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ENVIRONMENTAL RESEARCH BRIEF

Waste Reduction Activities and Options for a Manufacturer of Commercial Refrigeration Units

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Abstract

The U.S. Environmental Protection Agency (EPA) funded a project with the New Jersey Department of Environmental Protection and Energy (NJDEPE) to assist in conducting waste minimization assessments at 30 small- to medium-sized businesses in the state of New Jersey. One of the sites selected was a facility that manufactures commercial refrigeration units. The manufacturing operations include design, metal working, metal finishing, and blowing of polyurethane foam into panel jacketing for insulation purposes. A site visit was made in 1990 during which several opportunities for waste minimization were identified. Options identified included new techniques to reduce CFC emissions from foam manufacture, new foam production cleaning techniques to reduce methylene chloride usage, improved painting techniques to reduce VOC emissions, and reduction of solvent wastes from general cleaning procedures. Implementation of the identified waste minimization opportunities was not part of the program. Percent waste reduction, net annual savings, implementation costs and payback periods were estimated.

This Research Brief was developed by the Principal Investigators and EPA's Risk Reduction Engineering Laboratory in Cincinnati, OH, to announce key findings of this completed assessment.

Introduction

The environmental issues facing industry today have expanded considerably beyond traditional concerns. Wastewater, air emissions, potential soil and groundwater contamination, solid waste disposal, and employee health and safety have become increasingly important concerns. The management and disposal of hazardous substances, including both process-related wastes and residues from waste treatment, receive significant attention because of regulation and economics.

As environmental issues have become more complex, the strategies for waste management and control have become more systematic and integrated. The positive role of waste minimization and pollution prevention within industrial operations at each stage of product life is recognized throughout the world. An ideal goal is to manufacture products while generating the least amount of waste possible.

The Hazardous Waste Advisement Program (HWAP) of the Division of Hazardous Waste Management, NJDEPE, is pursuing the goals of waste minimization awareness and program implementation in the state. HWAP, with the help of an EPA grant from the Risk Reduction Engineering Laboratory, conducted an Assessment of Reduction and Recycling Opportunities for Hazardous Waste (ARROW) project. ARROW was designed to assess waste minimization potential across a broad range of New Jersey industries. The project targeted 30 sites to perform waste minimization assessments following the approach outlined in EPA's *Waste Minimization Opportunity Assessment Manual* (EPA/625/7-88/003). Under contract to NJDEPE, the Hazardous Substance Management Research Center at the New Jersey Institute of Technology (NJIT) assisted in conducting the assessments. This research brief presents an assessment of the manufacturing of commercial refrigeration units (1 of the 30 assessments performed) and provides recommendations for waste minimization options resulting from the assessment.

Methodology of Assessments

The assessment process was coordinated by a team of technical staff from NJIT with experience in process operations, basic chemistry, and environmental concerns and needs. Be-

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cause the EPA waste minimization manual is designed to be primarily applied by the in-house staff of the facility, the degree of involvement of the NJIT team varied according to the ease with which the facility staff could apply the manual. In some cases, NJIT's role was to provide advice. In others, NJIT conducted essentially the entire evaluation.

The goal of the project was to encourage participation in the assessment process by management and staff at the facility. To do this, the participants were encouraged to proceed through the organizational steps outlined in the manual. These steps can be summarized as follows:

- Obtaining corporate commitment to a waste minimization initiative
- Organizing a task force or similar group to carry out the assessment
- Developing a policy statement regarding waste minimization for issuance by corporate management
- Establishing tentative waste reduction goals to be achieved by the program
- Identifying waste-generating sites and processes
- Conducting a detailed site inspection
- Developing a list of options which may lead to the waste reduction goal
- Formally analyzing the feasibility of the various options
- Measuring the effectiveness of the options and continuing the assessment.

Not every facility was able to follow these steps as presented. In each case, however, the identification of waste-generating sites and processes, detailed site inspections, and development of options was carried out. Frequently, it was necessary for a high degree of involvement by NJIT to accomplish these steps. Two common reasons for needing outside participation were a shortage of technical staff within the company and a need to develop an agenda for technical action before corporate commitment and policy statements could be obtained.

It was not a goal of the ARROW project to participate in the feasibility analysis or implementation steps. However, NJIT offered to provide advice for feasibility analysis if requested.

In each case, the NJIT team made several site visits to the facility. Initially, visits were made to explain the EPA manual and to encourage the facility through the organizational stages. If delays and complications developed, the team offered assistance in the technical review, inspections, and option development.

No sampling or laboratory analysis was undertaken as part of these assessments.

Facility Background

The facility is a manufacturer of commercial refrigeration units typically used for food storage and sale. The manufacturing process involves creation of the metal framework and surfaces of the final unit, priming and painting of the unit, installation of the refrigeration components, and blowing in polyurethane foam which hardens into rigid insulation. The facility is located in an urban area and employs 200-300 people.

Manufacturing Processes

The production process for the refrigeration units can be divided into three general sections—sheet metal cutting and forming, metal coating and curing, and blowing of foam insulation. Each of the steps results in the creation of different types of waste.

The sheet metal cutting and forming step involves cutting, punching, and molding to form the desired shape for the unit. While this portion of the manufacturing process does not directly result in significant quantities of waste (particularly because care is taken in laying out metal pieces to minimize any waste from that source) the machinery used to accomplish the metal cutting and forming does require maintenance. This machinery care results in the generation of about 1,400 gal of waste lubricating oil each year. This oil comes from the engine and gear box oil changes.

The cut and formed metal is finished in three stages, all of which are required to provide the type and quality of finish desired by the manufacturer. The first step is degreasing of the metal surface using a hot caustic cleaner. The degreasing is necessary to remove the anti-oxidant protective oils which are applied to the sheet metal to prevent corrosion between the sheet metal manufacture and the time it is used. The second step is priming the metal using zinc phosphate. The zinc facilitates the retention of the finish coat to the metal surface. The finishing coat is a high solid, solvent-based paint. The color of the paint applied varies depending upon customer request. This variability results in frequent color changes on the manufacturing line. The paint is sprayed on using an electrostatic system reported to be approximately 81% efficient. When necessary the paint is thinned using isobutylcarbitol. Equipment is cleaned as required by the color changes. Xylol is used to clean pumps and other auxiliary equipment, and toluol is used to clean the hoses leading to the spray system from the paint reservoir.

The insulating polyurethane foam is produced at the facility by combining a polyol, diphenylmethane diisocyanate, and trichlorofluoromethane (R-11). While the exact formulation is proprietary, it is known that the R-11 represents about 10% of the mix. In addition, another chlorofluorocarbon, R-12, is used to blow the mixture into the steel panel jacketing. R-11 is encased in the cured solid structure of the mixture and, because of its heat transfer characteristics, helps provide the insulating characteristics of the mixture. According to the supplier of the chemicals used for generation of the polyurethane foam, about 40% of the R-11 and R-12 used in the process escapes into the air during the manufacture and curing phases and cannot be reduced significantly without development of new foaming technology.

The foam mixture cures very rapidly. The residual mix adhering to the foam blowing equipment would also cure and harden within a few minutes thereby ruining the equipment. To prevent this from occurring, the equipment is cleaned with 0.5 to 1.0 gal of methylene chloride after each unit is insulated. About 13,000 lb of the washing mixture is generated annually. Emissions of methylene chloride to the air from evaporation have not been quantified.

Existing Waste Management Activities

The company has already invested in equipment which is designed to improve efficiency and help prevent pollution. The acquisition of the electrostatic painting equipment demonstrates the interest by the company in improving the efficiency of the paint transfer process and in reducing the proportion of the material which is wasted.

The waste lubricating oil from maintenance and repair of the machinery used in metal cutting and shaping is collected and sent offsite for disposal. The annual volume of oil is about 1,400 gal. The oil changes generally occur at regularly scheduled intervals.

The waste stream from the degreasing operation has an annual volume of about 2900 lb and is also sent offsite for treatment.

The waste streams from the coating operations are somewhat more complex. Excess primer and solids from surface smoothing are captured in water and then filtered out before the bulk of the water is sent to the sewerage authority for treatment. Information about the volume of water from this use could not be obtained. The quantity of the filtered solids represents about 500 lb/yr. This appeared to be too small an amount to lead to consideration of metal recovery activities. The finish coat process uses a paint which has a high solids content and is solvent-based. The high solids means that the solvent content is relatively low (2.1-2.8 lb/gal). Performance requirements will not allow the substitute use of a water-based paint at this time. There is not a substitute product available which will allow the manufacturer to maintain the quality of the finish coat of the product. As indicated previously, the paint is sprayed on using an electrostatic system. When the painting equipment is cleaned, xylol is used to clean the pumps and other auxiliary equipment and toluol is used to clean the hoses leading to the spray system from the paint reservoir. The two solvent wastes are combined, accumulated in drums and disposed of as hazardous waste. About 18,000 gal of this waste is generated annually.

The insulating foam production operation generates a waste stream from the cleaning of the generation and blowing equipment. About 13,000 lb of the methylene chloride washings are generated annually and are sent offsite for disposal as hazardous waste.

Waste Minimization Opportunities

The type of waste currently generated by the facility, the source of the waste, the quantity of the waste and the annual treatment and disposal costs are given in Table 1. This particular facility presents a challenge in terms of describing and presenting opportunities for waste minimization. For example, the production of the polyurethane insulating foam results in a measurable waste stream only in terms of clean up solvents. On the other hand, there is a process-related air emission of a CFC which is thought to be of significant environmental concern. The available technological alternatives present some difficulties. Similarly, some improvements in the painting process will require significant capital investment in equipment which cannot be easily quantified presently based upon the information currently available.

Table 2 shows the opportunities for waste minimization recommended for the facility. 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 at the facility and possible waste reduction depend on the level of activity of the facility. 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. 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.

The cost savings are calculated both in terms of avoided costs of waste disposal and recovery of any value of raw material used again. Also, no equipment depreciation is factored into the calculations.

There are some commercially available alternatives to the present insulating foam process. The insulating process requires a gas for two purposes, one to generate foaming during the polymerization process and another to force the foam, prior to hardening, into the area where insulation is required. The CFC's that are presently being used do this job well. The relatively low boiling point leads to the foaming as a result of vaporization caused by the heat of reaction of the polymerization. Some of the CFC is entrained in the foam and contributes to the insulation performance of the product.

The use of other materials may result in loss of this added boost to the insulating characteristics of the foam. One of the available alternative technologies uses a hydrochlorofluorocarbon (HCFC) as the blowing agent. This class of materials has reduced impact on the upper atmosphere as compared to CFC's. The propulsion gas used in this system is nitrogen. Another alternative uses a proprietary composition and mixing approach which appears to use nitrogen as both blowing and propulsion agent. The cost of raw materials and equipment for this application is approximately the same as the currently used CFC technology. However, the insulation effectiveness of the resulting foam is only about 95% that of the existing foam material. This means that either the refrigeration units need to be redesigned to allow incorporation of an increased thickness of insulation or that the units will be in operation for longer periods. Either way more energy will be used because additional units may

Table 1. *Summary of Current Waste Generation*

Waste Generated	*Source of Waste*	*Annual Quantity Generated*	*Annual Waste Management Costs*
Waste Oil	*Repair and maintenance of metal cutting and forming equipment*	*1,400 gal*	*$600*
Water/Hydrocarbon Mixture	*Hot caustic degreasing operation*	*2,900 lb*	*3200*
Zinc Containing Solids	*Residues and smoothing solids from priming operation*	*500 lb*	*250*
Hydrocarbon Mixture (Toluol and Xylol)	*Equipment cleaning from spray painting*	*18,000 gal*	*22,000*
Methylene Chloride Solution	*Cleaning of polyurethane foam generation system*	*13,000 lb*	*16,000*

Table 2. *Summary of Recommended Waste Minimization Opportunities*

Waste Stream Reduced	*Minimization Opportunity*	*Annual Waste Reduction Quantity*	*Percent*	*Net Annual Savings*	*Implementation Cost*	*Payback Years*
Waste Oil	*Change to synthetic formula to lengthen time between oil changes*	*700 gal*	*50*	*$850*	*$2,800*	*3.3*
Hydrocarbon Mixture	*Keep separate the xylol and toluol streams. Acquire onsite distillation capability. Reuse*	*14,400 gal*	*80*	*31,000*	*20,000*	*0.6*
Methylene Chloride Solution	*Change to less hazardous solvent cleaning system available from the vendor of the polyurethane components. The newer solvent can be filtered and reused, reducing the need to purchase and dispose of cleaning solvent.*	*13,000 lb*	*100*	*19,400*	*5,000*	*0.25*
				(This option is somewhat more complex in the determination of savings and payback period. While all of the methylene chloride waste stream will be eliminated, another waste stream will be established. However, without some site experience, it is difficult to estimate the volume. If we assume an 80% reduction in the volume because of recycling and assume that disposal costs and chemical costs are the same as with methylene chloride, then the annual savings are $15,800 and the pay back period will be 0.3 yr. There will also be another waste stream resulting from the filtration of solids from the recycled solvent. Management costs for that stream will also reduce the net savings.)		

* Savings result from reduced raw material and treatment and disposal costs when implementing each minimization opportunity independently.

be required to refrigerate the same volume of material or the refrigeration equipment will run longer. It is difficult to determine, at this level of analysis, which choice is more environmentally favorable. However, the rapid escalation of CFC taxes and the impending ban on production and use of the materials will require a change at this facility.

It appeared that the electrostatic paint system which had been installed needed some additional adjustments in order to operate at its maximum high transfer efficiency. For some painting operations, portions of the spray were directed at areas where there was not metal to be painted resulting in a loss of the paint and increased VOC burdens. It is suggested that the number of spray nozzles be increased resulting in more precise control of the area being covered by paint. In addition, use of an optical recognition and control system could result in more savings. Discussions with the manufacturer of the painting system and with suppliers of optical control systems will be necessary to determine if this is feasible and to obtain a cost estimate.

Other coating alternatives should continue to be investigated. It is likely that none of them would be acceptable at present because of performance requirements. On the other hand, progress in broadening the technology of coating materials should be monitored. The goal of such changes is to reduce the level of VOC and associated hazardous waste streams. Powder coating virtually eliminates solvent, and any overspray is simply swept up and reused. The capital costs are comparable to those of the electrostatic spray system just acquired by the company. Another emerging technology utilizes supercritical carbon dioxide as the carrier for the solids in coatings. The coating system requires special equipment for production of the supercritical carbon dioxide. Generally, up to 70% of the volatile solvents can be replaced resulting in VOC reductions of the same amount. Additionally, it is reported that superior atomization occurs using this technology relative to solvent systems, resulting in fewer spraying defects.

Regulatory Implications

Changes in regulatory emphasis can be expected to have an impact on the manufacturing process at this facility. Particularly, the impending ban on production and use of most CFC's will cause a change in the production of the insulating foam. The technical and chemical details of this change are largely out of the hands of the company. They will acquire the equipment and supplies from someone else. In terms of the volume of waste generated at the facility, it is not clear whether this impending change will have a net positive or negative effect. It may take larger quantities of some solvent to clean the required equipment for example. The point is that regulatory changes do not always allow uniform movement to waste reduction. This is particularly true when cross media transfers of waste generation are considered. A change in a process such as this which has air emissions and may require a change in an air permit may be delayed while the air permitting process considers and approves (or disapproves) the application for a change. This facility will also be impacted by the increased regulatory scrutiny on methylene chloride. There are some alternatives available for this solvent which is used for cleaning purposes at this facility. It is not clear however, without some field trials whether the net effect on waste generation will be positive or negative. Methylene chloride is a particularly good solvent for the cleaning application here.

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