EPA/530-SW-89-056

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Pollution Prevention In Metal Manufacturing

Saving Money Through Pollution Prevention

U.S. Environmental Protection Agency
Office of Solid Waste

October 1989

Preface

Pollution Prevention in Metal Manufacturing is intended to provide you with a brief introduction to pollution prevention, including what it is, how it can put money back into your company's pocket, what its basic elements are, and where you can get additional assistance. This booklet also provides a sample of the various technical options available to a wide range of metal manufacturing facilities. Typical economics (for example, capital investment, annual savings, and payback periods) are also provided for many of the options.

The technical and economic information in *Pollution Prevention in Metal Manufacturing* is intended to be representative more than comprehensive. The collection and organization of this information is an ongoing and evolutionary process. The first version of this booklet reflects a sampling of information readily available at the time of preparation. As more pollution prevention activity takes place and technical approaches to pollution prevention change, EPA hopes to update and publish follow-up versions of this booklet.

Pollution Prevention in Metal Manufacturing is only one of many sources of pollution prevention information available to you from EPA. For additional information about pollution prevention, or to comment on this booklet, call:

- The RCRA/Superfund Hotline, at (800) 424-9346, or (202) 382-3000;
- Myles Morse, of EPA's Pollution Prevention Information Clearinghouse, at (202) 475-7161; or
- James Lounsbury, Director of EPA's Waste Minimization Staff, at (202) 382-4807.

The Purpose of this Booklet

If your metal manufacturing operations generate any wastes, the information in this booklet can help your firm.

POLLUTION PREVENTION CAN:

- Significantly reduce your firm's costs, liabilities, and regulatory burdens associated with waste management; and
- Enhance your firm's efficiency, product quality, and public image.

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The United States Environmental Protection Agency (EPA) developed this booklet to help your firm implement a pollution prevention program. It highlights the various components of a pollution prevention program. It also provides two tables to help you identify specific pollution prevention options, based on the types of processes or operations at your facility. The tables contain technical, cost, and waste reduction information on a variety of options that have actually been used at metal manufacturing facilities. The information contained in the tables will help you evaluate potential annual savings from numerous pollution prevention techniques.

The Information in this Booklet Will Be Helpful to Your Company

This booklet is designed to be most useful to firms that engage in metal manufacturing operations. You should read this booklet if your firm manufactures metal products, or is involved in any metal manufacturing-type processes.

METAL MANUFACTURING INCLUDES:

- Cutting or machining
- Degreasing
- Pickling
- Heat treating
- Finishing or painting
- Equipment and facility cleanup
- Electroplating

This booklet will also be useful if your facility uses any combustible or flammable solvents, strong acid or alkaline solutions, plating solutions, paints, cyanide solutions, or any solutions containing heavy metals. Table I identifies how these materials are typically used and Table II shows what many facilities have done to save money.

Your Company Can Save Money by Minimizing the Waste it Generates

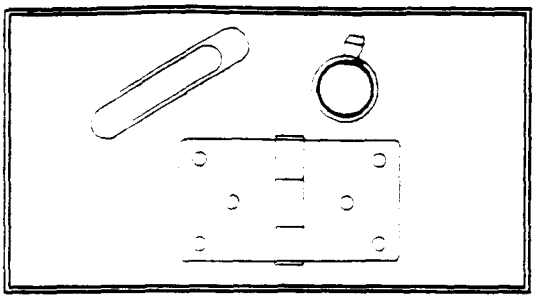
In addition to relying on traditional waste management approaches (such as treating or disposing of waste after it has been generated), many facility managers are finding that by minimizing the amount of waste their operations generate they can actually improve their firm's "bottom line."

POLLUTION PREVENTION REDUCES:

- Aggregate costs for raw materials
- Treatment/disposal costs
- Environmental liability and fines

In addition to these economic incentives for pollution prevention, EPA is taking several steps to create additional incentives for firms to reduce their waste generation. Some of EPA's actions include:

- Making technical information available to help firms identify ways of reducing waste generation.
- Supporting the development of State programs to assist firms in their waste reduction efforts.



- Requiring hazardous waste generators, under the Resource Conservation and Recovery Act (RCRA), to certify on their hazardous waste manifests and annual permit reports that they have a "program-in-place" to reduce the volume or quantity and toxicity of their hazardous wastes as much as economically practical.

- Requiring generators to describe on their RCRA biennial reports the efforts they have undertaken during the year to reduce the volume and toxicity of their hazardous waste, and to compare these efforts to previous years.

What is "Pollution Prevention?"

Pollution prevention emphasizes reducing or eliminating any releases of hazardous materials (including hazardous wastes) into the environment through the use of *source reduction* and environmentally-sound *recycling*. A pollution prevention program can be developed by any business that generates wastes. The program might include several elements intended to reduce, to the extent feasible, any air or water discharges, or any solid or hazardous waste that is generated at the facility.

Source reduction is intended to minimize or eliminate the waste at its source, before it is generated or released. *Recycling*, on the other hand, focuses on the *use*, *reuse*, or *reclamation* of the waste as an effective substitute for a commercial product or as an ingredient or feedstock in a process. Recycling by use or reuse involves returning a waste material to either the originating process or another process as a substitute for an input material. Reclamation is the recovery of a valuable material, or removal of impurities, from a waste.

Because it is significantly more efficient and less expensive to prevent the generation of waste in the first place, you should consider source reduction to be the most preferable waste management option. Source reduction is followed, in order of decreasing preference, by recycling, treatment (for example, incineration or stabilization), and land disposal.

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POLLUTION PREVENTION TERMS

Pollution Prevention - Reducing or eliminating discharges and/or emissions to the environment through the use of *source reduction* and environmentally-sound *recycling*.

Source Reduction - Reducing or eliminating waste at its point of generation.

Recycling - Reprocessing waste in a way that makes it useful again. Recycling focuses on the *use*, *reuse*, or *reclamation* of waste.

Use or Reuse - Returning a waste material to the original process that generated the waste or employing it in another process as a substitute for an input material.

Reclamation - Recovering valuable materials or removing impurities from a waste.

Many Pollution Prevention Options Are Available

A pollution prevention program might include any number of specific pollution prevention techniques, each with a potentially unlimited range of pollution prevention options. The options under each technique that may be appropriate to your operation are limited only by your ingenuity. Table II provides suggested pollution prevention options that have actually been used in industry. The options are organized by technique. You should use these suggested options only as a starting point for your own creativity. Pollution prevention techniques are described below:

- *Training and supervision* -- provide employees with the information and the incentive necessary to minimize waste generation in their daily duties.

  This technique may include ensuring that employees know and practice

proper and efficient use of tools and supplies, and that they are aware of, understand, and support your company's pollution prevention goals.

- *Production planning and sequencing* -- plan and sequence production so that only necessary operations are performed and that no operation is needlessly "undone" by a following operation.

  One example is to sort out "reject" parts prior to painting or electroplating. A second example is to reduce the frequency of having to clean equipment (e.g., painting all products of the same color at once). A third example is to schedule batch processing in a manner that allows the wastes or residues from one batch to be used as an input for the subsequent batch (e.g., to schedule paint formulation from lighter shades to darker) so that equipment need not be cleaned between batches.

- *Process or equipment modification* -- change the process, or the parameters or equipment used in that process, to reduce the amount of waste generated.

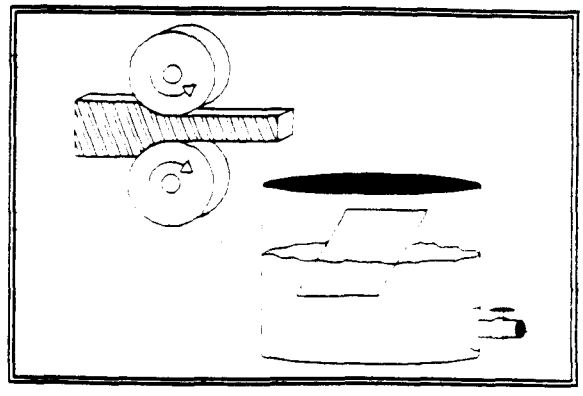
  You can change to a paint application technique that is more efficient than spray painting, reduce overspray by reducing the atomizing air pressure to paint spraying equipment, reduce drag-out by reducing the withdrawal speed of parts from plating tanks, or improve a plating line by incorporating dragout recovery tanks or reactive rinsing.

- *Raw material substitution* -- replace existing raw materials with raw materials that will result in the generation of less waste.

  Examples include substituting alkali washes for solvent degreasers, and replacing oil with lime or borax soap as the drawing agent in cold forming operations.

- *Loss prevention and housekeeping* -- perform preventative maintenance and manage equipment and materials so as to minimize opportunities for leaks, spills, and other releases of potentially hazardous wastes.

  For example, clean spray guns in a manner that does not damage leather



  packings and subsequently causes the guns to leak; or place drip pans under leaking machinery to allow recovery of the leaking fluid.

- *Waste segregation and separation* -- avoid mixing *different types* of wastes, and mixing hazardous wastes with non-hazardous wastes. This technique makes the recovery of hazardous wastes easier by minimizing the number of different hazardous constituents in any given waste stream. Also, it prevents the contamination of non-hazardous wastes.

  For example, segregate scrap metal by metal type, and segregate different kinds of used oils.

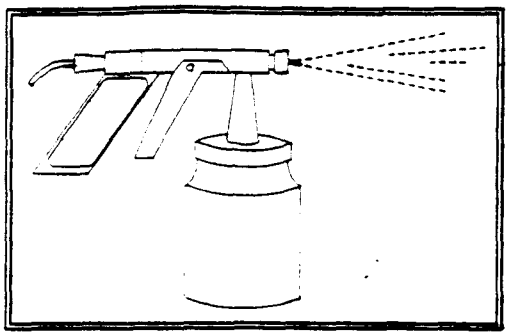
- *Recycling* -- use or reuse a waste as an effective substitute for a commercial product or as an ingredient or feedstock. Recycling can be on-site, or it can be off-site through another user or a waste exchange.

  Examples of recycling include using a small on-site still to recover degreasing solvents, and selling waste pickling acids as feedstocks for fertilizer manufacturing.

The Elements of a Successful Pollution Prevention Program

Experience demonstrates that successful pollution prevention programs share [illegible] common elements. These elements are described below:

- *Support from top management* -- Support for a pollution prevention program should



be clearly affirmed by your top management in a written statement. This statement should be circulated among all employees.

- *Explicit program goals and objectives* -- Explicitly identify the goals and objectives for the pollution prevention program in a written statement. The goals should include reducing the volume or toxicity of the waste as much as is technically and economically feasible. The objectives should include a commitment to evaluate technologies, procedures, and personnel training.

- *Accurate waste accounting* -- Carefully track changes over time in the types, amounts, and hazardous constituents of your wastes.

- *Accurate cost accounting* -- Ensure that your firm uses "fully-loaded" costs when accounting for waste management and disposal (i.e., costs should account for all liability, regulatory compliance, permitting, hauling, treatment, and oversight costs).

- *Involvement of all employees* -- Involve all appropriate employees in pollution prevention planning and implementation. You can use rewards and incentives to encourage employee involvement.

- *Exchange of technology and information* -- Encourage exchange of technology and information both within your firm *and* between your firm and others. Firms often contain a wealth of resources and information that results from years of operating experience. Such resources and information can play a major role in the efficient development of a pollution prevention program. Other organizations you should consult include EPA Region's and Headquarter's pollution prevention information clearinghouses, state agencies, trade associations, universities and colleges, nonprofit business assistance organizations, and professional consultants.

- *Periodic pollution prevention assessments* - - Periodically review individual processes (or facilities) to identify new or changing opportunities to undertake pollution prevention.

Basically, you should develop your own program for pollution prevention, and wherever possible, formally define the program in a written document. You should also develop an implementation plan for each of your facilities or processes and periodically review, revise, and update the program to reflect changing conditions. You will need a method of tracking changes in waste generation rates and accounting for sources of waste. Establishing an effective pollution prevention program is not difficult, but it does require commitment from you and all of your firm's employees, including corporate management.

Where To Go For Information and Help

While it is important that *you* be actively involved in establishing and promoting your firm's pollution prevention program, you may wish to seek the guidance or help of other experts. Some organizations that you may wish to contact include:

- *Trade Associations* -- Often trade associations can provide you with pollution prevention assistance directly, or they can refer you to someone who can.

- *State Waste Management Agencies* -- These agencies often have staff people who are knowledgeable about pollution prevention and are willing to provide assistance.

- *Regional Environmental Protection Agency Offices* -- There are ten Regional Offices of the Environmental Protection Agency. The easiest way to find out which Regional Office is responsible for your area is to call the toll free RCRA/Superfund Hotline (see below) and ask for the telephone number or address of the Regional Office responsible for your area.

- *Environmental Protection Agency* -- Within EPA Headquarters you may conveniently contact any of the following information sources:

Hazardous Waste Minimization Staff, at (202) 382-4807, can provide technical waste minimization information;

Waste Minimization Branch, at (513) 569-7529, can assist you with research and development activities regarding waste minimization assessments, innovative technology and pollution prevention evaluations, and activities of the Waste Reduction Institute for Scientists and Engineers;

Pollution Prevention Office, at (202) 382-4335, can assist you in understanding pollution prevention and provide you with a great deal of pollution prevention information; and the

Pollution Prevention Information Clearinghouse, which includes a collection of reference literature pertaining to pollution prevention, outreach efforts, the Electronic Information Exchange System, and the RCRA/Superfund Hotline:

> Electronic Information Exchange System (EIES), at (301) 589-8366, is an easy-to-use, interactive PC-based system. Using a personal computer and a modem, you can access EIES to obtain a wide variety of pollution prevention information, including case studies, a calendar of events, a directory of experts, a bibliography of publications, and descriptions of federal and state pollution prevention programs. You can use an interactive message center to pose pollution prevention questions or provide comments to other users. The information in Table II that is followed by an "EIES Number" has come from references that are available to you through EIES. You may examine these references for additional pollution prevention information or ideas.
>
> RCRA/Superfund Hotline, at (800) 424-9346 (or (202) 382-3000), can answer your pollution prevention questions, help you access information in EIES, and assist you in searching for and obtaining documents.

HAVE YOU TRIED POLLUTION PREVENTION?

If you have tried, or are planning on trying any pollution prevention activity at your facility and would like to share your ideas or experience, use your personal computer to access the Electronic Information Exchange System (EIES) at (301) 589-8366, and let others know! We can all learn from your experience!

How To Use the Pollution Prevention Tables

Two tables are included in this booklet as a quick guide to help you begin identifying specific pollution prevention options. The ideas represented in these tables have been used at actual facilities, resulting in cost savings. Table I identifies typical processes and operations in the metal manufacturing industry. This table also identifies typical materials used and types of waste generated for each process.

Table II is also broken down by process and operation. Table II, however, provides pollution prevention options for each process and operation. These pollution prevention options are organized by technique, as described in the previous section. In addition, Table II provides examples of cost and savings realized by other facilities, and additional relevant information.[1] You should use this information to help decide which options would best serve your needs. When properly installed and maintained, none of the options described on Table II should adversely affect the quality of your products and all should reduce your potential liability from improper waste management. The entries in Table II that are followed by an "EIES Number" have come from references that are available to you through EIES. You may request and examine these references for additional pollution prevention information or ideas.

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[1]The cost, savings, and waste reduction information provided in Table II is based on actual case studies and reflects the successes of actual metal manufacturing facilities. Because specific applications are highly variable, however, you should use this information only as an indicator of how a particular pollution prevention option may perform under your circumstances.

TABLE I

TYPICAL METAL MANUFACTURING OPERATIONS WHICH MAY PRODUCE WASTES

TYPICAL PROCESS OR OPERATION	TYPICAL MATERIALS USED	GENERAL TYPES OF WASTE GENERATED
Metal Cutting or Machining	• Cutting oils • Degreasing and cleaning solvents • Acids • Heavy metals	• Acid/alkaline wastes • Heavy metal wastes • Solvent wastes • Waste oils
Degreasing	• Acid/alkaline cleaners • Organic solvents	• Acid/alkaline wastes • Ignitable wastes • Solvent wastes • Still bottoms
Pickling	• Acid/alkaline solutions	• Acid/alkaline wastes • Heavy metal wastes
Heat Treating	• Acid/alkaline solutions • Cyanide salts • Oils	• Acid/alkaline wastes • Cyanide wastes • Heavy metal wastes • Waste oils
Metal Finishing and Painting Cleanup	• Solvents • Paint carrier fluids	• Heavy metal paint wastes • Ignitable paint wastes • Solvent wastes • Still bottoms
Facility Cleanup	• Cleaning solvents	• Solvent wastes • Still bottoms
Electroplating	• Acid/alkaline solutions • Heavy metal bearing solutions • Cyanide bearing solutions	• Acid/alkaline wastes • Cyanide wastes • Heavy metal wastes • Plating wastes • Reactive wastes • Wastewaters

TABLE II

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
METAL CUTTING OR MACHINING		
Production Planning and Sequencing	Improve scheduling of processes that require use of varying oil types in order to reduce the number of cleanouts.	
Process or Equipment Modification	Standardize the oil types used for machining, turning, lathing, etc. This reduces the number of equipment cleanouts, and the amount of leftovers and mixed wastes.	
	Use specific pipes and lines for each set of metals or processes that require a specific oil in order to reduce the amount of cleanouts.	
	Save on coolant costs by extending machine coolant life through the use of a centrifuge and the addition of biocides.	**Waste Savings/Reductions:** 25% reduction in plant-wide waste coolant generation. **Product/Waste Throughput Information:** based on handling 20,600 gallons of coolant per year. [EIES Number 100-101, p. 440]
	Install a second high speed centrifuge on a system already operating with a single centrifuge to improve recovery efficiency even more.	**Capital Investment:** $126,000. **Payback Period:** 3.1 years. **Product/Waste Throughput Information:** based on handling 20,600 gallons of coolant per year. [EIES Number 100-101, p. 441]
	Install a chip wringer to recover excess coolant on aluminum chips.	**Capital Investment:** $233,500. **Payback Period:** 0.9 years. **Product/Waste Throughput Information:** based on handling 20,600 gallons of coolant per year. [EIES Number 100-101, p. 441]
		Capital Investment: $11,000 to $23,000 (chip wringer and centrifuge system). [EIES Number 101-004, p. 8.2-6]
	Install a coolant recovery system and collection vehicle for machines not on the central coolant sump.	**Capital Investment:** $104,000. **Payback Period:** 1.9 years. **Product/Waste Throughput Information:** based on handling 20,600 gallons of coolant per year. [EIES Number 100-101, p. 441]
	** Use a coolant analyzer to allow better control of coolant quality.	**Capital Investment:** $5,000. **Payback Period:** 0.7 years. **Product/Waste Throughput Information:** based on handling 20,600 gallons of coolant per year. [EIES Number 100-101, p. 441]
	Use an ultrafiltration system to remove soluble oils from wastewater streams.	**Annual Savings:** $200,000 (in disposal costs). **Product/Waste Throughput Information:** Based on a wastewater flow rate of 860 to 1,800 gallons per day. [EIES Number 805-001]

* The cost, savings, and waste reduction information provided in Table II is based on actual case studies and reflects the successes of actual metal manufacturing facilities. Because specific applications are highly variable, however, you should use this information only as an indicator of how a particular pollution prevention option may perform under your circumstances.

** These options cost less than $30,000 to implement.

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	Use disk or belt skimmers to remove way oil from machine coolants and prolong coolant life. Also, design sumps for ease of cleaning.	**Waste Savings/Reduction:** Coolant is now disposed once per year rather than 3-6 times per year. [EIES Number 034-001, p. 78]
Raw Material Substitution	In cold forming or other processes where oil is used only as a lubricant, substitute a hot lime bath or borax soap for oil.	
	•• Use a stamping lubricant that can remain on the piece until the annealing process, where it is burned off. This eliminates the need for hazardous degreasing solvents and alkali cleaners.	**Annual Savings:** $12,000 (results from reduced disposal, raw material, and labor costs). **Waste Throughput Information:** The amount of waste solvents and cleaners was reduced from 30,000 lbs. in 1982 to 13,000 lbs. in 1986. Employee working conditions were also improved by removing vapors associated with the old cleaners. [EIES Number 034-006, p. 5]
Waste Segregation and Separation	If filtration or reclamation of oil is required before reuse, segregate the used oils in order to prevent mixing wastes.	
	•• Segregation of metal dust or scrap by type often increases the value of metal for resale (e.g., sell previously disposed metallic dust to a zinc smelter).	**Capital Investment:** $0. **Annual Savings:** $130,000. **Payback Period:** immediate. **Waste Savings/Reduction:** 2,700 tons per year. [EIES Number 306-001, p. 109]
	•• Improve housekeeping techniques to prevent cutting oils from becoming contaminated with 1,1,1-trichloroethane (e.g., use care when cleaning cutting equipment to prevent the mixture of cutting oil and the cleaning solvent).	**Capital Investment:** $0. **Annual Savings:** $3,000 in disposal costs. **Waste Savings/Reduction:** 60% (30 tons reduced to 10 tons). [EIES Number 005-043, p. 24]
Recycling	Where possible, recycle oil from cutting/machining operations. Often oils need no treatment before recycling:	**Capital Investment:** $1,900,000. **Annual Savings:** $156,000. **Waste Throughput Information:** 2 million gallons per year. Facility reclaims oil and metal from process water. [EIES Number 306-001, p. 137]
	Oil scrap mixtures can be centrifuged to recover the bulk of the oil for reuse.	
	Follow-up magnetic and paper filtration of cutting fluids with ultrafiltration. By so doing, a much larger percentage of cutting fluids can be reused.	**Capital Investment:** $42,000 (1976). **Annual Savings:** $33,800 (1980). [EIES Number 400-072]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	** Perform on-site purification of hydraulic oils using commercial "off-the-shelf" cartridge filter systems.	**Capital Investment:** $28,000. **Annual Savings:** $17,800/year based on operating costs, avoided new oil purchase, and lost resale revenues. **Payback Period:** less than 2 years. **Product/Waste Throughput Information:** example facility handles 12,300 gallons/year of waste hydraulic oil. [EIES Number 100-101, p. 144]
	** Use a continuous flow treatment system to regenerate and reuse aluminum chemical milling solutions.	**Capital Investment:** $465,000. **Annual Savings:** $342,000. **Payback Period:** less than 2 years. **Waste Savings/ Reduction:** 90%. [EIES Number 806-001, p. 11]
	** Use a settling tank (to remove solids) and a coalescing unit (to remove tramp oils) to recover metal-working fluids.	**Annual Savings:** $26,800 (resulting from reduced material, labor, and disposal costs). [EIES Number 034-009, p. 679]
DEGREASING		
Training and Supervision	** Improve solvent management by requiring employees to obtain solvent through their shop foreman. Also, reuse "waste" solvents from cleaner up-stream operations in down-stream, machine shop-type processes.	**Capital Investment:** $0. **Annual Savings:** $7,200. **Waste Savings/Reduction:** 49% (310 tons reduced to 152 tons). **Product/Waste Throughput Information:** original waste stream history: reactive anions (6,100 gallons/yr), waste oils (1,250 gallons/yr), halogenated solvents (500 gallons/yr). [EIES Number 005-043, p. 74]
Production Planning and Sequencing	Pre-cleaning will extend the life of the aqueous or vapor degreasing solvent (wipe, squeeze, or blow part with air, shot, etc.).	**Annual Savings:** $40,000. **Payback Period:** 2 years. **Waste Savings/Reduction:** 48,000 gallons of aqueous waste. Aluminum shot was used to preclean parts. [EIES Number 306-001, p. 239]
	Use countercurrent solvent cleaning (i.e., rinse initially in previously used solvent and progress to new, clean solvent).	
	Cold clean with a recycled mineral spirits stream to remove the bulk of oil before final vapor degreasing.	
	Only degrease parts that must be cleaned. Do not routinely degrease all parts.	
Process or Equipment Modification	The loss of solvent to the atmosphere from vapor degreasing equipment can be reduced by:	
	• increasing the free board height above the vapor level to 75% of tank width;	
	• covering the degreasing unit (automatic covers are available);	

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	• installing refrigerator coils (or additional coils) above the vapor zone;	
	• rotating parts before removal from the vapor degreaser to allow all condensed solvent to return to degreasing unit;	
	• controlling the speed at which parts are removed (10 ft/min or less is desirable) so as not to disturb the vapor line;	
	• installing thermostatic heating controls on solvent tanks; and	
	• adding in-line filters to prevent particulate buildup in the degreaser.	
	** Reduce grease accumulation by adding automatic oilers to avoid excess oil applications. [EIES Number 604-001]	
Raw Material Substitution	** Use less hazardous degreasing agents such as petroleum solvents or alkali washes. For example, replace halogenated solvents (e.g., trichloroethylene) with liquid alkali cleaning compounds.	**Capital Investment:** $0. **Annual Savings:** $12,000. **Payback Period:** immediate. **Waste Savings/Reduction:** 30% of 1,1,1-trichloroethane replaced with an aqueous cleaner. [EIES Number 034-010, p. 25]
		Capital Investment: $438,000. **Payback Period:** 5.1 years. Replaced trichloroethylene degreaser with aqueous cleaner system. [EIES Number 022-012, p. 125]
		Annual Savings: $2,000. **Payback Period:** 1.6 years. Substituted chlorofluorocarbon solvents with proprietary cleaner. [EIES Number 022-013]
		Annual Savings: 38% of cost savings and a 62% return on investment. **Payback Period:** 1.6 years. [EIES Number 022-011, p. A-4]
Recycling	** Recycle spent degreasing solvents on site using batch stills.	**Capital Investment:** $7,500. **Annual Savings:** $90,000. **Payback Period:** 1 month. **Waste Savings/Reduction:** 10,000 gallons annually of spent solvents by in-house distillation. [EIES Number 306-001, p. 79]
		Capital Investment: $2,600-$4,100 and $4,200-$17,000. **Product Throughput Information:** 35-60 gallons per hour and 0.6-20 gallons per hour, respectively. Two cost and throughput estimates for distillation units from two vendors. [EIES Number 005-003, p. 70]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	•• Use simple batch distillation to extend the life of 1,1,1-trichloroethane (1,1,1-TCA).	**Capital Investment:** $3,500 (1978). **Annual Savings:** $50,400. **Product/Waste Throughput Information:** facility handles 40,450 gallons 1,1,1-TCA per year. [EIES Number 100-101, p. 442]
	•• When on-site recycling is not possible, agreements can be made with supply companies to remove old solvents.	**Capital Investment:** $3,250 for a temporary storage building. **Annual Savings:** $8,260. **Payback Period:** less than 6 months. **Waste Savings/Reduction:** 38,000 pounds per year of solvent sent off site for recycling. [EIES Number 306-001, p. 149]
	•• Arrange a cooperative agreement with other small companies to centrally recycle solvent.	
PICKLING		
Process or Equipment Modification	Increase the number of rinses after each process bath and keep the rinsing counter-current in order to reduce dragout losses.	
	Acids in the wastewaters may be recoverable by evaporation.	
	Reduce rinse contamination via dragout by:	
	• slowing and smoothing removal of parts, rotating them if necessary;	
	• using surfactants and other wetting agents;	
	• maximizing drip time;	
	• using drainage boards to direct dripping solutions back to process tanks;	
	• installing dragout recovery tanks to capture dripping solutions;	
	• using a fog spray rinsing technique above process tanks;	
	• using techniques such as air knives or squeegees to wipe bath solutions off of the part; and	

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	• changing bath temperature or concentrations to reduce the solution surface tension.	
	Instead of pickling brass parts in nitric acid, place them in a vibrating apparatus with abrasive glass marbles or steel balls. A slightly acid additive is used with the glass marbles, and a slightly basic additive is used with the steel balls.	**Capital Investment:** $62,300 (1979); 50% less than conventional nitric acid pickling. [EIES Number 400-036]
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	•• Use mechanical scraping instead of acid solution to remove oxides of titanium.	**Annual Savings:** $0; cost of mechanical stripping equals cost of chemical disposal. **Waste Savings/Reduction:** 100%; **Waste Throughput Information:** previously disposed 15 tons/year of acid with metals. [EIES Number 005-043, p. 32]
	•• For cleaning nickel and titanium alloy, replace alkaline etching bath with a mechanical abrasive system that uses a silk and carbide pad and pressure to clean or "brighten" the metal.	**Capital Investment:** $3,250. **Annual Savings:** $7,500. **Waste Savings/Reduction:** 100%. **Waste Throughput Information:** previous etching bath waste total was 12,000 gallons/year. [EIES Number 005-043, p. 50]
	Clean copper sheeting mechanically with a rotating brush machine that scrubs with pumice, instead of cleaning with ammonium persulfate, phosphoric acid, or sulfuric acid (may generate non-hazardous waste sludge).	**Capital Investment:** $59,000. **Annual Savings:** more than $15,000. **Payback Period:** 3 years. **Waste Savings/ Reduction:** 40,000 pounds of copper etching waste reduced to zero. [EIES Number 101-028, p. H-3]
		Annual Savings: $15,000 in raw materials, disposal, and labor. **Payback Period:** 3 years. **Waste Savings/Reduction:** avoids generation of 40,000 pounds per year of hazardous waste liquid. [EIES Number 803-001]
	Reduce molybdenum concentration in wastewaters by using a reverse osmosis/precipitation system.	**Capital Investment:** $320,000. **Waste Throughput Information:** permeate capacity of 18,000 gallons per day. **Savings Relative to an Evaporative System:** installed capital cost savings: $510,000; annual operating cost savings: $90,000. [EIES Number 207-001, p. 5]
Raw Material Substitution	Change copper bright-dipping process from a cyanide and chromic acid dip to a sulfuric acid/hydrogen peroxide dip. The new bath is less toxic and copper can be recovered. [EIES Number 306-001, p. 130]	
	•• Use alcohol instead of sulfuric acid to pickle copper wire. One ton of wire requires 4 liters of alcohol solution, versus 2 kilograms of sulfuric acid.	**Capital Investment:** $0. [EIES Number 400-069]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	Replace caustic wire cleaner with a biodegradable detergent. [EIES Number 604-001]	
	Replace chromated desmutting solutions with nonchromated solutions for alkaline etch cleaning of wrought aluminum.	**Annual Savings:** $44,541. **Waste Savings/Reduction:** sludge disposal costs reduced by 50%. [EIES Number 806-001, p. 10]
Recycling	Sell waste pickling acids as feedstock for fertilizer manufacture or neutralization/ precipitation.	
	Recover metals from solutions for resale.	**Annual Savings:** $22,000. **Payback Period:** 14 months. Company sells copper recovered from a bright-dip bath regeneration process employing ion exchange and electrolytic recovery. [EIES Number 306-001, p. 171]
	** Send used copper pickling baths to a continuous electrolysis process for regeneration and copper recovery.	**Capital Investment:** $28,500 (1977). **Product Throughput Information:** pickling 12,000 tons of copper; copper recovery is at the rate of 200 g/ton of processed copper. [EIES Number 400-097]
	** Recover copper from brass bright dipping solutions using a commercially available ion exchange system.	**Annual Savings:** $17,047; based on labor savings, copper sulfate elimination, sludge reduction, copper metal savings and bright dip chemicals savings. **Product Throughput Information:** example facility processes approximately 225,000 pounds of brass per month. [EIES Number 804-001]
	** Treat industrial wastewater high in soluble iron and heavy metals by chemical precipitation.	**Annual Savings:** $28,800; based on reduced water and sewer rates. **Waste Throughput Information:** wastewater flow from facility's "patening" line is 100 gallons per minute. [EIES Number 034-013]
HEAT TREATING		
Process or Equipment Modification	** When refining precious metals, reduce the acid/metals waste stream by maximizing reaction time in the gold and silver extraction process.	**Capital Investment:** $0. **Annual Savings:** $9,000. **Waste Savings/Reduction:** 70% (waste total reduced from 50 tons to 15 tons). [EIES Number 005-043, p. 73]
Raw Material Substitution	Replace barium and cyanide salt heat treating with a carbonate/chloride carbon mixture, or with furnace heat treating.	
	Replace thermal treatment of metals with condensation of saturated chlorite vapors on the surface to be heated.	**Waste Savings/Reduction:** this process is fast, nonoxidizing, and uniform; pickling is no longer necessary. [EIES Number 400-108]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	Replace cyanurated salt hardening process with one using fluidized baths of nitrogen and corundum.	**Relative Savings:** nitrogen and corundum hardening costs 60% of the conventional cyanurated salts process, and generates no waste. [EIES Number 400-071]
Recycling	Oil quench baths may be recycled on site by filtering out the metals.	
	Alkali wash life can be extended by skimming off the oil layer (this skimmed oil may be reclaimed).	

METAL FINISHING AND PAINTING

Training and Supervision	Always use proper spraying techniques.	
	Improved paint quality, work efficiency, and lower vapor emissions can be attained by formal training of operators.	
	Avoid buying too much finishing material at one time, due to its short shelf life.	
Production Planning and Sequencing	Use the correct spray gun for particular applications: • conventional air spray gun for thin-film-build requirements; • airless gun for heavy film application; and • air assisted airless spray gun for a wide range of fluid output.	
	Preinspect parts to prevent painting of obvious rejects.	
Process or Equipment Modification	Ensure the spray gun air supply is free of water, oil, and dirt.	
	Replace galvanizing processes requiring high temperature and flux with one that is low temperature and does not require flux.	**Capital Investment:** $900,000. **Annual Savings:** 50% (as compared to conventional galvanizing). **Product Throughput Information:** 1,000 kg/h. [EIES Number 400-008]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	Investigate use of transfer methods that reduce material loss such as:	
	• dip and flow coating;	
	• electrostatic spraying; and	
	• electrodeposition.	
	•• Change from conventional air spray to an electrostatic finishing system.	**Annual Savings:** $15,000. **Payback Period:** less than 2 years. [EIES Number 310-001, p. 136]
	Use plastic blast media for paint stripping rather than conventional solvent stripping techniques.	**Waste Savings/Reduction:** volume of waste sludge is reduced by as much as 99% over chemical solvents; wastewater fees are eliminated. [EIES Number 503-001]
	Use solvent recovery or incineration to reduce the emissions of volatile organics from curing ovens.	**Annual Savings:** $400,000. [EIES Number 806-001, p. 7]
	Regenerate anodizing and alkaline silking baths with contemporary recuperation of aluminum salts.	**Annual Savings:** $0.02/m^2 of aluminum treated. **Annual Savings:** (including sale of the recovered dry aluminum sulfate) $0.05/m^2 **Waste Throughput Information:** based on an example plant that previously disposed 180,000 liters of acid solution per year at $0.07/litre. [EIES Number 451-501]
Raw Material Substitution	Use alternative coatings for solvent based paints to reduce volatile organic materials use and emissions, such as:	
	• high solids coatings (this may require modifying the painting process; including high speed/high pressure equipment, a paint distribution system, and paint heaters);	**Waste Savings/Reduction:** 30% net savings in applied costs per square foot. [EIES Number 038-003]
		Waste Savings/Reduction: 41% reduction in VOC emissions. The VOC of the paint decreased from 5.5 lb./gallon to 3 lb./gallon. [EIES Number 739-001, p. 182]
	• water based coatings; and	**Waste Savings/Reduction:** 87% drop in solvent emissions and decreased hazardous waste production. [EIES Number 739-001, p. 182]
	• powder coatings.	**Capital Investment:** $1.5 million. **Payback Period:** 2 years. Example is for a large, wrought iron patio furniture company. [EIES Number 739-001, p. 185]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	•• Substitute chromic acid cleaner with non-fuming cleaners such as sulfuric acid and hydrogen peroxide.	**Annual Savings:** $10,000 in treatment equipment costs and $2.50/lb. of chromium in treatment chemical costs. **Product/Waste Throughput Information:** rinse water flowrate of 2 gallons per minute. [EIES Number 101-027, p. 115]
	Substitute non-polluting cleaners such as trisodium phosphate or ammonia for cyanide cleaners.	**Annual Savings:** $12,000 in equipment costs and $3.00/lb. of cyanide in treatment chemicals costs. **Product/Waste Throughput Information:** rinse water flowrate 2 gallon per minute. [EIES Number 101-027, p. 115]
Waste Segregation and Separation	Segregate non-hazardous paint solids from hazardous paint solvents and thinner. [EIES Number 604-001]	
Recycling	Do not dispose of extended shelf life items that do not meet your facilities' specifications: They may be returned to the manufacturer, or sold or donated as a raw material. [EIES Number 005-043, p. 26]	
	Recycle metal sludges through metal recovery vendors. [EIES Number 005-043, p. 27]	
	Use activated carbon to recover solvent vapors, then recover the solvent from the carbon by steam stripping, and distill the resulting water/solvent mixture.	**Capital Investment:** $817,000 (1978). **Waste Savings/ Reduction:** releases of solvent to the atmosphere were reduced from 700 kg/ton of solvent used to 20 kg/ton. [EIES Number 400-032]
	Regenerate caustic soda etch solutions for aluminum by using hydrolysis of sodium aluminate to liberate free sodium hydroxide and produce a dry, crystalline hydrate alumina byproduct.	**Capital Investment:** $260,000. **Annual Savings:** $169,282; from reduced caustic soda use, income from the sale of the byproduct, and a reduction in the cost of solid waste disposal. **Payback Period:** 1.54 years. **Product/Waste Throughput Information:** anodizing operation for which the surface area is processed at a rate of 200 m^2/hour. [EIES Number 505-001]
METAL FINISHING AND PAINTING CLEANUP		
Production Planning and Sequencing	Reduce equipment cleaning by painting with lighter colors before darker ones.	
	Reuse cleaning solvents for the same resin system by first allowing solids to settle out of solution.	

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	Flush equipment first with dirty solvent before final cleaning with virgin solvent.	**Waste Savings/Reduction:** 98%; from 25,000 gallons of paint cleanup solvents to 400 gallons. Company uses cleanup solvents in formulation of subsequent batches. [EIES Number 034-010, p. 14]
	Use virgin solvents for final equipment cleaning, then as paint thinner.	
	Use pressurized air mixed with a mist of solvent to clean equipment.	
Raw Material Substitution	•• Replace water-based paint booth filters with dry filters. Dry filters will double paint booth life and allow more efficient treatment of wastewater.	**Annual Savings:** $1,500. **Waste Savings/Reduction:** 3,000 gallons/year. [EIES Number 806-001, p. 7]
Loss Prevention and Housekeeping	To prevent spray gun leakage, submerge only the front end (or fluid section) of the gun into the cleaning solvent.	
Waste Segregation and Separation	Solvent waste streams should be kept segregated and free from water contamination.	
Recycling	•• Solvent recovery units can be used to recycle spent solvents generated in flushing operations.	
	• Install a recovery system for solvents contained in air emissions.	**Annual Savings:** $1,000. [EIES Number 034-010, p. 10]
	• Use batch distillation to recover isopropyl acetate generated during equipment cleanup.	**Payback Period:** 2 years. [EIES Number 034-010, p. 17]
	• Use batch distillation to recover xylene from paint equipment cleanup.	**Payback Period:** 13 months. **Annual Savings:** $5,000. [EIES Number 034-010, p. 18]
	• Use a small solvent recovery still to recover spent paint thinner from spray gun cleanups and excess paint batches.	**Capital Investment:** $6,000 for a 15 gallons capacity still. **Annual Savings:** $3,600 in new thinner savings; $5,400 in disposal savings. **Payback Period:** less than 1 year. **Waste Savings/Reduction:** 75% (745 gallons of thinner recovered from 1,003 gallons). **Product/Waste Throughput Information:** 1,500 gallons of spent thinner processed per year. [EIES Number 034-006, p. 6]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	• Install a methyl ethyl ketone solvent recovery system to recover and reuse waste solvents.	**Annual Savings:** $43,000/year; MEK recovery rate: 20 gallons/day, reflecting a 90% reduction in waste. [EIES Number 806-001, p. 7]
	Arrange an agreement with other small companies to jointly recycle cleaning wastes.	
FACILITY CLEANUP		
Loss Prevention and Housekeeping	Improve housekeeping practices to reduce spillage of cleaning solvents.	
	Install collection/drip pans under machinery and lubrication operations to recover oils.	
	Use rags to their full oil absorbing capacity, and use a laundering system to clean oil-laden rags.	
ELECTROPLATING		
Training and Supervision	Educate plating shop personnel in the conservation of water during processing and in material segregation. [EIES Number 005-043, p. 20]	
Production Planning and Sequencing	Preinspect parts to prevent processing of obvious rejects.	
Process or Equipment Modification	Employ countercurrent rinsing to greatly reduce rinse water usage. Increase drain time to allow parts to drain 10 seconds or more after removal from bath. [EIES Number 002-016, p. 12]	
	Add wetting agents to the plating baths to reduce adhesion of solution to the parts. [EIES Number 002-016, p. 12]	
	Increase bath temperature to reduce viscosity and improve drainage. [EIES Number 002-016, p. 13]	

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	Use spray rinsing to increase rinsing efficiency for non-complex part configurations.	
	Use air agitation in rinse tanks to improve rinsing efficiency.	
	Change continuous treatment to a batch system to account for upsets in effluent levels.	**Capital Investment:** $210,000. **Payback Period:** 3 years. **Waste Savings/Reduction:** reduced water usage from 12,000 gallons per day to 500 gallons per day. [EIES Number 306-001, p. 133]
	Reduce bath evaporation by covering the surface with a blanket of polypropylene balls.	
	Continuously filter process baths to extend their life. [EIES Number 005-043, p. 17]	
	If etching is done only to put a shine on the parts, some customers may agree to buy them unetched, thus, greatly reducing etch bath wastes. [EIES Number 005-043, p. 22]	
	** Use low concentration plating solutions rather than mid-point concentrations in order to reduce the total mass of chemicals being dragged out.	**Annual Savings:** $1,300. **Product/Waste Throughput Information:** a nickel operation having 5 nickel tanks and an annual nickel dragout of about 2,500 gallons. [EIES Number 101-027, p. 121]
	Use the Kushner and Providence methods of double dragout followed by treatment or recycle of the concentrated dragout solution to minimize rinse water use.	**Annual Savings:** using the Providence method in lieu of conventional water treatment: Shop size (gpd): 6,000 36,000 184,000 Annual Savings: $17,110 $60,080 $44,095 [EIES Number 101-027]
	Employ countercurrent and conductivity controls to reduce rinse water flows.	**Annual Operating Costs:** $10.00/1,000 gallons. **Annual Savings:** $170,000. **Waste Savings/Reduction:** rinse water was reduced from 43,000 gallons per day to 8,000 gallons per day. [EIES Number 806-001, p. 8]
	** Use electrolytic cells to recover metals from waste plating solutions. Applicable to recovery of gold, silver, cobalt, nickel, cadmium, copper, and zinc from solutions with 100 mg/l to 1,000 mg/l of metal.	**Capital Investment:** $8,750 - $17,500. **Metal Recovery:** 1-2 tonnes/yr. **Waste Savings/Reduction:** metal losses reduced by a factor of 100. [EIES Number 400-101]
Raw Material Substitution	Use less toxic materials whenever possible.	
	• Substitute zinc for cadmium in alkali/saline environments.	

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	• Substitute nitric or hydrochloric acid for cyanide in certain plating baths in order to produce a less hazardous sludge. [EIES Number 024-001, p. 26]	
	• Substitute zinc chloride for zinc cyanide. [EIES Number 024-001, p. 26]	
	• Substitute a non-chlorinated stripper in place of methylene chloride. [EIES Number 005-043, p. 16]	
Waste Segregation and Separation	Wastewaters containing recoverable metals should be segregated from other wastewater streams.	
Recycling	Instead of disposing of plating bath when strength has decreased, filter and reconstitute it.	
	•• Instead of disposing of process baths, attempt to make them marketable for resale.	**Annual Savings:** $16,300. [EIES Number 306-001]
	Recycle used rinse waters into bath makeup solutions for their respective process baths.	
	•• Reduce the quantity and toxicity of wastewaters by employing technologies such as:	
	• evaporation;	**Annual Savings:** greater than $100,000. **Payback Period:** less than 1 year. **Waste Savings/Reduction:** from about 8,000 pounds of chromium consumed per month to less than 200 pounds per month. Company used a closed-loop evaporator on the chromium bearing rinse waters. [EIES Number 450-001, p. 7-6]
		Capital Investment: $12,200. **Annual Operating Costs:** $24,741. **Annual Savings:** $60,964. **Payback Period:** 7 months. Evaporative recovery employed on the company's nickel plating rinse waters. [EIES Number 034-011]
		Payback Period: 2-2.5 years. **Waste Savings/Reduction:** 84% reduction of chromium usage, 15-20% sludge reduction Company installed an evaporative recovery unit for a chromium plating process. [EIES Number 450-001, p. 7-6]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
		Capital Investment: $25,000, estimated for evaporative recovery equipment. [EIES Number 005-033, p. 29]
		Installed Cost: $35,680. **Annual Operating Cost:** $9,160 **Annual Savings:** $21,000. System operates for 5,000 hours/year, recovering 9,375 lbs/year chromic acid. [EIES Number 400-047]
	• ion exchange;	**Capital Investment:** $375,000. **Payback Period:** 2 years. **Waste Savings/ Reduction:** 92% recovery of ion exchange-treated wastewater for reuse. [EIES Number 310-001 pp. 57-58]
		Payback Period: 5 years. Nickel sulfate solution is treated by ion exchange and returned to nickel plating process. [EIES Number 306-001, p. 21]
		Capital Investment: $15,000 (1981). Ion exchange unit installed to recover chromium. [EIES Number 459-001 p. 7-5]
		Capital Investment: $1.3 million. **Annual Savings:** $[illegible] million. **Product/Waste Throughput Information:** 55,000 [illegible]/year of wastewater. [EIES Number 400-057]
	• reverse osmosis;	**Capital Investment:** $16,000. **Payback Period:** [illegible] mths. **Waste Savings Reduction:** [illegible] and 60% of wastewater recovered. **Waste Throughput Information:** [illegible] gallons per hour of wastewater. [EIES Number 310-001, pp. 54-55]
		Capital Investment: $62,000 ($39,000 for the reverse osmosis unit). **Payback Period:** Less than 2 years. Company installed reverse osmosis unit and evaporative heaters to recover nickel and rinse waters. [EIES Number 034-010, p. 2]
		Capital Investment: $8,500. **Waste Savings/Reduction:** about 85% of the nickel dragout. Company installed reverse osmosis to recover nickel and rinse water. [EIES Number 450-001, p. 7-2]
		Capital Investment: $200,000 (330 ft^2 membrane). **Annual Operating Cost:** large, due to high pressures in system. Publication discusses reverse osmosis in general and states that it is applicable to many electroplating baths. [EIES Number 005-033, pp. 29-30]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
		Capital Investment: $21,500. **Operation Cost:** $9,113. **Gross Annual Savings:** $17,464. **Annual Savings:** $8,351. **Payback Period:** 2.4 years. **Product/Waste Throughput Information:** economic information for a watts nickel plating line with dragout rates greater than one gallon per hour. [EIES Number 504-001]
	• electrolysis;	**Capital Investment:** $8,500. **Annual Savings:** $26,060 in chemical usage and process water. **Product Throughput Information:** 60,000 ft^2 cadmium electroplating plant. Company implemented a high surface area (HSA) electrolytic reactor for cadmium recovery. [EIES Number 310-001, p. 48]
		Capital Investment: $43,000 (1979). **Annual Savings:** treatment costs eliminated, between 5 and 14 kilograms each of silver, nickel, and copper are recovered weekly. Company used fluidized bed electrolysis to recover metals from electroplating rinse waters. [EIES Number 450-001, p. 7-6]
	• electrodialysis with ion exchange; and	**Capital Investment:** $21,050 (15-cell-pair unit). **Payback Period:** 9 months. Company recovers gold from plating rinse water using electrodialysis and ion exchange. [EIES Number 450-001, p. 7-4]
		Capital Investment: $109,600 (1980). **Annual Savings:** $26,000/year (reduction detoxification costs). [EIES Number 400-100]
		Capital Investment: $220,000. **Annual Savings:** $45,000. A medium sized jewelry plating and manufacturing company; updating the existing water treatment facility would have cost $500,000. [EIES Number 022-011, p. A-1]
	• cyanide destruction.	**Capital Investment:** $20,000-$50,000 for hydrolysis process. **Waste Savings/Reduction:** Can reduce cyanide from 50,000 mg/l to less than 30 mg/l. **Waste Throughput Information:** 300 gallons per day. [EIES Number 005-033, pp. 44-45]
		Capital Investment: $10,000-$50,000 for chlorine and hypochlorite processes. **Waste Throughput Information:** 200 gallons per day - 20 gallons per minute. [EIES Number 005-033, pp. 41-42]
		Capital Investment: $300,000 for ozone oxidation. **Product/Waste Throughput Information:** Rinse tanks operated at a rate of 4 gallons per minute (reactive rinsing) can eliminate 2 out of 3 plating line rinse tanks). [EIES Number 034-012, p. 2391]

TABLE II (continued)

POLLUTION PREVENTION PRACTICES FOR PROCESSES AND OPERATIONS IN METAL MANUFACTURING

POLLUTION PREVENTION TECHNIQUES	POLLUTION PREVENTION OPTIONS	EXAMPLES OF COSTS AND SAVINGS, AND OTHER INFORMATION*
	•• Use reactive rinsing in nickel plating operations to reduce rinse water use, improve plating efficiency, and conserve process chemicals.	**Capital Investment:** $250 for plumbing and installation. **Product/Waste Throughput Information:** rinse tanks operated at rate of 4 gallons per minute (reactive rinsing can eliminate 2 out of 3 plating line rinse tanks). [EIES Number 034-012, p. 239]
	Recover phosphate from aluminum bright dipping operations by reacting rinse acid with soda alkalies to yield a trisodium phosphate solution. Filter the solution, cool it (so trisodium phosphate crystallizes out), and recycle the remaining mother liquor with further batches of rinse acid. [EIES Number 807-001]	
OVERALL		
Loss Prevention and Housekeeping	Reduce the number of hazardous materials purchased for similar purposes, (e.g., from 275 different types of adhesive to 2 or 3). [EIES Number 005-043, p. 27]	
	Employ a strict preventative maintenance system to prevent spills and leaks. [EIES Number 005-043, p. 27]	