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ENVIRONMENTAL RESEARCH BRIEF

Waste Minimization Assessment for a Manufacturer of Rotogravure Printing Cylinders

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Abstract

The U.S. Environmental Protection Agency (EPA) has funded a pilot project to assist small and medium-size manufacturers who want to minimize their generation of waste but who lack the expertise to do so. Waste Minimization Assessment Centers (WMACs) were established at selected universities and procedures were adapted from the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). The WMAC team at the University of Louisville performed an assessment at a plant manufacturing cylinders for rotogravure printing. A considerable amount of waste is generated by the various plating operations in the plant. The plant operates its own wastewater treatment system. The team's report, detailing findings and recommendations, indicated that the most significant cost savings could be realized by installing a batch still onsite to recover xylene.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory (RREL), Cincinnati, OH, to announce key findings of an ongoing research project that is fully documented in a separate report of the same title available from University City Science Center.

Introduction

The amount of waste generated by industrial plants has become an increasingly costly problem for manufacturers and an additional stress on the environment. One solution to the problem of waste is to reduce or eliminate the waste at its source.

University City Science Center (Philadelphia, PA) has begun a pilot project to assist small and medium-size manufacturers who want to minimize their formation of waste but who lack the inhouse expertise to do so. Under agreement with EPA's RREL, the Science Center has established three WMACs. This assessment was done by engineering faculty and students at the University of Louisville's WMAC. The assessment teams have considerable direct experience with process operations in manufacturing plants and also have the knowledge and skills needed to minimize waste generation.

The waste minimization assessments are done for small and medium-size manufacturers at no out-of-pocket cost to the client. To qualify for the assessment, each client must fall within Standard Industrial Classification Code 20-39, have gross annual sales not exceeding $75 million, employ no more than 500 persons, and lack inhouse expertise in waste minimization.

The potential benefits of the pilot project include minimization of the amount of waste generated by manufacturers, reduced waste treatment and disposal costs for participating plants, valuable experience for graduate and undergraduate students who participate in the program, and a cleaner environment without more regulations and higher costs for manufacturers.

Methodology of Assessments

The waste minimization assessments require several site visits to each client served. In general, the WMACs follow the procedures outlined in the EPA *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003, July 1988). The WMAC staff locate the sources of waste in the plant and identify the current disposal or treatment methods and their associated costs. They then identify and analyze a variety of ways to reduce or eliminate the waste. Specific measures to achieve that goal are recommended and the essential support-

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ing technological and economic information is developed. Finally, a confidential report that details the WMAC's findings and recommendations (including cost savings, implementation costs, and payback times) is prepared for each client.

Plant Background

Chrome-plated, engraved, copper-plated steel and aluminum cylinders for rotogravure printing are manufactured by this plant. Approximately 70 employees operate the plant 6,240 hr/yr to produce nearly 4,000 engraved cylinders annually.

Manufacturing Process

The manufacturing processes used in this plant and the wastes generated are described below.

Preparation of Used Cylinders

Customer-provided used cylinders are heated by a warm water rinse over an open rinse tank. Next, rust and some of the chrome plating are stripped from the cylinders in an acid stripping tank which contains muriatic acid. The cylinders are rinsed again over the open rinse tank. Then, the engraved design, including the rest of the chrome and most of the copper plating, is cut out of the cylinders using a lathe.

The waste rinse water is sent to the plant's onsite wastewater treatment plant (WWTP). Spent stripping acid, which contains heavy metals, is disposed of offsite as hazardous waste. Copper shavings and turnings generated by the lathe are sold to a recycler.

Preparation of New Cylinders

Purchased steel cylinders are cleaned with a detergent and then degreased with a heated sodium hydroxide solution. Cylinders are rinsed with deionized water. Spent rinse water is drained to the plant's water treatment facility.

The purchased aluminum cylinders are washed with an enzyme cleaner and rinsed with a mixture of tap and deionized water. Then the aluminum cylinders are rinsed with hydrofluoric acid to make them less reactive prior to plating and rinsed with water. Spent rinse water and acid are sent to the onsite water treatment plant.

Nickel Plating of Steel Cylinders

Steel cylinders are nickel-plated in order to promote the bonding of copper to steel during subsequent copper plating. The heated plating bath contains copper sulfate, nickel chloride, boric acid, and water. After the cylinders are plated, they are rinsed with deionized water; spent rinse water goes to the WWTP. The spent plating bath is disposed of as a hazardous waste every two years.

Zinc Plating of Aluminum Cylinders

The aluminum cylinders are zinc-plated so that the copper will bond to the cylinders during subsequent copper plating. Sodium hydroxide, zinc oxide, and water make up the zincating bath. Tap water which is used to rinse the cylinders following zinc plating is sent to the plant's WWTP. The zincating bath is dumped every three years and disposed of as hazardous waste.

Cyaniding of Aluminum Cylinders

Aluminum cylinders are also treated with cyanide prior to copper plating. The cyanide bath contains copper cyanide, sodium cyanide, potassium sodium tartrate, and water. The cylinders are cleaned with a brass brush, dipped in the cyanide bath, and rinsed over a rinse tank with warm tap water. Wastewater is sent to the plant's treatment facility. The cyanide bath is dumped only as it becomes contaminated (about once every four to five years).

Copper Plating of All Cylinders

All cylinders are plated with copper after processing as described above. The plating bath contains copper sulfate, sulfuric acid, and water. The copper anodes are enclosed in cloth filter bags to reduce contamination of the bath with accumulated sludge. Spent anodes are reclaimed offsite.

Plating bath wastes, residue from the baths, and spent plating baths are disposed as hazardous waste.

After plating, the cylinders are rinsed with warm tap water over a rinse tank; spent rinse water goes to the WWTP.

Lathing and Polishing of Cylinders

The cylinders are then processed in the lathe room. Imperfections in the copper plating are cut off with a lathe and the plating is polished with a stone grinder. Copper shavings are sold to a recycler.

The cooling and lubrication of the stone grinder with water generates a colloidal copper sludge. The sludge is processed in a settling tank where sodium hydroxide is used to precipitate dissolved copper. The settled wet sludge is sent to a nonhazardous industrial waste landfill. Decanted water from the settling tank and water from the grinder are sent to the WWTP.

Image Processing

While the cylinders are plated, customer-provided art work is prepared for etching. First the artwork is photographed. Then the colors in the artwork are separated, using graphic arts film to produce one negative per color. The method used for further processing the film depends upon the process by which the image will be etched on the cylinder. If mechanical engraving is to be used, the negatives are developed onto bromide films. For the "direct transfer" process, positives are made from the negatives.

Both liquid and solid wastes are generated by image processing. Silver and some cadmium are removed from the film emulsion when the negatives are washed in the fixing agent solution. Rinse water from the film processors goes to the electrolytic silver recovery units. Water from two of the processors goes directly to the sewer; silver levels in the effluents are below the POTW limits. Overflow water from the other three processors goes to the WWTP.

Silver removed from the anodes in the electrolytic silver recovery units is sent offsite to a reclaimer. Used films and used negatives are also sent to the reclaimer.

Mechanical Engraving

Images are processed onto some of the cylinders using mechanical engraving. In this process, the bromide film is attached to a scanning drum in tandem to the cylinder to be engraved. A scanning device reads the image from the rotating scanning drum and sends electronic impulses through a computer to a diamond stylus which etches the rotating cylinder. The completed cylinder is then sent for proofing. A small amount of fine copper dust is generated and sold to a recycler.

Direct Transfer

Images are processed onto most of the cylinders using a "direct transfer" method. Cylinders are scrubbed with an enzyme cleaner and rinsed with muriatic acid and softened water. Then the cylinders are coated with a photoresist solution. The positives produced are retouched to fill in any flaws and are wrapped around the cylinders and exposed to a mercury lamp. Light from the lamp exposes bare copper to create an image on the cylinder. Cylinders then go to a bath where a xylene-based developer is poured over the cylinders while they rotate over a collecting basin. Blue dye is then poured over the cylinders and the cylinders are rinsed with softened water, dried briefly with compressed air, and wiped dry with paper towels.

Wastewater from the initial rinse drains to the plant's WWTP. Rinse water containing xylene is collected in a tank for phase separation. The xylene phase is disposed of offsite as hazardous waste and the water phase is sent to the WWTP.

Staging and Etching

Cylinders which were processed in the direct transfer area are then sent to the staging area where an asphalt paint is brushed onto the cylinders to protect areas which will not be etched. Next, the cylinders are cleaned with a muriatic acid-methanol mixture. The acid removes tarnish and the methanol provides quick drying. Waste acid/methanol goes to the WWTP.

The cylinders then undergo an etching process in which copper is removed by a reduction-oxidation process. A ferric chloride/bentonite clay slurry is applied to the rotating cylinders to remove the exposed copper plating. Waste slurry is disposed of as hazardous waste. Cylinders are then rinsed with tap water; wastewater drains to the WWTP.

After etching, excess asphalt paint is removed with a naphtha-wetted rag and excess photoresist is removed with citric-based solvent on a rag. The rags are laundered and returned to the plant by an outside company. Cylinders then undergo a quick-drying rinse with a muriatic acid-methanol mixture. Waste rinse solution goes to the WWTP.

Proofing

All engraved and etched cylinders go through the proofing process. Lithographic ink is applied to the cylinders for one-color proofs. Full-color proofs are then made for the customers to check the accuracy of the cylinders. If necessary, a cylinder may be re-etched using the same processes described previously. Between colors, ink is wiped off of the cylinders with paper towels which go to a nonhazardous waste landfill. Waste ink is disposed with waste xylene generated in the direct transfer process.

Following the printing of full-color proofs, the cylinders are cleaned with ethyl acetate and glycol thinner using rags. Rags are cleaned by a local cleaning service and reused.

Chrome Plating

All cylinders are chrome-plated as a final process step. Cylinders are first washed with an enzyme cleaner and rinsed with hot tap water over an open drain. Wastewater goes to the WWTP.

Tape is then placed over the cylinders' shafts to prevent them from being plated. Cylinders are submerged in the heated chrome bath which is composed of chromic acid, sulfuric acid, and water. An exhaust hood over the plating tank carries fumes and mist to a water spray scrubber. Wastewater from the scrubber goes directly to the WWTP.

The cylinders are removed from the bath and rinsed with tap water which drains into the tank. Cylinders are then immersed in a second tank filled with tap water. Overflow from the rinse tank goes to a chrome reduction tank.

Hydrazine is added to the chrome reduction tank to reduce chromium (VI) to chromium (III) which then precipitates as a hydroxide. The settled sludge is shipped offsite as hazardous waste. Wastewater from the chrome reduction unit is treated in the plant's WWTP. Plating bath correction waste is disposed offsite.

The chrome-plated cylinders are then polished with fine polishing paper, inspected and shipped.

An abbreviated process flow diagram for printing cylinder manufacturing is shown in Figure 1.

Wastewater Treatment Plant

The plant's wastewater treatment plant processes wastewater to meet pretreatment requirements prior to discharging the effluent to the POTW. The first treatment step is the addition of sodium hydroxide to precipitate heavy metals. Next a flocculant is added to promote the settling of metal hydroxide precipitates in the settling tanks; overflow water goes to the POTW. The sludge from the settling tank is disposed of as a hazardous waste.

Existing Waste Management Practices

This plant has already taken the following steps to manage and minimize its wastes:

- Copper shavings from the lathes, grinders, and polishing machines are collected and sold to a recycler.
- Air agitation and constant circulation are used in all of the plating tanks except for the zincating tank to minimize drag-out.
- Cyaniding of steel cylinders has been replaced by nickel plating because of concerns over cyanide in the effluent going to the POTW.

- Deionized water is used in nickel plating in order to minimize the amount of sludge generated.
- Dry-film photoresist is used instead of chlorinated solvents in the image processing area.
- A brand of film containing a small amount of cadmium is used to reduce the amount of cadmium in wastewater.
- Silver is reclaimed from the anodes in the electrolytic silver recovery units and waste film by a recycler.
- Chromium (VI) is reduced to chromium (III) before disposal.
- The plant operates its own wastewater treatment plant.

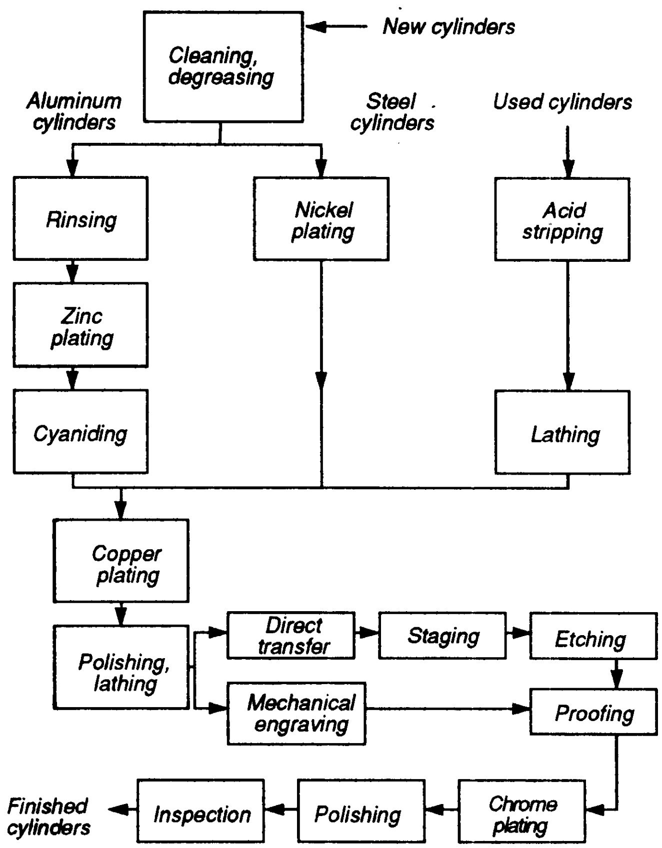

Figure 1. *Abbreviated process flow diagram.*

Waste Minimization Opportunities

The waste streams currently generated by the plant, the management methods applied, the quantities of waste, and the annual treatment and disposal costs are given in Table 1.

Table 2 shows the opportunities for waste minimization that the WMAC recommended for the plant. Current plant practice, the proposed action, and waste reduction, savings, and implementation cost data are given for each opportunity. The quantities of waste currently generated by the plant and possible waste reduction depend upon the production level of the plant. All values should be considered in that context.

It should be noted that the economic savings of the Waste Minimization Opportunities (WMOs) address only the raw material cost avoidance and reduction of present and future costs associated with waste treatment and disposal. Other savings not quantifiable by this study include a wide variety of possible future costs related to changing emissions standards, liability, and employee health.

Additional Recommendations

In addition to the opportunities recommended and analyzed by the WMAC team, several additional measures were considered. These measures were not analyzed completely because of insufficient data, implementation difficulty, or a projected lengthy payback as indicated below. Since one or more of these approaches to waste reduction may, however, increase in attractiveness with changing conditions in the plant, they were brought to the plant's attention for future consideration.

- Recover copper plating chemicals from rinse water using evaporation or ion exchange. High operating and implementation costs were predicted for this measure.
- Recover zinc from plating rinse water using electrodialysis. A high implementation cost and low cost savings were predicted for this measure.
- Recover naphtha solvent from the rags used for wiping cylinders. The amount of solvent recovered probably would not justify the investment required.
- Investigate the possibility of using a cyanide-free solution prior to copper plating

This Research Brief summarizes a part of the work done under Cooperative Agreement No. CR-814903 by the University City Science Center under the sponsorship of the U.S. Environmental Protection Agency. The EPA Project Officer was Emma Lou George. She can be reached at:

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Table 1. Summary of Current Waste Generation

Waste Stream Generated	Waste Management Method	Annual Quantity Generated	Annual Waste Management Cost
Cylinder preparation			
Spent acid stripping solution	Offsite disposal	495 gal	$ 760
Wash and rinse water	Treated onsite and sewered	77,500 gal	990
Nickel plating			
Spent nickel-plating solution	Offsite disposal	175 gal	690
Contaminated nickel-plating solution/sludge	Offsite disposal	110 gal	440
Rinse water	Treated onsite and sewered	27,000 gal	350
Zinc plating			
Spent zinc-plating bath	Offsite disposal	18 gal	70
Rinse water	Treated onsite and sewered	2,600 gal	30
Cyaniding			
Spent copper cyanide bath	Offsite disposal	14 gal	380
Rinse water	Treated onsite and sewered	2,600 gal	30
Copper plating			
Spent copper-plating solution and residue	Offsite disposal	2,900 gal	5,350
Solution corrections	Offsite disposal	1,430 gal	2,750
Spent copper anodes	Sold to a reclaimer	1,000 lb	(1,800)*
Rinse water	Treated onsite and sewered	19,500 gal	250
Chrome plating			
Solution corrections	Offsite disposal	550 gal	3,070
Chromium sludge	Offsite disposal	400 gal	2,530
Rinse water and fume scrubber water	Treated onsite and sewered	320,000 gal	4,110
Polishing and lathing			
Copper shavings	Sold to a recycler	6,200 lb	(11,160)*
Copper sludge	Offsite disposal as non-hazardous waste	6,000 lb	**
Cooling and lubrication water	Treated onsite and sewered	52,000 gal	670
Image processing			
Overflow water from developing, rinsing, and silver recovery	Sewered	338,000 gal	370
Overflow water from developing, rinsing, and silver recovery	Treated onsite and sewered	507,000 gal	6,510
Negatives and recovered silver	Sold to a reclaimer	3,600 lb	(6,480)*
Direct transfer			
Waste xylene and ink	Offsite disposal	1,200 gal	2,950
Wash and rinse water	Treated onsite and sewered	52,000 gal	670
Etching			
Hydrochloric acid/methanol rinse	Treated onsite and sewered	3,600 gal	1,740
Spent ferric chloride etch bath	Offsite disposal	2,730 gal	4,350
Rinse water	Treated onsite and sewered	52,000 gal	680
Rags containing ink and photoresist	Cleaned and reused through offsite service	104,000 units	**
Mechanical engraving			
Copper dust	Sold to a recycler	1 lb	(5)*
Proofing			
Paper towels containing ink	Conventional landfill	1,872 boxes	**
Rags containing ink	Cleaned and reused through offsite service	78,000 units	**
Waste water treatment plant			
Sludge from settling tanks	Offsite disposal	11,000 gal	22,070

* (Revenue received)
** Cost not available

Table 2. Summary of Recommended Waste Minimization Opportunities

Present Practice	Proposed Action	Savings
Rinsing is done with open garden hoses.	Install hand-held spray rinse guns for rinsing in conjunction with acid stripping nickel plating, zincating, copper cyaniding, copper plating, direct transfer, etching, and chrome plating. Reduced water usage and increased return of solutions to appropriate baths will result.	Estimated waste reduction = 90,200 gal/yr Waste management cost savings = $1,160/yr Raw material cost savings = $120/yr Operating cost = $10/yr Total cost savings = $1,270/yr Implementation cost = $330 Simple payback = 0.3 yr
Nickel plating rinse water is discharged to the onsite waste water treatment plant.	Use a reverse osmosis system to recover plating chemicals; recycle them to the plating bath. Use the purified water for rinsing or make-up.	Estimated waste reduction = 25,650 gal/yr Waste management cost savings = $330/yr Raw material cost savings = $2,520/yr Operating cost = $540/yr Total cost savings = $2,310/yr Implementation cost = $5,000 Simple payback = 2.2 yr
Nickel plating rinse water is discharged to the onsite waste water treatment plant.	Rinse cylinders directly over the plating bath to return drag-out to the bath.	Estimated waste reduction = 23,590 gal/yr Waste management cost savings = $310/yr Raw material cost savings = $1,110/yr Operating cost = $20/yr Total cost savings = $1,400/yr Implementation cost = $60 Simple payback = 0.1 yr
Hydrochloric acid-methanol rinse from the etching process is sent to the plant's waste water treatment facility and causes high biological oxygen demand (BOD) surcharges.	Following the application of hydrochloric acid, rinse the cylinders with hot deionized water and dry them with an air knife.	Estimated waste reduction = 510 mg/l BOD Waste management cost savings = $1,620/yr Raw material cost savings = $2,000/yr Operating cost = $2,400/yr Total cost savings = $1,220/yr Implementation cost = $410 Simple payback = 0.4 yr
Xylene waste from the direct transfer process is drummed and sent offsite for disposal through a fuels program.	Ship waste offsite for xylene recovery.	Estimated waste reduction = 0 Waste management cost savings = $670/yr Implementation cost = $0 Simple payback is immediate.
Xylene waste from the direct transfer process is drummed and sent offsite for disposal through a fuels program.	Purchase a small batch still to recover and reuse xylene. Ship still bottoms offsite for disposal.	Estimated waste reduction = 1,050 gal/yr Waste management cost savings = $1,900/yr Raw material cost savings = $8,450/yr Operating cost = $300/yr Total cost savings = $10,050/yr Implementation cost = $6,000 Simple payback = 0.6 yr
Chrome-plating rinse water goes to a chrome reduction unit which generates sludge that is drummed and sent offsite for disposal.	Install an ion-exchange unit to remove bath impurity metals from the rinse water. Recycle purified water containing chromic acid back to the plating bath.	Estimated waste reduction = 39,950 gal/yr Waste management cost savings = $6,100/yr Raw material cost savings = $2,660/yr Operating cost = $670/yr Total cost savings = $8,090/yr Implementation cost = $9,240 Simple payback = 1.1 yr

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