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ENVIRONMENTAL RESEARCH BRIEF

Pollution Prevention Assessment for a Manufacturer of Combustion Engine Piston Rings

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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. In an effort to assist these manufacturers 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). That document has been superseded by the *Facility Pollution Prevention Guide* (EPA/600/R-92/088, May 1992). The WMAC team at the University of Tennessee performed an assessment at a plant that manufactures piston rings. Steel and iron rings are machined, chrome-plated or coated, machined again, cleaned, and shipped to customers. The assessment team's report, detailing findings and recommendations, indicated that wastewater and wastewater treatment sludge are the waste streams generated in greatest quantity and that the greatest cost savings could be achieved by modifying the method of masking the rings prior to chrome plating.

This Research Brief was developed by the principal investigators and EPA's National Risk Management Research 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 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 generation 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 generation of waste but who lack the in-house expertise to do so. Under agreement with EPA's National Risk Management Research 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 pollution prevention opportunity 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 in-house expertise in pollution prevention.

The potential benefits of the pilot project include minimization of the amount of waste generated by manufacturers, and reduction of waste treatment and disposal costs for participating plants. In addition, the project provides 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 pollution prevention opportunity assessments require several site visits to each client served. In general, the WMACs follow the procedures outlined in the EPA *Waste Minimization*

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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 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

This plant produces piston rings that are used in diesel engines. Almost four million piston rings are produced by the plant each year during 6,000 hr of production.

Manufacturing Process

Each of the major processes used by this plant—piston ring machining and hard chrome electroplating—is described here in detail.

Piston Ring Machining

The necessary raw materials, steel and ductile iron rings, are received and stored until needed in production. To begin production, approximately 100 rings are placed on a steel rod for ease of processing. Next, the rings enter a sequential machining line where they are blank-turned, bored, slot-milled, and finish-turned. After these initial machining operations, the rings are separated according to their final use as bottom-rings, top-rings, or intermediate-rings, and further processed as required.

Following these machining operations, approximately 95% of the rings are prepared for chrome plating. First, those rings are degreased to remove protective oils and machining residue. Then the inside ring surfaces are masked using lacquer-based paint film to prevent chrome plating on those surfaces. After paint masking, the outer ring surfaces are grit blasted to enhance chrome adhesion during plating. The final step is removal of grit blast residue using a high-pressure spray-wash. The rings are then transported to the chrome-plating process.

The other 5% of the rings are prepared to receive a magnesium phosphate coating in a hot water wash for removal of remaining machining debris and protective oils. The rings are then dipped into the magnesium phosphate tank. After the coating has dried the rings are dipped in rinse tanks for removal of residual coating solution. Depending on their final use, the coated rings undergo additional machining and grinding. The rings are then cleaned in solvent, marked with identification numbers, cleaned again, dipped in a rust preventative, and shipped to customers.

Chrome Electroplating

The plant's plating line operation is semi-automated. Use of a computer reduces human error and standardizes plating operations.

A heated sulfuric acid etch is the first tank in the plating line. The etch is used to enhance the ring's surface to facilitate chrome adhesion. Following etching, the rings are rinsed and placed in one of four heated chromic acid plating tanks. Residence time varies according to the type and thickness of chrome deposit required.

Next, the rings are rinsed in a cold water rinse tank and then with a high-pressure water spray. Masking paint on the inside ring surfaces is removed by dipping the rings into a series of tanks containing paint stripping agents and water rinses. The rings are then dipped in a tank containing rust inhibitor solution. Inspection of the rings for proper chrome application is done next. Unacceptable rings are stripped of chrome and replated.

After chrome plating the rings are machined and ground as needed. The rings are then cleaned in solvent, marked with identification numbers, cleaned again, dipped in a rust preventative, and shipped to customers.

An abbreviated process flow diagram for piston ring manufacture is shown in Figure1.

Existing Waste Management Practices

This plant already has implemented the following techniques to manage and minimize its wastes.

- Personnel from the plant's parent corporation conduct a waste assessment each year to specify waste reduction measures for the facility.
- A local university performed a waste audit for the plant several years ago.
- Waste cardboard is baled and sold.
- Sludge from the plant's general wastewater treatment system is shipped to a facility for fuels blending.
- Sludge from the plant's chrome wastewater treatment system is shipped to an outside firm for metals extraction.

Pollution Prevention Opportunities

The type of waste currently generated by the plant, the source of the waste, the waste management method, the quantity of the waste, and the annual treatment and disposal cost for each waste stream identified are given in Table 1.

Table 2 shows the opportunities for pollution prevention that the WMAC team recommended for the plant. The opportunity, the type of waste, the possible waste reduction and associated savings, and the implementation cost along with the simple 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 also should be noted that the savings given for each opportunity reflect the savings achievable when implementing each opportunity independently and do not reflect duplication of savings that may result when the pollution prevention opportunities are implemented in a package.

Additional Recommendations

In addition to the opportunities recommended and analyzed by the WMAC team, several other measures were considered. These measures were not analyzed completely because of insufficient data, implementation difficulty, or a projected lengthy payback. 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.

- Install covers on all heated tanks to minimize evaporative water losses and to conserve energy.
- Use aqueous cleaners instead of solvents for washing piston rings.
- Separate nonhazardous from hazardous wastewater streams to reduce the volume of sludge from treatment that must be considered hazardous and its associated costs.

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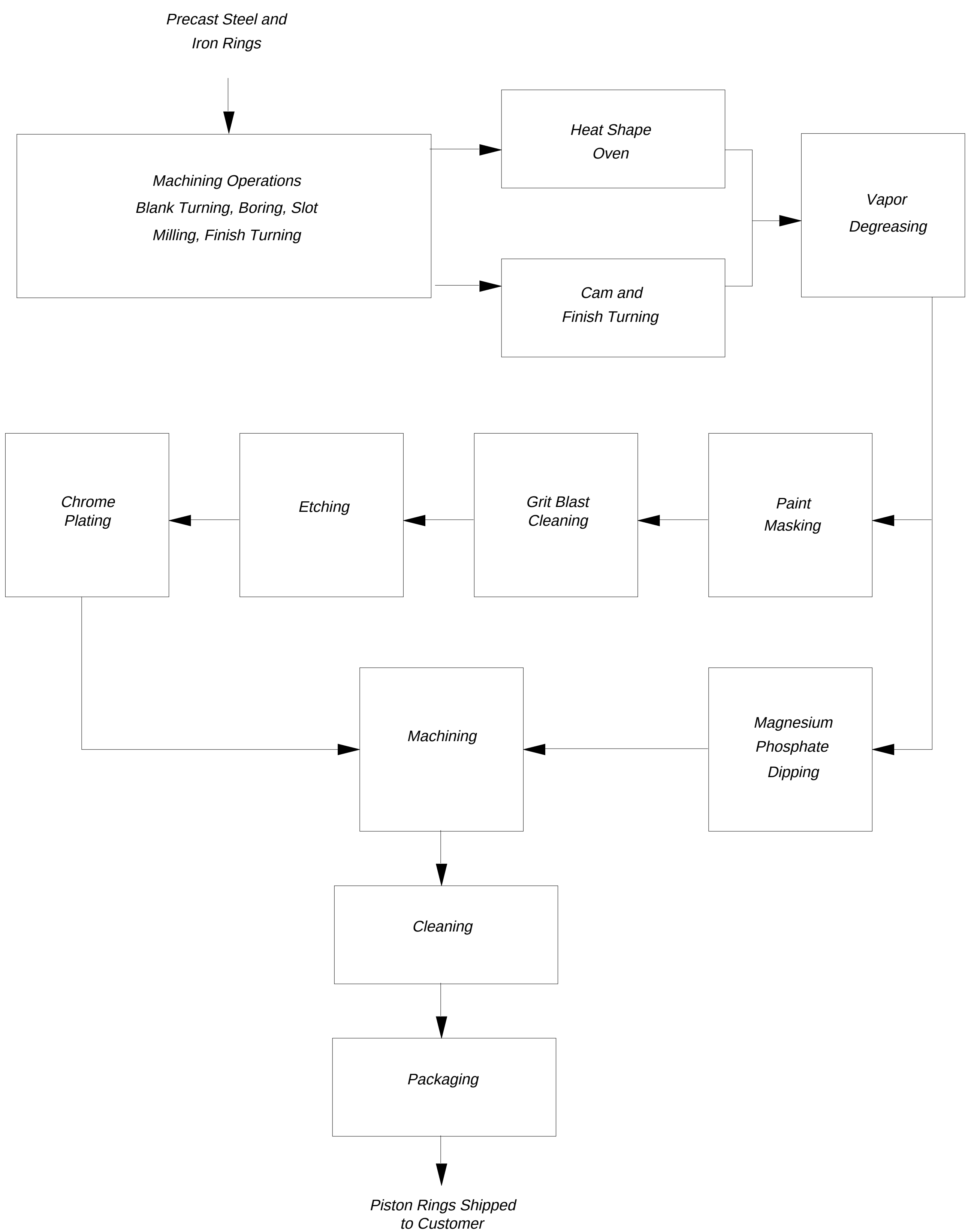

Figure 1. *Abbreviated process flow diagram for piston ring manufacture.*

Table 1. *Summary of Current Waste Generation*

Waste Generated	Source of Waste	Waste Management Method	Annual Quantity Generated (lb/yr)	Annual Waste Management Cost[1]
Packaging materials	Incoming materials	Shipped offsite to landfill	1,620,000	$18,240
Off-specification piston rings	Machining	Sold to recycler	18,750	1,260
Scrap metal shavings and grinding residue	Machining	Shipped offsite to landfill	750,000	10,380
Spent 1,1,1-trichloroethane	Vapor degreasing	Regenerated offsite	33,630	9,240
Evaporated 1,1,1-trichloroethane	Vapor degreasing	Evaporates to plant air	17,410	0
Waste masking paint	Masking of piston rings prior to plating	Shipped offsite to landfill	400	2,625
Evaporated paint thinner	Masking of piston rings prior to plating	Evaporates to plant air	7,580	0
Grit-blast sludge	Grit-blast cleaning of piston rings	Shipped offsite to landfill	41,700	6,710
Spent naphtha	Cleaning of piston rings	Regenerated offsite	98,600	29,260
Evaporated naphtha	Cleaning of piston rings	Evaporates to plant air	74,520	0
Spent chrome plating solution	Plating of piston rings	Shipped offsite for disposal	32,500	8,220
Spent scrubber filters	Chrome exhaust scrubbers	Shipped offsite for disposal	600	5,770
General plant wastewater	Machining	Pretreated in general wastewater treatment system; treated in chrome wastewater treatment system; sewered	1,037,500	4,700
General plant wastewater sludge	General plant wastewater treatment system	Shipped offsite to landfill	273,900	40,500
Wastewater	Grit-blast cleaning, magnesium phosphate coating, etching, stripping, rinsing	Treated in chrome wastewater treatment system; sewered	14,111,250	63,850
Chrome wastewater sludge	Chrome wastewater treatment system	Dried; shipped offsite for metals recovery	75,120	40,520

[1] *Includes waste treatment, disposal, and handling costs.*

Table 2. *Summary of Recommended Pollution Prevention Opportunities*

Pollution Prevention Opportunity	Waste Stream Reduced	Annual Waste Reduction		Net Annual Savings	Implementation Cost	Simple Payback (yr)
		Quantity (lb/yr)	Percent			
Use plastic sleeves instead of masking paint to prevent chrome plating of piston ring inner perimeters.	Waste masking paint Wastewater from stripping	400 2,768,120	100 20	$214,230[1]	$0	0
Replace 1,1,1-trichloroethane vapor degreasing with a high pressure hot water spray system for removal of machining residues prior to plating. A small additional quantity of wastewater will be generated if this opportunity is implemented.	Spent 1,1,1-trichloroethane	16,820	50	10,560[1]	15,000	1.4
Purchase a solvent distillation unit to regenerate spent solvents onsite instead of shipping them offsite for regeneration. A small quantity of still bottoms will be generated and shipped offsite if this opportunity is implemented.	Spent 1,1,1-trichloroethane Spent naphtha	33,630 98,600	100 100	26,560	35,000	1.3
Utilize all of the three existing cold water rinse tanks to completely remove chromic acid from piston rings, thus eliminating the need for manual spray rinsing.	N/A[2]	—-	—-	20,310	0	0

[1]Total annual savings have been reduced by an annual operating cost required for implementation.
[2]This WMO achieves no waste reduction but leads to significant operating cost savings.

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