EPA/310-R-95-007

EPA Office of Compliance Sector Notebook Project

Profile of the Fabricated Metal Products Industry

September 1995

Office of Compliance
Office of Enforcement and Compliance Assurance
U.S. Environmental Protection Agency
401 M St., SW (MC 2221-A)
Washington, DC 20460

This report is one in a series of volumes published by the U.S. Environmental Protection Agency (EPA) to provide information of general interest regarding environmental issues associated with specific industrial sectors. The documents were developed under contract by Abt Associates (Cambridge, MA), and Booz-Allen & Hamilton, Inc. (McLean, VA). This publication may be **purchased** from the Superintendent of Documents, U.S. Government Printing Office. A listing of available Sector Notebooks and document numbers is included at the end of this document.

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LIST OF ACRONYMS

AFS -	AIRS Facility Subsystem (CAA database)
AIRS -	Aerometric Information Retrieval System (CAA database)
BIFs -	Boilers and Industrial Furnaces (RCRA)
BOD -	Biochemical Oxygen Demand
CAA -	Clean Air Act
CAAA -	Clean Air Act Amendments of 1990
CERCLA -	Comprehensive Environmental Response, Compensation and Liability Act
CERCLIS -	CERCLA Information System
CFCs -	Chlorofluorocarbons
CO -	Carbon Monoxide
COD -	Chemical Oxygen Demand
CSI -	Common Sense Initiative
CWA -	Clean Water Act
D&B -	Dun and Bradstreet Marketing Index
ELP -	Environmental Leadership Program
EPA -	United States Environmental Protection Agency
EPCRA -	Emergency Planning and Community Right-to-Know Act
FIFRA -	Federal Insecticide, Fungicide, and Rodenticide Act
FINDS -	Facility Indexing System
HAPs -	Hazardous Air Pollutants (CAA)
HSDB -	Hazardous Substances Data Bank
IDEA -	Integrated Data for Enforcement Analysis
LDR -	Land Disposal Restrictions (RCRA)
LEPCs -	Local Emergency Planning Committees
MACT -	Maximum Achievable Control Technology (CAA)
MCLGs -	Maximum Contaminant Level Goals
MCLs -	Maximum Contaminant Levels
MEK -	Methyl Ethyl Ketone
MSDSs -	Material Safety Data Sheets
NAAQS -	National Ambient Air Quality Standards (CAA)
NAFTA -	North American Free Trade Agreement
NCDB -	National Compliance Database (for TSCA, FIFRA, EPCRA)
NCP -	National Oil and Hazardous Substances Pollution Contingency Plan
NEIC -	National Enforcement Investigation Center
NESHAP -	National Emission Standards for Hazardous Air Pollutants
NO_2 -	Nitrogen Dioxide
NOV -	Notice of Violation
NO_X -	Nitrogen Oxide
NPDES -	National Pollution Discharge Elimination System (CWA)

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LIST OF ACRONYMS (CONT'D)

NPL -	National Priorities List
NRC -	National Response Center
NSPS -	New Source Performance Standards (CAA)
OAR -	Office of Air and Radiation
OECA -	Office of Enforcement and Compliance Assurance
OPA -	Oil Pollution Act
OPPTS -	Office of Prevention, Pesticides, and Toxic Substances
OSHA -	Occupational Safety and Health Administration
OSW -	Office of Solid Waste
OSWER -	Office of Solid Waste and Emergency Response
OW -	Office of Water
P2 -	Pollution Prevention
PCS -	Permit Compliance System (CWA Database)
POTW -	Publicly Owned Treatments Works
RCRA -	Resource Conservation and Recovery Act
RCRIS -	RCRA Information System
SARA -	Superfund Amendments and Reauthorization Act
SDWA -	Safe Drinking Water Act
SEPs -	Supplementary Environmental Projects
SERCs -	State Emergency Response Commissions
SIC -	Standard Industrial Classification
SO_2 -	Sulfur Dioxide
TOC -	Total Organic Carbon
TRI -	Toxic Release Inventory
TRIS -	Toxic Release Inventory System
TCRIS -	Toxic Chemical Release Inventory System
TSCA -	Toxic Substances Control Act
TSS -	Total Suspended Solids
UIC -	Underground Injection Control (SDWA)
UST -	Underground Storage Tanks (RCRA)
VOCs -	Volatile Organic Compounds

FABRICATED METAL PRODUCTS
(SIC 34)

I. INTRODUCTION OF THE SECTOR NOTEBOOK PROJECT

I.A. Summary of the Sector Notebook Project

Environmental policies based upon comprehensive analysis of air, water, and land pollution are an inevitable and logical supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, enforcement and compliance assurance, education/outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water, and land) affect each other, and that environmental strategies must actively identify and address these inter-relationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition of the need to develop the industrial "sector-based" approach within the EPA Office of Compliance led to the creation of this document.

The Sector Notebook Project was initiated by the Office of Compliance within the Office of Enforcement and Compliance Assurance (OECA) to provide its staff and managers with summary information for eighteen specific industrial sectors. As other EPA offices, States, the regulated community, environmental groups, and the public became interested in this project, the scope of the original project was expanded. The ability to design comprehensive, common sense environmental protection measures for specific industries is dependent on knowledge of several inter-related topics. For the purposes of this project, the key elements chosen for inclusion are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; Federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community, and the public.

For any given industry, each topic listed above could alone be the subject of a lengthy volume. However, in order to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is available. Text within each profile was researched from a variety of sources, and was usually condensed from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be further explored based upon the citations and references listed at the end of this profile. As a check on the information included, each notebook went through an external review process. The Office of Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate, and up-to-date summaries. Many of those who reviewed this notebook are listed as contacts in Section IX and may be sources of additional information. The individuals and groups on this list do not necessarily concur with all statements within this notebook.

I.B. Additional Information

Providing Comments

OECA's Office of Compliance plans to periodically review and update the notebooks and will make these updates available both in hard copy and electronically. If you have any comments on the existing notebook, or if you would like to provide additional information, please send a hard copy and computer disk to the EPA Office of Compliance, Sector Notebook Project, 401 M St., SW (2223-A), Washington, DC 20460. Comments can also be uploaded to the Enviroene Bulletin Board or the Enviroene World Wide Web for general access to all users of the system. Follow instructions in Appendix A for accessing these data systems. Once you have logged in, procedures for uploading text are available from the on-line Enviroene Help System.

Adapting Notebooks to Particular Needs

The scope of the existing notebooks reflect an approximation of the relative national occurrence of facility types that occur within each sector. In many instances, industries within specific geographic regions or States may have unique characteristics that are not fully captured in these profiles. For this reason, the Office of Compliance encourages State and local environmental agencies and other groups to supplement or re-package the information included in this notebook to include more specific industrial and regulatory information that may be available. Additionally, interested States may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with State and local requirements. Compliance or technical assistance providers may also want to develop the "Pollution Prevention" section in more detail. Please contact the appropriate specialist listed on the opening page of this notebook if your office is interested in assisting us in the further development of the information or policies addressed within this volume.

If you are interested in assisting in the development of new notebooks for sectors not covered in the original eighteen, please contact the Office of Compliance at 202-564-2395.

II. INTRODUCTION TO THE FABRICATED METAL PRODUCTS INDUSTRY

This section provides background information on the size, geographic distribution, employment, production, sales, and economic condition of the Fabricated Metal Products industry. The types of facilities described within the document are also described in terms of their Standard Industrial Classification (SIC) codes. Additionally, this section contains a list of the largest companies in terms of sales.

II.A. Introduction, Background, and Scope of the Notebook

The fabricated metal products industry comprises facilities that generally perform two functions: forming metal shapes and performing metal finishing operations, including surface preparation. The Standard Industrial Classification (SIC) code 34 is composed of establishments that fabricate ferrous and nonferrous metal products and those that perform electroplating, plating, polishing, anodizing, coloring, and coating operations on metals. Since the main processes associated with this industry can be divided into three types of operations (i.e., metal fabrication, metal preparation, and metal finishing), this profile is organized by the techniques that fall within these three groups.

II.B. Characterization of the Fabricated Metal Products Industry

To provide a general understanding of this industry, information pertaining to the industry size and distribution, product characterization, and economic health and outlook is presented below. This information should provide a basic understanding of the facilities developing the products, the products themselves, and the economic condition of the industry.

II.B.1. Industry Size and Geographic Distribution

Variation in facility counts occur across data sources due to many factors, including reporting and definitional differences. This document does not attempt to reconcile these differences, but rather reports the data as they are maintained by each source.

The U.S. fabricated metal products industry comprises approximately 34,000 companies. Exhibit 1 lists the largest companies in selected metal fabricating industries. Companies are ranked by sales figures.

Exhibit 1
Metal Fabrication Companies

Company	Sales ($ Millions)	Number of Employees

SIC 3444 -- Sheet Metal Work		
Stolle Corp., Sidney, OH	480	4,600
Alcan Alum. Corp., Warren, OH	120	1,200
Nytronics, Inc., Pitman, NJ	110	2,000
Hart and Cooley Inc., Holland, MI	100	1,200
Syro Steel Co., Girard, OH	100	400
Consolidated Systems, Inc., Columbia,_SC	100	300
SIC 3465 -- Automotive Stampings		
Budd Co., Troy, MI	1,000	9,000
Douglas and Lomason Co., Farmington Hts., MI	391	5,800
Northern Engraving Corp., Sparta,_WI	280	3,000
Randall Textron Inc., Cincinnati, OH	210	2,000
SIC 3469 -- Metal Stampings		
Hexcel Corp., Pleasanton, CA	386	2,900
JSJ Corp., Grand Haven, MI	260	2,500
Mirro-Foley Co., Manitowoc, WI	210	2,000
Tempel Steel Co., Niles, IL	210	1,100
SIC 3499 -- Fabricated Metal Products		
Steel Technologies, Louisville, KY	155	500
R.D. Werner Company, Inc., Greenville, PA	150	1,600
BW/IP Int., Inc., Seal Div., Long Beach,_CA	104	400
LeFebure Corp., Cedar Rapids, IA	100	1,100
Dura Mech. Components, Inc., Troy,_MI	100	1,000

Source: Fabricators & Manufacturers Association, Intl.

Exhibits 2 and 3 show the distribution of employees and the total shipments for the metal finishing industry. A typical "job shop" (i.e., small, independently owned metal finishing company) employs 15 to 20 people and generates $800,000 to $1 million in annual gross revenues.

Exhibit 2
Number of Employees in Metal Finishing Industry

	1988	**1989**	**1990**	**1991**	**1992**
SIC 3471	76,300	76,600	73,200	66,600	65,400
SIC 3479	47,000	44,600	44,300	43,400	43,700
Total	123,300	121,200	117,500	110,000	109,100

Source: U.S. Department of Commerce, 1992 Census of Manufacturers.

Exhibit 3
Value of Shipments for Metal Finishing Establishments ($ Millions)

	1988	1989	1990	1991	1992
SIC 3471	4,324	4,452	4,513	4,124	4,726
SIC 3479	4,867	4,756	4,929	4,634	5,161
Total	9,191	9,208	9,442	8,758	9,887

Source: U.S. Department of Commerce, 1992 Census of Manufacturers.

Exhibits 4 and 5 list the largest companies in selected metal finishing industries. Companies are ranked by sales figures.

Exhibit 4
Inorganic Coating Job Shops

Company	Sales ($ Millions)	Number of Employees
Windsor Plastics, Evansville, IN	50	600
Crown City Plating, El Monte, CA	25	425
Pioneer Metal Finishing, Minneapolis,_MN	20-30	380
Metal Surfaces, Bell Gardens, CA	15-25	310
Victory Finishing Technologies, Inc., Providence, RI	15-25	245
State Plating, Inc., Elwood, IN	15-20	400

Source: "Large Plating Job Shops," Beverly A. Greaves, Products Finishing, April 1994.

Exhibit 5
Organic Coating Job Shops

Company	Sales ($ Millions)	Number of Employees
Metokote Corp., Lima, OH	25+	800
The Crown Group, Warren, MI	25+	659
Industrial Powder Coatings, Inc., Norwalk, OH	25+	620
PreFinish Metals, Chicago, IL	25+	600
E/M Corp., West Lafayette, IN	15-25	300
Chicago Finished Metals, Bridgeview, IL	25+	250
Linetec Co., Wausau, WI	10-15	200
B.L. Downey Co., Inc., Broadview, IL	10-15	175

Source: "Large Coating Job Shops," Beverly A. Greaves, Products Finishing, December 1994.

Between 1982 and 1987, the total number of independent metal finishers employing less than 20 employees declined slightly, while those employing more than 20 employees increased by a corresponding amount. Exhibit 6 shows the number and percent of metal finishers of various sizes.

Exhibit 6
Metal Finishing Establishments, by Size

	1987		1992	
Establishments With and Average of :	**Number of Companies**	**Percent Total**	**Number of Companies**	**Percent Total**
1 to 9 Employees	2481	47.1	2553	48.7
10 to 49 Employees	2262	43.0	2186	41.7
50 to 99 Employees	365+	6.9	381	6.8
100 to 249 Employees	137	2.6	356	2.4
250 or more Employees	20	0.4	127	0.4
Total	**5265**	**100.0**	**5603**	**100.0**

Source: Census of Manufacturers: 1992, U. S. Department of Commerce, Bureau of the Census.

Although the metal finishing industry is geographically diverse, the industry is concentrated in what are usually considered the most heavily industrialized regions in the United States (See Exhibit 7). This geographic concentration occurs in part because it is cost-effective for small metal finishing facilities to be located near their customer base.

Exhibit 7
Geographic Distribution of Fabricated Metal Products Industry

Source: Census of Manufacturers: 1987.

California has more establishments that produce metal-related products than any other State. California's establishments constitute 10.2 percent of the total establishments that produce fabricated structural metal (SIC_3441). In addition, California leads in the number of establishments of other related industries: 15.6 percent of the sheet metal work establishments (SIC_3444); 13 percent of the metal doors, sash, and trim establishments (SIC_3442); and 13.7 percent of the architectural metal work establishments (SIC_3446). California also has the majority of plating and polishing (SIC_3471) and metal coating and allied services (SIC_3479) establishments at 17.3 and 16.1 percent, respectively.

Michigan, Illinois, and Ohio have large numbers of various metal-related industries. Michigan has the largest number of companies in the screw machine products (SIC_3451) and automotive stampings (SIC_3465) industries, at 14 and 46.7 percent of the total companies in the United States, respectively. Illinois is home to 14.1 percent of companies that produce bolts, nuts, rivets, and washers (SIC 3452) and Ohio contains 12.6 percent of companies that produce iron and steel forgings (SIC_3462).

Establishments engaged primarily in metal finishing tend to be small, independently owned job shops, also are referred to as independent metal finishers. Establishments that conduct metal finishing operations as part of a larger manufacturing operation are referred to as "captive" metal finishers. Captive metal finishing facilities are approximately three times more numerous than independent metal finishers. Numerous similarities exist between the independent and captive facilities; for the purposes of this profile, they are considered part of one industry. In addition, the two segments have parallel ties with suppliers and customers. Captive operations may be more specialized in their operations, however, because they often work on a limited number of products and/or employ a limited number of processes. Independent metal finishers, on the other hand, tend to be less specialized in their operations because they may have many customers, often with different requirements.

II.B.2. Product Characterization

The Department of Commerce classification codes divide this industry by product and services. SIC code 34 is further divided as follows:

SIC 341	- Metal Cans and Shipping Containers
SIC 342	- Cutlery, Handtools, and General Hardware
SIC 343	- Heating Equipment, Except Electric and Warm Air, and Plumbing Fixtures
SIC 344	- Fabricated Structural Metal Products
SIC 345	- Screw Machine Products, and Bolts, Nuts, Screws, Rivets, and Washers
SIC 346	- Metal Forgings and Stampings
SIC 347	- Coating, Engraving, and Allied Services
SIC 348	- Ordnance and Accessories, Except Vehicles and Guided Missiles
SIC 349	- Miscellaneous Fabricated Metal Products.

II.B.3. Economic Trends

Most industries in SIC 34 are largely dependent upon the demands of other industries. For example, the success of the commercial construction industry is fundamental to the success of the fabricated structural metal industry; 95 percent of the output from the latter is consumed by the former. The general component-producing industries (e.g., screw machine products, industrial fasteners, etc.) display the same demand structure; the demand for such products is directly related to the demand for automobiles and public works construction.

Fabricated structural metal output declined two percent in 1993 due to a decrease in construction of office buildings, commercial structures, manufacturing facilities, and multi-family housing. Ninety-five percent of structural metal output is consumed by the construction industry. Low demand for structural metal is expected to continue, attributable to the recent overbuilding of commercial space and high levels of vacant office space. A slight increase in demand from the public sector (e.g., highway construction) is expected, however, which will positively influence demand for structural metal products. An increased demand for plumbing products is also likely, as the residential construction industry continues to grow.

Total shipments of general components (e.g., screw machine products, industrial fasteners, valves, and pipe fittings) increased by about 3.1 percent in 1993. Strong demand from the automotive sector, combined with increased demand from equipment and machinery manufacturers, were the major factors causing the increased shipments.

The two primary markets for metal finishing services are the automotive and electronics industries. As illustrated in Exhibit 8, consumer durables, aerospace, and the government also are large segments served by metal finishers.

Exhibit 8
Markets Served by Metal Finishers
Percent of 1992 Market

Source: Surface Finishing Market Research Board, Metal Finishing Industry Market Survey 1992-1993.
NOTE: Data includes both job and captive shops.

The sale of metal finishing services is also essentially a derived demand (i.e., sales depend entirely upon the production of other industries). However, sales by the metal finishing industry have not kept up with sales of the industries served.

In the last several years, many U.S. fastener (nuts, screws, bolts, rivets) companies have become more competitive in the global market by incorporating new technology into production lines to improve efficiency and quality. In 1993, U.S. exports of industrial fasteners edged up about 0.6 percent; Canada and Mexico were the largest importers. U.S. imports of industrial fasteners also increased 11 percent over the last several years. This is because demand in the U.S. out-paced production. The expansion of the U.S. automotive and residential construction sectors was a major factor in the increase in fastener imports.

Exports of U.S. valve and pipe fittings are also expected to grow. 1993 industry exports increased six percent compared with 1992 figures. Although Canada remains the principal foreign market, exports to Chile and the Philippines almost tripled, and exports to developing countries increased dramatically.

III. Industrial Process Description

This section describes the major industrial processes within the Fabricated Metal Products industry, including the materials and equipment used and the processes employed. The section is designed for those interested in gaining a general understanding of the industry, and for those interested in the inter-relationship between the industrial process and the topics described in subsequent sections of this profile: pollutant outputs, pollution prevention opportunities, and Federal regulations. This section does not attempt to replicate published engineering information that is available for this industry. Refer to Section IX for a list of reference documents that are available.

Specifically, this section contains a description of commonly used production processes, the associated raw materials, the byproducts produced or released, and the materials either recycled or transferred off-site. This discussion, coupled with schematic drawings of the identified processes, provides a concise description of where wastes may be produced in the process. This section also describes the potential fate (air, water, land) of these waste products.

III.A. Industrial Processes in the Fabricated Metal Products Industry

In view of the high cost of most new equipment and the relatively long lead time necessary to bring new equipment into operation, changes in production methods and products are made only gradually; even new process technologies that fundamentally change the industry are only adopted over long periods of time. In addition, the recent financial performance of the Fabricated Metal Products industry combined with the difficulty of raising funds in the bond market, have left many establishments with a limited ability to raise the capital necessary to purchase new equipment.

For the purposes of this profile, the industrial processes associated with the Fabricated Metal Products industry will be grouped into three categories: fabricated metal products; surface preparation; and metal finishing. Each category is discussed in greater depth in the following subsections.

III.A.1. Fabricated Metal Products

Once molten metal (ferrous or nonferrous) containing the correct metallurgical properties has been produced (see SIC 33, which comprises activities associated with the nonferrous metals industry), it is cast into a form that can enter various shaping processes. Recently, manufacturers have been using continuous casting techniques that allow the molten metal to be formed directly into sheets, eliminating interim forming stages. This section identifies some of the many forming and shaping methods used by the metal fabrication industry. In general, the metal may be heat treated or remain cold. Heat treating is the modification of the physical properties of a workpiece through the application of controlled heating and cooling cycles. Cold metal is formed by applying direct physical pressure to the metal.

Regardless of the forming method used, the metal fabricating process usually employs the use of cutting oils (e.g., ethylene glycol), degreasing and cleaning solvents, acids, alkalis, and heavy metals. The oils are typically used when forming and cutting the metal. The solvents (e.g., trichloroethane, methyl ethyl ketone), alkalines, and acids (e.g., hydrochloric, sulfuric) are used to clean the surface of the metals. The current trend in the industry is to use aqueous non-VOCs to clean the metals, whenever possible. The use of 1,1,1-trichloroethane and methyl ethyl ketone is declining.

Once molten metal is formed into a workable shape, shearing and forming operations are usually performed. Shearing operations cut materials into a desired shape and size, while forming operations bend or conform materials into specific shapes. Cutting or shearing operations include punching, piercing, blanking, cutoff, parting, shearing, and trimming. Basically, these operations produce holes or openings, or produce blanks or parts. The most common hole-making operation is punching. Cutoff, parting, and shearing are similar operations with different applications. The rate of production is highest in hot forging operations and lowest in simple bending and spinning operations.

Forming operations, as illustrated in Exhibit 9, shape parts by bending, forming, extruding, drawing, rolling, spinning, coining, and forging the metal into a specific configuration. Bending is the simplest forming operation; the part is simply bent to a specific angle or shape. Other types of forming operations produces both two- and three-dimensional shapes.

Exhibit 9
Forming Operations

Extruding is the process of forming a specific shape from a solid blank by forcing the blank through a die of the desired shape. Extruding can produce complicated and intricate cross-sectional shapes. In rolling the metal passes through a set or series of rollers that bend and form the part into the desired shape (See Exhibit_10). Coining is a process that alters the form of the part by changing its thickness to produce a three-dimensional relief on one or both sides of the part, like a coin.

Exhibit 10
Rolling

In drawing, a punch forces sheet stock into a die, where the desired shape is formed in the space between the punch and die. In spinning, pressure is applied to the sheet while it spins on a rotating form, forcing the sheet to acquire the shape of the form. Forging operations produce a specific shape by applying external pressure that either strikes or squeezes a heated blank into a die of the desired shape. Forging operations may be conducted on hot or cold metal using either single- or multi-stage dies.

Once shearing and forming activities are complete, the material is machined. Machining refines the shape of a workpiece by removing material from pieces of raw stock with machine tools. The principal processes involved in machining are drilling, milling, turning, shaping/planing, broaching, sawing, and grinding.

III.A.2. Surface Preparation

The surface of the metal may require preparation prior to applying a finish. Surface preparation, cleanliness, and proper chemical conditions are essential to ensuring that finishes perform properly. Without a properly cleaned surface, even the most expensive coatings will fail to adhere or prevent corrosion. Surface preparation techniques range from simple abrasive blasting to acid washes to complex, multi-stage chemical cleaning processes. Exhibit 11 provides a flow chart of a representative process used when preparing metal for electroplating. Various surface preparation methods are discussed below.

Exhibit 11
Process for Preparing Metal for Electroplating

Source: Metals Handbook, Ninth Edition; Volume 5, Surface Cleaning, Finishing, and Coating, 1982, American Society for Metals.

Some cleaning techniques involve the application of organic solvents to degrease the surface of the metal. Other techniques, emulsion cleaning, for example, use common organic solvents (e.g., kerosene, mineral oil, and glycols) dispersed in an aqueous medium with the aid of an emulsifying agent. Emulsion cleaning uses less chemical than solvent degreasing because the concentration of solvent is lower.

Alkaline cleaning may also be utilized for the removal of organic soils. Most alkaline cleaning solutions are comprised of three major types of components: (1) builders, such as alkali hydroxides and carbonates, which make up the largest portion of the cleaner; (2) organic or inorganic additives, which promote better cleaning or act to affect the metal surface in some way; and (3) surfactants. Alkaline cleaning is often assisted by mechanical action, ultrasonics, or by electrical potential (e.g., electrolytic cleaning).

Acid cleaning, or pickling, can also be used to prepare the surface of metal products by chemically removing oxides and scale from the surface of the metal. For instance, most carbon steel is pickled with sulfuric or hydrochloric acid, while stainless steel is pickled with hydrochloric or hydrofluoric acids, although hydrochloric acid may embrittle certain types of steel and is rarely used. The metal generally passes from the pickling bath through a series of rinses. Acid pickling is similar to acid cleaning, but is usually used to remove the scale from semi-finished mill products, whereas acid cleaning is usually used for near-final preparation of metal surfaces before electroplating, painting, and other finishing processes.

III.A.3. Metal Finishing

Surface finishing usually involves a combination of metal deposition operations and numerous finishing operations. A diagram depicting the general metal finishing process, including surface preparation, is provided in Exhibit 12. Wastes typically generated during these operations are associated with the solvents and cleansers applied to the surface and the metal-ion-bearing aqueous solutions used in the plating tanks. Metal-ion-bearing solutions are commonly based on hexavalent chrome, trivalent chrome, copper, gold, silver, cadmium, zinc, and nickel. Many other metals and alloys are also used, although less frequently. The cleaners (e.g., acids) may appear in process wastewater; the solvents may be emitted into the air, released in wastewater, or disposed of in solid form; and other wastes, including paints, metal-bearing sludges, and still bottom wastes, may be generated in solid form. Several of the many metal finishing operations are described below.

Exhibit 12
Overview of the Metal Finishing Process

Source: ***Sustainable Industry: Promoting Strategic Environmental Protection in the Industrial Sector, Phase 1 Report, U.S. EPA, OERR, June 1994.***

Anodizing

Anodizing is an electrolytic process which converts the metal surface to an insoluble oxide coating. Anodized coatings provide corrosion protection, decorative surfaces, a base for painting and other coating processes, and special electrical and mechanical properties. Aluminum is the most frequently anodized material. Common aluminum anodizing processes include: chromic acid anodizing, sulfuric acid anodizing, and boric-sulfuric anodizing. The sulfuric acid process is the most common method.

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

Chemical Conversion Coating

Chemical conversion coating includes chromating, phosphating, metal coloring, and passivating operations. Chromate conversion coatings are produced on various metals by chemical or electrochemical treatment. Solutions, usually containing hexavalent chromium and other compounds, react with the metal surface to form a layer containing a complex mixture of compounds consisting of chromium, other constituents, and base metal. Phosphate coatings may be formed by the immersion of steel, iron, or zinc-plated steel in a dilute solution of phosphate salts, phosphoric acid, and other reagents to condition the surfaces for further processing. They are used to provide a good base for paints and other organic coatings, to condition the surfaces for cold forming operations by providing a base for drawing compounds and lubricants, and to impart corrosion resistance to the metal surface.

Metal coloring involves chemically converting the metal surface into an oxide or similar metallic compound to produce a decorative finish such as a green or blue patina on copper or steel, respectively. Passivating is the process of forming a protective film on metals by immersion into an acid solution, usually nitric acid or nitric acid with sodium dichromate. Stainless steel products are often passivated to prevent corrosion and extend the life of the product.

Electroplating

Electroplating is the production of a surface coating of one metal upon another by electrodeposition. Electroplating activities involve applying predominantly *inorganic* coatings onto surfaces to provide corrosion resistance, hardness, wear resistance, anti-frictional characteristics, electrical or thermal conductivity, or decoration. Exhibit_13 illustrates the important parts of typical electroplating

equipment. The most commonly electroplated metals and alloys include: brass (copper-zinc), cadmium, chromium, copper, gold, nickel, silver, tin, and zinc.

In electroplating, metal ions in either acid, alkaline, or neutral solutions are reduced on the workpieces being plated. The metal ions in the solution are usually replenished by the dissolution of metal from solid metal anodes fabricated of the same metal being plated, or by direct replenishment of the solution with metal salts or oxides. Cyanide, usually in the form of sodium or potassium cyanide, is usually used as a complexing agent for cadmium and precious metals electroplating, and to a lesser degree, for other solutions such as copper and zinc baths.

Exhibit 13
Typical Electroplating Equipment

Source: McGraw Hill Encyclopedia of Science and Technology, Volume 6, 1987.

The sequence of steps in an electroplating includes: cleaning, often using alkaline and acid solutions; stripping of old plating or paint; electroplating; and rinsing between and after each of these operations. Sealing and conversion coating may be employed on the metals after electroplating operations.

Electroless Plating

Electroless plating is the chemical deposition of a metal coating onto a plastic object, by immersion of the object in a plating solution. Copper and nickel electroless plating is commonly used for printed circuit boards. The basic ingredients in an electroless plating solution are: a source of metal (usually a salt); a reducer; a complexing agent to hold the metal in solution; and various buffers and other chemicals designed to maintain bath stability and increase bath life. Immersion plating produces a thin metal deposit, commonly zinc or silver, by chemical displacement. Immersion plating baths are usually formulations of metal salts, alkalis, and complexing agents (e.g., lactic, glycolic, malic acid salts). Electroless plating and immersion plating commonly generate more waste than other plating techniques, but individual facilities vary significantly in efficiency. Exhibit 13 illustrates a typical plating process.

Exhibit 14
Electroless Plating Process

Source: Pollution Prevention and Control Technology for Plating Operations, First Edition, National Center for Manufacturing Sciences and National Association of Metal Finishers, 1994.

Painting

Painting involves the application of predominantly *organic* coatings to a workpiece for protective and/or decorative purposes. It is applied in various forms, including dry powder, solvent-diluted formulations, and water-borne formulations. Various methods of application are used, the most common being spray painting and electrodeposition. Spray painting is a process by which paint is placed into a pressurized cup or pot and is atomized into a spray pattern when it is released from the vessel and forced through an orifice. Electrodeposition is the process of coating a workpiece by either making it anodic or cathodic in a bath that is generally an aqueous emulsion of the coating material. When applying the paint as a dry powder, some form of heating or baking is necessary to ensure that the powder adheres to the metal. These processes may result in solvent waste (and associated still bottom wastes generated during solvent distillation), paint sludge wastes, paint-bearing wastewaters, and paint solvent emissions.

Other Metal Finishing Techniques

Polishing, hot dip coating, and etching are processes that are also used to finish metal. Polishing is an abrading operation used to remove or smooth out surface defects (scratches, pits, or tool marks) that adversely affect the appearance or function of a part. Following polishing operations, area cleaning and washdown can produce metal-bearing wastewaters. Hot dip coating is the coating of a metallic workpiece with another metal to provide a protective film by immersion into a molten bath. Galvanizing (hot dip zinc) is a common form of hot dip coating. Water is used for rinses following precleaning and sometimes for quenching after coating. Wastewaters generated by these operations often contain metals. Etching produces specific designs or surface appearances on parts by controlled dissolution with chemical reagents or etchants. Etching solutions commonly comprise strong acids or bases with spent etchants containing high concentrations of spent metal. The solutions include ferric chloride, nitric acid, ammonium persulfate, chromic acid, cupric chloride, and hydrochloric acid.

III.B. Raw Material Inputs and Pollution Outputs in the Production Line

The material inputs and pollution outputs resulting from metal fabrication, surface preparation, and metal finishing processes are presented by media in Exhibit 15. Exhibit 16 illustrates the general processes associated with this industry, the pollutants generated, and the point in the process at which the pollutants are produced.

Exhibit 15
Process Materials Inputs and Outputs

Process	Material Input	Air Emission	Process Wastewater	Solid Waste
Metal Shaping				
Metal Cutting and/or Forming	Cutting oils, degreasing and cleaning solvents, acids, alkalis, and heavy metals	Solvent wastes (e.g., 1,1,1-trichloroethane, acetone, xylene, toluene, etc.)	Waste oils (e.g., ethylene glycol) and acid (e.g., hydrochloric, sulfuric, nitric), alkaline, and solvent wastes	Metal chips (e.g., scrap steel and aluminum), metal-bearing cutting fluid sludges, and solvent still-bottom wastes
Surface Preparation				
Solvent Degreasing and Emulsion, Alkaline, and Acid Cleaning	Solvents, emulsifying agents, alkalis, and acids	Solvents (associated with solvent degreasing and emulsion cleaning only)	Solvent, alkaline, and acid wastes	Ignitable wastes, solvent wastes, and still bottoms
Surface Finishing				
Anodizing	Acids	Metal-ion-bearing mists and acid mists	Acid wastes	Spent solutions, wastewater treatment sludges, and base metals
Chemical Conversion Coating	Metals and acids	Metal-ion-bearing mists and acid mists	Metal salts, acid, and base wastes	Spent solutions, wastewater treatment sludges, and base metals
Electroplating	Acid/alkaline solutions, heavy metal bearing solutions, and cyanide bearing solutions	Metal-ion-bearing mists and acid mists	Acid/alkaline, cyanide, and metal wastes	Metal and reactive wastes
Plating	Metals (e.g., salts), complexing agents, and alkalis	Metal-ion-bearing mists	Cyanide and metal wastes	Cyanide and metal wastes
Painting	Solvents and paints	Solvents	Solvent wastes	Still bottoms, sludges, paint solvents, and metals
Other Metal Finishing Techniques (Including Polishing, Hot Dip Coating, and Etching)	Metals and acids	Metal fumes and acid fumes	Metal and acid wastes	Polishing sludges, hot dip tank dross, and etching sludges

Exhibit 16
Fabricated Metal Products Manufacturing Processes

III.B.1. Metal Fabrication

Each of the metal shaping processes can result in wastes containing chemicals of concern. For example, the application of solvents to metal and machinery results in air emissions. Additionally, wastewater containing acidic or alkaline wastes and waste oils, and solid wastes, such as metals and solvents, are usually generated during this process.

Metal fabrication facilities are major users of solvents for degreasing. In cases where solvents are used solely in degreasing (not used in any other plant operations), records of the amount and frequency of purchases provide enough information to estimate emission rates, based on the assumption that all solvent purchased is eventually emitted. Section V.D., Pollution Prevention Options, illustrates techniques that may be used to reduce the loss of solvents to the atmosphere.

Metalworking fluids are applied to either the tool or the metal being tooled to facilitate the shaping operation. Metalworking fluid is used to:

- Control and reduce the temperature of tools and aid lubrication,
- Control and reduce the temperature of workpieces and aid lubrication,
- Provide a good finish,
- Wash away chips and metal debris, and
- Inhibit corrosion or surface oxidation.

Fluids resulting from this process typically become spoiled or contaminated with extended use and reuse. In general, metal working fluids can be petroleum-based, oil-water emulsions, and synthetic emulsions. When disposed, these fluids may contain high levels of metals (e.g., iron, aluminum, and copper). Additional contaminants present in fluids resulting from these processes include acids and alkalis (e.g., hydrochloric, sulfuric, nitric), waste oils, and solvent wastes.

Scrap metal may consist of metal removed from the original piece (e.g., steel), and may be combined with small amounts of metalworking fluids (e.g., solvents) used prior to and during the metal shaping operation that generates the scrap. Quite often, this scrap is reintroduced into the process as a feedstock. The scrap and metalworking fluids, however, should be tracked since they may be regulated as solid wastes.

III.B.2. Surface Preparation

Surface preparation activities usually result in air emissions, contaminated wastewater, and solid wastes. The primary air emissions from cleaning are due to the evaporation of chemicals from solvent degreasing and emulsion cleaning processes. These emissions may result through volatilization of solvents during storage, fugitive losses during use, and direct ventilation of fumes.

Wastewaters generated from cleaning are primarily rinse waters, which are usually combined with other metal finishing wastewaters (e.g., electroplating) and treated on-site by conventional hydroxide precipitation. Solid wastes (e.g., wastewater treatment sludges, still bottoms, cleaning tank residues, machining fluid residues, etc.) may also be generated by the cleaning operations. For example, solid wastes are generated when cleaning solutions become ineffective and are replaced. Solvent-bearing wastes are typically pre-treated to comply with any applicable National Pollutant Discharge System (NPDES) permits and then sent off-site, while aqueous wastes from alkaline and acid cleaning , which do not contain solvents, are often treated on-site.

III.B.3. Metal Finishing

Many metal finishing operations are typically performed in baths (tanks) and are then followed by rinsing cycles. Exhibit 17 illustrates a typical chemical or electrochemical process step in which a workpiece enters the process bath containing process chemicals that are carried to the rinse water (drag-out). Metal plating and related waste account for the largest volumes of metal- (e.g., cadmium, chromium, copper, lead, and nickel) and cyanide-bearing wastes. Painting operations account for the generation of solvent-bearing wastes and the direct release of solvents (including benzene, methyl ethyl ketone, methyl isobutyl ketone, toluene, and xylene). Paint cleanup operations may contribute to the release of chlorinated solvents (including carbon tetrachloride, methylene chloride, 1,1,1-trichloroethane, and perchloroethylene). Compliance with one law through emission or effluent controls may generate waste regulated under another statute (e.g., effluent controls required by the Clean Water Act may generate sludges which are regulated by the Resource Conservation and Recovery Act). The nature of the wastes produced by these processes is discussed further below.

Exhibit 17
Typical Metal Finishing Process Step

Source: Guides to Pollution Prevention: The Metal Finishing Industry, U.S. EPA, ORD, October 1992.

Anodizing

Anodizing operations produce air emissions, contaminated wastewaters, and solid wastes. Mists and gas bubbles arising from heated fluids are a source of air emissions, which may contain metals or other substances present in the bath. When dyeing of anodized coatings occurs, wastewaters produced may contain nickel acetate, non-nickel sealers, or substitutes from the dye. Other potential pollutants include complexers and metals from dyes and sealers. Wastewaters generated from anodizing are usually combined with other metal finishing wastewaters and treated on-site by conventional hydroxide precipitation. Wastewaters containing chromium must be pretreated to reduce hexavalent chromium to its trivalent state. The conventional treatment process generates a sludge that is usually sent off-site for metals reclamation and/or disposal.

Solid wastes generated from anodizing include spent solutions and wastewater treatment sludges. Anodizing solutions may be contaminated with the base metal being processed due to the anodic nature of the process. These solutions eventually reach an intolerable concentration of dissolved metal and require processing to remove the dissolved metal to a tolerable level or treatment/disposal.

Chemical Conversion Coating

Chemical conversion coating generally produces contaminated wastewaters and solid waste. Pollutants associated with these processes enter the wastestream through rinsing and batch dumping of process baths. The process baths usually contain metal salts, acids, bases, and dissolved basis materials. Wastewaters containing chromium are usually pretreated to reduce hexavalent chromium to its trivalent state. The conventional treatment process generates a sludge that is sent off-site for metals reclamation and/or disposal. Solid wastes generated from these processes include spent solutions and wastewater treatment sludges. Conversion coating solutions may also be contaminated with the base metal being processed. These solutions will eventually reach an intolerable concentration of dissolved metal and require processing to remove the dissolved metal to a tolerable level.

Electroplating

Electroplating operations produce air emissions, contaminated wastewaters and solid wastes. Mists arising from electroplating fluids and process gases can be a source of air emissions, which may contain metals or other substances present in the bath. The industry has recently begun adding fume suppressants to electroplating baths to reduce air emissions of chromium, one of the most frequently electroplated metals. The fume suppressants lower the surface tension of the bath, which prevents hydrogen bubbles in the bath from bursting and producing a chromium-laden mist. The fume suppressants are highly effective when used in decorative plating, but less effective when used in hard-chromium plating. Contaminated wastewaters result from workpiece rinsing and process cleanup waters. Rinse waters from electroplating are usually combined with other metal finishing wastewaters and treated on-site by conventional hydroxide precipitation. Wastewaters containing chromium must be pretreated to reduce hexavalent chromium to its trivalent state. These wastewater treatment techniques can result in solid-phase wastewater treatment sludges. Other wastes generated from electroplating include spent solutions which become contaminated during use, and therefore, diminish performance of the process. In addition to these wastes, spent process solutions and quench bathes may be discarded periodically when the concentrations of contaminants inhibit proper function of the solution or bath.

Electroless Plating

Electroless plating produces contaminated wastewater and solid wastes. The spent plating solution and rinse water are usually treated chemically to precipitate out the toxic metals and to destroy the cyanide. Electroless plating solutions can be difficult to treat; settling and simple chemical precipitation are not effective at removing the chelated metals used in the plating bath. The extent to which plating solution carry-over adds to the wastewater and enters the sludge depends on the type of article being plated and the specific plating method employed. However, most sludges may contain significant concentrations of toxic metals, and may also contain complex cyanides in high concentrations if cyanides are not properly isolated during the treatment process.

Painting

Painting operations result in emissions, contaminated wastewaters, and the generation of liquid and solid wastes. Atmospheric emissions consist primarily of the organic solvents used as carriers for the paint. Emissions also result from paint storage, mixing, application, and drying. In addition, cleanup processes can result in the release of organic solvents used to clean equipment and painting areas. Wastewaters are often generated from painting processes due primarily to the discharge of water from water curtain booths. On-site treatment processes to treat contaminated wastewater generate a sludge that is sent off-site for disposal. Sources of solid- and liquid-phase wastes include:

- Paint application emissions control devices (e.g., paint booth collection systems, ventilation filters, etc.)
- Equipment washing
- Disposal materials used to contain paint and overspray
- Excess paints discarded upon completion of a painting operation or after expiration of the paint shelf-life.

These solid and liquid wastes may contain metals from paint pigments and organic solvents, such as paint solvents and cleaning solvents. Still bottoms also contain solvent wastes. The cleaning solvents used on painting equipment and spray booths may also contribute organic solid waste to the wastes removed from the painting areas.

Other Metal Finishing Techniques

Wastewaters are often generated during other metal finishing processes. For example, following polishing operations, area cleaning and washdown can produce metal-bearing wastewaters. Hot dip coating techniques, such as galvanizing, use water for rinses following pre-cleaning and sometimes for quenching after coating. Hot dip coatings also generate solid waste, anoxide dross, that is periodically skimmed off the heated tank. These operations generate metal-bearing wastewaters. Etching solutions are comprised of strong acids (e.g., ferric chloride, nitric acid, ammonium persulfate) or bases. Resulting spent etchant solutions may contain metals and acids.

III.C. Management of Chemicals in Wastestream

The Pollution Prevention Act of 1990 (EPA) requires facilities to report information about the management of TRI chemicals in waste and efforts made to eliminate or reduce those quantities. These data have been collected annually in Section 8 of the TRI reporting Form R beginning with the 1991 reporting year. The data summarized below cover the years 1992-1995 and is meant to provide a basic understanding of the quantities of waste handled by the industry, the methods typically used to manage this waste, and recent trends in these methods. TRI waste management data can be used to assess trends in source reduction within individual industries and facilities, and for specific TRI chemicals. This information could then be used as a tool in identifying opportunities for pollution prevention compliance assistance activities.

While the quantities reported for 1992 and 1993 are estimates of quantities already managed, the quantities reported for 1994 and 1995 are projections only. The EPA requires these projections to encourage facilities to consider future waste generation and source reduction of those quantities as well as movement up the waste management hierarchy. Future-year estimates are not commitments that facilities reporting under TRI are required to meet.

Exhibit 18 shows that the fabricated metals industry managed about 798 million pounds of production-related waste (total quantity of TRI chemicals in the waste from routine production operations) in 1993 (column B). Column C reveals that of this production-related waste, 34 percent was either transferred off-site or released to the environment. Column C is calculated by dividing the total TRI transfers and releases by the total quantity of production-related waste. In other words, about 62 percent of the industry's TRI wastes were managed on-site through recycling, energy recovery, or treatment as shown in columns D, E and F, respectively. The majority of waste that is released or transferred off-site can be divided into portions that are recycled off-site, recovered for energy off-site, or treated off-site as shown in columns G, H, and I, respectively. The remaining portion of the production-related wastes (13.2 percent), shown in column J, is either released to the environment through direct discharges to air, land, water, and underground injection, or it is disposed off-site.

From the yearly data presented below it is apparent that the portion of TRI wastes reported as recycled on-site is projected to decrease and the portions treated or managed through energy recovery on-site have increased between 1992 and 1995 (projected).

Exhibit 18
Source Reduction and Recycling Activity for SIC 34

A	B	C	D	E	F	G	H	I	J
Year	**Production Related Waste Volume (10^6lbs.)***	% Reported as Released and Transferred	**On-Site**			**Off-Site**			**Remaining Releases and Disposal**
			% Recycled	% Energy Recovery	% Treated	% Recycled	% Energy Recovery	% Treated	
1992	750	38%	23.22%	12.24%	23.11%	26.03%	1.57%	2.02%	12.05%
1993	798	34%	26.48%	11.04%	24.24%	21.31%	1.54%	2.10%	13.28%
1994	735	—	27.91%	8.90%	26.33%	22.18%	1.53%	2.32%	10.84%
1995	697	—	19.20%	13.86%	27.78%	23.94%	1.63%	2.46%	11.13%