8%
Electrodialysis	<1.0%

Solution Maintenance Technologies	
Ion transfer	5.0%
Ion exchange	3.5%
Membrane Electrolysis	1.6%
Acid Sorption (anodizing)	1.6%
Microfiltration	<l.0%

Source: Pollution Prevention and Control
Technology for Plating Operations
National Center for Manufacturing Sciences, 1994

1.2.4 Customer Markets

Metal finishing is ubiquitous, and as an industry based on derived demand for manufacturing products, sales are heavily influenced by the economic and market forces shaping individual manufacturing sectors. As these sectors rise and fall with business cycles and general economic conditions, so will the respective demand for metal finishing services.

The Department of Commerce Benchmark Input and Output Accounts identifies 52 major economic sectors purchasing plating and related services led by electronic components and semiconductors, motor vehicle parts and accessories, and hardware and related. For the metal coating industry, 89 purchasing sectors are listed headed by prefabricated metal buildings, crowns and closures, and fabricated structural metal. It is worthwhile to note the critical connection between the health of the manufacturing sector and the metal finishing industry -- all 52 purchasing sectors for plating are manufacturing related as are 87 of the 89 purchasing sectors for metal coating and related services.

The SFMRB identifies three dominant markets in metal finishing -- automotive, consumer durables, and electronics with 1993 sales-weighted shares of 47.9%. 7.9% and 11.1% respectively. Not surprisingly, aerospace and other industries heavily reliant on government or defense contracts are currently identified as declining segments.

Another way to define industry segments is based on the type of metal finishing or metal finishing process. In many respects, the more dynamic nature of the metal finishing industry is reflected by the use or substitution of different finishing processes for a given finishing requirement. The regulatory framework has been the primary force in the gradual decline of classes of metal finishing like cyanide based systems and cadmium plating and will continue to create "winners and losers" in metal finishing. The result is often a renewed interest in new applications of older process technologies which, for example, has been a positive for the nickel plating industry. Likewise technical advances in powder coating technologies have not only captured painting segments but also resulted in inroads into a number of decorative plating markets as well.

Following, from the NCMS survey, is a listing of the seven most commonly operated plating processes. It should be noted that many experts believe zinc processes - cyanide and non-cyanide -- are "underreported" in this survey and are in fact the most common processes.

Plating type	Percent of respondent shop using
1. Nickel	**42**
2. Non-cyanide zinc	**39**
3. Copper cyanide	**38**
4. Cadmium cyanide	**30**
5. Electroless nickel	**30**
6. Decorative chrome	**29**
7. Tin acid plating	**27**

Source: Pollution Prevention and Control
Technology for Plating Operations
National Center for Manufacturing Sciences, 1994

Likewise, following are North American market share numbers for painting technologies (1991)

Solventborne	34.7%
High solids	27.0%
Waterborne	17.0%
Powder coating	10.7%
Electrocoat	7.0%
ultra-low VOC	3.6%

Source: Powder Coatings Markets and Applications
Powder Coatings Institute, 1993

Summary Statistics for Metal Finishing Industry (1992)

Total 1992 non-captive metal finishing facilities: 5,236
Total Employment (non-captive): 109,000
Estimated number of captive operations: 20,000 - 80,000
Estimated employment in captive operations: 40,000 - 160,000
Value of shipments (job shop only): Over $10 billion

1.3 Analysis of Industry Structure

The following section provides an overview of competitive and economic forces shaping the metal finishing industry. This discussion is based on literature reviews as well as the comments of platers, suppliers, consultants and industry analysts contacted in conjunction with the development of this report.

1.3.1 Captive vs. Job Shop Finishing

The reason for the existence of the job shop metal finishing industry can be understood by looking at the relationship of metal finishing to the rest of the manufacturing process. Metal finishing is generally the last operation before sale or assembly. It can require capital intensive operations but may have only a minor financial impact on the overall value-added of the product. It also has a lot to do with effluents, process chemicals and regulations. As a result of all these characteristics, it - makes manufacturing sense for many firms to outsource their finishing to specialist firms.

The decision of whether finishing should be done in a captive environment or contracted to a job shop is based upon a number of business. production, and economic ,factors. Several general "rules of thumb" exist for each finishing strategy.

Captive finishing is common when:

- proprietary technology is involved
- quality assurance demands are very high (finish is a "critical process")
- one of a kind parts/ very large parts (difficult to transport)
- finishing is an integral part of&e production line (outsourcing would disrupt or increase manufacturing lead times)
- finishing capacity can be utilized at high rates

Outsourcing to job shops is common when:

- finishing is "low value added"
- capacity utilization of finishing is low
- environmental regulations become too much trouble or require too much investment

Industry professionals note **a** trend toward outsourcing more metal finishing activities to job shop operations. This may be reflected in the growth of the number of enterprises in the metal coating and related sector. Although environmental compliance issues and costs are undoubtedly a driver for outsourcing, for many firms it may be a secondary issue to mainstream manufacturing and production changes. With the advent of cellular manufacturing, flexible manufacturing systems, and the need to reexamine cost structures, manufacturers are finding it unacceptable to have finishing capacity which takes up valuable floor space, but may only be utilized at 20-30% and entails potentially substantial overhead.

1.3.2 Ownership

As noted earlier, the metal finishing industry continues to be dominated by small, single establishment firms. As an illustration, from the period 1987 - 1992, there was a 6.7% increase in the number of metal coating establishments, but of this increase, 8 1% was comprised of facilities with fewer than 20 employees. Approximately 79% of plating and related operations and 81% of metal coating and related operations are incorporated with the rest existing largely as partnerships or proprietorships[8]. Although incorporated, the majority of firms are privately held, often within families.

It is likely that any metal finishing facility older than 15 or 20 years has some type of site contamination problem. A portion of these problems may result in significant liability and clean-up expenditures. Although most metal finishers are incorporated to shelter owners from precisely this type of liability, governments may attempt to "pierce the corporate veil" if assets are insufficient and the business was run as a proprietorship or partnership without the procedures and formalities of an incorporated enterprise. This battle may soon be evident since an initial wave of metal finishing closures has begun.

Cost Structure of Metal Finishing Facilities

Job shop operating cost breakdown - The SFMRB research study found the breakdown of job shop costs to be as follows:

Labor	28.0%
Materials	14.4%
Environmental	5.1%
Safety and Health	2.5%
Overhead and Profit	50.0%
	100.0%

Source: Surface Finishing Market Research Board
1992-1993 Industry Survey

Data does not yet appear to exist for a further breakdown and study of the interrelationship between these cost elements. Future SFMRB research studies as well as the work of other organizations (such as the environmental benchmarking activities of the Industrial Technology Institute of Ann Arbor, MI) is expected to shed more light on these issues.

Environmental management cost breakdown - Labor and materials inputs, including energy, comprise the largest cost portion for environmental management activities in both classes of metal finishing facilities.

1992 Estimated Pollution Abatement Operating Costs (Average per facility)

	3471 -- Plating and Related (sample of 951 facilities with 20 or more employees)		3479 -- Metal Coating and Related (sample of 639 facilities with 20 or more employees)	
	Estimated ave cost	Percent of total env.mgmt.	Estimated ave. cost	Percent of total env.mgmt.
Labor	$31,230	24.2%	$14,866	20.8%
Energy	$11,357	8.8%	$16,901	22.1%
Depreciation	$12,092	9.3%	$ 8,138	11.3%
Contracts	$17,876	13.9%	$14,241	19.9%
Materials	$37,960	29.4%	$14,710	20.6%
Payments to govt*	$18,191	14.1%	$ 3,756	5.2%
TOTALS	$128,706	100%	$71,517	100%

* Payment to government includes payments to federal, state, or local government units for sewerage or waste collection/disposal. It dues of include permit or legal fees, tines. and taxes

Source: U.S. Department of Commerce
Current Industrial Reports - Pollution
Abatement Costs and Expenditures, 1992

For plating facilities, the focus for environmental management costs is the wastewater treatment system. The cost of treatment chemicals in plating facilities can be over half the annual operating costs for a wastewater treatment system, and the total annual operating costs for wastewater treatment is frequently one half or more of the original capital cost of the system. In painting facilities, energy requirements for VOC control mechanisms like thermal oxidizers are a notable cost element.

Environmental Management Operating Cost Expenditures by Media

	3471 -- Plating	3479 -- Painting
Air	8%	37%
Water	62%	31%
Waste	32%	32%

Source: U.S. Department of Commerce
Current Industrial Reports -- Pollution
Abatement Costs and Expenditures, 1992

Analyzing operating costs by media illustrates the emphasis on water wastestreams in plating and related operations. In painting facilities, the costs are divided equally among all three media reflecting VOC emissions concerns, waterwash discharges, and paint waste.

1.3.4 Business Resources

1.3.4.1 Capital Investment

Capital availability, as with other small manufacturing enterprises, is an ongoing issue for many metal finishing firms. Surveys of metal finishers show that capital investments are highly dependent on the economy and expected business conditions from year to year and largely driven by customer demand. Average annual investment per plating establishment is only 17% of the average for all other types of manufacturing. The average for coating establishments is only slightly higher at 23%. Given the preponderance of very small enterprises, a more appropriate way to compare capital investment is based on investment amounts per production worker. Plating facilities' annual investment per production worker is 36% of the national manufacturing average. while painting facilities are 42%[9].

Total capital expenditures (all facilities) averaged $53,878 per plating and related facility and $65,496 per coating and related facility in 1992. Over 75% of this investment was in new equipment[10]. However, comparing these figures to profitability figures cited earlier in this report demonstrates how misleading the concept of a "numerical average" of capital investment for metal finishing can be. This is due to the different sizes of metal finishing establishments, the varying degree of capitalization needed to compete in different plating markets, and the "lumpiness" of capital investment (a purchase of a major piece of equipment may be equal to or greater than the entire net profit of a facility for a given year but be expected to last for many years).

Annual capital expenditures in environmental management would also be expected to "spike" as different rules and regulations are promulgated. Likewise, "average" capital expenditures for pollution abatement may be misleading in that a facility may need to make a significant investment in a new system in one year to comply for subsequent years. However, a 1993 survey by Finishers Management magazine showed the investment levels to be generally stable from year to year suggesting that facilities may be becoming more sophisticated in identifying, planning, and implementing their environmental technology needs rather than suddenly reacting to new laws.

The media percentages again reflect where the environmental pressure points have been for both classes of finishing.

Estimated Average 1992 Pollution Abatement Capital Expenditures
(facilities with more than 20 employees)

	3471 -- Plating and Related	3479 -- Coating and Related
Average/facility	$11,672	$5,477
For Air	25%	63%
For Water	62%	23%
For Waste	13%	17%

Source: U.S. Department of Commerce
Current Industrial Reports -- Pollution
Abatement Costs and Expenditures, 1992

Although the sample group for total capital expenditures is different from the environmental expenditure survey (which only included facilities with more than 20 employees) the data does suggest that plating operations need to devote a significantly greater share of their capital budget to compliance related concerns than the painting sector.

1.3.4.2 Workforce Resources

Workforce skill requirements may vary substantially depending on the type of metal finishing activity. On one end of the plating spectrum, low value added plating of simple parts may require little in the way of skilled labor. On the other end, expensive intricate parts, precious metal plating, and/or plating to tight specifications will likely require a skilled labor force intimately familiar with total quality management tools and statistical process control. Likewise, in painting and coating operations, varying skill levels can be found.

Experienced platers and, to a lesser extent, painters are highly valued for the knowledge they accumulate over time. Metal finishing has historically been as much art as science, and the years of experience in knowing what works and what doesn't work can be invaluable in production and troubleshooting. This historical reliance on "know-how" has had a negative impact on openness to change. However, finishing experience is now being supplemented with formal personnel training as evidenced by a number of finisher surveys.

In general, there appears to be a steady trend toward an increasing professionalization and development of the workforce both at the operator and management level. Both environmental and business factors are driving this change. The ongoing challenges of environmental compliance requires a closer attention to process control and optimizing process parameters. The advent of alternative technologies - typically featuring tighter operating windows - reinforces this need. On the business management side, the dynamics of the relationship between finishers and their customers is changing. As manufacturers look to thin their supply base and use programs such,as IS0 9000 certification as a filtering tool, finishing operations must respond by formalizing training programs and investing in workforce development. In addition, insurance and health and safety concerns are also potent forces for training in improved operating practices

1.3.4.3 Engineering Resources

Engineering resources are a precious, and too often rare, commodity for metal finishers. For many shops, process engineering expertise is often based on the cumulative know-how of experienced platers and guidance from suppliers rather than on formal, internal engineering expertise.

A growing and more critical engineering need - even more rare among metal finishing facilities -- is chemical engineering. Process chemistries are becoming increasingly complex to understand and maintain. As a result, finishing facilities are relying even more on their suppliers to provide assistance and instruction. Understanding processes is a proven cornerstone for waste reduction and improved manufacturing practice. Relying on outside agents for process understanding may prove to be one of the most significant challenges facing industry members.

Although captive shops may have far more engineering skills available for consultation, this does not necessarily mean that the resources are utilized. Consultants have commented that metal finishing is often considered the "least sexy" of possible engineering and problem solving areas and will not attract the level of attention or investigation that other more prominent process or design areas will have. This is especially true in coating operations and doubly unfortunate as this "straightforward" operation often holds some of the greatest efficiency improvement and cost savings opportunities for a facility.

1.3.5 Competition in the Metal Finishing Industry

Like other industries, low price, delivery time and quality are three important competitive issues for metal finishing companies. However, several general characteristics of the industry itself have made it one of the most intensely price competitive and -- in the words of several platers -- "cutthroat" industries in existence:

- Customers have the bargaining power -- Given the number of firms available for metal finishing and the fact that the service itself is relatively undifferentiated, manufacturers can aggressively pursue the best price and play firms off each other. Moreover, there are few switching costs for manufacturers in changing suppliers.

- Finishers can adapt -- The segmentation and differentiation that does exist in metal finishing in some circumstances can be overcome by relatively small investments in different finishing processes and chemistries. Even if finishers are strongly tied to existing equipment and treatment systems, surveys of metal finishers have demonstrated a "survivors will" to move into other markets.

- Exit barriers can be high -- Although these market forces would normally cause some firms to drop out and potentially ease price pressures, regulatory concerns can overwhelm these forces. A conclusion of the US EPA Sustainable Industry Report on Metal Finishing noted that there are bottom tier firms which stay in business and lose money rather than face potential liabilities and clean-up costs.

Recent trends, however, suggest that the competitive futures of companies in the industry will largely be determined by whether they perform "high value added" or "low value added" metal finishing. A discussion of each "class" of finishers and the competitive implications follow.

"Low value added' finishing firms are those which finish relatively simple parts (often at high volumes) and would include markets like hardware (nuts and bolts) decorative chrome, tubular steel, etc. "Low value added" firms will typically serve a variety of these markets and be flexible enough to finish most anything that does not have special performance or specification needs associated with the finish. These firms compete almost exclusively on price and strive to be the low cost leader. Although no statistics are available, it is likely that well over half of the metal finishing establishments in the United States would fall into this "low value added" segment. These firms are predominant among the smaller job shops.

The general competitive position of these firms is often poor and likely to remain so for several reasons:

- There are many of them, all competing on price, which leaves the entire segment worse off from a profitability standpoint.

- Technical upgrade is more risky. Investments are made by management when there is assurance that new and continued business will result. Thus, customer loyalty is an important key to technology adoption, but loyalty is rare in this segment.

- They are more likely to be "trapped" in older processes, unable to make the investment to accommodate new process technologies.

- The segment is also highly susceptible to international competition which will continue to increase in the future. The phrase "all finishing is local" refers to the concept that metal finishing is always done near the manufacturing operations since transportation costs and longer lead times would overwhelm any marginal cost savings from using finishers distant from the manufacturing plant. However, fundamental change has taken place -- all finishing is still local but the manufacturing isn't. As more companies fabricate and assemble offshore to take advantage of cheaper labor, metal finishing has followed. Some experts expect classes of simple finishing, like tin plating, to be largely overseas operations as time progresses.

These international competitive pressures are exacerbated by international development efforts. Economic development funds are being directed toward the growth of small, labor-intensive enterprises -- like metal finishing -- in developing countries. As a result, "stone age" finishing operations are now leapfrogging many U.S. companies and featuring 90s technologies (but still paying stone age wages).

High value added finishing can be classified as featuring one or more of the following characteristics -- expensive/intricate parts, use of precious metals, or finishing to specifications. Electronics, medical devices, and aerospace would be examples of this class of finishing. The competitive position of these finishers is more positive for the following reasons:

- They are not as susceptible to price competition. Their expertise in specialty, high quality plating provides an important level of differentiation from other finishers.

- As preferred or frist tier suppliers, their relationships with customers is likely to be closer, longer term, and more loyal and supportive.

- They are likely to have more latitude to thoroughly understand process control issues and specialize in a few types of finishes further reenforcing their competitive position in their -chosen segments and also making them able to supply manufacturers outside their immediate area.

- International competition is unlikely to be able to infiltrate the markets these firms serve.

Not surprisingly. both competitive contexts have environmental implications. High value added finishing typically demands the type of process control and understanding associated with pollution prevention, and such firms are mote likely to implement such practices. Technical resources and skilled process operators improve the likelihood of implementation. The ability to specialize in a few finishing types and technologies is also likely to provide environmental benefits to the firm by having to manage and treat only a few wastestream types rather than a potpourri of metal bearing wastestreams. In contrast, the low value added finishing shops are less likely to have the time or resources to invest in environmental planning and process optimization given how quickly business contexts change. Moreover, they are typically second, third, or even fourth tier suppliers, making it very difficult to discuss design or specification changes to accommodate waste reduction practices.

Following is a summary list of key issues affecting competitive advantage

Past	Future
• experienced finishers	• more specialization
• recognition among customers	• investment in labor skill development
• ability to reduce labor costs	• investment in process control
• ability to do wide variety of finishing and "ride out" business cycles	• less reliance on suppliers/ability to to create processes
• larger shops with economies of scale	• "professionalization" of business management
	• access to capital to take advantage of process innovation

1.3.6. External Relationships

External relationships influence environmental and manufacturing practices. This section highlights three relationships of special concern: customers, suppliers and government.

1.3.6.1 Customer Relationships

As suggested in the previous section, the nature of the relationship between metal finishers and customers is largely dependent on whether or not the finisher provides a speciality finish and/or is a first tier supplier. To assure quality and reduce costs, manufacturers in general are looking to reduce the number of suppliers they use but establish closer working relationships with the remaining preferred vendors. This type of supply chain management also extends to some metal finishing firms. Specific practices may include:

- vendor qualification which reviews environmental management and compliance activities
- working with the finisher to implement alternative finishing technologies
- working with the finisher on part design and specification changes to reduce waste
- training programs

Environmental concerns, as well as quality incentives, drive this relationship. Legal staff in manufacturing organizations are concerned over sourcing relationships with facilities having potential environmental liabilities. Although the "stream of commerce" is not typically used to assign liability for site clean-up, a long-term, sole sourcing relationship with a metal finishing facility may be cause for concern. Direct interaction with the supplier on environmental management activity is discouraged for liability reasons.

Manufacturers may be willing to pay more for quality assurance -- and environmental security -- but being a preferred supplier to a manufacturing company does not make a metal finisher immune from price considerations. Examples exist of high-end finishers who have installed new environmental controls, added depreciation to the overhead, and priced themselves out of a contract.

Second and lower tier suppliers typically have do not have the same flexibility or quality of relationship with manufacturers. Delivery and price point are everything, and first tier suppliers will quickly subcontract elsewhere if these conditions are not met.

1.3.6.2 Supplier Relationships

The relationship between finishers and suppliers is a key element to understanding environmental and process performance within the industry. It is estimated that an average metal finisher will have 2-4 suppliers of process chemistries, l-2 suppliers of generic chemicals and 1-2 suppliers of recovery and treatment equipment.

In addition to equipment and materials sales, vendors will provide a variety of other support activities including technical support for troubleshooting and engineering, process design assistance, and financial support such as covering switching costs for process chemistry changes. Not surprisingly, finishers are heavily reliant on suppliers for information on technology availability and proper operating practices. As process chemistries and equipment become more and more sophisticated, this dependency can be expected to increase in the future.

Although suppliers have been active in promoting environmentally preferable chemistries and technologies, this reliance results in three potentially negative influences on the environmental performance of finishers. First, it minimizes the amount of process investigation undertaken at the facility which is the cornerstone for source reduction. Second, it has created a dependency on "black box" materials recovery and maintenance technologies at the expense of upstream process control and optimization. Finally, as several industry surveys have noted, many investments in recovery, recycling, and treatment equipment have been failures. Such experience has made finishers highly cautious and reticent to implement process change.

A secondary issue pertaining to the supplier network and environmental performance is the historical lack of coordination between materials and equipment suppliers. Proponents of environmentally preferable process chemistries (often proprietary) have generally failed to investigate the problems which are created when these new materials are put into existing chemical recovery, concentration, and treatment equipment. Likewise, the equipment manufacturers are focusing on improving the efficiency and recovery capabilities of these systems but failing to examine the implications of adopting new environmentally preferable process chemistries. This segmented and uncoordinated R&D will likely create at least occasional problems for firms willing to take the risks in process change. In response, a movement toward sole sourcing is a likely evolution within metal finishing.

1.3.6.3 Government Relationships

Metal finishing has an image of being a magnet for regulatory inspection and enforcement, although the data suggests that this activity is somewhat comparable to other industries in the fabricated metal products sector (SIC Code 34)

	Average no. of inspections per facility per year	No. of facilities currently out of compliance	No. of enforcement actions per facility (1989 - present)
Metal Finishing	.59	23.6%	.36
Cans/Containers	.69	26.1%	.51
Hardware/Tools	.58	20.3%	.22
Heating Equip.	.58	26.3%	.25
Fabricated Structural Metal	.33	16.0%	.19
Screw Machine	.31	19.2%	.19
Forging/Stamping	.55	22.8%	.27
Ordnance & Accessories	1.37	37.8%	.27
Industrial Fabricated Metal	.51	21.2%	.30

Source: U.S. EPA Office of Enforcement and Compliance Assurance, Profile for Fabricated Metal Products

The metal finishing industry has worked hard to build a relationship of understanding and cooperation with regulatory agencies through its three primary trade and professional association arms -- the National Association of Metal Finishers (NAMF), the Metal Finishing Suppliers Association (MFSA) and the American Electroplaters and Surface Finishers Society (AESF). Representatives from these associations have diligently invested time and effort in a number of environmental policy initiatives at state and federal levels including the Sustainable Industries Project, the EPA Sector Compliance and Enforcement Program, and the current Common Sense Initiative. Representatives have also served on a number of advisory hoards for technology transfer programs and have assisted in reviewing an extensive set of publications pertaining to pollution prevention and waste minimization in the industry.

Despite these efforts, a sense of an adversarial relationship remains and has been the focus of many of these strategic policy discussions. An important insight into its source was identified in the 1994 Sustainable Industries Report of the US EPA Office of Policy Planning and Evaluation. In it, the existence of "bad actors" in the industry was discussed at length. The task force participants noted that the actions of these chronically non-compliant firms has served to drag down the reputation of the industry as a whole and its individual members. It is worth noting that there are hundreds of metal finishing organizations which are not members of these trade or professional group associations.

Ongoing discussions through the Common Sense Initiative are focusing on the need to develop a regulatory strategy that targets problem firms but also provides positive regulatory incentives for top performers.

Ironically, bad experiences with a percentage of outwardly hostile regulatory agencies also has seemed to negatively influence the relationship for metal finishers. Commonly cited complaints are:

- inspectors do not know or understand processes and business constraints
- variability and inconsistency in interpretation of regulations
- failure to have their environmental protection efforts result in tangible business or financial benefits for the facility
- the problems of "one size fits all" regulations.

In many respects it appears that the 20% problem experience on both sides has served to define and contaminate the working relationship. The ongoing discussions of industry and regulatory participants in the Common Sense Initiative holds promise for a new relationship based on 80% content of shared environmental protection values and a strong manufacturing economy.

1.3.7 Technology Trends

Environmental concerns have been the primary drivers for technology R&D in both the plating and painting sectors. Material suppliers in both sectors are aggressively pursuing technology alternatives. In the plating sector, cyanide, cadmium, and hexavalent chrome alternatives are receiving the majority of the attention. In the painting sector, VOCs and hazardous air pollutant concerns have resulted in a number of alternative technologies.

Most of these technologies are highly application and niche specific, since metal finishing does not lend itself well to sweeping/cross cutting technology advancements. Looking ahead, however, there are short, medium and long range trends for metal finishing.

Short Range Trend: Growth of *Powder Coating*

Powder coating is likely to be an increasingly popular finishing technology for years to come. It has already made major inroads into liquid coating markets and has penetrated traditional decorative plating markets as well. Advances in powder technology and delivery systems continue to open up new applications. The desirability of powder coating is based on the near elimination of water wastestreams and VOC releases as well as superior materials use efficiency. Consultants have suggested that new finishing capacity currently being built or planned for the future will almost certainly have a strong powder coating element to it.

Medium Range Trend: Expansion of Physical and Chemical Vapor Deposition

Like powder coating for the painting sector vapor deposition technologies are "dry" finishing processes for metal plating. Several technologies are currently available to transport metals in a vapor state to a part to achieve a solid metal coating. Currently limited to very specific, often high end applications, advances in vapor deposition technologies to accommodate larger parts and higher production rates hold the promise for a substantial reduction in water wastestreams in metal finishing operations.

Long Range Trend: Next Generation Technologies

Advances in materials science hold the promise of one day being able to finish parts in radically different ways or reduce the need for finishing through alternative substrates. Four classes of technologies emerging on the horizon are:

- Non-aqueous liquid baths -- processes which rely on materials other than water (like alcohols) for the matrix
- Physical bonding -- metals are deposited as a result of physical rather than electrochemical contact
- "Nannotechnologies" -- advancements in laser technology holds the promise of finishing parts by individually placing metal ions onto substrates.
- Alternative substrates -- advances in ceramics and plastics engineering will reduce the need for metal finishing

1.3.8. Summary

The metal finishing industry is a highly fragmented service industry dominated by small enterprises and typically located near manufacturing customer bases. Environmental policy has undoubtedly reduced the number of firms in the industry but not to the extent that the basic structure of the industry has changed. Competitive pressures, especially offshore manufacturing, can be expected to contribute as much or more to a very gradual consolidation of the industry.

Environmental policy has a much mote significant effect on the competitive dynamics within the industry. Firms that are able to keep up with compliance demands and accommodate increased costs of operations can be expected to reap some benefit from increased outsourcing activity and transferred business from defunct shops. Environmental policy is also a contributing factor to changes in business strategy among some finishers such as a trend toward specialization -- knowing and doing a few processes superbly well. Most significantly, technology advances and adoption within the industry are largely driven by environmental protection issues. "Winners and losers" are largely determined by how well these technology decisions are evaluated and implemented.

[1] Surface Finishing Market Research Board, "Metal Finishing Industry Market Survey, 1992-1993" Metal Finishing Suppliers Association and National Association of Metal Finishers

[2] Darnay, Arsen J.. editor, "Plating & Polishing." *Manufacturing. U.S.A., Industry Analysis Statistics & Leading Companies*, 4th edition, volume 2. pp. 1427-1436. Gale Research. Inc.. Detroit, MI (1994).

[3] Dun and Bradstreet Credit Services. *Industry* Norms *and Key Business Ratios 1993-1994* -- *Manufacturing* Dun and Bradstreet. New York, NY

[4] Cushnie. George C. Jr., *Pollution Prevention & Control Technology for Plating Operations,* first edition, National Center for Manufacturing Sciences, Ann Arbor, MI (1994).

[5] Steward, F.A., *Environment & Competitiveness in the Metal Finishing Industry*. report prepared for Congress of the United States Office of Technology Assessment. Washington, D.C.. submitted by F.A. Steward Consulting, Inc.. Wexford. PA (January 28, 1993).

[6] U.S. Department of Commerce, Economics & Statistics Administration, Bureau of the Census, 1987 Census *of Manufactures.* Industry Series. report MC87-I-34D, Washington, D.C. (October 1990)

[7] Bocchi. Gregory J., "Powder Coatings - Markets and Applications." The Powder Coating Institute, Arlington. VA (1993)

[8] U.S. Department of Commerce, Economics & Statistics Administration, Bureau of the Census. 1992 *Census* of *Manufactures. Preliminary Report Industry Series,* report MC92-I-34D(P), Washington, D.C. (October 1994)

[9] Darnay, Arsen J., editor, "Plating & Polishing," *Manufacturing, U.S.A., Industry Analysis* Statistics *& Leading Companies, 4th* edition, volume 2, pp. 1427-1436. Gale Research, Inc., Detroit, MI (1994).

[10] U.S. Department of Commerce, Economics & Statistics Administration, Bureau of the Census.1992 Census of *Manufactures. Preliminary Report Industry Series*, report MC92-I-34D(P), Washington, D.C. (October 1994)

CHAPTER 2
METAL FINISHING PROCESSES ANALYSIS

2.1 Introduction

Metal finishing is a term for a highly diverse group of technologies and industrial processes. Forty-six different processes are regulated under metal finishing standards featuring different technologies, operational steps, inputs, and outputs. Moreover, it is common for several of these individual metal finishing processes to be combined in one overall finishing process. For example, a part may first be etched, then plated, then receive a conversion coating. The wide variety of possible substrate/finish combinations and finish specifications only adds to the complexity of analysis. As a result, the development of a "standard" metal finishing process is difficult to develop even with a particular category of finishing.

Figure 2A presents a highly simplified typology for the metal finishing industry and illustrates the major "families" of metal finishing processes. For purposes of this profile report, metal finishing processes are divided into four major categories.

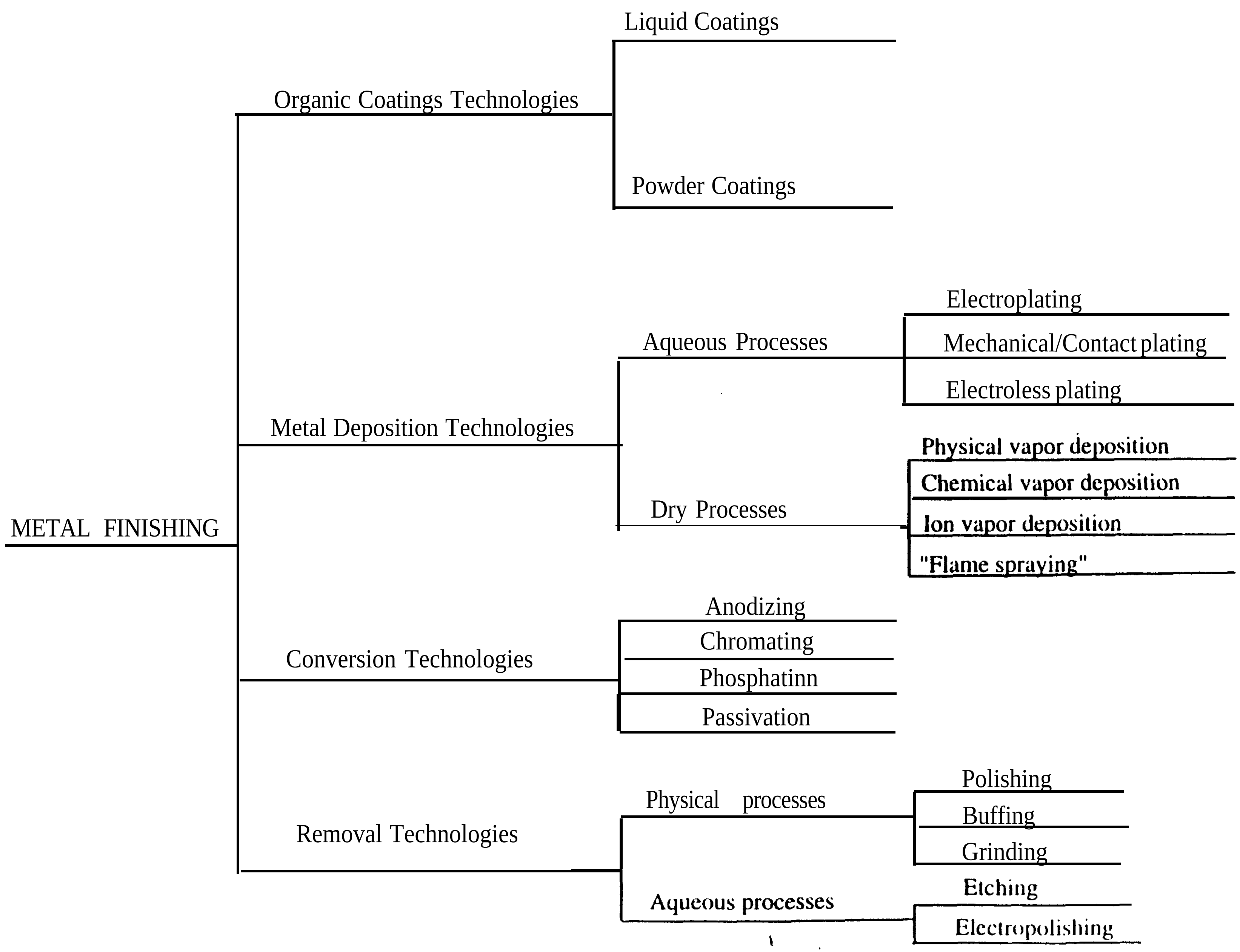
2.1.1. Organic Finishing Technologies

Organic finishing is the application of paint and related materials onto the metal substrate. The organic coating may be either in powder or liquid form and is comprised of several materials serving different functions. Paint formulations typically include pigments to provide the color and/or "body", additives to provide the coating the desired properties, resins/binders to act as the adhesive to the substrate, and (in the case of liquid coatings) solvents or thinners to dissolve the resin and lower the viscosity of the coating. The choice of the coating technology is based on the desired mix of physical and chemical finishing properties needed for the product. Common examples of desirable physical properties include hardness, abrasion resistance, flexibility, and gloss. Examples of chemical properties would include resistance to corrosion, chemicals, water, high temperatures, and sunlight.

2.1.2 Metal Deposition Technologies

A second class of metal finishing entails those technologies which deposit a metal coating onto a metal substrate. "Plating" can generally be divided into two segments - aqueous based processes and dry processes. Aqueous based processes deposit metal ions onto a substrate through the use of electrical current (electroplating), through chemical reactions (electroless plating), or through direct contact with metal bearing solution (contact and mechanical plating). Aqueous based process are used to deposit a wide variety of metals and combinations of metals onto metal substrates. As

Figure 2A Simplified Metal Finishing Typology



their name implies, dry processes plate metals onto parts without the use of process solutions. Many of the methods in dry processes are called "vapor phase methods" in which the coating material goes from a vapor phase to solid phase when deposited on the part.

2.1.3. Conversion Technologies

Unlike the previous two categories of metal finishing which are additive processes in which a material is actually deposited on the part to an appropriate thickness, conversion processes are finishing methods in which the "plated" materials interact with and physically change the make-up of the substrate. Often used to prepare surfaces prior to another finishing process such as painting, conversion processes also can serve as a final finish because of excellent corrosion and wear protection that they provide.

Conversion methods commonly employed in metal finishing include phosphating, chromating, and anodizing. Phosphating entails a carefully controlled corrosion of the metal surface followed by the deposition of a mineral coating which becomes tightly bonded to the surface. Chromating abides by the same principle - a slight removal of the substrate to allow, in this instance, the penetration of a chromium-metal gel. Anodizing is an eletrochemical process which converts an aluminum surface substrate to a coating of aluminum oxide providing wear resistant properties and the ability to receive decorative coatings.

Passivation is a fourth process generally identified as a conversion process although it functions differently from other conversion techniques. Passivation is the immersion of stainless steel parts in a nitric acid based solution in order to remove metal contaminants as well as provide a corrosion resistant oxide surface. It is a particularly common finishing process for a part which has undergone handling and processing operations in which iron or tool steel particles may have become embedded in the substrate.

2.1.4. Removal Technologies

A final class of metal finishing are subtractive processes which involve the removal of metal from the substrate either through physical action or chemical reaction. Hand polishing, buffing, and grinding are examples of physical processes used to create a smooth clean finish. Aqueous chemical processes - electropolishing and etching - entail a richer number of environmental considerations. Electropolishing is actually the reverse of electroplating - the electrical current in solution is used to remove metal from the part and deposit it onto a cathode leaving a smooth, highly reflective surface. Etching is the selective removal of metals from targeted areas on a workpiece.

The following sections present an overview of plating (electroplating and electroless plating), organic coating (Powder and liquid), and other primary chemically-based surface finishing processes (conversion coatings and electropolishing).

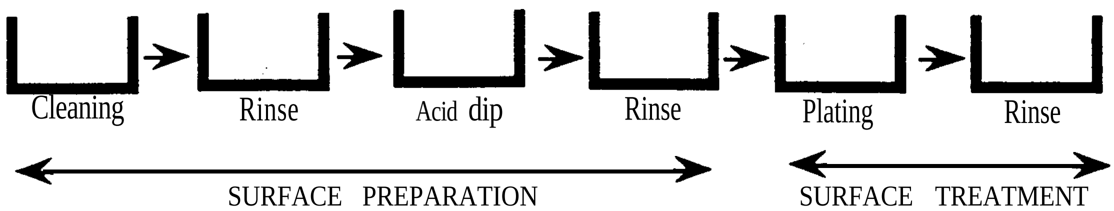
2.2 Plating

Plating is an extremely flexible and efficient method for providing metal substrates with many desirable properties. Unfortunately it also generates a broad range of pollutants such as heavy metals, acid and alkaline wastewaters, and organics.

2.2.1 Overview of Electroplating Process

Figure 2B illustrates a process flow diagram for an electroplating operation. Parts are plated using several types of equipment. In barrel plating, smaller parts are loaded into a perforated container which is rotated during processing. Barrel plating is good for high volume plating of smaller parts. In rack plating, the parts are hung on hooks or clamped into fixtures and sent through the plating line. Rack plating is used for larger parts. pieces with more complex geometries, or those which cm be damaged easily. A third, less common form of plating is called "reel to reel" in which an unplated material is unwound from a feed coil, plated, then rewound. Reel to reel plating is an automated process whereas both barrel and rack plating can be accomplished manually or with automated operations.

FIGURE 2B -- Simplified Process Flow Diagram for Plating Process



In general, workpieces go through two primary stages of processing:

1) Surface preparation -- Any part 'that is to be plated must first be pretreated to remove greases, soils, oxides and other materials which would interfere with the application of the surface treatment. The first step entails having the part be introduced to a cleaning system - typically either organic solvent or aqueous based. Following the cleaning phase the work piece will go through a water rinse bath to remove any cleaning materials remaining on the part. The workpiece then proceeds to an acid dip which further prepares the part for plating by removing any oxides which may have formed on the part. The final step in surface preparation is another rinse stage to remove any acid residues.

2) Surface finishing - The surface finishing stage is the actual modification of the workpiece surface. Exhibit 2B is a highly simplified diagram of the plating process -- the actual surface finishing process likely involves a series of deposition baths and rinses to achieve the desirable final finish. For example, a common three step plating system is "copper-nickel-chrome" -- the copper is plated first to improve the adhesion of the nickel to the steel substrate and the final chrome bath provides additional corrosion resistant protection. Following each process bath a rinse stage removes excess process solution. The final step in the electroplating process is a drying stage. This may include simple air drying or a slightly more involved process such as forced air evaporation or spin dry.

In many plating operations one or more post treatment processes may be found following the core finishing processes to either enhance the appearance of the part or add some physical or chemical property. An example of a physical post-treatment process would be heat treating to adjust the hardness of the parts. Conversion coating, discussed later in this report, is another particularly common post-treatment process.

Two ancillary processes exist in plating which are of critical concern in reviewing the environmental performance of the facility: wastewater treatment and metal stripping. Rinse waters, process solutions and other wastewaters will go to the facility's treatment system prior to their discharge. These treatment systems vary significantly in levels of sophistication and are often used to recover materials as well as make wastewaters safe for discharge. Stripping processes are found in nearly every shop to allow rework of improperly plated or out of specification parts.

Productivity and output in plating operations is influenced by a number of production parameters. The following factors are especially influential in plating productivity:

Part geometry -- Both the shape and size of the part will influence manufacturing throughput. Larger workpieces and pieces with complex geometries will typically take longer to finish than smaller workpieces or parts with simple geometries. Moreover, larger complex pieces typically must be rack plated whereas smaller, simpler pieces can be batch processed together through barrel plating. Large complex parts also have environmental implications because they are generally more difficult to rinse thus requiring greater water use and time to achieve the desired cleanliness.

Plating specifications -- Plating thickness, corrosion resistance. and brightness are primary quality specification areas in electroplating. The manufacturing specifications and the process steps needed to accomplish them impact manufacturing throughput. Inspection for thickness is especially problematic since real-time (in process) inspection is especially difficult requiring the plater to stop the line, clean the part, check for thickness, make adjustments, and restart the process.

Masking or plugging -- Productivity is also affected by the amount of masking or plugging which must be done on a part. In many electroplating applications only a portion of the part may need to be plated. Masking and plugging prevents metals from being deposited on inappropriate areas of, the workpiece but also affects throughput rates.

Single load versus long runs - The need to change processes frequently to accommodate different plating jobs will reduce manufacturing throughput when compared to the ability to run a particular piece or group of pieces needing the same finishing process for extended periods.

Unfamiliar parts - Although production specifications will often provide guidance on running parts, a significant element of "art" and experience is involved in quality plating because of the chemistry of the processes. Familiarity and experience with certain process chemistries, achieving particular production specifications, or similar workpiece geometries will benefit an organization from the standpoint of productivity and throughput.

One of the principles of manufacturing excellence is to reduce cycle times - the total processing time needed to manufacture a part. Platers, like other manufacturers, look for ways to reduce their processing times while maintaining high quality. As the following sections will illustrate, a critical issue in plating operations is that (quality issues aside) the adoption of many environmentally preferable technologies and practices may often increase processing times -- sometimes substantially. Productivity and pollution prevention are at potential loggerheads in many metal plating situations.

2.2.2 Analysis of Technology, Chemical and Waste Issues in Process Operations

The major sources of waste in plating operations can be broken into two categories - drag out and bath dumps. Drag out is the quantity of bath carried on the workpiece as it moves from one processing step to another. The process solution taken into rinse steps creates a source of waste which is typically high in volume and low in concentration. Bath dumps occur because both process baths and cleaning baths may need to be periodically discarded. This waste source is typically low in volume but high in chemical concentration. The two sources are interrelated --

high drag out rates may result in high volumes of contaminated rinsewaters and faster contamination of subsequent process baths. Drag-out and bath dump considerations are found in each step of the plating process.

Following is a closer examination of the typical inputs and outputs associated with each process step, the environmental issues which result. and their respective environmental management considerations. Technology profiles highlighting "low-end", standard, and "best in practice" characteristics are also provided for critical process steps. In reviewing these profiles two cautions must be given. First the economic and environmental logic of implementing various techniques and technologies is extremely case-specific in metal finishing operations. A facility may have a number of legitimate production, economic, and technical reasons for not employing a technique or technology that, independent of a specific process context, could be labeled "environmentally preferable." As a result, the following technology profiles should be used as information tools, not as absolute indicators of environmental performance or commitment by a facility. Second, best in practice profiles assumes the availability of capital funds and shop floor space -- an assumption that conflicts with the reality of many metal finishing job shops.

2.2.2.1 Surface preparation/cleaning. The environmental issues stemming from surface preparation depends on the type of cleaning system employed. Two primary types of cleaning approaches can be found in electroplating operations -- solvent based systems and aqueous systems. Solvent-based systems include vapor degreasing, cold cleaning (room temperature solvent spray, dip or wipe) and ultrasonic agitation. Because of regulatory phase-outs and air toxic concerns, the use of halogenated solvent cleaning with materials like 1.1.1 trichloroethane (TCA) and trichloroethylene (TCE) are decreasing although a number of non-halogenated solvents are used as alternatives. Aqueous systems are a popular alternative to traditional solvent cleaning and have become the preferred surface preparation system of electroplaters. Aqueous systems use. alkaline cleaners comprised of alkaline salts with emulsifiers and surfactants to lift, remove, and dissolve the oils and soils. Aqueous systems include spray systems, ultrasonic systems, soak cleaners, and electrocleaners which use electrical current as part of the cleaning process. The choice of the appropriate cleaning technology is a function of both the type of production (intermittent vs. continuous high production) and the type of cleaning concern (oil and grease, metal chips and cutting fluid, polishing compounds, etc.)

Alkaline based systems are the most common in metal plating operations. In a typical aqueous system an alkaline salt pow&r is combined with water and heat to make up the operation inputs. The operation outputs can be categorized as:

- dilute cleaning chemistry
- metals in solution stemming from lead in machining oil and sources of this nature
- oils and greases
- bottoms comprised of unreacted process chemistry and soil based sludges

Historically, these waste products seldom created significant environmental management issues for the plating facility. However, the advances in alkaline cleaning chemistries have proven to be problematic for some facilities featuring older water treatment systems. In most instances the tank bottoms are non-hazardous solid waste and the other outputs are pre-treated or directly sewered. Occasionally, the alkaline concentrations may result in wastewater pH levels approaching or exceeding RCRA standards thereby technically becoming hazardous waste. Most facilities send these waters to their "end of pipe" treatment system for pH adjustment although some electroplaters will dilute these wastewaters before discharging directly into the sewer.

Technology profiles -- A "low-end" technology profile for parts cleaning might include a heavy reliance on chlorinated solvents, most notably TCA, TCE. PERC or methylene chloride. Actual cleaning would be accomplished through hand wipe, cold cleaner application or vapor degreasing

concern, this output may be either discharged directly to the sewer or first sent to treatment system. Low-end shops may employ an environmental short-cut called the “trickle tank.” Spent acid bath solution will have a pH too low to be legally discharged to sewer. A tank is used to hold the spent baths, and the acid solution is allowed to “trickle” out and mix with the alkaline cleaning solutions of the earlier cleaning step. This neutralizes the pH of the wastewater and keeping the facility within effluent standards. Although such blending is common to create a neutral compliant water wastestream, doing this outside of a monitored treatment system is illegal.
practice profiles again feature efforts to optimize the performance of the acid bath and extend its useful life. Chemical recovery and reuse technologies (discussed later in this report), may be employed to purify and extend acid bath lives.

In many circumstances the primary regulatory concern surrounding acid baths pertains to OSHA rather than the environmental regulatory agency. Especially when acid mist systems are used, air concentrations may pose a concern to worker health and safety.

2.2.2.4 Plating -- The core plating process is often actually a series of deposition and rinse steps to achieve the desired metal finish characteristics. Multiple depositions of different metals may be needed with each metallic layer serving a different finish function. There are many different types of plating processes which are differentiated from each other by:

- existence or absence of electrical current(electroplating or electroless plating)
- type of metal substrate (ferrous or non-ferrous)
- type of plating metals (base metals, precious metals, or combinations of both)
- characteristics of process solution (alkaline or acid, cyanide or non-cyanide)

Electroplating - Electroplating process bath inputs depend on the type of plating and product specifications but can generally be grouped into four categories of materials.

- positively charged metal anodes or metallic salts which are placed in the bath and provide the material to be plated for the plating process.
- process solution which is either acid or alkaline based.
- brighteners - organic and inorganic materials which generate a brighter, cleaner finish.
- other active chemical components - mostly organics, these materials are added to modify the properties of the deposit (like hardness or ductility) or improve the performance and preserve the life of the bath.

Process outputs from the plating baths largely mirror the process inputs. Many factors may cause process baths to become unusable after a period of time. Some of the most prominent factors include 1) chemical breakdown of process chemicals or side reactions, 2) contaminants entering the bath from make-up water or shop atmosphere, 3) corrosion of parts, racks. tanks, etc., 4) dropped parts in tanks, and 5) drag-in of non-compatible chemicals. Bath dumps are an occasional operation for many plating baths and would include process solution with its metal and organic constituents and contaminants as well as tank bottoms with reacted and unreacted materials. It should also be noted that in addition to the process inputs, these bath dumps may also include new byproducts from chemical reactions taking place in the process tank. Spent process baths and the metal sludges of the tank bottoms are considered hazardous waste.

Although spent solution and sludges are the primary waste materials from the actual plating baths, some types of plating may create air releases of importance. Chief among these are chromium plating operations which release hexavalent chrome - a primary air release of concern. However, as with acid bath processes, OSHA regulations are likely to be the primary compliance issues for the facility.

with no solvent emission controls in open buckets or tanks. Organic solvent is also present in wastewater as the result of spills or drips. No solvent recovery is attempted.

A standard technology profile would include use of the alkaline based aqueous systems previously mentioned. Non-chlorinated solvent alternatives would be used for spot cleaning. Vapor degreasing may still be used for certain parts although these activities would feature best practices to control emissions such as increased freeboard, an automatic rolltop, and a refrigeration zone to supplement conventional cooling.

A best-in-practice technology profile would feature the elimination of chlorinated solvents from operations. Cleaning technologies would look similar to the standard profile with a couple of operating differences. First, efforts would be made to understand specific soil types and their sources to identify source reduction options. For example, in a lower technology profile shop, an alternative to solvent for the removal of polishing compounds might be determined to be ineffective. A high profile shop would explore how the polishing technique itself can be changed to allow alternative cleaning strategies. Second, efforts are made to extend the lives of "expendable" aqueous cleaning baths through cleaning process optimization using technologies such as oil skimming' and microfiltration.

2.2.2.2 "Non-critical" rinsing -- Although this step appears quite innocuous, the electroplating facility may find this step to be an area of importance for environmental compliance. The water rinse removes any remaining cleaning chemistry from the part. Many facilities use tap water for this process step without examining the quality of the water supply itself. Occasionally the concentration of metals from the public water supply exceeds the permissible levels that the facility can discharge into the sewer. Thus, even before the rinse is conducted, the facility will be facing-a potential compliance concern. As a means of overcoming this problem, some facilities will soften the water prior to introducing it to the rinse tank. This stopgap strategy is not without its own pitfalls as the introduction of salts to soften the rinsewaters can poison process baths like bright nickel limiting their process life and thus creating waste.

Technology profiles -- Although it is a highly simplified measure and very dependent on the type of work being produced, a rough evaluation of the performance of the rinsing system might be gained by examining rinse flow rates. A low end technology profile might feature noncritical rinse flow rates in excess of five gallons per minute. Tap water is used and discharged to the treatment system or sewered without reuse.

A standard technology profile might feature non-critical rinse rates in the range of 3 gallons per minute. Tap water is used, although softened or otherwise modified. Rinse waters are reused, perhaps in the acid dip rinse.

Best practice would feature water use rates around 1 gallon per minute. Deionized water, rather than tap water, would be used as rinse inputs. Sensor technologies would also be employed to monitor pH levels and automatically control rinsewater inputs. Agitation would be added to further facilitate the rinsing process.

2.2.2.3 Acid bath - Common inputs into this surface preparation step include acid salts or sulfuric, hydrochloric, muriatic, and (less commonly) nitric acids. Acid baths are typically 5% - 10% concentration by volume and may also feature the use of organic chemical inhibitors to limit the acid to the removal of oxidation and limit damage to metal substrate. Parts may be placed into an acid bath or subject to an acid mist spray. Outputs and wastes are comprised of spent acid solution with trace metals and organics. Another rinse step is required following this bath.

Technology profile - Environmental management options and technology profiles are similar to that of previous process steps like rinse tanks. Depending on the concentration of the material of

Electroless plating - As described earlier, electroless plating deposits a metal coating on a substrate through chemical reactions when immersed in an appropriate plating solution. The actual plating is accomplished without the aid of electrical current. Electroless plating baths are extremely complex chemistries comprised of the plating metals, chelating agents to hold metals in solution, and a variety of other organic materials serving a number of different functions such as buffers (which artificially extend a pH range in solution), inhibitors (which prevent removal of substrate metal while allowing removal of oxides), and reducing agents (which actually cause the metal to plate out). Electroless plating operations require high temperature baths and are therefore also energy intensive.

Although similar to electroplating in many ways, electroless operations feature four rather distinctive characteristics which in turn have special environmental and waste implications.

1. Electroless plating demands much tighter control over process parameters than electroplating. Critical electroless plating parameters include metal concentration, reducer concentration. pH, temperature, agitation, and contamination control. Improper control over these process variables can quickly result in bad parts and substantial waste.

2. Chemical reactions in the electroless process baths cause “plate-out” in which everything coming in contact with the process solution -including the process tank itself - receives the *metal* coating over time. Plate out is exacerbated when facilities attempt to plate parts too rapidly because the changes in heat and pH to accommodate faster plating may be outside of the normal operating parameters for the chemistry. To treat plate-out. the tanks must be taken off line and, in the case of electroless nickel, stripped with nitric acid. In some shops, this stripping must be done every few days. The nitric acid stripping process can cause significant air releases of NOx with accompanying environmental and workplace hazards, and the nitric acid/nickel solution is difficult to treat.

3. The frequency of electroless bath dumps is much greater than that of electroplating. Electroless baths are extremely sensitive to contaminants from sources like drag in, and the key ingredients are constantly breaking down. Unlike electroplating where a number of solution maintenance and recovery techniques can extend bath lives indefinitely. electroless baths have a significantly shorter life expectancy. “Turnover” is a measure of the age of the electroless plating bath and is the term given to the number of times the starting mass of metal at make-up is replaced through replenishment. Current process bath technologies typically allow a l0-12 turnovers; in practice 5 6 turnovers is common. Some process chemistries claiming l00+ turnover potential exists, although this assumes perfect plating control and additional time to plate the part - two rare commodities among metal finishers. It is not uncommon for some job shops to have to dump process baths twice a week or have electroless baths last a half a day. Volume and frequency issues aside, the bath constituents are also especially difficult to treat. The chemistries are complex and the presence of chelators - used to keep metals in solution in the process - makes waste treatment challenging when the objective is to precipitate the metals out of solution.

4. The concentration of organics in electroless process chemistries may create special wastewater treatment challenges. The focus for most of the regulatory activity in metal finishing is the concentration of metal in the wastewaters. For electroless facilities, the levels of chlorinated organics can be equally problematic. The amines used in the process chemistries can readily metamorphize into chlorinated organics when introduced with other chemicals into the pretreatment system. Especially for facilities with NPDES permits and under requirements for aquatic toxicity testing, this can be an troublesome regulatory compliance problem.

Air issues, while seldom significant enough to trigger permit requirements, are more common in electroless plating than in electroplating. Nitrogen oxides from stripping operations, and ammonia, chlorine, and formaldehyde outgassing from bath pH adjustment are particularly common air issues.

Technology profiles -- A low-end technology profile for the plating process would include one or more "first tier" efforts to preserve bath lives through bath maintenance techniques. Filtration, carbon treatment, electrolysis and batch precipitation of contaminants are common techniques employed by platers that have been around for decades. It is important to note that such corrective maintenance techniques produce waste streams themselves such as spent filter cartridges and sludges. Among low technology profile shops there is little effort to understand when or why corrective solution maintenance activities like filter changes are needed. Corrective treatments are initiated by "eyeballing" process solutions or only after part rejects begin to occur.

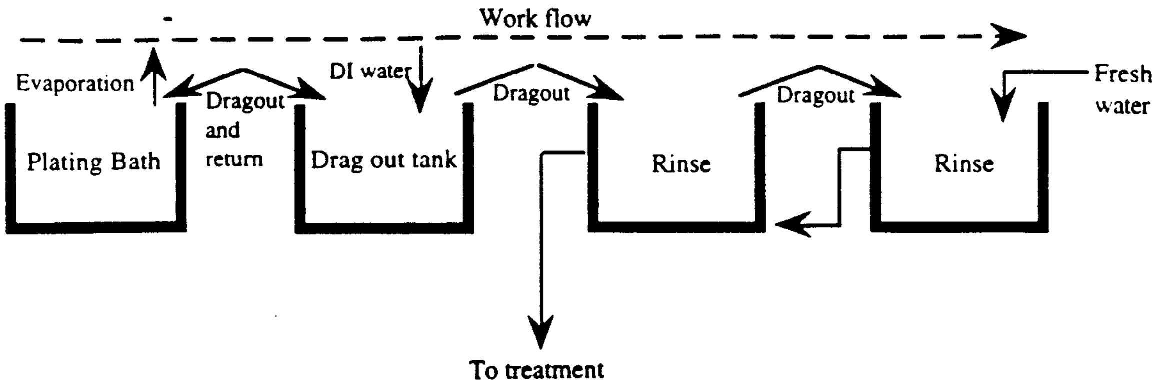
A standard technology profile would combine first tier solution maintenance efforts with more sophisticated bath regeneration technologies. Efforts are made to minimize waste resulting from the use of corrective technologies. These efforts would include the use of reusable filters and the development of standard operating procedures for filter changes so that reject parts are not the first prompt for corrective action. These efforts are combined with the implementation of one or more regeneration technologies described in Section 2.2.3.1.

A best-in practice technology profile would emphasize careful monitoring and process control of bath chemistries to optimize performance of the bath itself as well as regenerate bath process outputs. Since recovery and regeneration technologies have their own input and waste issues, efforts are made to optimize their environmental performance. More importantly, efforts are also made to determine the sources and causes of contaminants and to understand why baths become unusable. This understanding precedes the implementation of appropriate source reduction strategies.

2.2.2.5 Critical Rinse -- As with the plating process itself, the critical rinse may actually be a series of rinse steps to remove plating solution and chemical agents following the completion of the plating process. Water use and drag-out minimization are the primary environmental issues of concern.

Often a part will first be immersed into a non-flowing or "dead rinse" where the highest concentration of process solution "drag-out" is removed. Following the dead rinse, the part may enter series of flow rinse tanks to further remove process chemistries. A common arrangement and description for these flow rinses is called countercurrent rinsing. The rinse tanks are arranged so that the part travels to progressively cleaner rinse tanks and "upstream" in the sense that the water input for the overall rinse is piped into the final "cleanest" rinse tank Each tank in the series provides the water input for the tank that precedes it (see figure 2C). The logic of countercurrent rinsing and the actual number of rinse tanks ate driven by both quality and economics. A general rule of thumb is that for each rinse tank added the amount of water needed to get the same quality rinse can drop by a factor of ten. For example, if 100 gallons per hour is needed to rinse a part using one tank, only 10 gallons per hour will be needed to achieve an equivalent rinse through the installation of a second tank with counterflow rinsing. A third rinse tank would reduce water input to 1 gallon per hour. The concentration following the dead rinse typically drives the number of tanks -- for some barrel plating operations where dragout is extremely high, six or more counteflow rinse tanks may be used. There are limits for countercurrent rinsing since the line pressures involved in industrial processes are such that counterflow rinses cannot be controlled at input rates much under 0.5 gallons per hour.

Figure 2C: Single Stage Recovery / Two Stage Counterflow Rinse



Most material inputs in a flow rinsing process consist simply of water, although deionized water is preferable. Process outputs in rinsing consist of the potpourri of chemicals, metals, and agents contained in the process solution.

Technology profiles - A rough but simple benchmark for the efficiency of all rinsing done in a plating process is a "total water flow to tank ratio calculated as:

$$\frac{\text{Total process water input to plating line (in gals/minute)}}{\text{Number of rinse tanks}}$$

A low end technology profile would feature a ratio of process water to tank tanks ratio which is greater than 5. Tap water is used in a two stage critical rinsing process -- a dead rinse followed by one flowing rinse. A main water valve turns on water to all rinse tanks. Rinse waters go directly to the pretreatment system prior to discharge.

A standard technology profile features countercurrent rinsing lines and a "total water flow to total number of tanks" ratio between 1 and 5. Typically, one or more of several chemical recovery and concentration technologies described in Section 2.2.3.1 are employed on the rinsewaters. Many waste reduction efforts may have been tried but abandoned for reasons such as "hassle" or lack of maintenance. For example, a standard firm may evaluate and perhaps (despite the expense) install conductivity cells to make sure water flows only when needed and only to a set value of contamination in the rinse tank. However, over time the cells become corroded and no longer close the water valve. Other "low maintenance" efforts are implemented such as improved rinsing procedures by extending the contact time the part is actually in the rinse bath.

A best-in-practice profile features countercurrent rinsing, a water flow to tank ratio of less than 1 and a number of mostly low cost techniques and technologies to minimize drag out and optimize rinsing effectiveness. Drain boards are in place to catch drips and return the plating solution back to the process tank. Drain times over process tanks are extended and parts are oriented on racks to minimize solution carry-over into the rinse. Spray rinses and air knives are mounted on the process tank to *knock* process solution back into the plating tank before it can enter the rinse. Air agitation is also installed in the tank to improve rinsing efficiencies. Recovery and concentration technologies found in the standard technology profile are also likely to be used.

2.2.2.6 Ancillary processes -- Two other operations found in electroplating facilities which are typically not directly associated with the plating process but significantly influence the environmental management profile of the facility are metal stripping and wastewater treatment. Most shops will have stripping operations to reprocess reject parts and to strip the racks. The input and waste issues generated by the stripping process are largely dependent on the type of metal substrate of the parts or racks and the plated material.

Stripper solutions consist of highly complex mixes of chemicals and cyanide compounds. Alternative stripping technologies do exist although they are extremely slow. Since the stripping operation is a “red ink” process (dealing with quality defects and rejects), speed is of the essence for the electroplater. Strippers can be extremely difficult to breakdown -- one plater has described it as “attempting to turn chocolate cake back into chocolate bars and flour” -- and can be one of the more expensive wastes to dispose of. As a result, several creative management strategies have been pursued to take advantage of regulatory idiosyncrasies -- most notably the purposeful addition of precious metals such as gold into the stripping waste allowing it to be sent to, and accepted by. a metals reclaimer.

The wastewater treatment process for most electroplaters is the focus of the environmental management activity. Conventional “end of pipe” treatment systems may accept metal bearing wastewaters from several steps of the electroplating process and typically consists of three elements:

1) reduction and oxidation of special materials of concern (chromium and cyanide)
2) metals removal of combined metal bearing waste waters using hydroxide precipitation techniques
3) sludge dewatering to reduce volume of remaining wastes

Chromium reduction is achieved by reacting hexavalent chrome with a reducing agent to obtain trivalent chrome which can then be precipitated out in the treatment system. Inputs into this process are usually either a powder sodium bisulfite or sulfur dioxide gas. Although the sulfur dioxide gas is less expensive at high feed rates, the toxic nature of the gas presents a potential health hazard requiring additional capital expenditures to prevent gas losses.

Cyanide oxidation most commonly involves chlorination to breakdown the cyanide portion of the wastestream into carbon dioxide and nitrogen. Material inputs to this process include chlorine gas, liquid or solid hypoclorite compounds, sodium hydroxide, as well as sulfuric acid to facilitate the reaction. The hazardous nature of the input materials, as well as the potentially volatile chemical reactions associated with the operation, demands careful maintenance and control practices by the facility.

The precipitation of metals out of the wastestrearns is usually accomplished by adding alkaline materials (typically sodium hydroxide or lime) to create metal hydroxides. Additional chemicals are typically added to foster particle growth after which wastewater will pass through a clarifying system to remove the suspended metal bearing solids before being discharged. The resulting metalbearing sludge is F006 hazardous waste and regulated under RCRA. To reduce its volume, a facility may pass the sludge through a dewatering or dehydration system before manifesting and shipping.

The primary challenge in metals removal is that the pH necessary for optimum precipitation varies depending on the type of metal in the wastestream. For facilities sending several different metalbearing waste streams to the treatment system this can represent a significant problem. Attempts to compensate for “spikes” in certain metal levels of the effluent by adjusting the pH may trigger a new potential wastewater compliance problem involving a different metal.

Another complicating factor in wastewater treatment is the presence of the non-metal chemical agents from process solutions. Their presence may inhibit or slow the treatment reactions. For this reason, many facilities will input significantly more treatment chemicals than theoretically is required and, as a result, generate more sludge volume.

Technology profiles -- Not surprisingly, technology profiles in wastewater treatment are largely driven by the set of regulatory standards under which a facility must operate. “Conventional” wastewater treatment as described above was widely adopted in the late 70’s and early 80’s when categorical pretreatment standards for plating operations were first promulgated. Conventional treatment still may be sufficient to meet federal discharge standards. However, the subsequent promulgation of tighter federal effluent standards, more stringent local limits. and treatment challenges resulting from non-plating or electroless plating wastewaters may create a need for more sophisticated treatment technologies.

Thus, the “low-end” profile may be represented by the conventional treatment system described above. It would also feature mixed metal wastestreams ail going to the treatment system directly from the process. These combined wastestreams are likely to cause chronic compliance problems for reasons discussed earlier.

A standard technology profile may be represented by conventional treatment systems complemented by the use of recovery and concentration technologies for significant wastestreams. These technologies, described later in the report, also effectively serve as “pretreatment for the treatment system” by removing metals and other contaminants from the wastewater stream.

A best-m-practice profile of wastewater treatment might feature (at substantial cost) complete segregation of all metal beating wastestreams and extensive use of appropriate recovery and concentration technologies for each stream prior to discharge to the treatment system. Most importantly the best- in-practice profile also features an extensive maintenance, training, and troubleshooting program for the treatment system operation. The performance of the system -- and the status of facility compliance - is ultimately dependent on how the technology is operated.

2.2.3 Energy, Environment, and Manufacturing ("EEM") Technologies

Since the basic chemical principles of metal finishing do not change, the core processes of metal plating remain largely unchanged over the years. A process flow diagram of a 1940 operation would appear markedly similar to that of a 1994 facility. Technological advancements have largely centered on process chemistries and supplemental “output optimization” technologies to recover metals and treat wastewaters.

Most of the major in-process “EEM” gains are in process control and operating practices rather than through “hard” technology. Careful understanding and control of critical process parameters (temperature, flow rates, contaminant control, pH, density, etc.) and process modifications (extended drain times and parts orientation) are the key to source reduction of wastes in plating operations. The “technologies” associated with these activities ate quite simple and include valves, dram boards, spargers, flow restrictors, sensors, etc. Moreover, these are likely to have a more direct and positive impact on quality than recovery technologies and thus are more deserving of the “EEM” label.

The following section discusses four classes of EEM “technologies” - chemical recovery technologies, solution maintenance technologies, material and process substitutions, and general waste reduction practices. All of these have been extensively profiled in many pollution prevention guides, electroplating manuals and engineering handbooks. Although a brief description is included, the primary purpose of this section is to highlight the key environmental, economic, and manufacturing tradeoffs associated with their use.

2.2.3.1 Chemical Recovery Technologies

Recovery technologies are used to separate plating metals and chemicals from rinsewaters and concentrate them. Following is a list of typical recovery technologies found in plating and a brief description of their common application.

Direct dragout recovery is not a technology per se but a practice used to return and reuse diluted process solution. After the process tank, parts enter a "dead rinse" or "still rinse" to remove process chemistry which is then returned back to the process tank. This simple strategy. however. has three limiting characteristics. First, dragout recovery returns contaminants as well as process solution which can build up to problem levels. Second, it can also build up metal values themselves to inappropriate levels. Third, direct recovery also requires solution temperatures in excess of around 130 degrees Farenheit in order to create the necessary evaporation or "headroom" in the process tank allowing solution return.

- Atmospheric evaporation is an add-on technology to overcome the "headroom" issue and allow dragout recovery. As before, the dead rinse tank solution is returned to the process solution tank in order to recover chemicals. Now, however, the process solution is first pumped from the process tank into the evaporation unit where the heat present in process solution is used to "humidify" air blown through the evaporator. This concentrates the solution and makes it suitable for return to the process tank. thus returning concentrated solution back to the tank. Most atmospheric evaporators are used to recover nickel from the dragout of nickel plating baths and hexavalent chrome from chrome plating bath dragout. They are also used on copper cyanide, acid and alkaline zinc, and trivalent chrome baths. They are relatively simple technologies, low users of electrical energy, and perhaps the least expensive of the recovery technologies to purchase and operate. Atmospheric evaporation units typically range from $5,000 - $15,000 fully installed. Annual operating costs average about half the capital cost.

- Vacuum evaporation also concentrates solution through evaporation of water. However, unlike atmospheric evaporation, heat is added and the water is taken from the rinse tank rather than the solution bath. A vacuum is introduced to prevent thermal degradation of process chemistries. Vacuum systems are technically and economically feasible for a wider range of plating solutions compared to atmospheric systems. They offer the advantages of reduced air pollution problems and the ability to recover both temperature sensitive baths and solutions with volatile components. Capital costs (fully installed), however, can be ten times that of atmospheric systems with annual operating costs averaging around 25% of capital costs. Because of the high initial investment, the economic logic of purchasing such a system is largely dependent on the amount and type of chemicals available for recovery from the rinse streams.

- Reverse osmosis is a pressure driven membrane separation process and is a well established technology in the plating industry. Feed streams from rinse tanks are separated under pressure through microscopic pores of a membrane into a permeate stream (mostly water) and a concentrate (primarily process solution). It is applied to a wide range of processes including nickel, brass, chromium, copper, tin and zinc. Its advantages include the ability to process dilute solutions and produce purified water streams for reuse, and lower energy requirements than evaporation systems for processing an equivalent amount of wastewater. A major disadvantage involves the ability to maintain membrane performance and life. Capital costs depend on the size of the system but can average about $30,000. Annual operating costs are about l/3 of capital costs.

- Ion exchange is a technology that has alternative applications in metal finishing. Besides metal recovery, it is also used for producing deionized water for bath inputs and to remove trace pollutants following a conventional treatment process. Ion exchange removes both positively and negatively charged metal and chemical ions from solution by passing rinsewaters through resin beds. These resin beds or columns will remove contaminants until their exchange capacity is exhausted after which they are regenerated for reuse. Ion exchange has been used for a wide variety of metals recovery including nickel, chromium, zinc, and cadmium. One technology advantage is that, unlike most recovery technologies, ion exchange can work well with low concentration of recoverable materials. It also has relatively low energy requirements. Disadvantages include the fact that ion exchange is a complex process requiring careful operation and maintenance, and that regeneration activity washwaters add to the wastewater treatment load. Capital costs for ion exchange metal recovery vary widely depending on the size and engineering of the system and can range from $5,000 to $500,000. Primary annual operating costs include labor, regeneration chemistry, and resin replacement and may average 25% - 50% of capital costs.

- Electrodialysis is another membrane process to concentrate and recover dragged-out plating chemicals contained in rinsewaters. Rinsewater passes through permeable membrane stacks which remove both anions and cations resulting in concentrated solution and a purified water stream. Nickel plating is its most common application although it is also used in copper, cadmium and zinc systems as well. Electrodialysis can achieve higher concentrations than reverse osmosis or ion exchange and uses substantially less energy than vacuum evaporation. However, electrodialysis also recovers and concentrates contaminants and fails to recover other important bath contents like brighteners and additive agents. Capital costs can run from $10,000 - $50,000 installed with annual operating costs between 15% - 30% of investment.

- Electrowinning is one of the most widely used metal recovery technologies. An electrolytic cell composed of positive and negative electrodes is used with electrical current to remove metal ions. This simple technology is occasionally constructed in-house and is commonly used on cyanide-based metal solutions. Chromium is the only commonly plated metal that is not recoverable using electrowinning. It is typically used on high concentration baths such as &ad rinses immediately following the plating baths. Capital cost is a function of the design features which can be incorporated into the system and its capacity. Equipment price can range from $1,000 to $100,000. Operating costs are relatively low since the technology is not labor intensive or expensive to run.

Ideally, the above technologies are employed for in-process recycling to return materials back to the original process bath thus reducing waste and saving on input materials. However, several issues must be considered in evaluating the desirability of implementing any of these technologies from the standpoint of achieving the joint goals of improved environmental performance and productivity. These are highlighted below.

Production Issues:

- *Recovery and return techniques can result in potential quality problems. All* of the recovery technologies identified above create two common problems which limit their application and acceptance by platers. First impurities which are normally purged by drag out can accumulate and sometimes be **concentrated** through recovery technologies resulting in product quality problems. Second, baths using soluble anodes have a tendency to build up in concentration if drag-out is returned. This "bath growth" can cause other process imbalances, particularly with nickel.

- *Overcoming these quality concerns often requires additional capital investment in solution maintenance technologies.* To overcome these problems solution maintenance technologies (section 2.3.2.2) are often purchased to purify the recovered materials before reintroduction to process baths. This adds to the capital investment requirement and operating costs and may only be economically feasible with high value baths and high volume operations.

- *Full technology implementation still doesn't guarantee success. The* NCMS metal finishers survey noted that 30% - 40% of these recovery efforts have not been successful. Even with subsequent investments in regeneration technologies, their application is frequently plagued by technical, design, maintenance and quality problems. Combined with the general complexity of many of these systems, the utility and performance of these technologies in materials recovery can be overrated. As the NCMS survey noted, the environmental management benefits (regulatory compliance and reduced waste shipments) were identified as often as materials recovery as the original reason for purchasing this type of equipment.

- *Optimum performance of recovery systems is dependent on careful process control.* The best application and utilization of these technologies is often dependent on other EEM practices. Potential recovery and quality problems highlighted above can be minimized by a thorough maintenance of key process parameters and an understanding of contaminant issues back in the plating and rinsing steps.

Environmental Issues;

- *Optimal recovery performance may conflict with source reduction efforts.* The goal of source reduction is to have low drag out concentrations. However, many of these technologies, like reverse osmosis, perform best when drag out concentrations are high.

- *Recovery technologies result in their own wastes and residuals.* The recovery technologies themselves feature inputs and residuals of potential environmental concern such as spent filters, membranes, reject streams of concentrated wastes, cathodes, resins, etc.

- *Recovery technologies seldom completely solve wastewater issues.* As “pretreatment” to the treatment system, recovery technologies provide some of their greatest benefits and cost savings in helping the facility meet effluent guidelines and reduce sludge generation. However, 100% recovery efficiency is practically impossible to achieve. For most facilities, some metal bearing wastewaters still must be treated periodically.

Thus the technical feasibility, the full environmental impact, and the production and quality implications should be carefully assessed before investment in any recovery system. In general, the best candidate streams for recovery technologies are those featuring careful process control practices throughout the plating process, high replacement chemical costs, and rinse streams which result in high treatment and sludge disposal costs.

2.2.3.2 Solution Maintenance Technologies

Bath contamination has several negative environmental effects. In addition to increasing the frequency of bath dumps, commonly applied corrective measures (such as increasing concentration of plating chemicals to maintain efficiency) will exacerbate drag-out problems and increase electrical consumption. Solution maintenance technologies are used to preserve or restore the operating integrity of process baths and extend their useful lives. They are also used to improve operating efficiencies and effectiveness of solutions with subsequent benefits on production rates and product quality. Many corrective technologies are quite simple and found in most operations. Yet even these common approaches have EEM options which can be pursued:

- Filtration and Carbon Treatment - Filtration removes suspended solids from plating solutions and carbon treatment removes organic contaminants. Both are very common and widely used in all types of plating operations. The EEM considerations for both these techniques is based on how they are used. There is significant latitude in both these systems to improve regeneration efforts by 1) targeting filtration and treatment efforts to specific contaminants and 2) using the systems more efficiently by better understanding the specific cause and effect relationships between contaminant growth and regeneration needs. Employing both these strategies allows regeneration efforts to take place only when they are really needed.

- Electrolysis, or dummy plating, removes unwanted metallic ions from process solution and leaves the desired metallic ions for reintroduction to the process bath. Dummying is commonly used to remove copper, zinc, iron, and lead. Historically, dummying has been a very wasteful process because in plating out the low density metals of concern, the design of the system would also plate out significant amounts of the higher density metals which should be left in solution. The EEM alternative is to reengineer the dummying bath for low density plating only.

More sophisticated regenerative technologies are available for both cleaning and process baths. Two of the most promising follow:

- Microfiltration is a technique that is applied to regenerate aqueous and semi-aqueous degreasing and cleaning baths. Although cleaning baths have often been considered expendable, the make-up of solvent free cleaning baths has changed the economics making a stable cleaning system more attractive. Microfiltration employs a ceramic or polymer membrane technology to remove soils and oils and return the cleaning solution to the bath. It is not applicable to all degreasing and cleaning applications, but the savings in replacement of spent cleaner bath, labor, and neutralization chemicals may make an investment in this system worthwhile. Typical upfront capital costs for microfiltration in cleaning bath regeneration can range from $15,000 - $30,000 although an installed system can be considerably more.

- Ion exchange can also be used to purify process baths as well as rinse waters. It is an especially common application for hard chrome recovery. Advances in resin systems increase the potential applications of this technology in solution maintenance. Other attractive characteristics of this technology include long equipment life and low down time. As with recovery applications, ion exchange can generate residuals of acid wastes which may be of concern to the facility. Capital costs for ion exchange systems will depend on the size of system (some can be as low as $5,000) but an average range of capital costs might be estimated as $20,000 - $60,000.

2.2.3.3 Material and Process Substitutions

Of the four EEM classes, material and process substitutions are the most fraught with implementation barriers. In many cases the status quo is nearly codified either informally through customer acceptance and existing investments in recovery and concentration technologies, or formally through customer specifications which require specific processes. The status quo is best overcome when regulatory drivers are pointing toward a complete “sunsetting” of materials of concern. This section examines substitutions for three high profile materials of concern commonly found in plating operations and which are targets for reduction and/or elimination -- cyanide, cadmium, and chromium. A final technology set which will be discussed involves dry processes or vapor phase methods in which metal plating is accomplished without solution and, therefore, without process wastewaters.

2.2.3.3.1 Cyanide Replacement

Cyanide has been a key constituent of plating baths for many years. It is used to plate such metals as zinc, copper, brass, precious metals, and cadmium. These baths have been popular both for their performance and their ease of control. Some cyanide-based plating processes provide the extra benefit of reducing the need for pre-part cleaning to a minimum. However, health and safety concerns, use reduction laws, air releases and other compliance problems, and treatment and disposal costs are all driving platers to seek alternatives. Moreover, the cyanide treatment and destruction process in the wastewater treatment system typically requires significant amounts of potentially problematic materials like chlorine, as well as significant energy inputs, adding to the negative environmental profile of cyanide plating.

The availability and performance of cyanide substitution technologies varies with the type of plating. In the NCMS metal finishing study, over a quarter of the respondents indicated a technology transfer insufficiency with respect to non-cyanide finishing. On the more successful end of the substitution spectrum is the use of zinc chloride and zinc alkaline plating as substitutes for zinc cyanide. As NCMS reports, two characteristics make this a particularly favorable "EEM" alternative. First, it is very implementation-friendly -- only two percent of their survey respondents were unsuccessful in their substitution efforts. Second, many of the platers also reported production benefits such as higher quality and brighter plating as a result of the switch. These alternatives, however, do not work well in applications in which corrosion protection is critical. Thus alkaline zinc and zinc chloride plating technologies are often limited as alternatives for cosmetic finishing applications.

Zinc chloride (acid) baths, one of the industry's fastest growing baths, have several intrinsic EEM advantages over zinc cyanide baths

- waste disposal costs reduced with elimination of cyanide oxidation
- higher operating efficiencies (95% - 98%)
- superb brightness and appearance
- substantial energy savings through improved bath conductivity
- ability to plate more metals (cast iron, malleable iron)
- less hydrogen embrittlement

The primary disadvantages stem from the corrosive nature of the solution. As a result, plating equipment must be coated with resistant materials and the process may not be suitable for parts with complex geometries and recesses where plating solution may be trapped.

Zinc alkaline systems are inexpensive to prepare and maintain and also result in bright deposits. However, a critical EEM consideration is that they also have very tight operating windows which, if violated, results in dramatic losses in efficiency and appearance. Because of the closer analytical control needed, these systems are found most frequently in captive operations rather than job shops.

Technologies to replace other cyanide plating systems such as copper, brass, gold and silver exist but generally have not demonstrated the success rates that zinc cyanide replacements have. These substitute processes must be tested and evaluated on a case-by-case basis since a wide variety of technical, production, and quality challenges are typically associated with their use.

2.2.3.3.2 Cadmium Replacement

Cadmium is a silver-white metal often used for corrosion protection of parts consisting of dissimilar metals and for pieces exposed to harsh environments. Other useful engineering properties like high ductility, natural lubricity and electrical conductivity, have made cadmium plating a popular finish for steel and cast iron pieces -- especially for moving parts and threaded assemblies. Cadmium, however, is an acute toxin and the ingestion of dissolved cadmium or the inhalation of cadmium dust or fumes are a significant human health and safety concern. Moreover, most cadmium plating uses cyanide bath processes creating an especially challenging plating system from an environmental standpoint. Manufacturers such as the auto industry have initiated programs to eliminate cadmium plating. Such supply chain initiatives along with increasing regulatory pressures make cadmium plating a primary target for alternative technologies.

As with many noncyanide systems, non-cadmium alternatives have had a mixed record of success. The most common alternative processes include zinc based alloys (cobalt zinc, nickel zinc, and zinc iron) and tin or tin alloys. The implementation challenges have proven once again to be a mix of context-specific factors such as the the loss of one or more finish properties, higher costs, customer acceptance, and finish quality. In general, zinc-based replacement technologies will most likely work best in industrial environments and in circumstances where buildup of corrosion products over time is not a critical finish concern, since cadmium forms a smaller amount of corrosion products than zinc.

2.2.3.3.3 Hexavalent Chromium Replacement

Chromium deposition on metal can be broken into two major categories: decorative chromium plating and hard chromium plating. These two types of plating are differentiated from each other primarily by the thickness of the deposition. Decorative chromium coatings are very thin. Hard chromium coatings, used to create parts which are highly resistant to wear and corrosion, can be 500 or more times thicker. The primary environmental issue of concern for both types of chrome plating is the use of hexavalent chrome based processes which are highly toxic, entail air releases, and feature significant costs for treatment and disposal. Hexavalent chrome solutions have proven to be very amenable to both "recover and return" source reduction techniques and the development of high efficiency, low concentration solutions. However, the epidemiology of the health effects from exposure and the regulations being written in reaction to this data, are driving alternative technologies. Even if control devices can be developed to satisfy lower emission standards, worker exposure to air emissions at the line level will keep the pressure on to eliminate hexavalent chrome plating.

The technology substitution of greatest interest and adoption is trivalent chrome based processes. Trivalent chromium processes have several attractive EEM features. First trivalent form of chrome poses a significantly lower health risk than chrome in its hexavalent state. Water and waste treatment costs are reduced since many experts believe trivalent chrome creates less sludge, and the reduction step needed to pretreat hexavalent chrome prior to precipitation can be eliminated. On the production side, since trivalent processes are much more dilute than hexavalent processes, parts are easier to rinse and the corresponding chemistry losses to the rinsing system are greatly reduced. Trivalent chrome also uses the same equipment as hexavalent baths making it a "drop-m" replacement. NCMS reports that substituting trivalent for hexavalent processes has met with good success among electroplaters.

However, as with other plating technology substitutions, several production factors exist limiting the application of this technology. Two of special note are color and thickness. Trivalent processes have a deeper, slightly darker color than hexavalent chrome raising potential objections in decorative chrome applications. A more serious barrier lies in hard chrome applications (a large market) in which a thicker coating is needed to serve the wear and corrosion resistant functions. Generally, the relatively thin coatings achievable with trivalent processes are not sufficient for the demanding functions for which hard chrome finishes are employed.

One other issue on the environmental performance of trivalent substitution is worth noting. Conventional wisdom holds that a certain amount of "natural flux" exists between chrome in its trivalent and hexavalent states, and that acidic conditions facilitates trivalent reoxidation into hexavalent chrome. This has led some experts to suspect that any trivalent chrome remaining in wastewaters or in landfill sludges subjected to acidic conditions may create problems.

2.2.3.3.4 Vapor Phase Deposition Technologies

The previous set of "EEM" technologies in metal plating centers around alternative process chemistries. Several technologies exist for metal plating without electrolytic solutions or plating baths. Instead, these technologies involve the passage of a metal coating material from a solid phase into a vapor transport phase and then back into the solid phase on the substrate surface. The technologies differ from each other primarily in the mechanism by which the metal coating is passed into the vapor phase. The mechanism determines the range of metal coatings which can be applied and their deposition rates. Since these technologies (as a group) can be used for nearly any metal coating material, and because they do not utilize bath solutions or feature wastewater streams, they are becoming increasingly important in a number of industrial applications.

Vacuum metallizing includes such technologies as vacuum evaporation and sputtering. Vacuum evaporation uses a vacuum chamber in which the parts to be plated are mounted. The pressure in the chamber is reduced, and the metal to be plated is heated beyond its boiling point. The metal travels in vapor form and coats the substrate--the first substance it comes in contact with. Vacuum evaporation is typically used only for aluminum substrates and thin film coatings.

Sputtering uses a gas plasma discharge in a vacuum chamber to bombard a coating material cathode with positively charged gas ions. The impact knocks coating atoms off the cathode which travel through the vacuum and deposit on the anode substrate. Since the coating is passed into vapor phase by a mechanical rather than a chemical or thermal process, virtually any metal is a candidate coating for sputtering. Electronics applications, decorative coatings and protective coatings applied to high speed cutting tools are common uses of this technology.

In chemical vapor deposition (or gas plating) a preheated part receives vaporized compounds containing metallic salts. The heated part facilitates a chemical reaction which decomposes the reactant gasses leaving the desired coating material as a reaction product on the metal substrate. Commonly used in the electronic industry, chemical vapor deposition applications are very effective for metals like chromium, nickel, and compounds such as metal carbides, silicides, and oxides.

in plasma spraying. the coating material is in powder form and heated to near or above its melting point and sprayed onto the substrate. Almost any material that can be melted without decomposition can be used to form the coating. This includes a wide range of metals and metal alloys.

The primary environmental benefit from these vapor-phase systems is the elimination of metalbearing water wastestreams (although wastewater is produced in these operations as a result of area and equipment clean-up). As to be expected, eliminating water wastes are not without environmental trade-offs. Energy use is a primary consideration; for example many reactant products in chemical vapor deposition require temperatures above 800 degrees centigrade. Moreover, the reactants used in the system often have corrosive or toxic properties. Environmental hazards associated with plasma spray operations are similar to those encountered in welding. All spray processes produce process fumes and overspray which is typically collected with filtered exhaust hoods. However the ability to control these risks and the elimination of water media issues makes these systems generally recognized as environmentally preferable.

From a production standpoint, high capital cost, lower throughput rates, and greater energy intensity have put vapor-phase methods at a disadvantage when compared to traditional aqueous processes. However technology advancements are likely to increase the number of applications in which vapor deposition becomes an environmentally and competitively preferable technology.

2.2.3.4 Operating Practices and Process Modification

General waste reduction techniques and practices in plating are still the most effective and cost-efficient “EEM” strategies available. The best and most successful way to achieve simultaneous environmental and quality gains in operations is to begin with a thorough understanding and control of process parameters and contaminants. Not only will this reduce waste at the source, but it will also improve the efficiency and effectiveness of recovery and regeneration technologies as well as positively influence the performance of wastewater treatment systems.

The list of pollution prevention and waste minimization strategies in plating has been well documented in any number of checklists, reports, and planning manuals. These strategies center around three themes -- preventive bath maintenance, drag out reduction, and rinsing/water use. Specific EEM considerations will be highlighted for each of these areas:

- Bath maintenance -- Preventive strategies to maintain bath life abound but the primary question of "why" and "when" a bath becomes unusable remains a mystery in many plating operations. The two key factors which contribute to this situation are the proprietary nature of process chemistries and the lack of research on sources and effects of contaminants. Full EEM bath maintenance would include a precise knowledge of the sources and chemical conditions and circumstances leading to bath deterioration. Once these parameters are identified, platers would be able to improve process control and better tailor the use of recovery and regeneration technologies.

The following table rates the general potential for source reduction through process optimization for several common plating processes:

Nickel	High
Noncyanide zinc	Low
Copper cyanide	Medium
Electroless Nickel	High
Hexavalent chrome	High
Tin acid	Low
Cleaning baths	High

- Drag-out reduction -- A concern found in many plating shops is the apparent conflict between cycle time improvement and operating practice changes required to minimize dragout. Process and operating modifications, like extended drain times, may conflict with throughput objectives. Often missing from this analysis, however, are the full cost considerations of losing process solution and the domino affect which may be felt all the way to the treatment system. Such an analysis may point out that the benefits gained in cycle time reduction are lost due to the costs of wasteful manufacturing practices

A second potential conflict between pollution prevention and manufacturing performance through drag-out reduction is the potential contamination effects of the plating bath and their effect on product quality. Many platers use drag-out as a de facto means of purging impurities from process baths. The importance of process understanding and control is again evident. A rule of thumb may be that aggressive efforts to reduce drag out is a good thing if there is an understanding of contaminant sources and subsequent effect of contaminants on baths. Lessons might be learned from many precious metal platers who, because of the high value of process baths, have accomplished zero dragout with total contaminant control preserving bath life indefinitely. Unlike precious metals, the economics of traditional metal plating operations (like copper, zinc, and nickel) has not driven research on sources and effects of contaminants. A proper consideration of contaminants and sources is a necessary first step toward minimizing quality risks of drag-out reduction while advancing the adoption of EEM operating practices.

- Rinsing and "Zero-Discharge" -- Much attention has been given to the concept of "closed loop" or zero discharge plating systems. While the concept of water use reduction is a very valid objective, the advancement of closed loop plating as an EEM goal must be qualified. Cross-media transfers will necessarily occur as non-water waste stream volumes increase to preserve the water looping effect. Residuals are inevitable in plating, and if they are not found in rinsewaters, they will occur in bath dumps or in the residuals of various recovery and regeneration technologies. Water recovered and reused from the treatment system will need to be passed through reverse osmosis, sand filters or carbon treatment before it can be used again in process resulting in other residuals. Pursuit of zero-discharge plating should be based on a determination that the regulatory and cost benefits of near zero water discharge and water use reduction outweigh increased costs in hazardous waste disposal and shipping of spent process solutions.

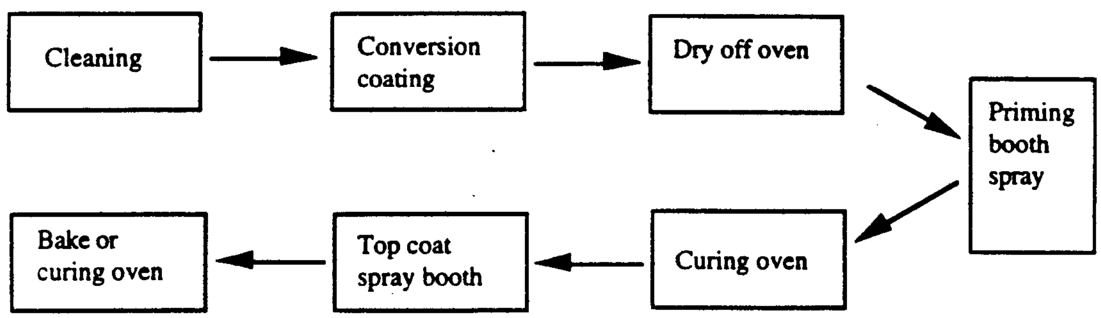
2.3 Organic Coating

Organic finishing processes provide both decorative and performance functions to metal substrates and are found in a wide variety of industries. The painting line itself can be one of the most significant sources of environmental releases for a manufacturing facility.

2.3.1 Overview of Organic Coating Process

Figure 2D provides a simplified overview of a painting line. In general, parts go thorough three stages of processing

FIGURE 2D: Process Flow Diagram for Painting Operation



1) Surface preparation - Before a coating can be applied to a part, the substrate surface must be prepared. In many cases a solvent or aqueous based cleaning system will satisfactorily remove oils and greases. In other circumstances an additional chemical treatment (conversion coating) is required to promote additional adhesion to the metal substrate, prevent flash rusting of the unpainted surface, and prevent rust creepage under the film. Application of these conversion coatings are "processes within a process" in that they are typically made up of multiple stages and rinse steps.

2) Coating application - Paint application can actually require **a** series of application steps to provide the metal substrate its final finish characteristics. A primer may first be deposited to promote adhesion and contribute to film thickness. An intermediate coat may then be added to provide a "tie" (or compatibility) between the primer and the final coat. This is followed by one or more applications of **a** final top coat which can have a variety of performance and chemical properties.

The actual application process is defined by four technologies:

1) the coating (liquid or powder, solvent or water borne, single or multiple component, air dry or baked, etc.)
2) the application system (spray, dip. roll, curtain, fluidized bed, etc.; electrostatic or non-electrostatic)
3) the application area (often a spray booth)
4) the curing oven.

Liquid coating application - The coating itself is first prepared for application. Two-component liquid coatings are created as a result of the chemical reactions of two substances when mixed together. Single component liquid coatings do not require special mixing, however viscosity adjustments may be necessary to apply the paint.

The coating is then fed to the applications system. Spray application actually entails a wide variety of technologies each with unique performance qualities and characteristics. Spray systems include a wide variety of application guns as well as rotary systems using centrifugal and electrical forces to "throw" the paint onto the part. Parts may be either painted singly, racked together and "batch" coated, or moved continuously on a conveyor system. Non-spray processes include roll coating in which the part itself passes through a roller; dip coating in which the part is immersed in the coating; and curtain coating in which material is pumped from a reservoir and flows onto the part as it passes through a coating "curtain."

A number of technique and technology choices exist for all these application methods to improve the productivity and environmental performance of the painting system. Chief among these adaptations is the use of electrical forces to provide a charge to the paint particles and improve the transfer efficiency of the paint onto the part. Electrical forces are used both in spray applications through electrostatic guns and in dipping methods such as electrocoating.

Spray applications are conducted in a spray booth which serves both environmental protection and OSHA functions. Spray booths serve as an abatement device for paint particulates. Dry filter booths employ some type of filter media or baffle to collect wet over-spray for disposal or reuse. Key performance characteristics of dry filter booths are the efficiency for removing particulates, low resistance to air flow and the holding capacity. Water wash booths takes paint particulates out of the air and transfers them to water media Typically used in higher volume painting operations, deflocculants are then added to the water to sink, disperse, or float the paint overspray which is then turned into a sludge for disposal. A critical consideration for spray booth design is the direction of the air flow. It will significantly effect the quality of the paint job and the performance of the particulate control system. A make-up air system may be required to replace the solvent-laden air flow leaving the paint booth. A well-designed spray booth also protects the paint operator from inhaling toxic chemicals and particulates and reduces the likelihood of fires.

Following paint application, the painted part must be cured. Curing times and technologies will depend on the coating technology. Some parts may be allowed to air dry although some form of high temperature oven is frequently used to speed the evaporation of solvents and accelerate curing. Some liquid coatings will only cure if baked.

Powder coating application - Powder coating is a dry coating process in which electrostatically charged particles of pigmented resin are sprayed onto a metal part. The piece is then placed in a curing oven where the powder melts to form a uniform finish. The use of solid resin systems to coat metal parts has been around for decades although the growth of powder coating can be attributed to a variety of technical advances in delivery systems and coating technologies.

After pretreatment, the part enters the powder spray booth. The powder is supplied to the spray gun through a delivery system comprised of a storage container and a pumping device. An electrostatic gun provides a charge to the powder and directs and controls the flow, pattern , shape, and density of the spray which is deposited evenly on the grounded workpiece. Airflows in the workbooth channel overspray into a powder recovery system where a high percentage of the resins are recycled back to the process. Three types of ovens are commonly used to cure parts. Convection ovens use gas or electricity to heat air which is circulated around the parts. Infrared ovens use gas or electricity to emit radiation in the IR band which is absorbed by the powder and the substrate underneath it but not necessarily the entire part. Combination ovens use IR to melt the powder quickly followed by a convection zone to permit faster heat transfer and provide a shorter cure time.

3) Ancillary Processes. Two support processes -- stripping and cleaning operations -- are critical contributors to the environmental profile of the facility. Stripping operations may be in place to reprocess out of specification parts or occasionally used as a first step in surface preparation to remove old coatings. In addition to chemical-based stripping operations which use solvents, blasting systems employ a wide variety of manufactured and naturally occurring abrasives such as glass beads, walnut shells, steel shot, and silica to remove the old coatings. Blasting operations will be done after the cleaning and degreasing stage to ensure that abrasives do not become contaminated with oils and greases.

Equipment cleaning and maintenance can be a significant source of environmental impact for a painting facility. Spray booths, lines, guns, racking equipment - anything that comes in contact with the coating will need to be cleaned to maintain performance and allow changeover to different colors.

The productivity and output of the painting line is influenced by several technology and operation factors. Overall throughput time can be broken into the following components:

- Drying time to oat -- the time required after surface preparation before a coating can be
- Drying time to handle -- the time required before parts can be removed from the racks or conveyor without marring the finish
- Time to recoat - the amount of time that must elapse before the next wet coat of paint can be applied. For some coating technologies there is a critical recoating time - a window of time before which or after recoating must be done. Recoating during the critical window will "lift" the coating
- Time to full hardness -- the time required for the coating to achieve its maximum hardness and be packaged or shipped.
- Turnover time - the time required to clean paint lines and systems in order to coat a new production run

A facility will seek to employ strategies and technologies to minimize these times and improve manufacturing throughput while achieving product specifications and maintaining product quality. Primary factors affecting this capability include:

- coating composition
- coating viscosity
- application technology and process design (both equipment and the way parts are processed
- curing system
- operator practices

Each of these production factors also have implications for facility environmental performance. In many circumstances both goals can be met concurrently; in others, trade-offs may exist. As with other manufacturing operations, the challenge for a coating facility is to identify environmentally preferable alternative coating strategies without sacrificing product performance or negatively impacting throughput.

2.3.2 Analysis of Technology. Chemical and Waste Issues in Process Operations

Exhibit 2E provides an overview of the the types and sources of pollution and waste in a painting facility. Unlike metal finishing operations in which water wastestream concerns drive technology adoption and change, air regulations are the primary motivating force in coating operations for alternative technology investigation although water and solid waste issues are prevalent here as well.

2.3.2.1 Cleaning and degreasing is an essential surface preparation step for coating operations. Both solvent and aqueous based systems are employed as cleaning steps and their waste and material input discussions are similar to those of electroplating and are reviewed in Section 2.3.

FIGURE 2E: Pollution and Waste in a Painting Facility

	AIR	WATER	WASTE
Surface preparation *cleaning *conversion *stripping	• Solvent emissions • Oven emissions	• Contaminated wastewater (oils, greases, soils, and chemicals) • Spent process solution with acids, cleaners, and metals •Rinsewater	•Spent/contaminated abrasives • Stripped paint and solvent • Spent filters • Contaminated solven • Rags and wipes
Application and curing	• Solvent evaporation • Bake oven emissions	• Wastewater from spray booths	• Overspray • Waste paint sludge and empty containers • Spray booth filters
Process Support -cleaning •maintenance •inv. control	• Solvent emissions	• Contaminated wastewater	• Rags and wipes • Paint sludges • Contaminated solvents • Paints with expired pot lives

2.3.2.2 Conversion Coating - After cleaning a conversion coating is often applied to the substrate. Conversion coatings are chemical treatments which react with metal surface to promote paint adhesion and improve corrosion resistance. An overview of conversion processes and their waste issues is provided in Section 2.4

2.3.3.3 Paint Application - Primary inputs for liquid paint application consist of the coating itself, possibly some reducing agents or solvent to prepare the coating, and energy for the application equipment. Primary process outputs are:

- volatile organic compound (VOC) and hazardous air pollutant (HAP) releases
- paint waste
- wastewaters from water wash booths
- filters from dry spray booths
- cleaning solvent and rags

The primary environmental issues of concern in coating technologies are the VOCs and HAPS from solvents contained in the coating. Many of the solvents used in paints are listed as VOCs because of their photochemical reactivity and contribution to low level ozone or smog. VOC standards for paint and coatings are stated in different ways and include

- pounds of VOC emitted per gallon of coating
- pounds of VOC emitted per gallon of solids as applied
- pounds per VOC emitted per square feet of surface coverage

It is assumed that all VOCs contained in the coating evaporate at some time. The EPA does not allow for the possibility of entrapped VOC in the coating film. Regulations also requires that water and designated exempt solvents (non-photochemically reactive) volumes be subtracted before computing VOC content. VOCs releases have been a driving force for change in painting operations.

In addition to solvents, paints also typically include additives to enhance application properties (like drying, flowing, and wetting) as well as binders and resins (which are high viscosity liquids or solid polymers) that determine the properties of the paint. Fifty-one chemicals found in paint formulations as binders, resins, and additives are classified and regulated as HAPS.

The final paint component - the pigment - also may entail environmental issues of concern since heavy metals are often a constituent of the pigment itself.

Paint waste is a RCRA hazardous waste and stems from:

- overspray from painting application
- empty pots and containers
- paints with expired shelf or "pot" lives
- cleaning activities from line changeovers.

The concept of transfer efficiency is critical in discussing paint waste minimization and in improving productivity of the painting line. Transfer efficiency is a measure of the efficiency of the coating application and can be calculated as the mass of solid coating &posited divided by the mass of solid coating used. For non-spray applications like dipping, flow coating, or roll coating, transfer efficiencies are typically weIl above 90%. For spray systems, transfer efficiencies are typically lower and will vary depending upon a wide range of production factors including the type of spray equipment, geometry and size of part. operator practice, racking design/arrangement on conveyor, volume of solids in coating, and air and fluid pressure. Poor process and operating control combined with difficult to paint parts can reduce transfer efficiencies to 5% or less causing substantial amounts of paint waste.

The over-spray in painting operations must be collected in the spray area to prevent release of paint particulate air emissions. Use of waterwash booths will result in a paint sludge while dry filter booths will result in paint waste in filter media. The actual volume of paint particulate emissions are a function of the transfer efficiency, the filter efficiency, the air velocity in the booth and the weight solids of the coating. Spray booths control only particulate emissions -- they are not considered control sources for VOCs or HAPS.

Production changes require flushing of paint lines and cleaning of paint equipment. Spent solvent and cleaning rags are another application process output.

Inputs into the powder coating application are simply the solid resin powders and high voltage power supply. An increasing number of resin systems are available. Thermoplastic powders --

the family of resins which are the most common substitutes for liquid paints -- chemically cross-link with themselves or other reactive components to form a final coating much different from the original resin. Epoxies, polyesters, acrylics. and numerous hybrids are commercially available.

Although toxic and hazardous materials are found in powders, their dangers are reduced when bound in resin. OSHA regulations set nuisance dust standards at 10 mg/m3 which powder coating facilities must meet. The other primary safety concerns are fire and explosion control. Any finely divided organic material can form an explosive mixture when dispersed in air. Design of spray booths need to ensure the concentration of powder dust is well below,lower explosive limits.

Technology Profiles -- As with other types of metal finishing operations, the diverse and specific metal finishing needs will largely determine the type of technologies which are appropriate for a facility to implement. Again, the following profiles should only be considered very general rules of thumb since a number of production, quality, and performance considerations will dictate the types of coating systems which can be used

- A low end technology profile would feature the use of conventional air atomizing guns providing the lowest estimated transfer efficiency rates (25% or less). A number of operating practices lead to excessive paint waste including excessive atomizing pressure causing particles to "bounce back" off the workpiece, poor gun triggering. and poor parts racking. Traditional solvent-borne coatings are used and ambient temperatures are permitted to vary thus changing the viscosity of the paint and perhaps requiring additional solvent as a corrective measure. Inexpensive ($1). low capacity (2 lbs), non-reusable filters are used in the spray booths.

- A standard technology profile might feature a movement away from conventional air guns and a use of alternative coating technologies. Spray systems would include: high volume, low pressure (HVLP) guns; air assisted airless and airless guns; and electrostatic guns. All of these systems have higher average transfer efficiency rates than can be achieved with conventional air atomizing guns. Low VOC coatings, water borne coatings, and high solids coatings are substituted for traditional solvent-borne paints. Spray booths feature high capacity, high efficiency filters and/or reusable filter media to reduce hazardous waste generation. Recycling and recovery systems for solvents and paint booth water may be installed. Attention is paid to good operating practices and procedures to improve transfer efficiency and minimize waste.

- A high technology profile might feature the substitution of thermoset powder coatings or ultra low VOC coatings (electrocoatings, ultraviolet curable coatings, polyurea coatings-- see section 2.) for traditional liquid coatings. Electrostatic equipment and robotics are extensively used to improve efficiency and control of paint application.

2.3.3 Energy, Environment, and Manufacturing ("EEM") Technologies

Unlike plating operations where the relationships between improved production and environmental performance can be complex and may often conflict, the relationship in painting operations is much more straightforward. The primary concern is wasted raw material, and efforts to reduce the amount of paint waste will result in simultaneous cost savings and environmental benefits. A wide variety of alternative technologies exist for painting and coating operations, although the feasibility and appropriateness of implementing these technologies are highly qualified by a number of environmental, production, economic, and performance factors. In addition, as in other types of metal finishing, many of the most implementable "EEM" gains are based in process control and improved operating practices rather than through "hard" technology.

The following section discusses three classes of EEM "technologies" -- coatings, application systems, and general waste reduction practices. A brief description is included, and the key environmental, economic, and manufacturing considerations associated with their use are highlighted.

2.3.3.1 Coating Systems

VOC and hazardous air pollutant regulations have driven the development of several alternatives to conventional solventbome paints. In considering coating substitution, three basic questions must be asked of any type of switch:

- Will the coating meet current VOC and HAP regulations?
- Would the use of coating trigger BACT or MACT?
- Does the coating satisfy the physical, chemical, production, and appearance requirements?

In addition to these "essentials," each type of alternative coating technology has its own specific implementation considerations. These alternatives and their considerations are highlighted below.

High solids -- A transition to high solids coatings from conventional coatings is often a first level EEM strategy for air emissions reductions. Unlike conventional coatings which typically may be only 30% solids, high solids feature substantially reduced solvent content with solids percentages of up to 80% of the coating composition. New technology developments and delivery systems have overcome many of the performance and application problems which initially plagued high solids implementation. Key questions to be asked in evaluating high solids coatings are:

- Can existing spray equipment properly atomize the paint? Will paint heaters be required, to provide proper viscosity?
- How will potentially longer drying times affect production schedules?
- Does an oven need to be installed?
- Will the coating require more diligent surface preparation?
- What film thickness differentials can be expected and will color and gloss patches result?
- Will changes need to be made to spray booth design/air flow, etc.?

Waterborne -- As the name implies, waterborne coatings use water instead of organic solvents for the solvent component of the coating, although most waterborne coatings will still have VOCs or HAPs as a reduced proportion of their composition. As with high solids paints, ongoing technology developments of waterborne coatings have extended their applications into a number of high performance areas including industrial maintenance, long a bastion of traditional solvent borne applications. Most any type of application technique can be used on water-borne coatings. The primary cost savings stem from reduced clean-up expense and reduced insurance premiums. The primary disadvantages often include a slower dry time and more potential for film defects without careful pretreatment operations. In the past, waterbor nes received the reputation of being inferior to solvent borne coatings for several performance characteristics. Although these technological advancements seemingly have yet to completely overcome this perceptual hurdle, they are likely to make waterbornes the compliant coating and EEM choice with the broadest potential for application. Key questions to be asked in evaluating waterborne applicability are:

- Is the current surface preparation adequate?
- Do drying time differences require installation of an oven?
- Can the same coating application equipment be used?
- What modifIcations will need to be made to electrostatic systems to accommodate a waterborne coating?
- Will it be compatible with existing water wash spray booths? Will it cause foaming?
- What learning curves exist for the operator to apply the coating successfully?

Powder Coating - Compared to liquid coating systems, powder coatings provide significantly better environmental performance. No solvents are used in the mixing, application, or cleaning of powder systems, and the resins themselves average around 1% volume VOC content. Paint waste is minimized through the electrostatic delivery, and the recycling capabilities of most powder systems provide material application efficiency rates of over 90%. Most powders are classified as non-hazardous so any resulting overspray or clean-up residues can be treated as a non water-soluble solid waste. Energy requirements may be lower for two primary reasons. First, VOC-free powder booth exhaust air can be recirculated to the plant eliminating the cost of heating or cooling make-up air. Second, ovens that cure solvent coatings must heat and exhaust large amounts of air to ensure solvent fumes do not reach dangerous limits. Required exhaust flow for powder is substantially lower.

As can be expected, despite the clear superiority of powder coating from an environmental standpoint, a number of production issues must be carefully considered and may limit its application. Key questions to be considered are:

- Is current surface preparation of substrate adequate for powder coating?
- What new equipment will be required by way of booths, guns and electronic controls?
- Will a new oven be needed?
- Will powder coating provide a finish that will satisfy customer expectations?
- How will reject parts be dealt with?
- Does the geometry and configuration of the parts lend themselves to powder application?
- Are length of production runs compatible with powder application?

Ultra low/ no VOC coatings -- These coatings have been developed for a number of specialty applications. Autophoretic coatings are dip-based coating for steel substrates and typically used as an intermediate coat. They are especially suitable for large volume coating operations with limited workpiece configurations such as automotive parts and structural components for appliances and furniture. Electrocoatings (which operate like electroplating baths) feature low VOCs, comparatively low hazardous waste, and low water pollution when properly operated, and are used for coating steel and aluminum substrates. They are also intended for high volume, captive operations. Polyurea coatings are 100% solids, impervious to water, applied to any substrate, and can be formulated for several performance characteristics. These alternatives hold promise for specific applications although capital, space, process control, and other cost considerations may limit broad acceptance and implementation.

2.3.3.2 Application Equipment

To improve transfer efficiency and reduce paint waste,. many facilities may switch to alternative application technologies. Alternatives to conventional spray systems (EPA transfer efficiency estimate: 25%) abound and each have their own unique performance and production considerations which need to be evaluated. Non-spray systems such as dip coating, roll coating, or curtain coating have significantly higher transfer efficiencies, although their ability to be used on traditionally sprayed parts is limited. The following set of available EEM technologies centers on alternative types of spray systems. Although transfer efficiencies estimates have been generated by the EPA and other organizations, they have very little meaning or benchmarking value since operator practice, maintenance, and other site specific production factors listed earlier will be the key determinants of the actual efficiency of a specific painting line. Nevertheless, these numbers are provided as a means of reference.

- High volume, low pressure (HVLP) gun uses an internal turbine to generate a high volume of low pressure air to carry the coating. Bounceback and overspray is reduced since the coating is atomized into particles at lower air pressure and propelled at low velocity. The heated air used in these systems has a secondary environmental benefit in that coating viscosity is decreased without the use of solvents. HVLP guns may be the most flexible of the conventional spray alternatives since they can be used for quality or functional finishes, can coat intricate parts as well as those with simple geometries and can be used with higher solids and waterborne coatings. The primary disadvantages are the relative newness of the technology and the operator training requirements. No EPA transfer efficiency estimate exists although ranges of 50 - 90% have been reported.

- Airless guns atomize paint through application of extremely high hydraulic pressures. By passing the coating under high fluid pressures (500 -4000 psi) through a very small gun orifice. the paint is atomized and carried to the workpiece with minimal overspray fog. Airless guns are especially good alternatives for high viscosity coatings and for painting large uncomplicated surfaces. The resulting paint particle sizes are typically too large for high quality finishes and the minimum operator control makes it impractical for intricate finishing. High pressure coatings in airless systems are also one of the more significant worker safety risks. EPA estimated transfer efficiency: 40%.

- Air assisted airless spray guns add compressed air to atomize the paint into finer droplets than airless systems. The compressed air has tk added benefit of reducing necessary fluid pressures by 50% or more. Air assisted airless is still largely limited to applications which do not need fine finishes. EPA estimated transfer efficiency: 40%.

- Electrostatic guns can be conventional, airless, or air assisted airless guns. The attraction between the charged paint particles and the workpiece substantially improves paint transfer efficiencies and reduces paint waste and clean up. Electrostatic guns can be used for both solvent and waterborne coatings and high production output ideally adapts to automation. They are not well suited for parts with recessed areas or for very small parts where a good ground is difficult to achieve. The cost of a single gun may be $3,000 and a complete change to an electrostatic application with redesign, safety interlocks, isolation stands etc. may run over $250,000. Worker safety is also a concern from electrostatic shocks and arcs in the presence of solvent fumes. EPA transfer efficiency estimate: >90%

- Rotary bells and disks are another means of electrostatic application in which the charged paint is centrifugally spun out by a rotating disk or bell into a predetermined field where parts are passed through on a conveyorized system. Rotary disks and bells are only feasible for high volume production runs of parts with similar geometries. EPA transfer efficiency estimate: 90%

All these alternative “EEM” application systems provide environmental benefits by reducing paint waste and clean-up. However, alternative technologies must also be evaluated for key production characteristics. Key production questions to be considered in any change are:

- Is the alternative on the “approved” list of the local air pollution regulatory agency?
- Will the alternative be able to handle the required production speeds?
- Can the alternative permit quick color changes?
- What clean-up procedures are required?
- What additional investment is needed for redesign of booths, new safety controls, etc.?
- Can the alternative properly atomize the coating?

2.3.3.3 Operating Practices

Good operating practices are critical to the environmental and process performance and are perhaps the most important set of “EEM” technologies.

- Equipment set-up and adjustment is essential to reduce paint waste and improve coating application. The viscosity of the coating, the air and fluid pressures, the shape and size of the spray pattern, and the positioning and racking of work will all influence transfer efficiencies and paint use. Careful attention to these process factors will improve painting performance.

- Operator training has a significant influence on paint consumption rates and paint waste problems. Indirectly, operator training will also affect the amount of solvents used for cleaning.

-- The gun position should be perpendicular to the surface whenever possible to reduce the chance of uneven paint coverage and paint bouncing off the workpiece surface.. Both tilting the gun (up or down) or arcing the gun (holding gun at an angle to the workpiece) is likely to result in these problems. The gun should be kept vertical and be moved parallel to the parts.

-- As a general rule, the distance between the gun and work should be between 6- 12 inches. Too little distance results in runs and sags and inefficient application. Too great a distance results in overspray problems and uneven coverage.

-- Timing the triggering of the gun is a key to reducing overspray, conserving paint, and preventing excess material buildup. The gun movement should be started before triggering, and the trigger should be released before the stroke ends. If the first stroke is begun on the left side of the workpiece, the gun is moved down at the end of that stroke and the second stroke should begin on the right side. Painters should strive for a 50% overlap on the return stroke for optimal efficiency.

-- Spray techniques should be matched as much as possible to the configuration of the workpiece. Banding is the application of a vertical stroke at each end of a flat surface or outside comers so that edges do not have to be covered with horizontal strokes and overspray can be reduced. Vertical applications, especially useful in painting slender workpieces, need faster gun movement to prevent sags and runs.

- Equipment maintenance is a simple but important EEM concept in painting application. Spray guns are precision finishing tools. Failure to keep equipment properly maintained can lead to a variety of application problems resulting in wasted paint, increased overspray and poor finishes. Guns should be lubricated daily per manufacturers instructions. Guns should be cleaned before shifts and line color changes as well as before lunches, breaks, and any other times when there is a risk of paint solidification. Guns should not be immersed in solvent since scale deposits and other foreign material can clog passages. Air and fluid filters and air caps should be kept as clean as possible. Gun tips should be cleaned frequently to prevent material buildup and clogging. Tips will also erode over time because of the abrasiveness of paint solids leading to changing shapes and difficult atomization. Tips should be replaced when these problems occur. Experts note that tip replacement is frequently neglected among paint operators.

- Waste paint can be significantly reduced through proper inventory management. Shelf life problems can be reduced by employing a “first in, first out” (or FIFO) inventory strategy. Good procurement policies and production scheduling can help minimze the disposal of expired or unused paints.

- Chemical conservation applies to both paint and solvent use. Waste paint can be avoided by computing and preparing only the amount needed for the run. Paints can be recycled, although the number of times paint is run through a heater should be minim&d to prevent degradation.

Delivery of paint is another area of opportunity. By using the shortest hoses and smallest pots feasible for a given production need, solvent use can be minimized “Pigs” are absorbent materials with a carbide tip which are used to clean as much excess paint from the hose lines as possible prior to washout thus minimizing solvent use.

2.4 Other Chemical Surface Finishes

In addition to additive finishing processes like plating and painting, metal finishing also include conversion and subtractive processes. These finishing processes can be performed physically or chemically. They may provide the actual metal finish, although in many circumstances they are a pretreatment or post-treatment operation within a larger metal finishing operation. This section addresses a few of the more commonly found chemical-based finishing processes.

2.4.1 Conversion Processes

The conversion coating is a chemical process in which a thin coat of material is applied to the metal substrate causing a reaction with the metal surface. As a result of the reaction, the coating forms part of (converts) the substrate.

Phosphating is the treatment of iron, steel, and other metals for corrosion protection and to promote the adhesion of paint. Phosphating is comprised of a series of application and rinse stages and results in a nonconductive, non-metallic surface. Phosphating typically involves the application of either an iron phosphate or zinc phosphate solution to a substrate. At its simplest, an iron phosphating process may be comprised of two stages-- an iron phosphate bath which both cleans the part and applies the conversion coating followed by a rinse stage(s) to remove dissolved salts from the treated metal surface. An advanced zinc phosphating line might feature seven stages of spray/dip and rinse baths. In addition, a final seal rinse comprised of a low concentrate acidic chromate or an organic non-chromate is often applied to further enhance the corrosion resistance of the conversion coating. Following the conversion application, the parts are sent to an oven to evaporate rinse water and prevent flash rusting. The choice of iron or zinc phosphate processes will depend on product requirements. In general the more extensive multistage zinc phosphate conversion process provides better paint adhesion, corrosion protection, and protection against rust creepage than do iron phosphate baths. However, zinc phosphate conversion coatings are typically more expensive, requires more maintenance, and will often result in more sludge for disposal.

Chromating is a conversion process for non-ferrous metals such as aluminum, zinc, copper, and cadmium to provide decorative, corrosion resistance, or paint adhering properties. Like phosphating, clean parts are deposited into a treatment bath (in this case comprised of highly acidic hexavalent chrome oxide or trivalent chrome phosphate, and other active organic or inorganic compounds) followed by rinsing and a final seal rinse.

Anodizing is an oxidation process employing sulfuric, chromic, phosphoric, or sulfuric+boric acids which converts the surface of a metal (aluminum in most cases) to an insoluble oxide for superior wear and corrosion resistance. Anodizing is a more involved conversion process than chromating or phosphating in that several additional preparatory and rinsing stages may be needed. These include:

- an acidic deoxidizing step to remove corrosion products from substrate
- an acidic or caustic etching step to create an active surface
- a acidic desmutting step to remove residues from the etching process
- a coloring step in which pigments or dyes are impregnated on the anodic coating

Because of its similarityto plating operations in terms of process workflow, the types of issues encountered will resemble those described in the previous section on plating. Spent baths and rinsewaters are the primary waste sources, and dragout minimization, contamination control, smart rinsing practices, and careful operating procedures to control critical process parameters form the strategies for minimizing these wastes and releases. As with plating, problems can occur with the buildup of contaminants through chemical reuse strategies. Materials of concern would include:

- substrate metals
- acidic solutions (sulfuric, nitric, chromic, phosphoric)
- conversion metals (hexavalent chrome, trivalent chrome, zinc, iron)
- nickel acetate from seal rinses
- active organics and inorganics from process chemistries

The differences between low-end, standard, and best in practice profiles is largely based on how the chosen process is designed and run. For most operations, the technology is a "given" and the distinguishing characteristics are based in process control and maintenance issues. As with plating operations, use of tap water for rinse inputs. single stage rinses, poor monitoring and control of bath temperatures and contact or "dwell" times in tanks, and poor operating practices are the indicators of "low-end practice" These ate the primary factors influencing the amounts of waste and pollution stemming from these processes.

Selected chemical substitutions are available for various stages of conversion process although, as always, these need to be highly qualified by production and performance demands. For example, non-chromate deoxidizing etches and seal rinses are available, and chrome phosphate coatings based on trivalent chrome might be used in place of chrome oxide coatings based on hexavalent chrome.

Certain types of products may allow an application of pretreatment primers as an alternative to conversion coating of steel or aluminum. A pretreatment primer is a two-component coating typically made up of an acid and a resin complex. As an alternative technology, pretreatment primers provide good adhesion base between the substrate and overcoatings. However, they provide limited corrosion resistance.

Similarly, for aluminum substrates, dried in place coatings might be substituted for chromating processes. These are not true conversion coatings (they are additive processes) but result in little or no water pollution or hazardous waste since they dry in place and do not need a final chrome rinse. Dried in place coatings provide good corrosion resistance and paint adhesion but may not perform as well as chromate conversions.

2.4.2 Electropolishing

Electropolishing is a subtractive process and the reverse of electroplating. The workpiece is made the anode in solution and when current is applied, metal is dissolved into solution from the microprojections of the workpiece leaving an even, smooth, and reflective finish. Electropolishing can be used as a surface treatment step before electroplating, but it is most commonly employed as a core finishing process.

Electropolishing processes are similar in structure to plating operations. Thorough cleaning and rinsing is a necessary pretreatment step. Various solutions exist for electropolishing -- most are acid based although some alkaline chemistries exist. As the metal is removed it chemically combines with bath components to form a metallic salt which drops to the bottom of the tank and forms a sludge. The part is then rinsed and dried.

Environmental and waste concerns are similar to plating operations in that bath dumps and drag out are primary issues. Periodically, the solution must be removed from the tank and stored. The sludge must be scooped out of the process tank and disposed according to RCRA regulation. The solution can then be replaced with fresh solution ad&d to obtain the proper operating level. Electropolishing operations feature significant dragout volumes and constituent problems. Acid concentrations in electropolishing baths are quite high creating pH problems. Moreover the metals, spent cathode material, other process chemistries, and removed substrate contaminants all agitated in solution create a highly viscous bath often more like syrup than solution. A drain tank, a dead rinse, and a multistage counterflow rinse are especially desirable.

Although wastewaters most certainly need treatment, electropolishing operations can be relatively simple to design and run and (without environmental optimizing steps like countercurrent rinsing) require little space. It is one process that can be purchased and operated in uncontrolled situations fairly easily. In other circumstances electropolishing is done as a relatively small adjunct operation to larger metal forming or physical finishing process like deburring and may be overlooked.

Physical (non aqueous) removal processes might be considered alternative EEM technologies but entail several functional disadvantages to electropolishing. Unlike physical processes, electropolishing completely removes surface contaminants and provides better appearance, corrosion protection, reception of conversion coatings and paints, and wear against other metal surfaces. As a result, advances in precision parts forming is likely to hold more potential for meeting EEM goals than alternative removal technologies.

[1] Description, discussion, and cost information of EEM technologies were assembled from several sources. Readers are encouraged to review the following sources for more detailed information on these technologies and their specific applications:

Cushnie. George *C.* Jr., *Pollution Prevention & Control Technology for Plating Operations, first edition, National* Center for Manufacturing Sciences, Ann Arbor, MI (1994).

Techniques for Reducing or Eliminating Releases of Toxic Chemicals in Electroplating, training manual to the U.S. EPA. published by Battelle.

Wood, William G.. coordinator, *Metals Handbook Ninth Edition, Volume 5 - Surface Cleaning, Finishing, & Coating*, prepared & published by the American Society for Metals Surface Treating & Coating Division Council, Metals, OH (1982).

Durney. *Lawrence* J.. editor, *Electroplating Engineering Handbook*, fourth edition, Van Nostrand Reinhold, New York, NY (1984).

Roy, Clarence.. *The Operation and Maintenance of Surface Finishing Wastewater Treatment Systems, American* Electorplaters and Surface Finishers Society, Orlando, FL (1988)

CHAPTER 3
REGULATORY ISSUES AND THE METAL FINISHING INDUSTRY

3.1 Introduction

Companies that perform metal finishing operations have traditionally been subject to extensive environmental, safety, and health regulations. Much of this attention stems from the hazardous nature of many of the primary feedstocks used in metal finishing processes. The use of metallic compounds in electroplating and the extensive use of organic solvents in all manner of metal finishing are the primary materials that draw the attention of government regulators. Since these materials are an indispensable part of metal finishing and therefore are unlikely to be replaced any time soon, it is important to understand the regulatory issues affecting these operations to achieve a full understanding of this important industrial sector.

As discussed in Chapter 2, the chemical and electrochemical processes involved in metal finishing are the sources of most of the significant waste concerns. Although the mechanical processes like abrasive blasting, grinding, and polishing can generate substantial solid waste, they generally do not generate hazardous materials in any significant quantities. The wastes generated by the chemical and electrochemical processes (like spent plating baths, spent cleaning solvent, degreaser still bottoms, paint sludge, expired or otherwise unusable paint, industrial wastewater treatment sludge, acid cleaners, and other process chemicals) make metal finishing operations some of the most heavily regulated sectors of the industrial economy. All indications are that environmental, and safety and health regulation will only become more stringent regarding the use, handling, and disposal of these materials. Facilities engaged in metal finishing operations are faced with an extensive **maze** of forms and reports that will lead them to the goal of regulatory compliance. Whether this complex regulatory system leads them to the ultimate goal, optimal environmental protection, is more doubtful.

The following is intended to provide a regulatory profile of the metal finishing industry. Although the material may be useful in determining the prospect that a facility might be subject to one kind of regulation or another, the only way to be sure about the regulatory responsibilities of a facility is to consult with an environmental professional or a state or local regulator.

3.2 Regulatory Profiles

3.2.1 Water Pollution Regulations for Metal Finishers

The first nationwide attempt to regulate the use of water by industries involved in metal finishing operations was the Federal Water Pollution Control Act (FWPCA) Amendments of 1972. Previous to the FWPCA, some states and municipalities regulated the use of their water resources through a variety of local laws and ordinances. With the passage of an amendment to the FWPCA referred to as the Clean **Water Act (CWA)** in 1977, the federal government finalized the legislative underpinnings for the regulatory context in which metal finishers operate today.

Companies involved in metal finishing operations are usually regulated by state and local authorities who have been delegated the responsibility of enforcing the regulations. In cases where there are no state or local authorities, the USEPA Regional Office is in charge of enforcement.

Generally speaking, electroplaters and metal finishers are subject to the following wastewater pretreatment regulations:

Federal

- General Pretreatment, 40 CFR 403

  OR
- Electroplating Standards 40 CFR 413

  OR
- Metal Finishing Standards 40 CFR 433

  AND MAYBE
- National Pollution Discharge Elimination System (NPDES)

State

- Same as USEPA if authority granted

Local Publicly Owned Treatment Works (POTW)

- Same or more stringent than USEPA
- Additional limitations on organics, solids, nitrogen, phosphate, and oil/grease loadings

3.2.1.1 Classification Scheme

The system devised by the USEPA divides the metal finishing sector into electroplaters and metal finishers. To be covered under the electroplating regulations (40 CFR 413), a facility must meet two criteria:

1. be a job shop electroplating or an independent printed circuit board shop in operation before 1980, and
2. operate any of the following processes
   - precious metal electroplating
   - common metal electroplating
   - anodizing
   - chemical conversion coatings (chromating, phosphating, etc.)
   - chemical etching and milling
   - electroless plating, or
   - printed circuit board manufacture

For a company to qualify as a metal finishing operator (40 CFR 433), it must perform the operations listed under the electroplating and be

- a captive electroplating operation, or
- a job shop or independent circuit board manufacturer that began construction after August 31,1982

The system further divides those populations into companies that discharge wastewater directly to the watershed and those that discharge their wastewater indirectly through a publicly owned treatment works (POTW). Companies are further divided into those that are captive shops (owning more than 50% of the basis material being finished) and job shops (owning less than 50% of that material). Regulations are slightly different depending upon the combination of factors that best define a company's situation.

Wastewater-s from the following operations are covered by the federal treatment standards:

electroplating	cleaning	machining
grinding	polishing	tumbling
burnishing	impact deformation	pressure deformation
shearing	heat treating	thermal cutting
welding	brazing	soldering

flame spraying	sand blasting	abrasive jet machining
electric discharge machining	electrochemical machining	electron beam machining
laser machine machining	plasma arc machining	ultrasonic cleaning
sintering	laminating	hot dip coating
sputtering	vapor plating	thermal infusion
salt bath descaling	solvent degreasing	paint stripping
painting	electrostatic painting	electropainting
vacuum metalizing	assembly	calibration
mechanical plating		

3.2.1.2 Direct Dischargers

Companies that discharge their wastewater directly to the surface water are regulated under the NPDES system. All facilities that discharge directly to a waterway are required to apply for a NPDES permit which specifies what pollutants may be discharged and a schedule for compliance. monitoring and reporting. In most states, the NPDES permit system is administered by the state environmental agency.

Regulations governing direct dischargers through the NPDES system differ for electroplaters and metal finishers. The regulations contain limitations on metals, cyanides, and total toxic organics. The same limitations apply whether the facility discharges directly to surface water or to the public sewer. The standards for electroplaters are contained in 40 CFR 413 and for metal finishers in 40 CFR 433.

An important initiative that affects direct dischargers took place in 1989 when the USEPA amended the Water Quality Planning and Management Regulations (40 CFR 130). The amendment was intended to develop water quality based effluent limitations for discharges to surface water. As a result of this amendment, more stringent effluent limitations, including biological toxicity testing in some states, are being imposed on direct dischargers. This also affects indirect dischargers to the extent that these more stringent limitations will lead treatment plant operators to tighten their standards in order to ensure that their effluent will meet the new limitations.

3.2.1.3 Indirect Dischargers

Most facilities engaged in metal finishing discharge their wastewater to POTWs. Industrial facilities that dispose of their wastewater in this way are referred to as “indirect dischargers.” Because wastewater treatment plants are designed primarily to deal with domestic sewage, the operators of these plants require indirect dischargers to treat their effluent in some way before sending it to the sewer system These requirements are designed to allow POTW operators to comply with their own NPDES permits and help them ensure that the sludge from their treatment operations can meet federal requirements.

All facilities discharging to local POTWs are governed by the General Pretreatment Standards, which state that discharges

- cannot create fire or explosion
- must have a pH greater that 5.0
- cannot obstruct the flow of wastewater through the system
- cannot interfere with the sewage plant operations
- cannot contain excessive heat
- cannot contain excessive petroleum, mineral, or non-biodegradable oils

In addition to these General Pretreatment Standards, facilities in metal finishing must also comply with specific pretreatment standards for either electroplating or metal finishing operations, depending upon the USEPA definitions described earlier. These pretreatment standards differ primarily in the way limits are set. The electroplating standards provide a daily maximum **and** a four day average for metals and total toxic organics for flow rates less than 10,000 gal/day and more than 10,000 gal/day. The metal finishing pretreatment standards provide a daily maximum and a thirty day average for these materials. In general, the metal finishing pretreatment standards are more stringent than the electroplating pretreatment standards.

Electroplating Limitations (40 CFR 413)
all values are milligrams per liter (mg/l)

Pollutant (or Pollutant Parameter)	less than 10,000 gallons per day of regulated process flow		more than 10.000 gallons per day of regulated process flow	
Cadmium	1.2	0.7	1.2	0.7
Chromium (total)	NR	NR	7.0	4.0
Copper	NR	NR	4.5	2.7
Cyanide (total)	NR	NR	1.9	1.0
Cyanide-amenable	5.0	2.7	NR	NR
Lead	0.6	0.4	0.6	0.4
Nickel	NR	NR	4.1	2.6
Silver	NR	NR	1.2	0.7
Zinc	NR	NR	1.9	1.0
Total Metals (sum CR, CU, NI, Zn)	NR	NR	10.5	6.8
Total Toxic Organics	4.57	-	2.13	-

Metal Finishing Pretreatment Standards (40 CFR 433)

Existing Source Limitations
all values are milligrams per liter (mg/l)

Pollutant (or Pollutant Parameter)	Daily Maximum	30day Average
Cadmium	0.69	0.26
Chromium (total)	2.77	1.71
Copper	3.38	2.07
Cyanide (total)	1.20	0.65
Cyanide-amenable	0.86	0.32
Lead	0.69	0.43
Nickel	3.98	2.38
Silver	0.43	0.24
Zinc	2.61	1.48
Total Toxic Organics	2.13	

New Source Limitations
all values are milligrams per liter (mg/l)

Pollutant (or Pollutant Parameter)	Daily Maximum	30-day Average
Cadmium	0.11	0.07
Chromium (total)	2.77	1.71
Copper	3.38	2.07
Cyanide (total)	1.20	0.65
Cyanide-amenable	0.86	0.32
Lead	0.69	0.43
Nickel	3.98	2.38
Silver	0.43	0.24
Zinc	2.61	1.48
Total Toxic Organics	2.13	

Local POTWs can apply to the USEPA for "approved control authority" status which allows them to issue their own effluent limitations as long as these local limitations are at least as stringent as the USEPA pretreatment standards. In the vast majority of cases, local effluent limitations are more strict than the federal standards. As a result, it is critical for metal finishers to contact local sewer authorities before specifying their pretreatment system. Local authorities can also require any of the following from metal finishing shops:

- operator certification
- operations and maintenance manuals
- a staffing plan
- an inspection schedule
- facility grading

Other considerations metal finishers must keep in mind when considering wastewater discharge include the fact that permit applications must be filed in sufficient time so they can be approved before discharge begins. In many states and localities, the permit approval process can take up to four months. The Baseline Monitoring Report is due 90 days before discharge begins. Many agencies are requiring that sampling for certain parameters, such as heavy metals, be done on a flow-proportion basis.

3.2.1.4 Stormwater Control

Recent changes to the NPDES permit system have increased the requirements for facilities that discharge stormwater runoff that has been exposed to industrial materials or operations. Depending upon the state or federal NPDES permit authority, facilities can be required to monitor their runoff for 15 base parameters and be required to collect data at least twice a year.

3.22 Hazardous and Toxic Materials Regulation for Metal Finishers

The national hazardous waste management system tracks the movement of wastes from their point of origin to their final disposition -- to follow them "from cradle to grave." The enabling legislation, referred to as the Resource Conservation and Recovery Act (RCRA), was passed in 1976 and the USEPA issued its regulations on hazardous waste management in 1980. Initial efforts concentrated on managing the largest generators of hazardous waste (those that generated more that 1,000 kg of hazardous waste per month) who were estimated to account for well over 90% of that type of waste. In 1984, the Hazardous and Solid Waste Amendments (HSWA) to RCRA were enacted to bring smaller waste generators into the system. HSWA also restricted the land disposal of hazardous waste, set guidelines for the design, removal, and installation of underground storage tanks, and established waste minimization requirements for generators of hazardous waste. These two laws, along with the Superfund law mentioned elsewhere in this report, form the basis of this country's approach to dealing with hazardous waste.

The system set up to control the generation of hazardous waste differs from other environmental regulatory approaches in that it is not triggered by the direct activity of the waste generator (discharging wastewater or air emissions) but rather by the special characteristics of certain waste materials. Because this system is based primarily on a special type of waste, it operates somewhat differently than the other regulatory approaches.

3.2.2.1 Identification of Hazardous Waste

Determining which of the waste products generated at a facility is hazardous is done in one of two ways. First, a waste product will be hazardous if it, or any constituent of it, is included in USEPA's list of hazardous wastes. This list is constantly changing. It is important to note that some states have lists of hazardous materials that include more substances than those included on the USEPA's list.

The second way of determining if a waste product is hazardous is to determine if it has any of the properties identified by the USEPA as characteristic of a hazardous material. These four properties are:

1. Ignitability: a flashpoint of, 60^0 C (140^0F) or lower
2. Corrosivity: a pH less than 2 or greater than 12.5, or if the material corrodes steel
3. Reactivity: displays a tendency to explode, autopolymerize, create a vigorous reaction with the air or water, or exhibits thermal instability with regard to shock or to the generation of toxic gases
4. Toxicity: materials that display toxicity according to approved USEPA toxicity tests

In addition, RCRA regulations define certain materials as hazardous unless they are proven. otherwise. Those of relevance to metal finishers include:

- wastewater treatment sludges
- spent plating bath solutions
- sludges from the bottom of plating baths
- spent stripping and cleaning bath solutions

RCRA authorities consider these materials hazardous by definition. Metal finishers would need to prove to the appropriate RCRA authorities that the waste in question is not hazardous in order to handle the material as non-hazardous. The material would have to be shown to not contain listed hazardous wastes and not display any of the four characteristics of hazardous materials to be treated as non-hazardous.

3.2.2.2. Counting Hazardous Waste

To determine its regulatory profile, the metal finisher must count the facility's hazardous waste. The way in which waste is counted is important in the RCRA system because waste generators are treated differently depending upon the amount of waste they generate.

There are four principles behind determining the quantity of waste generated in the USEPA's RCRA hazardous waste management system. The first principle is that material still remaining in a production process is not counted until it is removed from that process. Paint in a paint gun, plating solution in a bath, or solvent in a degreaser is not considered waste until it is removed from the process Equipment. The second principle is that waste is only counted once a month. For example, it used to be that a solvent was counted every time that it left the process equipment. even if the material was recycled on site. This rule led to counting the waste a number of times when in fact it was the same five gallons of solvent the facility was using. Under the current rules. only the initial quantity is counted.

The third principle of hazardous waste counting is that wastes discharged directly and legally to a Publicly Owned Treatment Works in compliance with the Clean Water Act Pretreatment Standards is not considered to be part of the RCRA system. Such wastes are regulated by the permitting authority. The final principle is that any material that is either a characteristic or a listed hazardous waste, and that is accumulated after its removal from the process before being sent off-site for treatment, storage, or disposal is considered a hazardous waste. By following these four principles, a facility should be able to develop an accurate count of the hazardous waste it has generated.

3.2.2.3 Classes of Hazardous Waste Generators

Depending on the count, the metal finisher will fall under one of three generator classes which will constitute the regulatory profiles. Each of these classes are subject to different regulatory requirements.

Large Quantity Generators -- A facility is a large quantity generator of hazardous waste if it generates more than 1000 kg (2.200 lbs) of hazardous waste per month, or if it generates or accumulates more than 1 kg (2.2 lbs) of acute hazardous waste at any time. If a facility is a large quantity generator (LQG), it must:

- notify the USEPA and obtain a USEPA ID number
- store waste no more than 90 days
- comply with container standards and tank rules
- prepare and retain a written Contingency Plan
- prepare and retain a written training plan including annual training of employees
- prepare a written Waste Minimization Plan
- dispose of hazardous materials only at a RCRA permitted site
- use only transporters with USEPA ID numbers
- use proper Department of Transportation (DOT) packaging and labeling
- use the full Uniform Hazardous Waste Manifest
- place a 24 hour emergency number on all manifests
- report serious spills or fires to the National Response Center
- obtain a DOT registration number for shipments over 5,000 lbs
- keep all records for 3 years
- make sure that any treatment or recycling done on-site is properly permitted
- report missing shipments in writing
- submit biennial reports of hazardous waste activities, including waste minimization

Small Quantity Generator -- If a facility generates between 100 kg (220 lbs) and 1,000 kg (2,200 lbs) of hazardous waste in any calendar month, it is considered a small quantity generator (SQG). A facility that is a SQG must:

- notify the USEPA and obtain a USEPA ID number
- store waste no more than 180 days (270 days if the waste must be shipped more than 200 miles for disposal)
- comply with container standards and tank rules

- dispose of hazardous materials only at a RCRA permitted site
- use only transporters with USEPA ID numbers
- use proper Department of Transportation (DOT) packaging and labeling
- use the full Uniform Hazardous Waste Manifest
- place a 24 hour emergency number on all manifests
- post emergency response telephone numbers near telephones
- provide informal employee training
- make sure that any treatment or recycling done on-site is properly permitted
- keep records for 3 years
- report all missing shipments

Conditionally Exempt Small Quantity Generator -- A facility that generates 100 kg (220 lbs) or less of hazardous waste, or less than 1 kg (2.2 lbs) of acute hazardous waste, in any calendar month is considered a Conditionally Exempt Small Quantity Generator (CESQG). A CESQG must:

- avoid accumulating more than 1,000 kg (2,200 lbs) of hazardous waste on-site at any time; and,
- send its waste to a facility that is at least approved to manage municipal or industrial solid waste.

3.2.3 Air Pollution Regulation for Metal Finishers

With the enactment of the Clean Air Act Amendments (CAAA) in 1990, air emissions have become a greater issue of concern for metal finishing operations. Any metal finishing operation with processes that could emit volatile organic compounds (VOCs), or hazardous air pollutants (HAPs as defined in the CAAA, could be required to obtain an operating permit and/or comply with other regulatory requirements for those processes.

The CAAA is possibly the most comprehensive attempt to regulate environmental management in U.S. history. The law itself is published in multiple volumes and the USEPA's rules governing just the establishment of state permitting systems take up 63 pages in the Federal Register. This complex law is intended to put in place a system for controlling ground level ozone, emissions from motor vehicles, toxic air pollutants, emissions affecting the upper ozone layer, and accidental releases of air pollutants. Of particular interest to metal finishing shops are the CAAA regulations affecting the emission of VOCs and hazardous air pollutants.

Metal finishing processes most affected by the CAAA are:

- painting operations that involve the use of halogenated solvents
- paint stripping involving solvents
- parts cleaning operations using solvent materials
- electroplating operations that have the potential to release certain metallic compounds to the atmosphere.

Although painting and organic solvent parts cleaning operations have been subject to air quality regulations in some jurisdictions, the system mandated by the CAAA will bring any painting or cleaning operation of any size into the regulatory loop. The system also targets a variety of plating operations, particularly chrome plating, for special attention.

3.2.3.1 State Regulatory Actions

Primary regulatory responsibility under the Clean Air Act is delegated to state environmental agencies. The Act directs the USEPA to set up National Ambient Air Quality Standards (NAAQS) and promulgate regulations intended to bring ail areas of the country into line with those **standards.** But it is the environmental agencies in the states that are responsible for developing the regulatory structure necessary to assure compliance with the ambient air quality standards and other guidelines laid out in the law.

States are required to develop State Implementation Plans (SIPs). which, among other things, include regulations that lay out a permitting system that the state will implement in order to assure air quality. The permitting guidelines are included in Title V of the CAAA and. as a result. permits issued under this system are called "Title V permits." This permitting system is based on the National Pollutant Discharge Elimination System (NPDES) system used to control water pollution. The key difference between the new and old air permitting system is that the ultimate measure of its effectiveness will not be the rate at which pollutants enter the atmosphere, but the actual air quality in an area.

A state's Title V permitting system is intended to assist the state in identifying sources of air pollution and to determine the kind of reductions that need to be made to bring the state in line with the national air quality standards. The federal guidelines set out the minimum conditions that need to be present for a facility to be pulled into the permitting system. The type and quantity of air emissions generated by a facility, in combination with the region of the country in which the facility is located, will determine the extent to which the facility in question will be subject to a state air quality permitting system. New and modified sources will be required to submit permit applications before construction begins. It is also likely that most states will require sources, new or existing, to register with the state.

3.2.3.2 Hazardous Air Pollutants

In the original Clean Air Act of 1970, USEPA was given the authority to regulate HAPs (otherwise know as "air toxics"). The original Clean Air Act directed the USEPA to set emission limitationsat levels adequate to protect public health with little consideration of the economic costs of the regulation. These emission limits are referred to as National Emission Standards for Hazardous Air Pollutants (NESHAPs). In spite of this broad mandate, prior to the CAAA of 1990 the USEPA had designated only eight substances to be HAPs.

The CAAA completely overhauled the nation's air toxics system. Congress jump-started the process by including a list of 189 substances that are to be regulated as HAPs. Substances on the HAP list of interest to metal finishers include:

- approximately 50 materials commonly used in paints,
- compounds containing cadmium, chromium, lead, and nickel, and
- most organic solvents commonly used for paint stripping and metal cleaning.

Metal finishers that are significant sources of HAPs will become subject to regulation. The USEPA has developed a list of HAP source categories and has divided this list into major sources and area sources. Facilities that are stationary sources and that emit more than 10 tons per year (tpy) of any one pollutant or 25 tpy of any combination of pollutants are considered major sources. Facilities that are sources of these air toxics, but are not major sources, are considered to be area sources. Most of these area sources are not required to be regulated by the CAAA, although it is up to states and localities to decide whether it is necessary to regulate businesses in this category in order to meet the ambient air quality standards.

The USEPA list of major and area sources of interest to the metal finishing industry are as follows:

Major sources

- aerospace industries
- auto and light duty truck (surface coating)
- large appliance (surface coating)
- metal can (surface coating)

- metal coil (surface coating)
- metal furniture (surface coating)
- miscellaneous metal parts and products (surface coating)
- ship building and ship repair (surface coating)
- chromic acid anodizing
- decorative chromium electroplating
- halogenated solvent cleaning
- hard chromium electroplating
- paint stripper users

Area sources
- chromic acid anodizing
- decorative chromium electroplating
- halogenated solvent cleaning
- hard chromium electroplating

These lists of major and area source categories serve as the basis for the regulatory agenda. The USEPA will publish emission standards for both new and existing sources in each of the listed categories. Emission standards will be enforced through the Title V permit system.

The standards will require regulated metal finishers to apply the Maximum Achievable Control Technology (MACT) to all new sources of HAPs, while existing sources could-be in compliance using less strict control measures. MACT is required to consider energy, environmental, and economic impacts in much the same way that Best Achievable Control Technology (BACT) determinations (older technology forcing standards) have been made in the past. The MACT determination for a particular industrial process is quite complicated. MACT is defined as the lowest emission rate or highest level of control demonstrated by 12 percent of the facilities in a source category. MACT determination will be subject to negotiation between industry and environmental groups, and the USEPA.

It is important to note that it will be the state environmental agency that will determine exactly which businesses will be subject to permit requirements. As states develop their SIPs -- particularly heavily industrialized states like Michigan and Ohio - it is likely that they will find that they must regulate smaller sources of HAPs in order to meet the USEPA's air quality guidelines. Metal finishing operations, along with dry cleaning and printing, are being targeted by state programs as the most likely small sources to be regulated.

An area where the regulation of HAPs will be of particular concern to metal finishers is in the use of halogenated solvents in their metal cleaning processes. The final rule governing the use of chlorinated solvents in metal cleaning operations (the NESHAP for halogenated solvent cleaning) proposes a set of three options through which facilities with degreasing operations can comply with HAP control requirements. These three options allow facilities to reduce their emission of HAPs by:
- the addition of control equipment and compliance with a set of work practice standards that includes the use of a cover, the reduction of draft around the degreaser, and other changes, OR
- compliance with an idling emission limit combined with the use of an automated parts handler and other work practice standards, OR
- compliance with a total emissions limit for the facility's solvent cleaning operation.

The solvent cleaning NESHAP has allowed facilities some time to develop a compliance strategy. Facilities should be judicious in their selection of a compliance strategy not only because of the regulation of these materials as HAPs, but also because halogenated solvents are subject to increased regulation as VOCs.

3.2.3.3. Volatile Organic Chemicals

In an effort to control the formation of smog, the CAAA required the USEPA to develop standards for the following substances:

- inhalable particulates (PM- 10)
- nitrogen oxides (NOx)
- ozone
- sulfur oxides (SOx)
- lead
- carbon monoxide (CO)

The standard of interest to metal finishers is ozone. Ground-level ozone results from the reaction of volatile organic compounds with nitrogen oxides. Many of the substances used by metal finishers in paint stripping and application, as well as metal parts cleaning, are VOCs. States must develop strategies to assure that they will meet the NAAQS through the appropriate regulatory activities and submit them to the USEPA as part of their SIPs. As a result, even the smaller sources of VOCs are likely to be regulated in some cases.

The extent to which a small source of VOCs will be regulated is highly dependent upon the air quality in the region in which the source is located. Basically. all sources in areas that are in compliance with the NAAQS (called areas of "attainment") and that have the potential to emit 100 tons of VOCs per year will be considered major sources and will be subject to regulation. Special provisions of the CAAA require that all sources of VOCs in the Northeast and Midatlantic states with the potential to emit 50 tpy will be required to obtain a permit.

The regulatory thresholds for sources in areas of non-attainment are significantly lower. How much lower will depend upon the degree of non-compliance with the NAAQS in that particular region. The USEPA classifies areas of nonattainment into those that are marginal, moderate, serious, severe and extreme. The higher up the scale a region goes, the more likely it will be that small sources of VOCs in that region will be required to obtain a permit.

For example, the Toledo, OH area is considered an area of moderate non-attainment for ground level ozone. A metal parts cleaning operation that uses halogenated solvents will have a lower regulatory threshold than the same operation in Canton, OH, which is considered an area of marginal non-attainment. The same cleaning operation in Bowling Green, OH would have a higher regulatory threshold than either Canton or Toledo because that area is in attainment for ozone. The upshot of this is that the regulatory burden for a facility regarding its VOC emissions will vary greatly according to the level of ozone attainment of the area in which it is located.

Designated Non-attainment Areas in Michigan and Ohio

Pollutant	Level of Non-Attainment	Area
Ground Level Ozone	Serious	Muskegon, MI
	Moderate	Cincinnati, OH-Hamilton. KY Cleveland-Akron-Loraine, OH Dayton-Springfield, OH Detroit-Ann Arbor, MI Grand Rapids, MI Toledo, OH
	Marginal	Canton, OH Columbus, OH Youngstown-Warren, OH-Sharon. PA

Another aspect of VOC regulation that affects metal finishing operations is the traditional use of halogenated solvents in paints. Since there are limits to the VOC reductions that can be achieved through alterations to the painting equipment and processes, it has become necessary for paint formulators to begin using other materials as solvents, pigments, and binders in their products. Some paint manufacturing companies have been working with low- and no-VOC coatings for a number of years in response to the tighter controls imposed on VOC emissions by local and state authorities in California and the Northeast states. Efforts to further reduce the amount of VOCs included in paint will increase as the regulations covering VOC emissions under the CAAA begin to come into force. It will be important for facilities with any kind of metal painting operation to carefully test both new paint delivery technologies as well as paint formulations in order to choose the right combination. Meeting local VOC emission standards while providing the best possible painted finish is a challenge to all facilities that must apply paint to their product.

3.2.3.4. Summary of Air Issues in Metal Finishing

The Clean Air Act Amendments of 1990 has added another set of concerns to the regulatory plate of metal finishers. Electroplating, surface finishing, and painting operations are now subject to additional controls on the amount of airborne emissions that will be allowed from them. These additional regulations will vary according to the substances used and the area of the country in which the process equipment is located. The use of halogenated solvents, a common material in most metal finishing operations, has been impacted particularly hard by the new air regulations. Processes that are likely to emit airborne metals, particularly chromium, are also going to be subject to increasing control.

Although the technology-based standards that will be issued as the CAAA becomes codified through state and federal rulemaking will be tailored to the concerns of a specific type of operation, any facility that is currently using halogenated solvents will certainly see the costs associated with the use of this material rise. Considering that the costs of compliance with air regulations will be combined with the increasing costs of hazardous waste disposal, facilities that use a great deal of this material will find themselves under increasing cost pressure to reduce and/or eliminate the use of this material. As facilities begin developing their strategies for compliance with these new air regulations, they must be careful not to lose sight of the other pressures on halogenated solvent use. Spending significant capital on controlling the air emission of material that are becoming more expensive and more highly regulated may in the end turn out to be a losing proposition. The elimination of the use of halogenated solvents is the only way to reduce the costs imposed by the regulation of these materials.

3.2.4 Superfund and Emergency Plan and Community Right-to-Know Regulations for Metal Finishers

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, known generically as the “Superfund” law, and its subsequent amendments are an attempt to provide for the clean-up of contaminated sites and to assign financial responsibilities for that clean-up.

CERCLA’s major impact on metal finishers in their everyday operations result from the additional reporting requirements they will be subject to as they generate and dispose of hazardous materials. Aside from the day to day concerns of complying with those reporting requirements, CERCLA impacts metal finishers by making them permanently responsible for all the hazardous materials they send off-site. Also of concern is the fact that the owner of a property is responsible to clean-up any hazardous waste contamination on their site before that site can be sold. This requirement will have the most impact of older operations that may have used disposal practices that were accepted at the time, but have led to the contamination of the site with hazardous materials.

All CERCLA requirements apply to hazardous substances as defined under the Clean Water Act, the Clean Air Act, the Resource Conservation and Recovery Act. and the Toxic Substances Control Act. Generally, CERCLA combines the "cradle to grave" responsibility for the hazardous wastes generated by a facility with "joint and several liability" for wastes to make a facility forever responsible for the ultimate disposition of any and all hazardous wastes they produce and the clean-up costs associated with remediating any sites that contain their wastes. It is important to note that this comprehensive liability extends to all hazardous wastes, whether the generator complied with all applicable regulations or not. In essence. the facility is not only responsible for its own actions in disposing of its waste, but also for the actions of the waste hauler as well as the treatment and disposal contractor they hire to handle, treat, and dispose of their hazardous wastes.

CERCLA impacts facilities by requiring them to report spills of hazardous materials, requiring reports and the notification of local authorities on the use, storage and release of hazardous materials, and requiring them to report the release of certain toxic substances if the facility meets a set of thresholds. These requirements combine those in the original CERCLA law and those added through the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA-a section of the Superfund Amendments and Reauthorization Act of 1986). Following is a short summary of the primary requirements likely to affect metal finishers.

3.2.4.1 Reporting Spills

Spills of hazardous substances must be reported to the appropriate authorities if "reportable quantities" are spilled. These quantities range from 1 to 5,000 pounds of substance spilled within a twenty-four hour period. In many cases, state and local authorities require facilities to report smaller spills.

3.2.4.2 Reporting the Use, Storage and Disposal of Hazardous Materials

The 1986 Amendments to the Superfund law require facilities that use, store, or dispose of hazardous waste to provide information concerning their on-site management of those materials to state and local authorities.

The EPCRA requirements are included in Title III of SARA. Section 302 of Title III requires a facility to notify the state emergency response commission (SERC) if the company exceeds the Threshold Planning Quantity for any extremely hazardous substance. Section of 304 of Title requires a facility to report any potentially dangerous release of any hazardous substance to the SERC and local emergency response committee in addition to reporting such a release to the federal authorities.

In Section 311 of EPCRA, facilities are required to submit Material Safety Data Sheets (MSDSs), or a list of MSDSs for each extremely hazardous substance or OSHA hazardous material that exceeds a certain threshold. This information is to be submitted to the USEPA (they prefer a list), the SERC, the local emergency response committee, and the local fire department.

Section 31 2 of EPCRA requires facilities to submit an inventory of the hazardous chemicals stored on-site. Facilities required to submit MSDSs under Section 311 are required to comply with this Section for the chemicals they report under 311. The inventory must be submitted on either Tier I or Tier II reporting forms, depending upon state requirements. The information on this inventory should include:

- an estimate of the maximum amounts of chemicals in each hazard category for the previous year,
- an estimate of the average daily amounts of chemicals in each hazard category, and
- the general location of the hazardous chemicals in each hazard category.

This information is to be submitted to the SERC the local emergency response committee. and the local fire department. Most states require the submission of Tier II forms. These forms contain more detailed information on the chemicals stored on-site and the locations of those chemicals at the facility.

The aspect of EPCRA that has gotten the most publicity is the requirement under Section 313 that facilities that "routinely" and/or accidentally release a defined set of chemicals must report annually on those releases. The compilation of this information is called the Toxics Release inventory, or TRI. Facilities required to report have the following characteristics:

- be classified in SIC codes 20-39
- have ten or more full time employees, and
- use any of the designated chemicals at a rate of 10,000 lbs or more a year. or
- manufacture and process any of the designated chemicals at a rate of 25,000 lbs or more a year.

The chemicals that must be reported are on the Section 31 3 Toxic Chemical Release list. Currently the list contains in the neighborhood of 300 chemicals. A sample list of materials of interest to metal finishers includes:

- halogenated degreasing solvents TCA, perchloroethylene, and others
  sodium hydroxide
- sulfuric and nitric acid
- chromic acid
- chelating agents like thiourea
- most plating and process bath components
- solvents included in paints (there are approximately 50 solvents currently on the TRI list)
- metal containing compounds used in pigments like lead chromate, titanium dioxide, and nickel titanate
- resin precursors like formaldehyde, vinyl chloride, and toluene-2,3-diisocynanate
- surfactants, defoamers, and other paint additives

Because the list of chemicals to which the TRI requirements apply is revised periodically, it is important for metal finishers to get an approved list from a relevant governmental agency to confirm its need to comply.

3.2.5 Occupational Safety and Health Regulations and.Metal Finishers

All manufacturing companies in the U.S. are subject to regulation under Section 6(a) of the Williams-Steiger Occupational Safety and Health Act of 1970. This law and its attendant regulations require conditions or the adoption or use of one or more practices, methods, operations or processes reasonably necessary or appropriate to provide safe or healthful conditions in places of employment.

3.2.5.1 Hazard-Communication Standard

Of particular interest to operators of metal finishing operations are the OSHA rules governing the dissemination of information to workers concerning the hazards posed by chemicals in the workplace. The extensive use of hazardous materials in metal finishing operations makes this an important standard for companies with those operations. These regulations are contained in 29 CFR 1910.1200.

Facilities that use materials included on the OSHA list of hazardous chemicals are required to make available all the MSDSs for those chemicals used in the work area. Hazardous chemicals are also to be labeled in a manner that clearly identifies the material to the worker. Facilities must also provide training for workers on the handling of these materials. The labeling, training, and MSDS requirements are all part of the required “Hazard Communication” program each company using such material is required to put in place. Also included in this program is the requirement for a complete inventory of all chemicals and an assessment of the hazard potential for all chemicals used in the workplace.

A number of states have their own Right-to-Know” laws. Court decisions have bolstered the OSHA contention that Federal OSHA regulations preempt these state laws affecting manufacturing in those states that do not have OSHA approved safety and health plans. However, states are able to enforce more stringent ‘Right-to-Know” regulations if the state complies with all OSHA planning and programmatic requirements.

3.7.5.2 Hazardous Waste Operations and Emergency Response Standard

This standard requires metal finishers to develop a written plan for emergency response, to have procedures for handling an emergency response, to tram employees for activities in areas related to the emergency response position held, to provide the appropriate protective clothing, and to have procedures for post-emergency situations.

3.2.5.3 Control of Hazardous Energy (Lockout/Tagout)

This set of standards is intended to provide for the safety of workers while major pieces of equipment are undergoing service and maintenance. The regulations, published in CFR 29 1910.147, protect workers from the unanticipated start-up or release of stored energy that could cause injury. The standards lay out requirements for a program to be initiated by the facility that provides for the lockout of equipment undergoing maintenance and a tagging system to identify those in charge of the lockout.

Every day maintenance operations such as minor tool changes or adjustments are not covered if they are routine, repetitive, and integral to the use of the equipment. Only major service and maintenance operations are subject to these rules. Major operations are defined as any activity in which a guard or other safety device is removed or bypassed, where workers are required to place any part of their body where work is being performed, or where an associated danger zone exists.

Included in these regulations are requirements for the establishment of lockout/tagout procedures, the proper selection of protective mate&l and hardware, annual inspection and certification of energy control procedures, informing outside contractors of lockout/tagout requirements, procedures for shift changes, and an employee training program on lockout/tagout procedures.

3.2.5.4 Respiratory-Protection Standard

OSHA has promulgated standards governing the protection of workers from air contaminated with harmful dust, fumes, vapors, mists, gases and smoke. In cases where the use of engineering controls does not sufficiently reduce the presence of contaminated air, or control measures are in the process of being implemented, workers must be protected by using appropriate respiratory devices. A facility-wide respiratory-protective equipment program is the focus of this protective effort. The requirements for such a program are included in 29 CFR 1910.134.

A respiratory-protective equipment program must include written standard operating procedure, the selection of proper equipment, procedures for the cleaning and storage of such equipment, emergency rescue procedures, and provisions for the physical examination of workers to determine if they are capable of performing their work while wearing a respirator.

3.2.5.5 Flammable-Storage Requirements

These standards state that all flammable and combustible liquids must be stored in either an approved storage cabinet or a room designed specifically for the storage of flammable and combustible materials. The features of an approved storage area for flammable liquids can be found in Section 30 of the National Fire Protection Association Standards.

3.2.5.6 Noise-Exposure Hearing-Conservation Program

OSHA requires that a facility must establish and administer a hearing conservation program whenever worker exposure levels equal or exceed an eight-hour time-weighted average level of 85 decibels measured on the "A" scale. Facilities must determine whether any worker's exposure meets or exceeds the standard. If any worker's exposure meets or exceeds the standard, the facility must maintain a hearing conservation program.

Requirements for a hearing conservation program include an audiometric testing program, the availability of hearing protectors and training on their use. Exposure measurement records must be kept by the facility for two years and the audiometric testing records must be kept for the duration of the worker's employment.

3.3 Regulatory Forecast

If history teaches us anything **about** environmental regulation it is this -- regulations only become more stringent over time. As monitoring technology becomes more sensitive and the concern over hazardous materials in the environment continues unabated, facilities operating metal finishing processes can be expected to be called on to further reduce the amount and toxicity of the waste they generate. And with the recent congressional efforts to reauthorize the two environmental laws that impact the metal finishing industry the most -- the Clean Water Act and the Resource Conservation and Recovery Act - it is certain that the regulatory framework within which these companies operate will change.

However, few things are ever certain when it comes to predicting regulatory trends. Even under the best of conditions, the political process that leads to the development of laws and regulations tends to twist and turn in response to the wide variety of influences, defying easy prediction. Predicting the actions of the USEPA is only marginally easier in light of the changes in congressional leadership. Although the Agency is part of the executive branch, Congress has significant oversight and budget responsibilities over its actions, and as a result, has quite a bit to **say about** the direction of its activities. USEPA personnel, aware of the impact of congressional actions on their mandates and budgets, tend to take a "wait and see" attitude in this context.

Congressionally mandated regulatory development (the development of effluent guidelines for Metal Products and Machinery sector, for example) is likely to move forward at their usual pace. Newer, less traditional initiatives like the Common Sense Initiative may move at **a** more measured pace. States and municipalities often follow the lead of the federal government when it comes to regulatory activities. Although there is usually a great deal more experimentation at the state and local level when it comes to environmental regulation, their regulatory mandate is limited and, therefore, they must take care to not get out too far ahead of the USEPA. Considering the current climate, it is likely that most states will stick to implementing programs and regulations already mandated. The development of State Implementation Plans (SIPs) under the Clean Air Act Amendments of 1990 is likely to keep state environmental agencies busy for the foreseeable future.

Following is a summary of the regulatory trends that will impact the metal finishing industry. It is an attempt to review the trends that are currently taking shape in an effort to get a sense of what the industry will be responding to in the next ten years, not the next ten months. Ultimately, the message of all this will be that so long as metal finishing operations use materials considered hazardous they will be subject to increasingly strict, and therefore expensive regulations.

3.3.1 Clean Air Act Amendments of 1990

The rule development process under the CAAA will continue to move ahead. The USEPA is required to develop Maximum Achievable Control Technology (MACT) standards for hazardous air pollutants for metal finishing operations over the next ten years. The MACT standards will likely favor the full enclosure of painting operations, the use of high solids paints and powder coatings, and the conversion of paint guns to the state-of-the-art high volume-low pressure guns. Paint manufacturers are scrambling to find new, low HAP paint formulations intended to help control airborne emissions from metal painting operations. MACT standards for chrome plating operations are currently being negotiated. The development of these MACT standards will greatly effect the regulatory landscape for painting and chrome plating operations in the future.

There will be continuing pressure on air emissions from halogenated solvent cleaning operations. The National Emissions Standards for Hazardous Air Pollutants from vapor degreasing operations has been proposed and is in the process of being finalized. States are developing their approaches to regulating volatile organic compounds as part of their SIPs, and the federal approval of these plans will determine the actual regulatory responsibilities of users of these materials.

The result of all this will be an ever-increasing effort to control air emissions from processes that use designated hazardous air pollutants and volatile organic compounds.

3.32 Clean Water Act

The USEPA is currently at work developing regulations under the CWA for a new industrial category, the Metal Products and Machinery Category, which directly impacts metal finishers. These regulations will be developed in two phases. In phase I, standards will be developed for the aerospace, ordnance, aircraft, and electronic equipment industries. These regulations are in the initial proposal stage as of this writing. Final rules are due to be issued on or before May 6, 1996. Phase II standards include industries involved in the manufacture of automobiles and ships. These standards expected to be finalized in 1999.

The reauthorization of the CWA will once again be the subject of some debate in the near future. It is likely that renewed attempts to reauthorize the CWA will be subject to more extensive debate, with an attempt to shift the focus of the bill away from metal finishing activities toward commercial, residential, and non-point discharges. Any reauthorization of the CWA will probably include an emphasis on pollution prevention, more stringent water quality and effluent standards, and stricter enforcement provisions.

3.3.3 Resource Co

Attempts to reauthorize the RCRA have been underway since 1989, and the most recent attempt to reauthorize the Act in the 1994 congressional session met with failure. Since the reauthorization of other environmental laws (notably Super-fund) appear to have priority, many analysts believe that Congress will not consider RCRA reauthorization until 1996.

After a successful court challenge, USEPA was forced to develop a new definition of hazardous waste and hazardous waste recycling. This new definition will affect metal finishing operations because the USEPA has stated that it will attempt to propose a definition that will favor recycling of the waste over treatment and disposal. It appears that this new definition will be proposed in 1995.

3.3.4 Superfund

The Comprehensive Environmental Response Compensation and Liability Act (commonly known as Superfund) was proposed for reauthorization in 1994 and is likely to be taken up by the 104th Congress in 1995. At this point in time, its fate is far from certain, although federal activities under Superfund have been the target of severe criticism. This criticism will presumably prompt the new Congress to action on CERCLA.

The provision from the latest reauthorization attempt that was of most interest to metal finishers will be the definition and responsibilities of "de minimis" contributors. "De minimis" contributors are those responsible for less than one percent of the total volume of hazardous waste at any specific site. Many metal finishers are likely to fall into this category industry groups have proposed a number of changes to these provisions to make the burden on smaller companies less onerous. They have proposed to establish a new category of potentially responsible parties, the "de micromis" category, which would allow for what they regard as **a** more equitable assignment of fiscal responsibility.

Other concerns about the Superfund system include the quality of evidence necessary to establish a potentially responsible party, the expenditure of funds on legal fees and other "transaction costs," and provisions of the current law that prevent even the smallest potentially responsible party from settling the claim in a timely fashion. These issues will be addressed in some way by any reauthorization of Superfund.

USEPA has also proposed to expand the list of chemicals included on the Toxics Release Inventory (TRI) list that was established under the Emergency Planning and Community Right-to-Know section of the 1986 Superfund reauthorization law. The USEPA Administrator Carol Browner has proposed that the list of TRI chemicals be increased from 320 to 632. The USEPA reviewed a list of 1000 chemicals and selected those to be added as a result of their acute human health effects and their environmental effects. Metal finishing operations could find themselves drawn into TRI as a result of this chemical list expansion. Although it is unlikely that most metal finishing facilities would release toxic wastes in sufficient quantities to be drawn into the TRI requirements, this TFI list expansion could impact some facilities.

3.3.5 OSHA Regulations

A number of proposals have been made to amend the Occupational Safety and Health Act. The most recent attempts to amend OSHA have included provisions mandating a safety and health committee be established in every company employing more than eleven people, allowing OSHA to charge employers for technical assistance and consultative services, creating a set of employee participation rights, increasing criminal penalties for violations, and expanding **risk** notification requirements. Revisions to the way in which exposure limits are set were also proposed.

It is difficult to predict the direction OSHA regulations will take. Facilities should anticipate increasing regulatory pressures on the use of hazardous materials in the workplace. An increase in the information provided to workers on the materials they use and a decrease in the allowed exposure levels to hazardous materials could be expected.

The Permissible Exposure Limits (PELs) established by OSHA are designed to protect workers from exposure to dangerously high levels of hazardous substances. The PEL for cadmium was reduced in 1992 as part of a review and revision effort. Hexavalent chromium appears to be the next substance to undergo such a review. A number of lawsuits are pending that call for OSHA to issue a reduced emergency **standard** for hexavalent chromium to be followed by a new permanent PEL. Although no other heavy metals are currently being reviewed in a similar way, some expens have expressed interest in revising the PEL for nickel.

3.3.6 Other Federal Initiatives

The USEPA has initiated programs and Agency reorganization efforts that could impact metal finishers. Following is a description of those efforts.

3.3.6.1 Common Sense Initiative

In proposing the Common Sense Initiative (CSI), USEPA Administrator Browner states that this is "a fundamentally different system of environmental protection that replaces the pollutant-by-pollutant approach of the past with an industry-by-industry approach for the future." CSI is intended to be a consensus driven approach to environmental regulation, by soliciting direct input from representatives from industry, government, communities and the environmental community. Managed out of the USEPA's Policy and Evaluation Branch, CSI will improve the regulatory structure to make it more responsive to the needs of industry while protecting the environment. The Electroplating and Metal Finishing sector has been chosen as one of the six industry groups to pilot this approach.

CSI is an attempt to restructure the regulatory system to

- make regulations more results oriented
- prevent pollution rather than simply control it after its generation
- make environmental information collection easier for industry and more accessible to the public
- provide for strong enforcement
- improve the permitting process
- encourage new technologies

The Common Sense Initiative approach to metal finishing is currently in development. No deadline for the development of the approach is available at this time.

3.3.6.2 Great Lakes Initiative

The Great Lakes Water Quality Initiative is a joint effort of the USEPA and state environmental agencies to revise water quality standards in the Great Lakes Basin. It began in response to the Great Lakes Critical Programs Act of 1990 which directed USEPA to prepare and publish water quality guidance for the Great Lakes. The Great Lakes Initiative (GLI) is an effort to coordinate the water quality standards of the states in the Great Lakes Basin and the federal government. The GLI proposes the establishment of numerous water quality standards, anti-degradation policies and the implementation procedures for waters within the jurisdiction of the eight Great Lakes states as well as Indian tribes in the Basin. Toxic pollutants are a special focus of GLI.

GLI requires states and Indian Tribes to develop total maximum daily loads for waters that are not expected to meet water quality standards even after the implementation of technology-based controls. Developing a consistent set of water quality standards is a primary goal of GLI. An analysis of GLI by DRI/McGraw-Hill of the economic impact of this initiative was critical of the cost of the effort to government and business measured against the benefits to the environment. The Council of Great Lakes Governors suggested revisions to GLI to redress the problems with the effort.

Metal finishing facilities in the Great Lakes Basin can expect GLI to be a driving force in tightening effluent guidelines on heavy metals, organic solvents, and other toxic materials. The materials of interest to metal finishers include toluene, trichloroethylene, cadmium. methylene chloride, zinc, chromium, zinc, copper, and nickel. Companies in the Basin can expect to find their pretreatment requirements become more stringent for these materials. NPDES permit holders can expect a similar tightening of effluent limits.

3.3.6.3 State Initiatives

As mentioned in an earlier section of this report, state and local regulatory efforts are determined by federal mandate. Most of the emerging state regulatory activity will be in response to the Clean Air Act Amendments of 1990, the new effluent guidelines promulgated for the Metal Products and Machinery sector, and the water quality standards developed under the Great Lakes Initiative. The development of the State Implementation Plans under the CAAA is likely to have the greatest effect on metal finishers.

Other state regulatory efforts of concern to metal finishers involve efforts on the part of some states to promote pollution prevention. Michigan and Ohio have been considering the imposition of pollution prevention planning requirements on certain types of hazardous waste generators. Ohio has passed a planning requirement for operators of injection wells, but this requirement has no impact on metal finishers. Since Congress has considered pollution prevention planning requirements as part of the CWA and RCRA reauthorization bills, it is likely that states will not go through the effort to pass such a law until Congress decides if planning will be required nationwide.

BIBLIOGRAPHY

Chapter 1

Metal Finishing Industry Market Survey 1992-1993 by Surface Finishing Market Research Board, published by Metal Finishing Suppliers' Association and National Association of Metal Finishers (1994).

Powder Coatings: Technology of the Future, Here Today, technical brief by The Powder Coating Institute, Alexandria, VA (February 1994).

Basler, Stephen, Hellwig, Maureen, & Tholin, Kathryn. *Investing In Sustainable Manufacturing: A Study of The Credit Needs Of Chicago's Metal Finishing Industry,* jointly published by the Center for Neighborhood Technology and the Woodstock Institute (312/427-8070). Chicago, IL (June 1990).

Cushnie, George C. Jr., *Pollution Prevention & Control Technology for Plating Operations,* first edition, National Center for Manufacturing Sciences, Ann Arbor, MI (1994).

Damay, Arsen J., editor, "Plating & Polishing," *Manufacturing, U.S.A., Industry Analysts Statistics & Leading Companies,* 4th edition. volume 2, pp. 1427-1436. Gale Research, Inc., Detroit, MI (1994).

U.S. Department of Commerce, *1991 Annual Survey of Manufactures. Statistics for Industry Groups and Industries,* U.S. Dept. of Commerce/Bureau of the Census, Survey M91(AS)-1, Washington, D.C. (December 1992).

U.S. Department of Commerce, *Current Industrial Reports - Pollution Abatement Costs and Expenditures.* 1992, U.S. Dept. of Commerce - Economics and Statistics Administration/Bureau of the Census Report MA200(92)-1, Washington, D.C. (March 1994).

U.S. Department of Commerce, ,Economics & Statistics Administration, Bureau of the Census, *1992 Census of Manufactures, Preliminary Report Industry Series,* report MC92-I-34D(P), Washington, D.C. (October 1994).

U.S. Department of Commerce, Bureau of the Census, *1991 Annual Survey of Manufactures - Value of Product Shipments,* U.S. Dept. of Commerce report M91(AS)-2, Washington, D.C. (November 1992).

Chapter 2

Metal Finishing Guidebook and 'Directory Issue, Volume 93, No. 1A. Journal published by Elsevier Science Inc., New York, NY (January 1995).

Finishers' Management, volume 39, No. 5. journal published by Publication Management, Inc., Glenview, IL (May 1994).

Plating & Surface Finishing. journal of the American Electroplaters & Surface

Finishers Society, Inc., volume 81, No. 3. Orlando, FL (March 1994).

Powder - Coatings: Technology of the Future, Here Today, technical brief by The Powder Coating Institute, Alexandria. VA (February 1994).

Techniques for Reducing or Eliminating Releases of Toxic Chemicals in Electroplating, draft of training manual to the U.S. EPA, published by Battelle.

Waste Audit Study, Metal Finishing Industry, report published by PRC Environmental Management, Inc., San Francisco, CA (May 1988).

Cushnie, George C. Jr., *Pollution Prevention & Control Technology for Plating Operations,* first edition, National Center for Manufacturing Sciences, Ann Arbor, MI (1994).

Durney, Lawrence J., editor, *Electroplating Engineering Handbook,* fourth edition, Van Nostrand' Reinhold, New York, NY (1984).

Foecke, Terry L.. *Source Reduction Opportunities in the Plating Industry,* paper published by the Waste Reduction Institute for Training & Applications Research, Inc.(WRITAR)(612/379-5995). Minneapolis, MN.

Joseph, Ron, "Environmental Coating Problems," *Metal Finishing,* Volume 92. No. 7, pp. 50-51. Journal published by Elsevier Science, Inc., New York, NY (July 1994).

Joseph, Ron, "Environmental Coating Problems," *Metal Finishing,* Volume 92. No. 10, pp. 29-30. Journal published by Elsevier Science, Inc., New York, NY (October 1994).

Manly, Brian A. & Weis, Melissa L.. *Characterization of Current Electroplating Processes,* report published by Concurrent Technologies Corporation, Johnstown, PA (August 5, 1994).

Steward, F.A., *Environment & Competitiveness in the Metal Finishing Industry,* report prepared for Congress of the United States Office of Technology Assessment, Washington, D.C., submitted by F.A. Steward Consulting, Inc., Wexford, PA (January 28, 1993).

Wood, William G., coordinator, *Metals Handbook, Ninth Edition, Volume 5 - Surface Cleaning, Finishing, & Coating,* prepared & published by the American Society for Metals Surface Treating & Coating Division Council, Metals, OH (1982).

U.S. Environmental Protection Agency, *The Product Side of Pollution Prevention, Evaluating the Potential for Safe Substitutes,* report EPA/ 600/R-94/178, Washington, D.C. (September 1994).

U.S. Environmental Protection Agency/SEDESOL Pollution Prevention Work-group. *Waste Minimization for the Metal Finishing Industry,* report by EPA, Washington, DC. (May 1993).

U.S. Environmental Protection Agency, *Sustainable Industry. Promoting*