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ENVIRONMENTAL RESEARCH BRIEF

Waste Minimization Assessment for a Manufacturer of Automotive Air Conditioning Condensers and Evaporators

Gwen P. Looby and F. William Kirsch*

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 automotive air conditioning condensers and evaporators - approximately 400,000 units per year. To make condensers, extrusions and steel coil are machined, degreased, welded, and painted. Header assemblies are brazed and degreased. Fins are produced and placed inside header assemblies before final brazing, leak testing, packaging and shipping. To make evaporators, aluminum side sheet stock and coil and box extrusions are machined and degreased along with aluminum tube stock. All parts are assembled with the fins before brazing, cleaning, and chromate surface treatment. After leak testing, evaporators are packaged and shipped. The team's report, detailing findings and recommendations, indicated that the majority of waste was generated in the non-chromate waste water treatment facility but that the greatest savings could be obtained by converting to a powder coating technique in the condenser line to eliminate both contaminated paint solids and paint liquids.

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 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 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, valuable experience for graduate and undergraduate students who participate in the program, and a cleaner environment without more regulations and higher costs for manufacturers.

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* University City Science Center, Philadelphia, PA 19104

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 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 condensers and evaporators for automotive air conditioners. The 250 employees operate the plant 3,840 hr/yr to produce 400,000 condensers and evaporators annually.

Manufacturing Process

An abbreviated process flow diagram is illustrated in Figure 1. The following discussion includes complete process summaries.

Condenser Line

Raw materials used in the condenser manufacturing line include aluminum coils, tube stock, header assemblies, and extrusions; steel coils; and miscellaneous hardware such as nuts, pins, clips, wire, and fittings.

The first operation in the condenser line is the production of fins from aluminum roll stock on a fin machine in a proprietary process. Some of the machine oil used in this operation evaporates and the remaining spent oil is shipped offsite as a non-hazardous waste. The fins are then transported to the core assembly station.

Aluminum extrusions and steel coils undergo cutting, bending, and piercing operations. A portion of the cutting oil used in these operations evaporates and the remaining spent oil is shipped offsite as non-hazardous waste. The steel coils and miscellaneous parts (nuts, pins, clips, wire, and fittings) are then degreased to remove dirt and oil prior to further processing. Other raw materials which undergo this degreasing step include the purchased aluminum tube stock and header assemblies. Degreasing is accomplished by hand-dipping parts into small troughs of 1,1,1-trichloroethane. Spent 1,1,1-trichloroethane solvent is shipped offsite as hazardous waste,

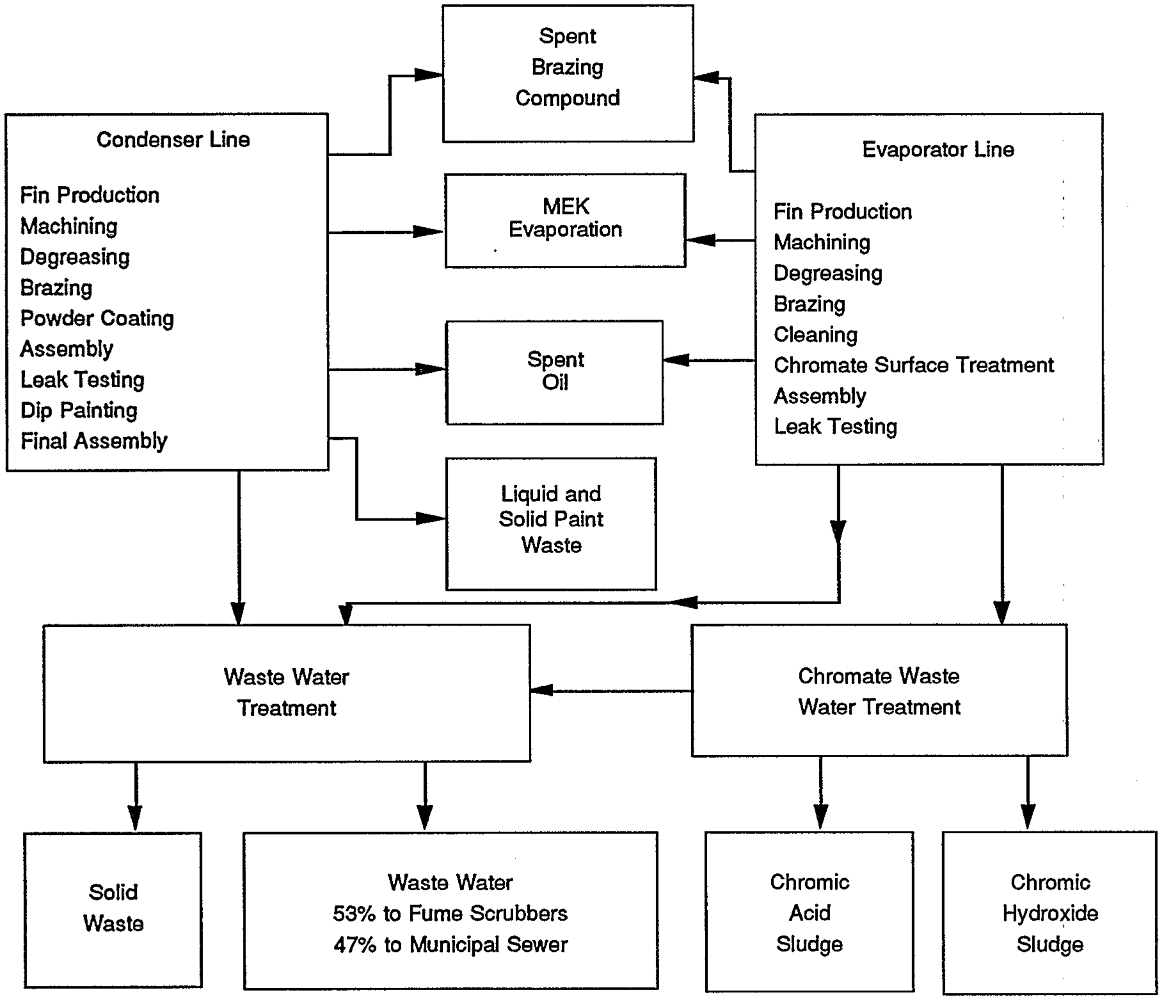

Figure 1. Abbreviated process flow diagram.

but the majority of the solvent consumed evaporates to the plant atmosphere.

Steel coils and the nuts, pins, and clips are spot-welded and conveyed through an electrostatic powder-paint coating booth followed by a curing oven. A small amount of waste coating is disposed of as a non-hazardous material. When the part racks become excessively coated with paint overspray, they are sent through a burn-off oven where the overspray is incinerated; ash from the cleaning process is shipped offsite as non-hazardous waste. The steel assemblies are then transported to the final assembly area.

Aluminum extrusions, aluminum tube stock, and 85% of the header assemblies, wire, and fittings are transported to a manual brazing area. The remaining 15% of the header assemblies, wire, and fittings are first sent to the "header brazing area" for spot-brazing. Next, those areas that are spot-brazed are hand-dipped in a trough of 1,1,1-trichloroethane for degreasing. Some of the solvent evaporates to the plant atmosphere and any spent solvent is shipped offsite as hazardous waste. After spot-brazing, these parts and the parts mentioned previously are brazed in the manual brazing area. After this brazing operation, the parts are stretched and bent in further shaping operations and are transported to the core assembly area.

The fins, aluminum tube stock, aluminum extrusions, and header assemblies are then assembled to form a condenser core. Banding wire is wrapped around the core to allow the fin contact points to touch the tube stock, thereby permitting proper brazing.

Next, cores are conveyed through a brazing-compound spray booth. The plant utilizes a proprietary brazing slurry to which methyl ethyl ketone (MEK) is added for thinning. This slurry mixture acts as a brazing flux and filler metal for the product. From the spray booth, the parts are conveyed through a 4-stage brazing oven. Stack gases from the oven are directed to a fume scrubber which removes brazing compound ash from the exhaust gases by trapping it in a continuous water stream that flows to the plant's non-chromate waste water treatment facility. The exhaust gases, which consist mainly of evaporated MEK, pass through the fume scrubber and are released to the outside atmosphere. Next, the product is conveyed through a spray water rinse, a compressed air blow-off station, and a dry-off oven. Waste water from the rinse stage is pumped to the non-chromate waste water treatment facility.

After the dry-off oven, the products are manually de-banded and leak tested. Units which fail the pressurized leak testing are sent to the repair department. Units which pass are conveyed through a water-based dip paint line. Contaminated paint solids and liquids are shipped offsite as hazardous waste. The product is then conveyed through a compressed air blow-off station and a curing oven and then to final assembly where the steel assemblies are added to the cores.

Evaporator Line

Several operations and wastes involved in the evaporator line are similar to those in the condenser line with the exception of the painting operation; paint is not applied to the evaporators. Raw materials for the evaporator line consist of several different aluminum parts including roll stock, side-sheet stock, extrusions, tube stock, and miscellaneous materials including nuts, pins, and clips.

Fins are produced from the aluminum roll stock on a fin machine. A portion of the cutting oil utilized in this operation evaporates and the remaining spent oil is shipped offsite as non-hazardous waste. Fin units are then transported to a core assembly station.

Side-sheet stock and extrusions undergo cutting, bending, and piercing operations. A portion of the cutting oil utilized in these processes evaporates and the remaining spent oil is shipped offsite as non-hazardous waste. The extrusions and tube stock are then cleaned with solvent to remove dirt and oil. The spent 1,1,1-trichloroethane solvent is shipped offsite from this operation as hazardous waste; most of the solvent evaporates to the plant atmosphere. A hand-brazing operation follows degreasing and then the extrusions and tube stock are transported to the core assembly station. At that station, aluminum fins, sheet stock, extrusions, and tube stock are assembled into an evaporator core. Banding wire is fastened around the unit to allow the fins to touch the tubing stock at the points where brazing is to occur.

From core assembly, the cores are first conveyed through a booth for spray application of brazing compound in a manner similar to that described for the condenser process line.

After the brazing oven, parts are de-banded and 95% are transported immediately to a 2-stage ultrasonic cleaning tank. The remaining 5% undergo a secondary brazing operation before being transported to the ultrasonic cleaning tanks. A 4-stage water rinse and a 2-stage air blow-off follow the ultrasonic cleaning. Waste water from these three steps is pumped to the waste water treatment facility. Next, parts are conveyed through a chromate surface treatment process which will be discussed next. Parts are then blown dry and moved through a dry-off oven from which they are transported to final assembly. The assembled product is then tested for leaks, the core face is blown dry, and units are sent to shipping.

Chromate Surface Treatment

The chromate surface treatment process is one of the steps in the evaporator production process.

Parts from the 2-stage compressed air blow-off station in the evaporator line enter the #1 tank, a pre-wash tank which contains hydrogen peroxide, sulfuric acid, and water. This solution microscopically etches the surface of the metal in preparation for chromium treatment. Contaminated water from tank #1 is pumped to 2 underground treatment pits in the chromate treatment facility which will be discussed. Next, the parts are conveyed through 2 water rinse tanks (tanks #2 and #3). A continuous flow of water passes through tank #2 and is directed to the non-chromate waste water treatment facility. Water is added to tank #3 daily in batch fashion and is subsequently emptied nightly during a non-production period. This waste water, similar to that drained from tank #2, is pumped to the non-chromate waste water treatment facility.

Tank #4 is the chromate conversion tank. In this tank, a phosphate coating is formed on surfaces for corrosion resistance and improved surface wettability. Three different chrome phosphate chemicals are used. Water from this tank is dumped periodically directly to the waste acid holding tank in the chromate treatment facility.

From the chromate conversion tank, parts are conveyed through two counterflowing rinse tanks (tanks #5 and #6). Make-up water is added to rinse tank #6 and overflow from this tank cascades back to tank #5. Waste water from both tanks is pumped to an underground pit located beneath the chromate line before being pumped to the waste acid holding tank in the chromate treatment facility. A wetting agent, which causes water to bead up and roll off the finished product, is added to tank #7. Waste water from this tank is dumped periodically to the underground treatment pits in the chromate treatment facility. The product is then conveyed to the next step in the evaporator line process, a compressed air blow-off station.

Chromate Waste Water Treatment

Waste water from several tanks (specifically tanks #1, 4, 5, 6 and 7) in the chromate surface treatment line is directed to the chromate waste water treatment process. Water from tanks #1 and #7 is pumped to 1 of 2 collection pits where sodium bisulfite is added to reduce the toxic hexavalent chrome level. Hydrated lime is then added to the solution to raise the pH and neutralize the acid and thereby convert the chromium to a less toxic trivalent form. Immediately after neutralization, sodium hydrosulfite is added to insure that all chromium remains in the trivalent form. Then the water is pumped to 1 of 2 sludge thickening tanks from which water is decanted and pumped to the non-chromate waste water treatment facility. Chromic hydroxide sludge is removed from the thickening tank and shipped offsite as hazardous waste.

In a separate operation, water from chromate line tank #4 is pumped directly to a waste acid holding tank. In addition, waste water from tanks #5 and #6 is directed to a holding pit. This water is then pumped to the waste acid holding tank, where it becomes mixed with the water from tank #4. This mixture is not treated in any manner before being shipped offsite as hazardous waste.

Non-Chromate Waste Water Treatment

Several waste water streams are fed from various processes in the plant to a large outside water collection pit. From the pit, water is pumped to a pH adjustment tank where hydrated lime is added to raise the pH of the water from approximately 3 to 6.5. Water is then pumped through 2 cooling towers to lower its temperature from 95°F to about 75°F. From there, the water is treated again in another pH adjustment tank where sodium hydroxide is added to raise the pH from 6.5 to 8.5. Water is then pumped into a large clarifier where a small amount of hydrated lime is added to initiate the precipitation of solids. Sludge is drawn from the bottom of this tank to a filter press where the water is removed by pressing it from the solid waste; the solid waste is removed from the plant as non-hazardous waste. The water from this pressing operation is directed back into the clarifier tank. Sludge-free water from the top of the clarifier tank is passed through a sand-filter polishing unit and a portion is recycled within the plant for operation of the fume scrubbers in the condenser and evaporator process lines. The remaining water is released to the municipal sewer system.

Existing Waste Management Practices

- The plant operates an extensive waste water treatment system described previously.
- Small run-off troughs have been installed on the spray brazing booths to capture some of the slurry run-off from the spray process.
- Fume scrubbers on the brazing oven stacks capture the slurry particulates from the stack gases. The slurry particulates are then directed to the water treatment facility.
- Toxic hexavalent chromic acid waste is converted to trivalent form before removal from the plant.

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 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 the economic savings of the minimization opportunity in most cases, results 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.

Additional Recommendations

In addition to the opportunities recommended and analyzed by the WMAC team, three 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.

- Pump the 1,1,1-trichloroethane to the cleaning troughs instead of transferring the solvent from the holding tank manually in buckets. The current transfer method leads to spillage and excessive evaporative losses.
- Explore the possibility of using an alternate fluxing system containing less hazardous materials.
- Analyze the treated water from the non-chromate waste water process to determine if more of it is acceptable for reuse in the process. Currently only two-thirds of the treated water is reused.

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
Evaporated 1,1,1-trichloroethane	Degreasing operations in the condenser process line	4,282 gal	$0[1]
Spent 1,1,1-trichloroethane	Degreasing operations in the condenser process line	2,805 gal	2,780
Contaminated brazing slurry	Spray-brazing booth in the condenser process line	522 gal	5,070
Evaported methyl ethyl ketone	Spray-brazing booth and fume scrubber in the condenser process line	12,569 gal	0[1]
Evaporated cutting oil	Machining operations in the condenser process line	2,140 gal	0[1]
Spent Cutting oil	Machining operations in the condenser process line	200 gal	2,320
Contaminated paint solids	Dip paint line in the condenser process line. The waste consists of spent paint filters, paint-covered plastic sheets, and paint residue.	38,520 lb	37,820
Contaminated paint liquids	Dip paint line in the condenser process line. The liquid paint waste was generated during the annual maintenance procedure.	5,220 lb	4,450
Paint ash	Burn-off oven for removing dried paint from the parts racks in the condenser process line	1 bbl	560
Evaporated 1,1,1-trichloroethane	Degreasing operations in the evaporator process line	1,428 gal	0[1]
Spent 1,1,1-trichloroethane	Degreasing operations in the evaporator process line	935 gal	2,060
Contaminated brazing slurry	Spray-brazing booth in the evaporator process line	698 gal	7,170
Evaporated methyl ethyl ketone	Spray-brazing booth and fume scrubber in the evaporator process line	6,770 gal	0[1]
Evaporated cutting oil	Machining operations in the evaporator process line	1,160 gal	0[1]
Spent cutting oil	Machining operations in the evaporator process line	100 gal	2,070
Chromic acid sludge	Acid holding tank in the chromate waste water treatment process	97,500 gal	53,180
Chromic hydroxide sludge	Sludge thickening tanks in the chromate waste water treatment line	45,000 gal	45,210
Waste water sludge	Filter press in the non-chromate waste water treatment line	576 yd^3	158,540

[1] *Plant personnel report no waste management cost associated with solvent evaporation.*

Table 2. *Summary of Recommended Waste Minimization Opportunities*

Waste Generated	Minimization Opportunity	Annual Waste Reduction Quantity	%	Net Annual Savings	Implementation Cost	Payback Years
Contaminated paint solids, Contaminated Paint liquids	Replace the dip paint system with an electrostatic epoxy powder paint coating system. The proposed system will lead to more even coating of complex surfaces and easier collection and reuse of drag-out powder.	38,520 lb 5,220 lb	100 100	\$133,820[1]	\$130,320	1.0
Waste water sludge	Install a sludge dry-off oven in the waste water treatment line to dry the sludge processed in the filter press. Evaporation of water from the sludge will greatly reduce the volume of sludge currently hauled offsite.	432 yd^3	75	23,910[2]	28,440	1.2
Contaminated paint solids	Modify the dip paint system to increase the holding time of the dip-painted parts over the paint tank. Parts should be tilted back and forth so that maximum paint drainage into the paint tank is achieved.	15,408 lb	40	19,720[1]	25,440	1.3
Evaporated 1,1,1-trichloroethane	Cover the troughs of 1,1,1-trichloroethane in the condenser and evaporator process lines to reduce solvent evaporative losses. Currently the troughs are open and unused 95% of the time.	2,855 gal	50	14,280[1]	1,880	0.1
Waste water sludge	Modify the brazing slurry run-off collection systems in the condenser and evaporator process lines to maximize the amount of slurry returned to the spray booth holding tanks. This WMO will make it possible to reuse approximately 40% of the slurry that is currently drained to the waste water treatment process.	6 yd^3	1	3,980[1]	4,980	1.3

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[1] Includes raw material cost savings.
[2] Total cost savings have been reduced by the operating cost of the oven.

*U.S. Government Printing Office: 1992 — 648-080/60079