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ENVIRONMENTAL RESEARCH BRIEF

Waste Minimization Assessment for an Aluminum Extrusions Manufacturer

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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 Tennessee performed an assessment at a plant manufacturing aluminum extrusions — over 36 million lb/yr. Primary and scrap aluminum is melted down, cast into logs, then heat treated. Next, the logs are extruded into desired shapes. Extrusions are sheared, heat treated, then either buffed, anodized (colorized), painted, or shipped. The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the anodizing line but that the greatest savings could be obtained by installing an electrostatic powder coating system to eliminate spent toluene, air filters, plastic sheets, paint ash, and evaporated solvents.

This Research Brief was developed by the principal investigators and EPA's Risk Reduction Engineering Laboratory, 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 the authors.

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 Risk Reduction Engineering Laboratory, the Science Center has established three WMACs. This assessment was done by engineering faculty and students at the University of Tennessee's (Knoxville) 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 $50 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

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WMAC staff locates the sources of waste in the plant and identifies 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 supporting 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

The plant produces aluminum extrusions for use by other product manufacturers. The plant operates 6,240 hr/yr to produce over 36 million lb of aluminum extrusions.

Manufacturing Process

This plant forms aluminum extrusions from virgin and scrap metal. Raw materials for this process include primary or virgin aluminum ingots, scrap aluminum, and alloying metals such as copper, zinc, and nickel. An abbreviated process flow diagram is illustrated in Figure 1.

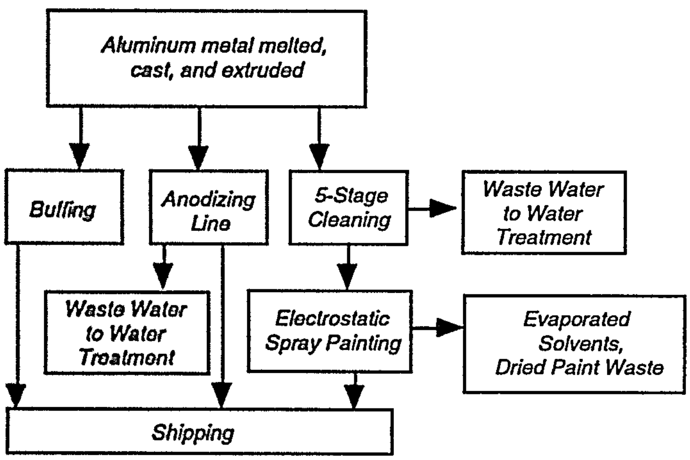

Figure 1. Abbreviated process flow diagram.

The following steps are involved in making the extrusions:

First, the primary and scrap aluminum and alloying metals are melted in natural gas-fired furnaces. Then the molten metal is cast into "logs" in the plant's water-quench hydraulic casting system. The logs are heat-treated and extruded into the desired cross-sectional shapes. Next the extrusions are sheared and heat-treated again. The finished extrusions are then sent to the buffing, anodizing, or painting areas of the plant for further processing.

Buffing

In the buffing area, a total of 1.3 million lb/yr of aluminum extrusions are manually positioned on a table where they are passed under a motor-driven cloth-pad buffing wheel several times. A buffing compound is sprayed onto the pads prior to buffing. Approximately 2% of the buffing compound powder is blown onto the floor, swept up, and disposed of in municipal waste. Spent buffing compound is blown and aluminum dust and buffing pad fibers are vacuum aspirated into a large water-filled separating tank. Sludge is chain-raked from the bottom of the tank and shipped to the onsite landfill. Waste water from the separating tank is directed to a skimming pit before being discharged to a nearby river. No other treatment is performed. Used buffing pads are also disposed of in the onsite landfill. The polished extrusions are then sent to shipping.

Anodizing

Aluminum extrusions which require anodizing for corrosion control and coloring (14 million lb/yr) are hung on an overhead crane to facilitate dipping into a series of tanks. The first tank contains an alkaline detergent wash heated to 140°F. A small quantity of waste is dumped from this tank to a caustic waste lagoon which is part of the plant's waste water treatment system. The parts are then dipped in a rinse tank (tank #2); overflow from this tank is directed to the rinse tank (tank #4) that follows the etch tanks described below.

Approximately 98% of those parts are then processed in one of two steam-heated etch tanks which contain sodium hydroxide and caustic solution. In the etch tanks, small quantities of the product surfaces are chemically removed in preparation for further treatment. Waste water from the etch tanks is sent to a reaction pit which is part of the waste water treatment system. Gases emitted from the two etch tanks are directed through duct work to a water spray fume scrubber. Waste water from the fume scrubber is sent to the caustic waste lagoon.

After etching, the extrusions are rinsed in two tanks (tank #4 and tank #6). The first rinse tank (tank #4) is fed by overflow water from tank #2 that follows the detergent wash tank and recirculated water from tank #6. Waste water is fed to the caustic waste lagoon.

The extrusions are then sent to an acid de-smut tank which contains hydrogen peroxide and sulfuric acid. Waste water from this tank is dumped once a year to an acid waste lagoon which is part of the plant's waste water treatment system. Parts are then dipped in a rinse tank from which overflow water is fed to the acid waste lagoon.

From that rinse tank, the extrusions are conveyed to one of three anodizing tanks. Anodizing is an electrolytic oxidation process in which an aluminum oxide layer is formed on the etched surface of the extrusions. This aluminum oxide layer is extremely porous and is useful in the coloring of the extrusions. Sulfuric acid is added to each anodizing tank; fumes from these tanks are ducted to a water spray fume scrubber which removes carryover sulfuric acid. Scrubber water is pumped to the acid waste lagoon of the water treatment facility. After anodizing, the parts are spray-rinsed in one of two spray-rinse tanks and then water-rinsed in an ambient tank. Waste water from these rinses is gravity-fed to the acid waste lagoon. Extrusions are then put into a holding tank where water is added with a constant overflow to the acid waste lagoon.

From the holding tank, extrusions may be conveyed to one of two coloring tanks or to rinse tank #19. Approximately 30% of the product being conveyed through the anodizing line is immersed in a coloring tank containing sulfuric acid and stannous sulfate. In this tank, tin is absorbed into the pores of the aluminum oxide coating and a dark brown-to-black product color results according to customer specifications. Color tests are made at this point and the product may be immersed in this solution several times to reach the desired color. Waste solution from this tank is dumped once a month to the acid waste lagoon. Next, the product is spray-rinsed and sequentially dipped into two water rinse tanks (tank #19 and tank #20). The first dip rinse receives overflow water from the second rinse tank. Waste water from all three of the aforementioned rinse steps is pumped to the acid waste lagoon. From rinsing, the extrusions are conveyed to one of three color sealant tanks which contain a nickel fluoride sealant. The product is then passed through a final rinse stage before air-drying and shipping.

The second coloring tank contains a Sandoz bronze solution which also is absorbed into the pores of the product surface but results in a bronze-colored product. Only about 1% of product goes through this coloring process. Waste water from the Sandoz bronze tank is dumped once a year to the acid waste lagoon. From this coloring tank, parts are rinsed in a water tank and then immersed in a nickel sealant tank. Parts are then water-rinsed and air-dried before shipping. Waste water from these rinse and sealant tanks is pumped to the acid waste lagoon.

The remaining 69% of the product that is sent through the anodizing line is sent directly to rinse tank #19, which precedes the nickel fluoride sealant tanks mentioned in the sulfuric acid-stannous sulfate coloring process. After rinsing in tanks 19 and 20, these extrusions are sealed in the nickel fluoride sealant tanks, rinsed, air-dried, and sent to shipping.

Painting

Approximately 21 million lb/yr of the extrusions are painted before shipping. Extrusions to be painted are manually hung on an overhead conveyor system which transports them through a series of spray booths for pretreatment and painting. The first pretreat booth consists of a recirculated heated alkaline cleaner spray which removes dirt and grease. Waste water from this step is dumped to the chromium treatment tanks which are part of the plant's waste water treatment system. Next, parts are spray-rinsed and conveyed through a spray chromic acid surface treatment booth which enhances paint adhesion. Drag-out and evaporative losses are so excessive that the chromic surface treatment collection tank is never dumped. Waste hexavalent chromic acid is pumped to the chromium treatment tanks. The chromic acid treatment of extrusions is followed by two rinse stages which complete the pretreatment steps in the paint line. Waste water from those rinse tanks is also pumped to the chromic treatment tanks.

Next, extrusions are conveyed through a natural gas-fired dry-off oven (250°F) before passing through two electrostatic paint booths. Over 180 different colors of paint are used, most of which are polyester and acrylic with the remaining paint being fluorocarbon-based. To achieve the desired color, the plant has six paint mixing stations. Acrylic and polyester paints are thinned with a "150 solvent". Fluorocarbon paint is thinned with both methyl isobutyl ketone (MIBK) and "DB" solvents. Toluene is pumped through the lines for cleaning between color changes. Air filters in the paint booths are changed periodically; plastic sheeting is placed on the floor to collect paint overspray. The plastic and filters are removed to a landfill. Paint-contaminated toluene is collected in barrels and hauled offsite as a hazardous waste. Toluene also evaporates to the plant atmosphere. After painting, the extrusions are conveyed through a gas-fired bake oven (350-480°F) for 10 to 12 min, manually removed from supporting conveyor hooks, and transferred to shipping. Unsatisfactorily painted stock is transported to the melt oven and used as scrap charge. Paint-laden conveyor hooks are periodically put in a natural gas-fired burn-off oven for paint removal by incineration; ash is hauled away with air filters and plastic sheeting as a non-hazardous waste.

Existing Waste Management Practices

- Toxic hexavalent chrome is transformed to non-toxic chrome before offsite shipment.
- An onsite waste water treatment facility controls suspended and dissolved species concentrations in effluent water.
- A water-spray fume scrubber is utilized in the anodizing area for air quality control.

Waste Minimization Opportunities

The type of waste currently generated by the plant, the source of the waste, the quantity of the waste, and the annual management costs are given in Table 1.

Table 2 shows the opportunities for waste minimization that the WMAC team recommended for the plant. The type of waste, the minimization opportunity, the possible waste reduction and associated savings, and the implementation cost along with the payback time are given in the table. The quantities of waste currently generated by the plant and possible waste reduction depend on the production level of the plant. All values should be considered in that context.

It should be noted that, in most cases, the economic savings of the minimization opportunities result from the need for less raw material and from reduced 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. It should also be noted that the savings given for each opportunity reflect the savings achievable when implementing each waste minimization opportunity independently and do not reflect duplication of savings that would result when the opportunities are implemented in a package.

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.

Table 1. Summary of Current Waste Generation

Waste Generated	Source of Waste	Annual Quantity Generated	Annual Waste Management Cost
Buffing compound sludge	Water-filled separating tank in the buffing line. Sludge is disposed in the on-site landfill.	26,000 lb	$ 4,770
Used buffing pads	Cloth-pad buffing wheels in the buffing line. Used pads are disposed in the on-site landfill.	7,271 pads	5,430
Spent toluene	Cleaning of paint lines between color changes. Spent toluene is hauled off-site as a hazardous waste.	1,430 gal	19,660
Evaporated toluene	Cleaning of paint lines.	13,130 gal	0[1]
Used air filters, used plastic sheeting, and paint ash	Electrostatic paint booths. Used air filters, used plastic sheeting, and ash which results from the removal of paint from conveyor hooks in the burn-off oven are combined and hauled away as non-hazardous waste.	50,000 lb	7,990
Evaporated paint solvents	Bake oven in the paint line.	6,973 gal	0[1]
Trivalent chromic sludge	Clarifier following the chromium treatment tanks in the waste water treatment system. Chromic sludge is disposed in the on-site landfill.	240,000 lb	14,230
Waste water sludge	Clarifier fed by the acid and caustic waste lagoons and the reaction pit in the waste water treatment system. Sludge is disposed in the on-site landfill.	1,800,000 lb	46,910
Waste water	Waste water treatment system. After treatment, water is discharged to a nearby river.	47,160,000 gal	0[2]

[1]Currently the plant reports no waste management cost associated with solvent evaporation.
[2]Currently the plant reports no waste management cost associated with water discharge.

Table 2. Summary of Recommended Waste Minimization Opportunities

Waste Generated	Minimization Opportunity	Annual Waste Reduction Quantity	Annual Waste Reduction Per Cent	Net Annual Savings	Implementation Cost	Payback Years
Spent toluene Evaporated toluene Used air filters, used plastic sheets, and paint ash Evaporated paint solvents	Replace the solvent-based painting system with an electrostatic powder painting system. The proposed system will eliminate the need for paint solvents and spray gun and paint line cleaning. In addition, the powder coating will provide for more even coating of the product surfaces and easy collection and reuse of overspray powder.	1,430 gal 13,130 gal 50,000 lb 6,973 gal	100 100 100 100	$ 1,084,440[1]	$ 147,580	0.1
Waste water sludge	Reduce drag-out from the tanks in the anodizing line. An array of rinse spray nozzles should be installed above the detergent, etch, acid de-smut, anodizing, stannous sulfate, nickel fluoride seal, "Sandoz" bronze, and "Sandoz" seal tanks to spray water onto each parts rack as it is raised from the tank. Drag-out boards should be installed on all tanks in the line and the drain time of parts over the tanks should be increased.	3,600 lb	0.2	52,900[2]	28,910	0.5
Buffing compound sludge	Install an automatic metering system to minimize the amount of buffing compound used.	5,200 lb	20	6,590[2]	25,960	3,9
Spent toluene	Recover spent toluene using a distillation unit. The recovered toluene can be used for cleaning the paint lines.	1,144 gal	80	17,030[2]	37,060	2.2
Waste water sludge Waste water	Recover and recycle caustic and acid solutions in the rinse tanks of the anodizing process line. Install dedicated reverse osmosis (RO) solution recovery systems on the rinse tanks following the etch, acid de-smut, and "Sandoz" bronze tanks. An electrodialysis unit in series with the etch rinse tank RO system will be required to remove aluminum hydroxide before reuse. Waste water collection tanks with RO units should be installed beneath the spray rinses that precede the anodizing and stannous sulfate tanks. In addition, the flow rates of water through the rinse tanks should be lowered to 5 gpm; air agitation units should be installed in the tanks to increase rinsing effectiveness and to compensate for the lower flow rates. Savings will result from recovery of raw materials lost in the rinsing operations and reduced water purchases.	3,600 lb 40,000,000 gal	0.2 85	105,480[2]	419,160	4.0

[1]Includes raw material cost savings attributed to the lower cost of powder coatings.
[2]Includes raw material cost savings.

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