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ENVIRONMENTAL RESEARCH BRIEF

Waste Minimization Assessment for a Manufacturer of Metal-Cutting Wheels and Components

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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 hazardous 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 metal-cutting wheels and components — approximately 6,000,000 units/yr. Tungsten carbide inserts for metal cutting are pressed, sintered, shaped by grinding, and ultrasonically cleaned. About half are coated with titanium nitride by chemical vapor deposition. Premolded ceramic inserts are ground to specifications and ultrasonically cleaned. Steel disks for diamond-plated cutting wheels are machined, cleaned, treated with sulfuric acid, coated with a diamond abrasive compound in a nickel lattice (plated from a nickel sulfamate solution) and given a final electroless plating of nickel. Aluminum and aluminum-resin disks for diamond cutting wheels are machined to working specifications, a diamond abrasive compound is applied, and the wheels are machined to final specifications. The team's report, detailing findings and recommendations, indicated that most waste, other than treated wastewater, consists of sludge filtered from machine coolant, and that the greatest savings could be obtained by recycling treated water from the plant's wastewater treatment facility to the gas/water separators of the chemical vapor deposition units.

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 hazardous 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 hazardous 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 hazardous waste but who lack the in-house 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 hazardous 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 in-house 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,

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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 locates the sources of hazardous 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 manufactures metal-cutting wheels and components. The plant operates 8,400 hr/yr to produce approximately 6,000,000 units.

Manufacturing Process

The plant makes tungsten carbide metal cutting inserts, ceramic metal cutting inserts, diamond-plated cutting wheels and diamond cutting wheels. Raw materials include tungsten carbide powder, premolded baked ceramic pieces, steel disks, aluminum-resin mixture, forged and cast aluminum disks, solvents, and chemical reagents.

- *Tungsten Carbide Metal-Cutting Inserts*

  Tungsten carbide powder with binder is pressed into insert shapes, sintered, and shaped by grinding. After ultrasonic cleaning, 50% of the parts are packaged, 45% are coated with titanium nitride (by chemical vapor deposition) and packaged, and 5% are electropolished (chemically etched), coated with titanium nitride and packaged. Wastes generated are spent solvent (trichloroethane) used to clean press and die parts, spent solutions from ultrasonic cleaning, spent acid hydrite (a commercial mixture of sulfuric and phosphoric acids) from electropolishing, effluent water from chemical vapor deposition furnace exhaust scrubbing, and spent rinse water. Spent trichloroethane and spent acid hydrite are shipped to an offsite recycler, and the spent cleaning solutions, scrubber effluent, and rinse waters are piped to the plant's wastewater treatment system. Grinding coolant is filtered and recirculated.

- *Ceramic Metal-Cutting Inserts*

  Premolded inserts are ground to specifications. After ultrasonic cleaning, the ceramic inserts are marked with ink and packaged. Grinding coolant is filtered and recirculated.

- *Diamond-Plated Cutting Wheels*

  Steel disks are machined, cleaned with acetone, cleaned further in a detergent bath, given surface treatment in sulfuric acid, coated with a diamond abrasive compound in a nickel lattice (plated from nickel sulfamate solution), and given a final "electroless plating" of nickel. Wastes generated are scrap from machining, spent solvent (acetone), spent cleaning rags, and spent detergent and reagent solutions. Spent acetone is sent to a recycler, the spent rags are laundered offsite, and spent detergent and reagent solutions are piped to the plant's wastewater treatment system.

- *Diamond Cutting Wheels*

  Purchased aluminum disks and aluminum-resin disks manufactured in the plant are used. Both forged and cast aluminum disks and the aluminum-resin disks are machined to working specifications. A diamond abrasive compound (including hexavalent potassium chromate) is then applied in a press, and the wheels are machined and ground to final specifications. Wastes generated are aluminum and aluminum-resin scrap from machining and grinding, and spent chromate solution. Scrap aluminum is shipped to a scrap metal dealer, waste aluminum-resin mixture is discarded in municipal trash, hexavalent chromate solution is converted to the less toxic trivalent by treatment with sodium bisulfate and hydrated lime and piped to the plant's wastewater treatment system, and grinding coolant is filtered and recirculated.

- *Wastewater Treatment*

  Spent solutions and rinse waters are pH adjusted and pumped to a floc tank before settling in a clarifier. Decanted water is discharged to the municipal sewer system, and sludge is partially dewatered in a sand bed filter and shipped for disposal as hazardous waste.

- *Coolant Filtering*

  Spent machine coolant is filtered under pressure through diatomaceous earth. The coolant is recirculated to the process, and sludge, which contains tungsten carbide, synthetic diamonds and diatomaceous earth, is shipped offsite for reclamation.

Existing Waste Management Practices

- Spent hexavalent chromate solution is converted to a less toxic trivalent form by treatment with sodium bisulfate and hydrated lime.
- Process wastewater is treated in the plant by pH adjustment and flocculation before discharge to the municipal sewer.

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 treatment and disposal costs are given in Table 1.

Table 2 shows the opportunities for waste minimization and cost savings that the WMAC recommended to the plant. The minimization opportunities, the possible waste reduction and associated savings, and the implementation cost with payback time are listed in the table. The quantities of waste generated and possible waste reduction depend on the production level of the plant. The values shown should be considered in that context.

It should be noted that the economic savings of the 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 possible future costs related to changing emission 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.

Additional Recommendations

In addition to the opportunities recommended and analyzed by the WMAC team, two additional measures were considered. These measures were not completely analyzed because of insufficient data or minimal savings as indicated below. They were brought to the plant's attention for future reference, however, since these approaches to waste reduction may increase in attractiveness with changing plant conditions.

- Reduce the flows of cleaning solution and rinse water to the solution and rinse tanks used in the ultrasonic cleaning process. (The WMAC team noted that the flows appeared to be high compared to the size of the tanks.) Test runs would be needed to obtain data on the feasibility of this measure. Without that data, the measure is not formally recommended.
- The sludge obtained from the wastewater treatment sand bed filter has a 63% water content, and vibration during shipment to a landfill might cause "free water" to separate. Because of a ban on landfill disposal of

Table 1. *Summary of Current Waste Generation*

Waste Generated	*Source of Waste*	*Annual Quantity Generated*	*Annual Waste Management Cost*
Spent solvent (trichloroethane)	*Spent trichloroethane from cleaning press rams and dies is removed from the plant by an outside recycler. Solvent vapors are lost from cleaning troughs.*	*605 gal*	*$3,335*
Spent solvent (acetone)	*Spent acetone from diamond-plated wheel cleaning is decanted from marking paint solids and shipped offsite to a recycler. Vapors are lost from a holding tank.*	*165 gal*	*825*
Spent acid hydrite	*Spent sulfuric/phosphoric acid solution from electropolishing tungsten carbide metal-cutting inserts is shipped offsite to a recycler.*	*324 gal*	*7,595*
Spent beeswax	*Molten beeswax binder, drained from tungsten carbide insert sintering furnaces, is cooled and discarded in municipal trash.*	*1,200 lb*	*75*
Furnace exhaust gases	*Sintering furnace exhausts are vented. Exhaust gases from chemical vapor deposition furnaces, used for titanium nitride coating of tungsten carbide cutting inserts, contain titanium chloride and chlorine. These are scrubbed with water and the effluent water piped to the plant's wastewater treatment system.*	*(Unknown)*	*(Unknown)*
Steel scrap and aluminum scrap	*Waste from machining of steel and aluminum cutting wheel disks is shipped to a scrap dealer at no charge to the plant.*	*10,000 lb [1]* *4,100 lb [2]*	*225* *225*
Aluminum-resin mixture	*Waste from machining of pressed aluminum-resin cutting wheel disks is discarded with municipal trash.*	*4,500 lbs*	*225*
Spent cleaning rags	*Acetone-soaked rags from spot cleaning of cutting wheel disks are laundered offsite and reused in the process.*	*480,000 rags*	*325*
Machining coolant sludge	*The coolant, mainly from grinding operations, is filtered through a diatomaceous earth filter. The sludge obtained (72% tungsten carbide) is reclaimed offsite. The filtered coolant is recirculated.*	*180,000 lb*	*3,000*
Treated wastewater	*Rinse water from process operations and effluent water from chemical vapor deposition furnace exhaust scrubbers are treated with caustic soda and calcium chloride for pH adjustment. After flocculation and settling of sludge the water is discharged to the sewer.*	*5,498,000 gal*	*10,996*
Water treatment sludge	*Sludge from wastewater flocculation is partially dewatered in a sand bed filter and shipped offsite for disposal as hazardous waste.*	*20,000 lb*	*15,875*
Waste oil	*Spent oil from maintenance is removed for off-site disposal as hazardous waste.*	*2,000 gal*	*150*
Masking paint residue	*Dried masking paint is manually stripped from completed diamond-plated cutting wheels and discarded in municipal trash.*	*(Unknown)*	*225*

[1] *Steel*
[2] *Aluminum*

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free liquids, landfill operators may require costly addition of cement kiln dust to soak up the free water. If recommended oven drying of the sludge were implemented, free water with the sludge would be reduced or eliminated.

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Table 2. Summary of Recommended Waste Minimization Opportunities

Waste Generated	Minimization Opportunity	Annual Waste Reduction Quantity	Annual Waste Reduction Percent	Net Annual Savings	Implementation Cost	Payback Years
Spent scrubber water	*Use water from the plant's wastewater treatment system in place of fresh water to scrub the chemical vapor deposition furnace exhaust gases.*	5,292,000 gal	100	$21,168[1]	$31,500	1.5
Sludge from the plant's wastewater treatment system	*Install a gas-fired drying oven for dewatering the sludge.*	15,000 lb	75	9,906	16,200	1.6
Spent acidic degreaser solution	*Preclean the tungsten carbide inserts with a hot water rinse before they enter the acidic degreaser tank. The quantity of degreaser solution needed will be reduced by about 50%.*	0	0	12,333[1]	1,196	0.1
Spent tricholoroethane and acetone from cleaning presses, maintenance cleaning, and cleaning cutting wheel disks	*Install a batch distillation unit to recover the solvents for reuse.*	493	90	3,542[1]	15,740	4.4

[1] *Includes savings on raw materials.*

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