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Guides to Pollution Prevention

The Fiberglass-Reinforced and Composite Plastics Industry

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Notice

This report has been subjected to the U.S. Environmental Protection Agency's peer and administrative review and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

This document is intended as advisory guidance only to processors of fiberglass-reinforced and composite plastics in developing approaches for pollution prevention. Compliance with environmental and occupational safety and health laws is the responsibility of each individual business and is not the focus of this document.

Worksheets are provided for conducting waste minimization assessments of fiberglass-reinforced and composite plastics businesses. Users are encouraged to duplicate portions of this publication as needed to implement a waste minimization program.

Foreword

Fiberglass-reinforced and composite plastic (FRP/C) product industries generate wastes (including air emissions) during the fabrication process and from the use of solvents for clean up of tools, molds and spraying equipment.. The wastes generated are: partially solidified resins, contaminated solvent from equipment clean-up, scrap coated fiber, solvated resin streams, and volatile organic compound (VOC) emissions.

Reducing the generation of these wastes at the source, or recycling the wastes on or off site, will benefit the FRP/C manufacturers by reducing raw material needs, reducing disposal costs, and lowering the liabilities associated with hazardous waste disposal. This guide provides an overview of the FRP/C process and operations that generate waste and presents options for minimizing waste generation through source reduction and recycling.

Contents

Acknowledgments

This guide is based on a waste assessment study by Jonathan Tuck and Diana Evans of Woodward-Clyde Consultants for the California Department of Health Services (DHS), under the direction of Benjamin Fries, of the Alternative Technology Division, Toxic Substances Control Program. Teresa Harten of the U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, was the project officer responsible for the preparation of this manual, which was edited and produced by Jacobs Engineering Group Inc. J. D. Shoemaker and Rajeev Krishnan served as authors for this manual.

We would like to thank the following people, whose review of this guide contributed substantially to its development:

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Much of the information in this guide that provides a national perspective on the issues of waste generation and minimization was provided originally to the U.S. Environmental Protection Agency by Versar, Inc. and Jacobs Engineering Group ***Inc.*** in ***Waste Minimization-Issues*** and Options, ***Volume*** 11, Report No. PB87-114369 (1986).

Section 1
Introduction

This guide is designed to provide fiberglass-reinforced and composites (FRP/C) plastics fabricators with waste minimization options appropriate for this industry. It also provides worksheets designed to be used for a waste minimization assessment of an FRP/C fabricating plant, to be used in developing an understanding of the plant's waste generating processes and to suggest ways to reduce the waste. The guide should be used by FRP/C fabricating companies, particularly their plant operators and environmental engineers. Others who may find this document useful are regulatory agency representatives, industry suppliers and consultants.

In the following chapters of this manual you will find:

- A profile of the fiberglass-reinforced and composite plastics industry and the processes used by the industry (Section 2);
- Waste minimization options for FRP/C fabricating firms (Section 3);
- Waste minimization assessment guidelines and worksheets (Section 4);
- Appendices containing:
  - Case studies of waste generation and waste minimization practices of FRP/C fabricating firms;
  - Where to get help: additional sources of information.

The worksheets and the list of waste minimization options for FRP/C fabricating were developed through assessments of FRP/C fabricating firms by Woodward-Clyde Consultants, commissioned by the California Department of Health Services (Calif. DHS 1989). The firms' operations, manufacturing processes, and waste generation and management practices were surveyed, and their existing and potential waste minimization options were characterized. Finally, eco nomic analyses were performed on selected options.

Overview of Waste Minimization Assessment

Waste minimization is a policy specifically mandated by the U.S. Congress in the 1984 Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act (RCRA). As the federal agency responsible for writing regulations under RCRA, the U.S. Environmental Protection Agency (EPA) has an interest in ensuring that new methods and approaches are developed for minimizing hazardous waste and that such information is made available to the industries concerned. This guide is one of the approaches EPA is using to provide industry-specific information about waste minimization. The options and procedures outlined also can be used in efforts to minimize other wastes generated in a business.

In the working definition used by EPA, waste minimization consists of source reduction and ***recycling.*** Of the two approaches, source reduction is considered environmentally preferable to recycling. While a few states consider ***treatment*** of hazardous waste an approach to waste minimization, EPA does not, and thus treatment is not addressed in this guide.

Waste Minimization Opportunity Assessment

EPA has also developed a general manual for waste minimization ***in industry. The Waste Minimization Opportunity Assessment Manual*** (USEPA 1988) tells how to conduct a waste minimization assessment and develop options for reducing hazardous waste generation. It explains the management strategies needed to incorporate waste minimization into company policies and structure, how to establish a company-wide waste minimization program, conduct assessments, implement options, and make the program an on-going one. The elements of waste minimization assessment are explained in the next section.

A Waste Minimization Opportunity Assessment (WMOA) is a systematic procedure for identifying ways to reduce or eliminate waste. The four phases of a waste minimization opportunity assessment are: planning and organization, assessment, feasibility analysis and implementation. The steps involved in conducting a waste minimization assessment are shown in Figure 1 and presented in more detail below. Briefly, the assessment consists of a careful review of a plant's operations and waste streams and the selection of specific areas to assess. After a particular waste stream or area is established as the WMOA focus, a number of options with the potential to minimize waste are developed and screened. The technical and economic feasibility of the selected options are then evaluated. Finally, the most promising options are selected for implementation.

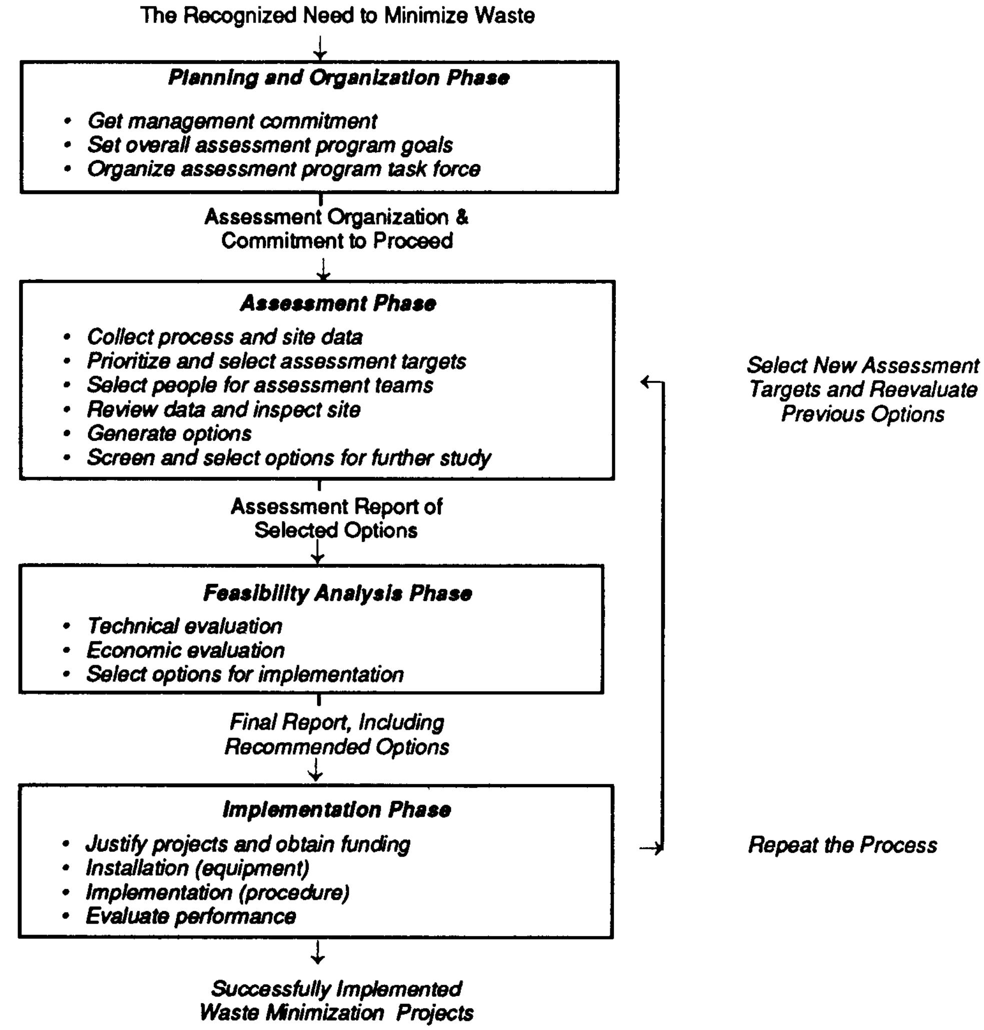

Figure 1. The waste minimization assessment procedure.

Planning and Organization Phase

Essential elements of planning and organization for a waste minimization program are: obtaining management commitment for the program; setting waste minimization goals; and organizing an assessment program task force.

Assessment Phase

The assessment phase involves a number of steps:

- Collect process and site data
- prioritize and select assessment targets
- Select assessment team
- Review data and inspect site
- Generate options
- Screen and select options for feasibility study

Collect process and site data. The waste streams at a site should be identified and characterized. Information about waste streams may be available on hazardous waste manifests, National Pollutant Discharge Elimination System (NPDES) reports, routine sampling programs and other sources.

Developing a basic understanding of the processes that generate waste at a site is essential to the WMOA process. Plow diagrams should be prepared to identify the quantity, types and rates of waste generating processes. Also, preparing material balances for various processes can be useful in tracking various process components and identifying losses or emissions that may have been unaccounted for previously.

Prioritize andselect assessment targets. Ideally, all waste streams in a business should be evaluated for potential waste minimization opportunities. With limited resources, however, a plant manager may need to concentrate waste minimization efforts in a specific area. Such considerations as quantity of waste, hazardous properties of the waste, regulations, safety of employees, economics, and other characteristics need to be evaluated in selecting a target stream.

Select assessment team. The team should include people with direct responsibility and knowledge of the particular waste stream or area of the plant Operators of equipment and the person who sweeps the floor should be included, for example.

Review data and inspect site. The assessment team evaluates process data in advance of the inspection. The inspection should follow the target process from the point where raw materials enter to the points where products and wastes leave. The team should identify the suspected sources of waste. This may include the production process; maintenance operations; and storage areas for raw materials, finished product, and work in progress. The inspection may result in the formation of preliminary conclusions about waste minimization opportunities. Full confirmation of these conclusions may require additional data collection, analysis, and/or site visits.

Generate options. The objective of this step is to generate a comprehensive set of waste minimization options for further consideration. Since technical and economic concerns will be considered in the later feasibility step, no options are ruled out at this time. Information from the site inspection, as well as trade associations, government agencies, technical and trade reports, equipment vendors, consultants, and plant engineers and operators may serve as sources of ideas for waste minimization options.

Both source reduction and recycling options should be considered. Source reduction may be accomplished through: good operating practices, technology changes, input material changes, and product changes. Recycling includes use and reuse of waste, and reclamation.

Screen and select options for further study. This screening process is intended to select the most promising options for full technical and economic feasibility study. Through either an informal review or a quantitative decision-making process, options that appear marginal, impractical or inferior are eliminated from consideration.

Feasibility Analysis Phase

An option must be shown to be technically and economically feasible in order to merit serious consideration for adoption at a facility. A technical evaluation determines whether a proposed option will work in a specific application. Both process and equipment changes need to be assessed for their overall effects on waste quantity and product quality.

An economic evaluation is carried out using standard measures of profitability, such as payback period, return on investment, and net present value. As in any project, the cost elements of a waste minimization project can be broken down into capital costs and economic costs. Savings and changes in revenue also need to be considered.

Implementation Phase

An option that passes both technical and economic feasibility reviews should then be implemented at a facility. It is then up to the WMOA team, with the management support, to continue the process of tracking wastes and identifying opportunities for waste minimization, throughout a facility and by way of periodic reassessments. Either such ongoing reassessments or an initial investigation of waste minimization opportunities can be conducted using this manual.

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Calif. DHS. 1989. ***Waste audit study: Fiberglass-reinforced and composite plastic products.*** Report prepared by Woodward-Clyde Consultants, Oakland, CA, for the Alternative Technology Section, Toxic Substances Control Division, California Department of Health Services.

USEPA. 1988. ***Waste minimization opportunity assess***ment ***manual.*** U.S. Environmental Protection Agency, H.azardous Waste Engineering Research Laboratory, Cincinnati, OH. EPA/625/7-88/003.

Section 2
Fiberglass-Reinforced and Composite Plastic Products Industry Profile

Industry Description

The fiberglass-reinforced and composite (FRP/C) plastic products industry is difficult to classify by Standard Industrial Classification Code (SIC), because it crosses several industrial categories, ranging from household vanity installations to complex structural composites for the aerospace industry. Some of the more common industries that fabricate fiberglass and composite plastics as part of the manufacturing process are the automotive, ship and boat building (SIC codes 3731 and 3732). aerospace and miscellaneous plastics products industry (SIC codes 3081 to 3089). Table 1 shows the consumption of fiberglass reinforced polyester resin in 1990 by major market, along with the estimated value of products.

Currently, reinforced plastics make up about 5 percent of the total plastic demand, but new developments in blending, compounding, and fabrication will increase the demand for reinforced plastics. Glass fiber is the dominant reinforcing material, representing about 90 percent of reinforcement materials in use. Other common types of reinforcement materials used are aramid and carbon fibers. The glassfiber-reinforced structural composites market is expected to grow at a rate of 10 to 15 percent per year, primarily as a result of its increasing importance in the construction of automotive components.

Products and Their Uses

Thousands of products are manufactured from reinforced plastics. Examples include hulls for recreational and commercial watercraft; bodies for recreational vehicles; building panels, sporting equipment, appliances, and power tools; bathtub, shower, and vanity installations; automotive, aerospace, and aircraft components; and structural components for chemical process equipment and storage tanks. The fiberglass reinforcing in these plastic products improves their structural strength and rigidity, as well as providing high heat resistance and dielectric strength. The businesses included in the waste minimization assessments of this guide supply finished FRP/C products for the automobile, aerospace, sporting goods, recreational and commercial watercraft, and vanity industries. However, considering the general nature of the fabrication processes, the results of the study can be extended to other FRP/C industries as well.

Plastics can be classified as either thermoplastic or thermosetting. Thermoplastic materials become fluid upon heating above the heat distortion temperature, and, upon cooling, set to an elastic solid The process of reheating and cooling can be repeated many times, although there may be some degradation in chemical or physical properties of the final product. Thermosetting materials, on the other hand, ineversibly polymerize and solidify at elevated temperature. The internal chemical structure of a themosetting plastic material is permanently altered by heat, resulting in a product that cannot be resoftened (Jones and Simon 1983).

Both thermoplastic and thermosetting resins are used to manufacture FRP/C plastic products. Thermoplastics processing offers faster molding cycles, lower emissions during processing, lower cost per pound of raw material, ease of recycling, and lower labor intensity. Open molding of thermosetting plastics is likely to continue as a viable process because of the design constraints associated with many products, limited unit production requirements, performance requirements, and market demands. Recent advances in processing technologies and thermoplastic resin systems are causing the thermoset-plastic industry to examine alternative approaches to molding processes.

Another rapidly growing market for fiber-reinforced structural composite plastics is the automotive and aerospace industry. Composites are becoming or have the potential to become preferred materials for certain passenger car components, such as leaf springs, suspension components, bumper beams, drive shafts, wheels, and door structures. Components such as these are expected to be processed largely from fabricator suppliers (Pishman 1989).

Table 1. Consumption of Fiberglass-Reinforced Polyester Resin by Market (1990)

	Millions of Pounds/Year	Fabricated Value Million $
Aircraft/Aerospace	34	408
Appliances/Business equipment	93	279
Construction	384	1,729
Consumer products	127	572
Corrosion-resistant products	336	2,688
Electrical	53	132
Marine	300	2,400
Transportation	215	1,075
Other	48	192
Total	1,590	9,474

Source: Fiberglass Fabrication Association

Raw Materials

The materials primarily used by the FRP/C plastic product manufacturing industry include resins, fiberglass or other fiber substrate, solvents, catalyst, and other specialty chemical additives. A brief description of each category of raw material is given below.

Resins

Typical resin classes used by FRP/C manufacturers include: polyesters, epoxies, polyamides, and phenolics. The type of resin to be used in a particular process depends on the specific properties required for the end product. The resin is usually supplied in liquid form, which may include a solvent. For example, polyester is typically dissolved in styrene monomer.

Fiber Reinforcement

Glass fiber substrates are manufactured in several forms. The basic forms include continuous-strand mat, chopped strand mat, fabrics (woven and knitted) and continuous strand weaving. The form in which the fiber is used is dependent primarily on the fabrication techniques. Fiberglass content in the product typically ranges from 25 to 60 percent.

Initiators and Catalysts

In the case of epoxy and polyester resins, curing employs hardeners or catalysts to develop desirable properties. Curing agents include amines, anhydrides, aldehyde condensation products, and Lewis acid catalysts. Aliphatic amines, such as diethylenetriamine and triethylenetetramine, are often used for room temperature curings. Aromatic amines, such as methylenedianiline, are used where elevated temperature cures are acceptable. Formulated epoxy systems generally contain accelerators, additives and tillers to reduce costs, shrinkage, and thermal expansion (Calif. DHS 1989).

Additives

Chemical additives are introduced to obtain certain product characteristics such as heat resistance, aging, electrical properties, optical clarity, permeability, flame retardants, and ease of application. Because of the diversity of consumer requirements, additive requirements are often complex. They may include fillers; flame retardants; plasticizers; tougheners and thickening agents; colorants; antioxidants; anti-static compounds and ultraviolet stabilizers. There are literally hundreds of chemicals used as additives. Four functional classes of additives (fillers, plasticizers, reinforcements and colorants) account for about 90 percent of all additives used in plastics. Compared to resins, these materials are generally chemically inert Except for plasticizers, they are unaffected by light, heat and atmosphere. The remaining 10 percent of plastics additives is dominated by flame retardants.

Solvents

Solvents such as acetone, methyl ethyl ketone and methanol are used in large quantities to clean equipment and tools. Of these, acetone is the most widely used. Many fabricators have begun to replace acetone with dibasic ester @BE). DBE is a mixture of the methyl esters of adipic, glutaric and succinic acids that is both less volatile and less flammable than acetone (Lucas 1988). Methylene chloride has been used widely for cleaning because it is an effective solvent for many cured resins, although its use has been declining due to health and safety concerns. Styrene is reportedly used by some resin manufacturers to clean equipment, but is not used by fabricators.

Process Description

The most significant processing activity for this industry involves the combination of polymerizing resin and reinforcing material, resulting in a product with an excellent strength-to-weight ratio. The reinforcing material is commonly fiberglass. The resin and reinforcing material are either sprayed onto a mold or the reinforcing material is coated with the resin. The product is usually lighter than metal or wooden products and is stronger than unreinforced plastic construction. Reinforced plastics products are fabricated using any of several processes, depending on their size, shape and other desired physical characteristics. The processes can be categorized into three groups: (a) mold-based processes; (b) fiberglass coating-based processes; and (c) pultmsion. Table 2 gives the consumption of resin and reinforcement by process in 1990.

Mold-Based Processes

The most common among the mold-based processes are contact molding centrifugal casting, resin transfer molding (RTM) and compression molding. A brief description of each of these processes followed by a detailed description of the general steps involved in the manufacture of molded fiberglass products is given below.

Contact molding is defined as a zero-pressure molding method in which only one side is the mold surface. There are two principal techniques - hand layup and sprayup. In the hand layup process, the reinforcement is manually fitted to a mold wetted with catalyzed resin mix, after which it is saturated with more resin. Spray layup, or "sprayup." differs from hand layup in that it uses mechanical spraying and chopping equipment for depositing the resin and glass reinforcement.

In the ***centrjfugal molding process,*** a cylindrical mold is spun about its long axis. The reinforcement is laid in the mold, resin is poured in, and the mold is turned. The laminate is compressed against the mold to produce parts with smooth surfaces and low void content.

In the ***RTM process,*** a skeletal "preform" of reinforcement is positioned in a mold that is then clamped and injected with a two-part thermoset system. RTM is becoming more common where high product strength, cost effectiveness, and production flexibility are critical factors (Wilder 1988).

Compression molding involves the use of two matched dies to define the entire outer surface of the part When closed and filled with a resin mix, the matched die mold is subjected to heat and pressure to cure the plastic.

Table 2. Consumption of Fiberglass-Reinforced Polyester Resin by Process or Application (1990)

Process	Millions of Pounds per Year	
	Resin	Reinforcement
Molded	504	141
Filament-wound	108	81
Pultruded	108	91
Sheet (flat and corrugated)	168	50
Surface coating	19	0
Auto body	81	2
Cultured marble	126	0
Other	93	14
Export	20	0
	1,227	379

Source: Fiberglass Fabrication Association

The steps involved in the manufacture of mold-based fiberglass products are largely common to all of the above processes. For illustrative purposes the major steps in the spray up process are listed and explained below:

- **Mold preparation**
- **Mold waxing**
- **Resin preparation**
- **Gelcoat application**
- **Fiberglass application**

The sequence of operations in a typical spray mold-based manufacturing process is shown in Figure 2.

Mold Preparation

At some plants, molds are constantly being built and redesigned. These molds often require a fine finish and considerable detail work. Most molds are made of wood with a plastic finish. An epoxy resin system with filler is sometimes used in the mold preparation, creating a clay-like material. For short and prototype runs, a very hard, durable gypsum plaster is sometimes used for making molds.

Mold Waxing

Mold waxing is done with paste wax and rags, similar to waxing a car.

Resin Preparation

Most companies purchase pre-promoted resin. Generally, the resin is stored either in a tank or 55-gallon drum and is pumped from storage into spray or chopper guns. Filler and pigment may be added to the resin in the tank or drum. Solvent and catalyst axe added through a separate feed line.

Gelcoat Application

Gelcoat is a pigmented resin containing approximately 35 percent styrene. Application to the product is with either an air-atomized or airless spray gun, usually conducted in a spray booth. The catalyst can be added to the resin by hand-mixing a weighed amount into a container feeding the spray gun. Alternatively, the catalyst can be injected through a separate line into the gun head, where it mixes with the resin.

Fiberglass Application

For fiberglass molded products, the viscous resin is either mixed with, sprayed or brushed onto fiberglass reinforcing material. Fiberglass comes in either a woven mat or cord-like roving which is applied with resin during fabrication. Fillers or thickeners can be stirred into the resin mix to provide additional body.

Fiberglass Coating-Based Processes

The steps involved in the manufacture of fiberglass coating based processes are explained below. Coating-based processes include sheet molding and filament winding. Filament winding is the process of laying resin-impregnated fibers onto a rotating mandrel surface in a precise geometric pattern, and curing them to form the product. Sheet molding involves the coating (and subsequent curing) of resin on to a woven material such as fiberglass matting. The production process for a typical composite plastic manufactured through a coating-based process is shown in Figure 3. Specific unit operations are described in the following paragraphs (Calif. DHS 1989).

Epoxy Resin Pretreatment

In this step, the epoxy resin, catalyst, any fillers, and solvent are added to a reactor, then heated to start the resin-curing process. The reactor must be washed and rinsed with solvent between pretreatment batches, especially when consecutive pretreatment batches consist of different epoxy formulations.

Resin Mixing

This step mixes resin, solvent, catalyst, filler, pigment, and stabilizer to result in properties tailored for the product being run. The batch quantity mixed is based on the quantity of fabric to be produced. Mixing the improper quantity can generate excess resin waste, although mix can be covered and stored in a cool room until it is used. Most mixes can be stored for about 14 days at 45°F without adverse effect on product quality. There are literally hundreds of possible mix types, each determined by each customer requirements, which the fabricator cannot control. The variety of resin mixes and strict customer specifications are two major factors limiting efforts to reduce and recycle wastes.

Fabric Coating and Heat Curing

The coating process begins by filling the treater pan, which holds the resin that coats the fabric. The specific gravity of the resin mix must be adjusted by adding solvent at a small reservoir tank upstream of the ***treater*** pan. During the coating process, resin is continuously circulated between the reservoir and the treater pan. The pan and associated piping typically hold about 100 pounds of resin mix. The fabric to be coated is loaded onto the unwind shafts. The fabric dips into the pan and then passes between two metering rollers, which squeeze the appropriate amount of resin into the fabric. The operator controls the speed of the fabric through the mix pan, the spacing of the rolls, and the final specific gravity of the resin. Improperly setting these parameters can result in offspec material and a shortage or excess quantity of resin applied.

The coated fabric is then fed to the treater, which cures the resin coating at an elevated temperature and evaporates the solvent. The solvent-laden air stream may be passed through a condenser for solvent recovery or burned in a thermal oxidizer. While the condenser is preferable for waste minimization, some plants may also need an oxidizer downstream of the condenser to meet local air emission limits. Heat recovered from the thermal oxidizer may be used to cure the composite in the treater. The cured composite is cooled before it is wound on the final roll. At the end of a run, the resin pan must be emptied and cleaned, and leftover solvated resin must be recycled or managed as hazardous waste.

Slitting/Rewind

If products are required in 2-inch widths, then a full-width product roll is slit and rewound into separate rolls of 2-inch-wide tape. If a product roll is solid or rolled imperfectly during production, the operator marks the damaged section for removal during rewind.

Pultrusion

Pultrusion, which can be thought of as extrusion by pulling, is used to produce continuous cross-sectional lineals similar to those made by extruding metals such as aluminum. Reinforcing fibers are pulled through a liquid resin mix bath and into a long machined steel die, where heat initiates an exothermic reaction to polymerize the thermosetting resin matrix. The composite profile emerges from the die as a hot, constant cross-sectional that cools sufficiently to be fed into a clamping and pulling mechanism. The product can then be cut to desired lengths. Example products include electrical insulation materials, ladders, walkway gratings, structural supports, and rods and antennas (USEPA 1988).

Waste Description

The generation of hazardous wastes in the manufacture of FRP/C plastic products is common to most fabricating processes. These hazardous wastes include used containers contaminated with residual chemicals, spent cleaning solvent, and wash-down wastewater. The quantities of waste generated range from one or two gallons per month to several tons, depending on the products manufactured and the capacity of the plant. The wastes and their process origins are listed in Table 3.

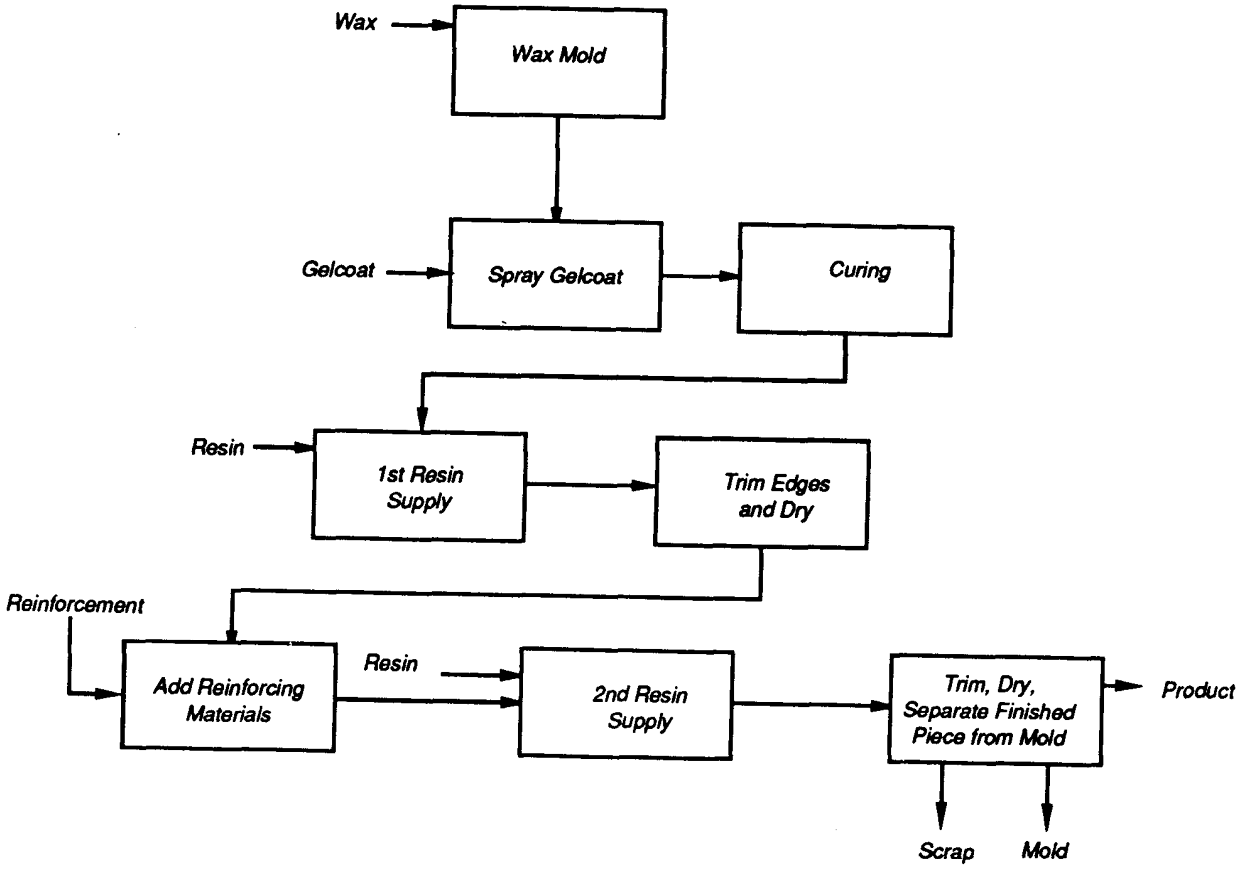

Figure 2. Block flow diagram—spray molding.
Adopted from California DHS 1989.

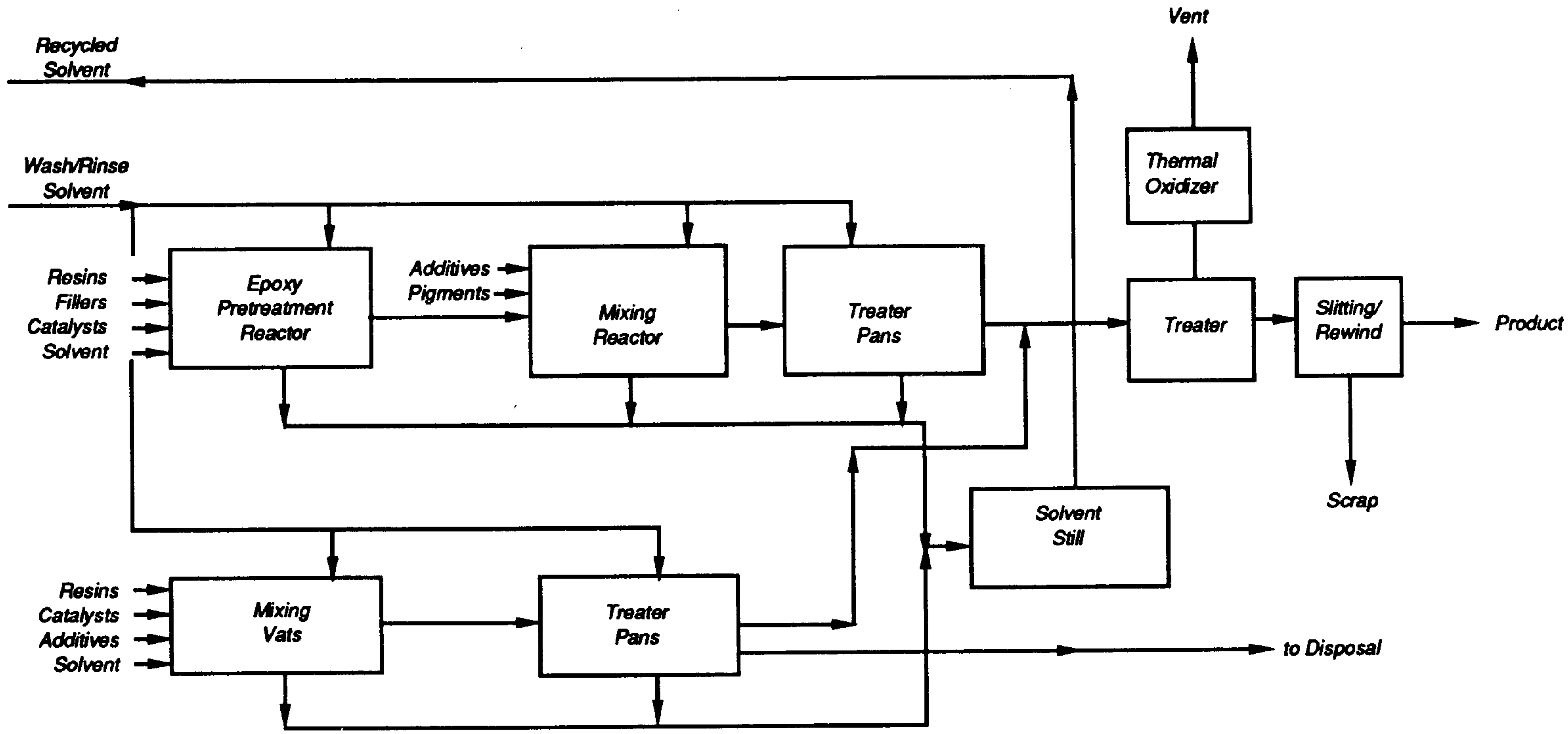

Figure 3. Composites manufacturing flow diagram.
Adopted from California DHS 1989

Table 3. Fiberglass-Reinforced and Composite Plastics Fabrication Waste

Waste Description	Process Origin	Composition
Waste solvent	Hands, tool mold and equipment cleaning	Resin-contaminated solvent
Empty resin and solvent containers	Unloading of materials into mixing tanks	Small amounts of residual resin and solvent
Laboratory analysis wastes	Formulating and testing	Spent resins, solvents, and finished and semi-finished trial products
Cleanup rags	Equipment cleaning operations	Solvents and small amount of resins
Pre-preg (previous& resin-impregnated) waste fabric	Leftovers from a particular batch or scrapped when product sample does not meet customer specification	Resins and fiberglass substrate (including minor quantities of chemical additives)
Empty plastic, paper and cardboard containers with residual peroxides, glass routing and chemical additives	Unloading of raw materials into process tanks	Chemical additives such as "Cab-O-Sil' and aluminum trihydrate
Expired raw materials	Raw material that has exceeded shelf life or otherwise became unusable	Usually semi-solid and self-cured resin
Gelcoat and resin overspray	Overspray during fabrication process	Resins, pigments, catalyst and chemical additives
Scrap solvated resin	Residue from piping and treater pan at the end of a run	Resins and resin-contaminated solvents
Partially-cured waste resins	Discontinued batch	Contaminated and unusable resin and solvents
Volatile organic compounds	Volatilized solvent and mold release agents, &ring curing and open vessels containing solvents	Solvents and volatile monomers (e.g. styrene)
Waste water	Equipment cleaning with emulsifiers	Water with organic chemical contaminants and emulsifier

Typical liquid hazardous wastes include spent cleaning solvent from equipment cleanup, scrap solvated resin left over in mix tanks, diluted resin from the treater pan, and partially-cured resin. The mix vessel and treater clean up waste solvent is contaminated with resin from the cleaning. The scrap solvated resin comes from the piping and treater pan at the end of a run, and any residual resin mix that cannot be stored for later use. The partially-cured resin generally results from a smallquantity product run that requires only a partial drumload of a resin, leaving the rest as waste.

Primary solid wastes include: gelcoat and resin overspray material that lands on the floor instead of on the mold; unused raw material resin that has exceeded the shelf life date or otherwise thickened beyond usefulness; raw material containers including plastic containers for organic peroxides, boxes for glass roving, drums for gelcoat, paper bags for "Cab-O-Sil" and aluminum trihydrate, and additives, and empty resin and solvent drums; pre-preg waste fabric; clean-up rags; and lab packs from research operations. Although the cost of gelcoat and resin waste disposal is often small, the losses due to unused and wasted raw material (resin and catalyst) are quite significant.

From the standpoint of waste minimization and occupational exposure, two solid wastes are most significant These are the gelcoat and resin overspray and the resin and gelcoat waste that has thickened. The gelcoat overspray accumulates as a paint-like coating wherever it settles and dries. Approximately 85 percent of the resin spray goes onto the mold and 15 percent ends up as waste (Calif. DHS 1989). Many fabricators simply spread paper, usually treated with a fire-retardant, on the floor to catch the overspray. Dried overspray is fully cured and non-hazardous, so periodically the paper is collected and sent to a landfill. Some fabricators prefer to use sand on the floor to further reduce the risk of fire. Although a few shops use sawdust (Calif. DHS 1989), this practice is strongly discouraged for safety reasons. Organic peroxide catalysts react strongly with sawdust to cause a fire. Thickened gelcoat and resin that is no longer suitable for spraying is solidified by mixing with catalyst, then discarded as a non-hazardous waste. Similar waste is also obtained when the resin tank is cleaned, which is often an annual occurrence. One study indicates that for each 100 pounds of resin disposed of in this way, approximately $70 of raw materials are lost (Calif. DHS 1989).

Organic vapors consisting of volatile organic compounds (VOC) are emitted from fresh resin surfaces during the fabrication process and from the use of solvents (usually acetone) for cleanup of tools, molds and spraying equipment. Organic vapor emissions from fiberglass fabrication processes occur when the polymerizing agents and solvents contained in the liquid resin mix evaporate into the air during resin application and curing. State-of-the-art techniques can economically recover solvents in concentrations above 70 ppm. through activated carbon adsorption. However, styrene can polymerize on the carbon and deactivate the adsorber. When solvent vapor reclamation is not feasible, thermal oxidation of the solvent emissions can be conducted with an oxidation efficiency exceeding 97 percent, although the cost per ton of VOC is quite high. There also may be some particulate air emissions from automatic fiber chopping equipment.

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Section 3
Waste Minimization Options for Fiberglass-Reinforced and Composite Plastics Fabricators

This section discusses waste minimization methods found useful for FRP/C fabrication operations. These methods come from the California DHS study, other accounts published in the literature and through industry contacts. The primary waste streams associated with FRP/C fabrication are listed in Table 4, along with recommended control methods.

The waste streams are: equipment cleaning wastes; scrap solvated and partially cured resin; gelcoat, resin and solvent oversprays; resin and solvent contaminated floor-sweepings; empty bags and drums; rejected and/or excess raw material; cleanup rags; laboratory and research wastes and monomer (resin) emissions due to the polymer-cross linking reaction. The waste minimization methods listed in Table 4 can be classified generally as source reduction, which can be achieved through material substitution, process or equipment modification, or better operating practices; or as recycling.

Many of the source reduction options available to composite plastic product manufacturers only require better operating practices or minor in-plant process modification to effect significant waste reduction and savings by virtue of less wasted raw materials and offspec products. Better operating practices are procedural or institutional policies that result in reducing waste. They include:

- Waste stream segregation
- Personnel practices
  - Management initiatives
  - Employee training
  - Employee incentives
- Procedural measures
  - Documentation
  - Material handling and storage
  - Material tracking and inventory control
  - Scheduling

Table 4. Waste Minimization Methods for Fiberglass Rainforced and Composite Plastics Fabricators

Waste Stream	Waste Minimization Methods
Equipment cleaning wastes	Restrict solvent issue. Maximize production runs. Store and reuse cleaning wastes. Use less toxic and volatile solvent substitutes. On-site recovery. Off-site recovery. Reduce rinse solvent usage. Waste segregation.
Scrap solvated and partially cured resins	Modify resin pan geometry. Reduce transfer pipe size. Waste exchange.
Gelcoat resin and solvent ovarsprays	Change spray design
Rejected and/or excess raw material	Improve inventory control Purchase materials in smaller containers. Return unused materials to suppliers.
Resin and solvent contaminated floor sweepings	Use recyclable floor sweeping compound. Reduce solvent and resin spillage and oversprays by employing alternate material application and fabrication techniques.
Empty bags and drums	Cardboard recovery. Container recycling. Returnable containers. Use plastic liners in drums.
Air emissions	Improve/modify material application. Cover solvent containers. Use emulsions or less volitile solvents.
Miscellaneous waste stream	Product/process substitution.
Cleanup rags	Efficient utilization of clean programs. Auto-cleaning process equipment.
Laboratory and research wastes	Reduce quantities of raw material and products for testing and analysis.

Many of these measures are used in industry to promote operational efficiency. In addition, they can often be implemented at little or no cost to the facility. When one considers the waste reduction potential, ease of implementation, and little or no implementation cost, better operating practices usually provide a very promising early focus area for any waste minimization effort. They should be addressed before proceeding with more difficult, technology-based measures.

In addition to the specific recommendations discussed below, rapidly advancing technology makes it important that companies continually educate themselves about improvements that are waste reducing and pollution preventing. Information sources to help inform companies about such technology include trade associations and journals, chemical and equipment suppliers, equipment expositions, conferences, and industry newsletters. By keeping abreast of changes and implementing applicable technology improvements, companies can often take advantage of the dual benefits of reduced waste generation and a more cost efficient operation.

The following sections discuss the waste minimization methods listed in Table 4 for specific waste streams.

Equipment Cleaning Wastes

Solvents are used to remove uncured resins from spray equipment, rollers, brushes, tools, and finished surfaces. Typical solvents used include acetone, methanol, methyl ethyl ketone (MEK), toluene and xylene.

Acetone and other similar solvents are used for general cleaning, as standard practice for most open-mold fabricators of fiberglass products. To clean the spray equipment, acetone is usually circulated through the lines after the spray operation is shut down for the day. A simple but effective method practiced by some fabricators to minimize wastes is placing the containers of solvent near the resin spray area to prevent spills and drippage for tool cleaning. Generally, the solvent is reused until the high concentration of resin contamination prevents effective cleaning. However, if the containers are left uncovered, solvent will evaporate, increasing air emissions as well as resin concentration.

Methylene chloride is an effective solvent for cured resins, and has been used by plastics fabricators. Although many other solvents have been tried, including multicomponent mixtures, these have had mixed results. The best way to minimize the need for this chemical is to clean equipment before the resin dries.

Disposal of contaminated solvents represents a major hazardous waste management expense. In addition, fugitive air emissions during the curing and cleaning processes are also of concern. Some of the potential waste reduction methods are described in the following paragraphs.

Restrict Solvent Issue

Many shops have limited the quantity of solvent issued each shift and indicate this has reduced waste, although the savings are difficult to quantify.

Maximize Production Runs

Production runs should be scheduled together to reduce the need for equipment cleaning between batches. Consideration should also be given to the potential for scheduling families of products in sequence, so that cleanup between batches can be minimized.

Store and Reuse Cleaning Solvents

Assessments performed at FRP/C fabricators indicate that some plants collect spent solvents for reuse in cleaning operations (Calif. DHS 1989). However, the solvents cannot be reused if contaminants build up to levels that do not permit effective cleaning.

Use Less Toxic and Less Volatile Solvents

Relatively less toxic and less volatile solvents that are biodegradable, water-soluble, resin bed compatible and recoverable are commercially available as substitutes for the conventional solvents used in the FRP/C industry. These substitutes can be used in the curing process and/or for cleaning, depending on the type of solvent For example, dibasic ester (DBE) based organic solvents do not evaporate as rapidly as acetone. When it spills during an operation; it will remain until it is cleaned up, collected and recovered by distillation, thus reducing VOC emissions and increasing the potential for reuse. One publication claimed a 60 percent savings by using DBE instead of acetone (Lucas 1990). DBE also does not have the fire hazard of acetone. Emulsifiers, which can be used instead of solvents in some services, are discussed in another section.

Reduce Solvent Rinse Usage

Substantial quantities of solvent are used for cleanout of epoxy pretreaters, mix tanks and treater pans. Using small lab type wash bottles for treater pan cleanouts can reduce solvent usage. Squeegee tools can also be used for the treater and vessel cleanouts, so that a smaller amount of solvent can be applied to the vessel to dissolve the remaining solvated resin. The squeegee may also be pressed against the vessel walls to force the remaining resin to the bottom of the pan or vessel for collection. One study estimated that using squeegees could reduce solvent requirement by 25 percent (Calif. DHS 1989). Additionally, a two-stage cleaning process may be used, where dirty equipment or a tool is first cleaned in dirty solvent (stored in a separate container), followed by a clean rinse with a smaller volume of fresh solvent, which is collected separately. When the dirty solvent approaches the maximum level of contamination, it should be removed for recycle and replaced with the accumulated "clean" rinse solvent.

Improving Recyclability of Solvent Waste

Solvent waste can be more easily recycled if the procedure below is followed (Calif. DHS 1986):

- Segregate solvent wastes by separating:
  - chlorinated from nonchlorinated solvent wastes;

- ahphatic from aromatic solvent wastes;
- chlorofluorocathons from methylene chloride;
- wastewater from flammables.

· Keep water out of the waste solvents

Drums should be covered to prevent contamination with water.

· Minimize solids

Solids concentrations should be kept at a minimum to allow for efficient solvent reclamation.

· Control solvent concentration

Maintain solvent concentration above 40 percent.

• Label waste

Keep a chemical identification label on each waste container. Record the exact composition and method by which the solvent waste was generated.

On-site Solvent Recovery

Batch-type distillation units have proven to be successful in meeting the needs of firms producing small-to-moderate quantities of contaminated solvents such as acetone. Commercially available sizes range from 5- to 55-gallon units. A basic batch-type system consists of four major components: a contaminated solvent collection tank, a heated boiling chamber, a condenser, and a clean solvent collection container. These units are usually contained within a single compact cabinet, so that the space required is generally less than that required for storage of virgin solvents and contaminated waste. Initial investment ranges from approximately $3,000 for a basic 5-gallon unit to more than $30,000 for a relatively sophisticated 55-gallon unit with labor-saving automatic control systems and pumps.

Large-volume generators of contaminated solvents may find continuous-feed distillation equipment better suited to their requirements than batch recovery units. Capacities for these systems can range from 250 gallons per shift to as much as 200 gallons per hour. Continuous units are not likely to be economical for firms with recovery needs of less than 100 gallons per day, because installation costs for large units are likely to exceed $50,000. The continuous-feed system consists of the same components included in a batch-type distillation unit, with more elaborate controls and materials-handling equipment. An automatic pumping system continuously transfers contaminated solvents from storage to the boiling chamber. Condensers may be either water- or air-cooled. The clean solvent collection system must be equipped with a monitoring system to avoid overflow.

Often, solvated epoxy is the only resin suited to the batch distillation process. Non-epoxy resins (phenolic, polyamide, and polyester) have lower flash points and are more suscep tible to runaway reactions. However, some fabricators have reportedly used batch distillation successfully with polyester resins. Reducing the solids content in solvated non-epoxy resin streams may be possible with filtration, yielding the same result without exceeding temperature constraints.

Off-site Solvent Recycling

Commercial solvent recycling facilities offer a variety of services, ranging from operating a waste treatment/recycling unit on the generator's property to accepting and recycling solvent waste at a central facility. Some recyclers accept both halogenated and non-halogenated solvents, while others specialize in one or the other. Off-site commercial recycling services are often well-suited to small quantity generators (SQGs). who may not generate sufficient volume of waste solvent to justify on-site recycling. The off-site services are also attractive to generators who prefer to avoid the technical, safety, and managerial demands of on-site recycling. However, off-site recycling has the disadvantage of potentially high transportation costs and liability.

Replace Solvents With Emulsifiers

Some fabricators now use emulsifiers instead of organic solvents. The emulsifier is an alkaline mixture of surfactants, wetting agents and various proprietary ingredients which can often be disposed of in the sewer. Advantages include: virtually no air emissions, biodegradability, and non-flammability. Some suppliers claim emulsifiers last twice as long as solvents. However, some emulsifier concentrates may contain solvents, dissolved metals, silicates and phosphates that make them unacceptable in some sewage systems. Different cleaning techniques must be employed when using emulsifiers, so adequate instruction of both management and workers is essential Changing over from solvents to emulsifiers is easiest for hand and tool cleaning, which usually represents the largest consumption of acetone (Halle and Brennan 1990). One study indicated that emulsions are inadequate for cleanup of gelcoat or cured resins (USEPA 1990a).

Scrap Solvated and Partially-Cured Resins

Modify Resin Pan Geometry

Pan widths should be no more than 10 inches wider than the fabric. If a narrow width fabric is run in an unnecessarily wide pan, additional solvated resin is wasted, since the wide pan holds a larger quantity at the end of the treater run. To alleviate this problem, simple adjusting devices made to fit into the treater pan to reduce its volume may be installed. This could consist of a plastic, wooden, or metal part molded to fit into the end of the treater pan, which would occupy the treater pan volume usually filled with resin but not required when coating the narrow fabric.

Reduce Transfer Pipe Size

Typically, a long pipe connects the mix tank to the treater tank. Each time a run ends the solvated resin in the treater pan is discarded, along with the resin in the interconnecting pipe. Significant resin savings can be realized by installing smaller diameter pipe. However, this requires detailed hydraulic analysis and possibly pump modifications to ensure that an acceptable flow rate is maintained.

Waste Exchange

Participation by a generator in a waste exchange program to reduce the volume of hazardous wastes satisfies the waste minimization certification requirement on the Uniform Hazardous Waste Manifest. In addition to helping meet regulatory requirements, participation in a waste exchange program pro vides the waste generator with an opportunity to explore alternative waste management options that may lead to a more cost-effective waste management program. Waste exchanges (see Appendix B) are an effective vehicle for increasing recycling and resource reuse opportunities, and can be an important part of a company's overall strategy to manage waste in an environmentally sound and cost-effective manner. According to representatives of several plastic recycling companies, there is a demand for thermoplastics, which can be melted and reformed. Two wastes of the FRP spray mold and composites industries appear to be particularly well suited for waste exchange listings: partially-solidified resin and scrap fiber.

Improve Material Application Procedures

Significant waste reduction can be achieved by optimizing material application processes. These processes include spray delivery systems and non-spray resin application methods. The latter include prespray fiber reinforcing, in-house resin impregnation, resin roller dispensers, vacuum bag molding processes and closed mold systems. Non-spray resin application methods reduce material waste and other expenses, in particular energy purchase cost. Lower operating pressures for spray delivery systems reduce the cost and maintenance of pressure lines, pumps, controls, and fittings. Routine cleanup of work areas is also reduced in terms of frequency and difficulty. The advantages and disadvantages of both spray and non-spray delivery systems are discussed below.

Gelcoat Resin and Solvent Overspray

Oversprays can be eliminated or reduced to a great extent through simple techniques such as spray reorientation and advanced measures such as equipment modification as discussed below.

Spray Orientation

Waste often accumulates around the bottom of sprayed objects because the tip of the spray gun is directed down toward the bottom of the object, rather than horizontally. Likewise, it may be difficult for the operator to shoot the top of high objects. If spraying is directed vertically instead of horizontally to the top of the object, the spray dissipates as a fine mist up to several feet away from the object. Hence, depending upon the shape of the objects, appropriate spray orientations may be developed.

Spray Delivery Systems

Most open-mold fabricators of fiberglass products use spray applicators for transferring and applying coatings, resins, and fibers to the mold. Delivery systems used by FRP fabricators include high-pressure air, medium-pressure airless, and low-pressure air-assisted airless spray guns. In the order listed, the atomization and spray patterns become more efficient, reducing excessive fogging, overspray, and bounceback. Other key issues associated with these delivery systems are as follows:

- The high-pressure air system is practically obsolete due to the large amounts of expensive high pressure compressed air required. Low styrene emissions limits generally cannot be met using a high-pressure air system.
- In the airless method, a pressurized resin stream is electrostatically atomized through a nozzle. The nozzle orifices and spray angle can be varied by using different tips. Orifice size affects delivery efficiency, with larger orifices resulting in greater raw material loss. Airless spray guns are considered to be very efficient in delivering resins to the work surface, although excessive fogging, overspray and bounceback may occur.
- The air-assisted technology modifies the airless gun by introducing pressurized air on the outer edge of the resin stream as it exits the pressure nozzle. The air stream forms an envelope that forces the resin to follow a controllable, less dispersed spray pattern. Lower resin delivery pressure can be used since the air assist helps distribute the resin. Low delivery pressure also reduces fogging, overspray, and bounceback, which in turn reduces raw material waste. Since more resin ends up on the product, the amount of spraying is reduced, leading to a reduction in styrene air emissions. Some vendors claim 5 to 20 percent savings in the resin spray waste for an air-assisted airless gun compared to a standard airless gun.

Non-spray Resin Application Methods

While use of spray delivery of resins has become standard practice for most open-mold fabricators of fiberglass products, alternative applications processes do exist. Conventional gun-type resin application systems are efficient in delivering large quantities of resins to the work surface. Spray delivery systems are also advantageous when the product mold has many recesses or is convoluted. Non-spray application techniques would be messy or even impossible in some cases. However, other delivery techniques merit consideration in other circumstances. The various non-spray resin application methods are as follows.

- Use of fiber reinforcements that are presaturated with resins ("prepregs'? offer a number of advantages over conventional spray techniques. In particular, resin-to-fiber ratios can be strictly controlled, atomization of pollutants is practically eliminated, and cleanup and disposal problems are greatly reduced. The disadvantages of this process are higher raw material cost, energy requirements for curing, and the refrigerated storage needs of prepregs. Therefore it is best suited for applications where extremely high strength-to-weight-ratios are required and cost factors are secondary.

- Impregnators appear to have considerable potential for the reduction of pollution associated with open molding operations. They provide the fabricator with some of the advantages offered by prepregs while using lower-cost polyester resins and fiberglass materials. Impregnators can be placed within the lamination area of a plant and can be mounted in such a manner as to feed resin-saturated reinforcing materials directly to the molding operations. Conventional resin pumps and catalyst-metering devices supply resins to a roller-reservoir system. Woven fiberglass is impregnated as it passes through this reservoir system.

- Resin roller dispensers can reduce material losses due to excessive fogging, overspray. turbulence, and bounceback. Low delivery pressures help maintain a cleaner work area. External emissions and the need for high levels of make-up air are also reduced with this type of unit operation. Precisely-measured quantities of resin and catalyst are pumped to a mixing head, then to the roller at a relatively low pressure (less than 100 psig). Very often, existing spray gun equipment can be adapted to resin rollers (Davis 1987).

- Vacuum bag molding is another technique that offers several benefits. With the exception of the gelcoat, resin delivery can be accomplished without atomization. Since final distribution of the resin to all areas of the layup is largely controlled by the vacuum, gel coating is the only step in vacuum bag molding that requires atomization of resin. Pumping or pouring premixed catalyst and resin into a closed mold eliminates fogging, bounceback, and overspray. Vapor emissions and odor are further reduced by confining the resins in the covered mold until curing is complete. Excess resin can be trapped by bleeder mate rial placed under the vacuum bag. Dust-generating secondary grinding operations are minimized because closed molding eliminates most flash removal and edge smoothing requirements (USEPA 1990a).

- Closed mold systems practically eliminate requirements for atomization of resins and may offer a number of production advantages over conventional approaches to molding. In closed mold processes, catalyzed resins are pumped instead of sprayed, which eliminates fogging, bounceback, and overspray. Vapor emissions and odor are further reduced by confining the resins in the mold until curing is complete. There is little, if any, waste of resin. Even dust-producing secondary grinding operations are reduced, because the closed molding system eliminates most trash removal and edge smoothing requirements. The closed molding technologies most frequently applied to production of fiberglass components are compression molding and resin transfer molding.

Rejected and/or Excess Raw Materials

Rejected and excess raw material wastes are generated through improper operating procedures and inventory control. Improper inventory control could result in two waste sources. One is material that has been in stock so long that it has exceeded its shelf life and must be disposed of. The other is material that is in stock but is no longer needed in carrying out the function of the plant. Some of the specific options to minimize wastes generated by way of rejected and excess raw materials are detailed in the following paragraphs.

Tighter Inventory Control

The following actions should reduce or prevent the generation of surplus inventory:

- Purchase materials used in large quantities in returnable or reusable containers.
- Purchase only the quantity of special-purpose materials needed for a specific production run, so that no material is left over.
- Use first-in/first-out (FIFO) inventory control.
- Check inventory before approval of new orders.
- Inquire whether suppliers can take back unused or expired materials. It is best done while placing large orders or changing suppliers.

Computerized Inventory Control

Computerized raw material purchases and waste generation data can improve inventory control and identify areas for waste minimization. A basic system can be set up using widely available spreadsheet or database programs. Alternately, more task-specific and user-friendly programs are available from software companies such as Waste Documentation and Control. Inc. (Beaumont, Texas) and Intellus Corporation (Irvine, California).

Empty Bags and Drums

Raw material containers, such as 36 and 55-gallon drums, can be cleaned for reuse or nonhazardous waste disposal. Many plants use the uncleaned empty drums to store and dispose of other hazardous wastes such as contaminated solvents, clean rags and empty packages. Options for minimizing other container waste include container recycling, cardboard recovery, returning containers for reuse, and solid waste segregation.

Container Recycling

Acceptable practices for on-site management of drums include cleaning of reusable containers and selling them to scrap dealers or drum recycling firms. Some drums can be returned to the chemical supplier for refilling. Used containers may also be suitable for the storage of other wastes. The most important aspect in reuse or recycling of drums is that they be completely empty. One way to reduce the volume of waste is to use drums lined with a disposable liner that can be removed when the drum is empty. Disposal of the plastic liner is much easier than disposing of the drum, and eliminates the need for drum cleaning. The number of containers and the associated waste residuals can be greatly reduced by increasing container size or converting to bulk handling altogether.

Cardboard Recovery

Cardboard cartons used to deliver glass roving can be saved and sold to a paper recycling firm instead of being thrown into the dumpster. Other paper waste suitable for recycling includes empty Cab-O-Sil and aluminum trihydrate bags and balsa wood cut-outs discarded from reinforcing operations.

Solid Waste Segregation

An effective way of reducing hazardous waste associated with packaging is to segregate the hazardous materials from the non-hazardous materials. Non-hazardous packaging material may be sold to a recycler. Empty packages that contained hazardous material should be placed in plastic bags (to reduce personnel exposure and eliminate dusting) and stored in a special container to await collection and disposal as a hazardous waste.

Air Emissions

Organic vapor emissions from polyester resin/fiberglass fabrication processes occur when the monomer contained in the liquid resin evaporates during resin application and curing. In addition, cleaning solvent emissions can account for over 36 percent of the total plant VOC emissions. There also may be some release of particulate emissions from automatic fiber-chopping equipment. Potentially effective air emissions reduction methods include improved material application procedures and changing resin formulation.

Improved Material Application Procedures

Emissions vary according to the way in which the resin is mixed, applied, handled and cured. These factors vary among the different fabrication processes. For example, the spray layup process has the highest potential for VOC emissions because atomizing resin into a spray creates an extremely large surface area, from which volatile monomer can evaporate. By contrast, the emission potential in synthetic marble casting and closed-molding operations is considerably lower, because of the lower monomer content in the casting resins (30 to 38 percent, versus about 43 percent) and because of the enclosed nature of these molding operations. It has been found that styrene evaporation increases with increasing gel time, wind speed and ambient temperature, and that increasing the hand rolling time on a hand layup or sprayup results in significantly higher styrene emissions. Thus, production changes that lessen the exposure of fresh resin surfaces to the air should be effective in-reducing these evaporation losses. For a more detailed review of material application procedures, see waste minimization options described in the previous section on gelcoat resin and solvent oversprays.

Changing Resin Formulation

In addition to production changes, resin formulation can be modified to reduce the VOC emissions. In general, a resin with lower monomer content should produce lower emissions. Evaluation tests with low-styrene-emissions laminating resins having a 36 percent styrene content found a 60 to 70 percent decrease in emission levels, compared to conventional resin (42 percent styrene), with no sacrifice in the physical properties of the laminate. Vapor suppressing agents (e.g. paraffin waxes) also are sometimes added to resins to reduce VOC emissions. Limited laboratory and field data indicate that vapor suppressing agents reduce styrene losses by 30 to 70 percent (USEPA 1988).

Other techniques for reducing air emissions have been described above. These include switching to less volatile solvents or emulsifiers and covering solvent containers.

Miscellaneous Waste Streams

Waste streams discussed in this section include floor cleanup waste, equipment cleanup rags and laboratory wastes. Control measures include the use of autocleaning equipment, proper purchase of chemicals and reagents, and use of micro-scale glassware.

Floor Cleanup Waste

Overspray is material that lands on the floor instead of in the mold. Techniques to reduce the quantity of this waste have been described previously (see Gelcoat Resin and Solvent Overspray in this section). Fabricators employ some type of floor covering to facilitate periodic cleanup of the work area, and this represents an additional source of waste. Most fabricators use heavy paper which has been treated with flame-retardant, although some use sand. Since the dried residue is non-hazardous the coverings may be discarded as a non-hazardous waste. A few fabricators use sawdust to catch overspray, but this practice is very risky. Organic peroxide catalysts react vigorously with sawdust and are likely to cause a fire.

Equipment Cleanup Rags

Mechanized automatic resin-mixing and dispensing units equipped with air valves to blow out excess materials are commercially available. Contaminated exhaust air can be captured and directed to existing air scrubbers for treatment. Advantages of such units include reduced labor costs and elimination of cleaning rags.

Laboratory Wastes

Purchasing quantities of specialty chemicals that are seldom used in the smallest available amount helps to reduce waste by insuring that the material will more. likely be consumed before its shelf life expires. The purchasing agent should consider the cost of disposal of over-age material before deciding to purchase in large quantities. Many tests can be redesigned to use micro-scale glassware to reduce waste generation. Micro-scale testing volumes range from 1 to 10 ml, compared to conventional testing, which may require 50 to 100 ml (USEPA 1990b).

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Section 4
Waste Minimization Assessment Worksheets

The worksheets provided in this section are intended to assist FRP/C fabricators in systematically evaluating waste generating processes and in identifying waste minimization opportunities. These worksheets include only the waste minimization assessment phase of the procedure described in the ***Waste Minimization Opportunity Assessments Manual.*** A comprehensive waste minimization assessment includes a planning and organization step, an assessment step that includes gathering background data and information, a feasibility study on specific waste minimization options, and an implementation phase. For a full description of waste minimization assessment procedures, please refer to the manual. Table 5 lists the worksheets included in this section. After completing the worksheets, the assessment team should evaluate the applicable waste minimization options and develop an implementation plan.

Table 5. List of Waste Mlnlmlzatlon Assessment Worksheets

Number	*Title*	*Description*
1.	*Waste Sources*	*Typical wastes generated at FRP/C fabricating plants.*
2.	*Waste Minimization: Material Handling*	*Questionnaire on general material handling techniques.*
3.	*Waste Minimization: Material Handling*	*Questionnaire on procedures used for bulk liquid handling.*
4.	*Waste Minimization: Material Handling*	*Questionnaire on procedures used for handing drums, containers and packages.*
5.	*option* Generation: *Material Handing*	*Waste minimization options for material handling.*
6.	*Waste Minimization Material Substitution and Chopping/Grinding Operations*	*Questionnaire on material substitution and chopping/grinding operations.*
7.	*Waste Minimization: Cleaning Operations*	*Questionnaire on solvent cleaning operations.*
6.	*Option Generation: Material Substitution/Process Operations*	*Waste minimization options for material substitution and modification of process operations.*
9.	***Waste Minimization: Good Operating Practices***	*Questionaire on use of good operating* ***practices.***
10.	*Option Generation: Good Operating* Practicies	*Waste minimization options that are good operating practices.*
11.	*Waste Minimization: Reuse and Recovery*	*Questionnaire on opportunities for reuse and recovery of wastes.*

Firm ______	Waste Minimization Assessment	Prepared By ______
Site ______		Checked By ______
Date ______	Proj. No. ______	Sheet ___ of ___ Page ___ of ___

WORKSHEET

1

WASTE SOURCES

Waste Source: Material Handling	Significance at Plant		
	Low	Medium	High
Off-spec materials			
Obsolete raw materials			
Obsolete products			
Spills & leaks (liquids)			
Spills (powders)			
Empty container cleaning			
Container disposal (metal)			
Container disposal (paper, plastic)			
Pipeline/tank drainage			
Laboratory wastes			
Evaporative losses			
Other			
Waste Source: Process Operations			
Tank cleaning			
Container cleaning			
Blender cleaning			
Process equipment cleaning			
Gelcoat overspray			
Resin overspray			
Solvent overspray			
Other			

ws fiber 01

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET
2

WASTE MINIMIZATION:
Material Handling

A. GENERAL HANDLING TECHNIQUES

Are all raw materials tested for quality before being accepted from suppliers? ❑ yes ❑ no

Describe safeguards to prevent the use of materials that may generate off-spec product: ______

______

______

Is obsolete raw material returned to the supplier? ❑ yes ❑ no

Is inventory used in first-in first-out order? ❑ yes ❑ no

Is the inventory system computerized? ❑ yes ❑ no

Does the current inventory control system adequately prevent waste generation? ❑ yes ❑ no

What information does the system track? ______

______

______

______

Is there a formal personnel training program on raw material handling, spill prevention, proper storage techniques, and waste handling procedures? ❑ yes ❑ no

Does the program include information on the safe handling of the types of drums, containers and packages received? ❑ yes ❑ no

How often is training given and by whom? ______

______

______

______

Is dust generated in the storage area during the handling of raw materials? ❑ yes ❑ no

If yes, is there a dedicated dust recovery system in place? ❑ yes ❑ no

Are methods employed to suppress dust or capture and recycle dust? ❑ yes ❑ no

Explain: ______

______

______

ws liber 02

Firm ____ Site ____ Date ____	**Waste Minimization Assessment** Proj. No. ____	Prepared By ____ Checked By ____ Sheet ___ of ___ Page ___ of ___

WORKSHEET
3

WASTE MINIMIZATION:
Material Handling

B. BULK LIQUIDS HANDLING

What safeguards are in place to prevent spills and avoid ground contamination during the transfer and filling of storage and blending tanks?

High level shutdown/alarms ☐ Secondary containment ☐
Flow totalizers with cutoff ☐ Other ☐

Describe the system: ____

Are air emissions from solvent storage tanks controlled by means of:

Conservation vents ☐ Absorber/Condenser ☐ Adsorber ☐
Nitrogen blanketing ☐ Other vapor loss control system ☐

Describe the system: ____

Are all storage tanks routinely monitored for leaks? If yes, describe procedure and monitoring frequency for aboveground/vaulted tanks: ____

Underground tanks: ____

How are the liquids in these tanks dispensed to the users? (i.e., in small containers or hard piped.)

____

What measures are employed to prevent the spillage of liquids being dispensed? ____

Are pipes cleaned regularly? Also discuss the way pipes are cleaned and how the resulting waste is handled:

____

When a spill of liquid occurs in the plant, what cleanup methods are employed (e.g., wet or dry)? Also discuss the way in which the resulting wastes are handled: ____

Would different cleaning methods allow for direct reuse or recycling of the waste? (explain): ____

ws fiber 03

Firm ______ Site ______ Date ______	Waste Minimization Assessment Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET **4**

WASTE MINIMIZATION:
Material Handling

C. DRUMS, CONTAINERS, AND PACKAGES

Are drums, packages, and containers inspected for damage before being accepted? ❑ yes ❑ no

Are employees trained in ways to safely handle the types of drums & packages received? ❑ yes ❑ no

Are they properly trained in handling of spilled raw materials? ❑ yes ❑ no

Are stored items protected from damage, contamination, or exposure to rain, snow, sun & heat? ❑ yes ❑ no

Describe handling procedures for damaged items: ______________________

____

Heavy traffic increases the potential for contaminating raw materials with dirt or dust and for causing spilled materials to become dispersed throughout the shop.

Does the layout result in heavy traffic through the raw material storage area? ❑ yes ❑ no

Can traffic through the storage area be reduced? ❑ yes ❑ no

To reduce the generation of empty bag & packages, dust from dry material handling, and liquid wastes from cleaning empty solvent drums, has the plant attempted to:

- Purchase hazardous materials in preweighed containers to avoid the need for weighing? ❑ yes ❑ no
- Use reuseable/recyclable drums with liners instead of paper bags? ❑ yes ❑ no
- Use larger containers or bulk delivery systems that can be returned to supplier for cleaning? ❑ yes ❑ no
- Dedicate systems in the loading area to segregate hazardous from non-hazardous wastes? ❑ yes ❑ no
- Recycle the cleaning waste into a product? ❑ yes ❑ no

Discuss the results of these attempts: ______________________

____

Are all empty bags, packages, and containers that contained hazardous materials segregated from those that contained non-hazardous materials? Describe method currently used to dispose of this waste:

____

____

____

____

ws fiber 04

Firm ____ Site ____ Date ____	**Waste Minimization Assessment** Proj. No. ____	Prepared By ____ Checked By ____ Sheet ___ of ___ Page ___ of ___

WORKSHEET
5

OPTION GENERATION:
Material Handling

Meeting Format (e.g., brainstorming, nominal group technique) ____

Meeting Coordinator ____

Meeting Participants ____

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. General Handling Techniques		
Quality Control Check		
Return Obsolete Material to Supplier		
Minimize Inventory		
Computerize Inventory		
Formal Training		
B. Bulk Liquids Handling		
High Level Shutdown/Alarm		
Flow Totalizers with Cutoff		
Secondary Containment		
Air Emission Control		
Leak Monitoring		
Spilled Material Reuse		
Cleanup Methods to Promote Recycling		
C. Drums, Containers, and Packages		
Raw Material Inspection		
Proper Storage/Handling		
Preweighed Containers		
Soluble Bags		
Reusable Drums		
Bulk Delivery		
Waste Segregation		
Reformulate Cleaning Waste		

ws fiber 05

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET
6

WASTE MINIMIZATION:
Material Substitution
Process Operations

A. MATERIAL SUBSTITUTION

Are any of the formulation and preparation materials used in the plant considered hazardous (e.g., chlorinated solvents)? ❑ yes ❑ no

If so, can other less or non-hazardous materials substitute for the hazardous materials? ❑ yes ❑ no

(example: low styrene resin, non-hazardous solvents, mold release agents and additives)

Have you tried cleaning with emulsifiers instead of solvents? ❑ yes ❑ no

Describe results of any substitution attempts: ______

______

______

B. PROCESS OPERATIONS

Are dust suppression/collection systems employed during fabrication? ❑ yes ❑ no

Is this dust collected and recycled or reused? ❑ yes ❑ no

Would the installation of a dedicated baghouse or other type of dust collection system allow for reuse? ❑ yes ❑ no

Explain how dusts are handled and the potential for reuse: ______

______

Use recyclable adsorbent to collect overspray that lands on the floor? ❑ yes ❑ no

Is the adsorbent that is used to collect the solvent and resin oversprays tested for reuse potential and recycled? ❑ yes ❑ no

Decribe results of attempts to reuse adsorbent: ______

______

______

______

C. CLEANING

Is solvent cleaning done on a once-through basis between process batches? ❑ yes ❑ no

Has solvent cleaning been attempted with a smaller volume of solvent, to reduce overall solvent use? ❑ yes ❑ no

Do you routinely clean equipment before residual resin cures? ❑ yes ❑ no

Describe the results of attempts to use smaller volumes of solvent in repeated cleaning: ______

______

______

ws fiber 06

Firm ____ Site ____ Date ____	**Waste Minimization Assessment** Proj. No. ____	Prepared By ____ Checked By ____ Sheet ___ of ___ Page ___ of ___

WORKSHEET
7

WASTE MINIMIZATION:
Cleaning Operations

What methods are used to clean mixing tanks?:

	Solvent-Based	Water-Based
Dry Clean up (rags)	❑	❑
Air Blowing	❑	❑
Solvent Cleaning	❑	❑
Water Cleaning	❑	❑

Explain how these wastes are handled and the potential for their reuse: ____________________

____

____

To reduce the generation of waste, has the shop attempted to:

Employ vapor recovery systems to reduce solvent air emissions?	❑ yes	❑ no
Equip tanks with wipers to reduce clingage?	❑ yes	❑ no
Employ pressure washers to reduce cleaning solution usage?	❑ yes	❑ no
Reuse cleaning solutions for primary cleaning or as part of a compatible formulation?	❑ yes	❑ no
Equip hoses with spray nozzles to reduce water used for floor washing? (if water-based cleaning agents are used?)	❑ yes	❑ no
Dedicate equipment to reduce the need for cleaning?	❑ yes	❑ no
Use some of the solvent or water that should be added to the formulation to clean the preceding equipment before adding to the mix tank?	❑ yes	❑ no
Segregate wastes so that their reuse potential is increased?	❑ yes	❑ no

Discuss the results of methods employed or attempted: ____________________

____

____

____

ws fiber 07

Firm ____ Site ____ Date ____	Waste Minimization Assessment Proj. No. ____	Prepared By ____ Checked By ____ Sheet __ of __ Page __ of __

WORKSHEET

8

OPTION GENERATION:

Material Substitution
Process Operation

Meeting Format (e.g., brainstorming, nominal group technique) ____

Meeting Coordinator ____

Meeting Participants ____

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Substitution/Reformulation Techniques		
Solvent Substitution		
Product Reformulation		
Other Raw Material Substitution		
B. Chopping/Grinding		
Dust Suppression/Collection		
Dedicated Baghouse		
Use Less Cleaning Media		
Test for Reuse Potential		
C. Cleaning		
Vapor Recovery		
Tank Wipers		
Pressure Washers		
Reuse Cleaning Solutions		
Spray Nozzles on Hoses		
Mops and Squeegees		
Reuse Rinsewater		
Reuse Cleaning Solvent		
Dedicate Equipment		
Clean with Part of Batch		
Segregate Wastes for Reuse		

ws fiber 08

Firm ____ Site ____ Date ____	Waste Minimization Assessment Proj. No. ____	Prepared By ____ Checked By ____ Sheet __ of __ Page __ of __

WORKSHEET

9

WASTE MINIMIZATION: Good Operating Practices

A. PRODUCTION SCHEDULING TECHNIQUES

Is the production schedule varied to decrease waste generation? (For example, do you maximize size of production runs and minimize cleaning by accumulating orders or producing for inventory?)

Describe: ____

____

Does the schedule include sequential formulations that do not require cleaning between batches?

If yes, indicate results: ____

____

Are there any other attempts at eliminating cleanup steps between subsequent batches? If yes, results:

____

B. AVOIDING OFF-SPEC PRODUCTS

Is the batch formulation attempted in the lab before large-scale production?	❑ yes	❑ no
Are laboratory QA/QC procedures performed on a regular basis?	❑ yes	❑ no

C. GOOD OPERATING PRACTICES

Are plant material balances routinely performed?	❑ yes	❑ no
Are they performed for each material of concern (e.g. solvent) separately?	❑ yes	❑ no
Are records kept of individual wastes with their sources of origin and eventual disposal?	❑ yes	❑ no
Are the operators provided with detailed operating manuals or instruction sets?	❑ yes	❑ no
Are all operator job functions well defined?	❑ yes	❑ no
Are regularly scheduled training programs offered to operators?	❑ yes	❑ no
Are there employee incentive programs related to waste minimization?	❑ yes	❑ no
Does the plant have an established waste minimization program in place?	❑ yes	❑ no
If yes, is a specific person assigned to oversee the success of the program?	❑ yes	❑ no

Discuss goals of the program and results: ____

____

Has a waste minimization assessment been performed at this plant in the past? If yes, discuss: ____

____

ws fiber 09

Firm ____ Site ____ Date ____	**Waste Minimization Assessment** Proj. No. ____	Prepared By ____ Checked By ____ Sheet ___ of ___ Page ___ of ___

WORKSHEET
10

OPTION GENERATION:
Good Operating Practices

Meeting Format (e.g., brainstorming, nominal group technique) ____

Meeting Coordinator ____

Meeting Participants ____

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Production Scheduling Techniques		
Increase Size of Production Run		
Sequential Formulating		
Avoid Unnecessary Cleaning		
Maximize Equipment Dedication		
B. Avoiding Off-Spec Products		
Test Batch Formulation in Lab		
Regular QA/QC		
C. Good Operating Practices		
Perform Material Balances		
Keep Records of Waste Sources & Disposition		
Waste/Materials Documentation		
Provide Operating Manuals/Instructions		
Employee Training		
Increased Supervision		
Provide Employee Incentives		
Increase Plant Sanitation		
Establish Waste Minimization Policy		
Set Goals for Source Reduction		
Set Goals for Recycling		
Conduct Annual Assessments		

ws fiber 10

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page ___ of ___

WORKSHEET
11

WASTE MINIMIZATION:
Reuse and Recovery

A. SEGREGATION

Segregating wastes improves prospects for reuse and recovery.

Are different solvent wastes due to equipment clean-up segregated? ☐ yes ☐ no

Are aqueous wastes from equipment clean-up segregated from solvent wastes? ☐ yes ☐ no

Are spent alkaline solutions segregated from the rinse water streams? ☐ yes ☐ no

If no, explain: ______________________________

____

B. ON-SITE RECOVERY

On-site recovery of solvents by distillation is economically feasible for as little as 8 gallons of solvent waste per day.

Has on-site distillation of the spent solvent ever been attempted? ☐ yes ☐ no

If yes, is distillation still being performed? ☐ yes ☐ no

If no, explain: ______________________________

____

C. CONSOLIDATION/REUSE

Are many different solvents used for cleaning? ☐ yes ☐ no

If yes, can the solvent used for equipment cleaning be standardized? ☐ yes ☐ no

Is spent cleaning solvent reused? ☐ yes ☐ no

Are there any attempts at making the rinse solvent part of a batch formulation (rework)? ☐ yes ☐ no

Are any attempts made to blend various waste streams to produce marketable products? ☐ yes ☐ no

Are spills collected and reworked? ☐ yes ☐ no

Describe which measures were successful: ______________________________

____

Has off-site reuse of wastes been considered (e.g. waste exchange services or commercial brokerage firms)? ☐ yes ☐ no

If yes, results: ______________________________

____

____

ws fiber 11

Appendix A
Case Studies of Fiberglass-Reinforced and Composite Plastic Fabricators

In 1989, the California Department of Health Services commissioned Woodward-Clyde Consultants to conduct a waste minimization study of FRP/C fabricators (DHS 1989). The objectives of the waste minimization assessments were to:

- Gather site-specific information concerning the generation, handling, storage, treatment, and disposal of hazardous wastes;
- Evaluate existing waste reduction practices;
- Develop recommendations for waste reduction through source control, treatment, and recycling techniques; and
- Assess costs/benefits of existing and recommended waste reduction techniques.

The first steps in conducting the assessments were the selection of the FRP/C fabricators, and contacting the plants to solicit voluntary participation in the study. Plant selection emphasized small businesses that generally lack the financial and/or internal technical resources to perform a waste reduction assessment. One relatively large plant was also selected for study because it offered the opportunity to evaluate a wide variety of fabrication operations, as well as a number of in-place waste reduction measures.

This Appendix presents both the results of the assessments of two plants, here identified as A and B, and the potentially useful waste minimization options identified through the assessments. Also included are the practices already in use at the plants that have successfully reduced waste generation from past levels. During each of the plant assessments, the assessment team observed fabrication processes; inspected waste management facilities; interviewed the plant manager, environmental compliance personnel, and operations supervisors; and reviewed and copied records pertinent to waste generation and management.

Summary of Assessments Findings

From the assessments that were conducted, it was evident that employee knowledge of waste streams, waste minimization approaches and the hazardous waste regulatory structure varied greatly. The larger plant had an engineering staff and had some mechanisms in place to track total hazardous waste generation. The smaller plant did not have trained technical staff, so most of the technical expertise came from on-the-job experience or vendor contacts. Records of hazardous waste generation were sketchy, and there was little understanding of the importance of waste minimization. Accurate material balances could not be prepared because of inadequate records.

The original assessments may be obtained from Mr. Benjamin Fries at:

California Department of Health Services
Alternative Technology Division
Toxic Substances Control Program
714/144 "P" street
Sacramento, CA 94234-7320
(916) 324-1807

In addition, the results of the waste assessments were used to prepare waste minimization assessment worksheets to be completed by other FRP/C fabricators in a self-assessment process. Examples of completed worksheets are included at the end of this Appendix.

Plant A Waste Minimization Assessment

Plant Description

Plant A produces coated composite sheeting which consists of two distinct parts, the substrate and the coating. The substrate is usually a woven material such as fiberglass matting or paper. The coating is a synthetic resin. The combination of these two materials results in a product with high strength-to-weight ratio, which makes it a valuable starting material for the aerospace and transportation industries, which make up approximately 60 percent of Plant A's business. Many types of sporting goods, such as pole vaulting poles, skis, and golf club shafts, also use the composite sheets as a raw material.

Raw Material Management

Raw materials include fabrics, resins, catalysts and curing agents, additives and property modifiers. and solvents.

Fabrics. The fabric usually comes on rolls 38 to 72 inches wide, typically woven. Frequently-used materials are Kevlar, glass, graphite, nylon, polyvinyl alcohol (PVA), and paper.

Resins. Plant A uses over 100 resins, classed broadly as epoxy, polyamide, polyester, or phenolic. More than 70 percent used are types of epoxies, while the other types are approximately 10 percent each. The epoxy comes in either liquid or solid form. The solid form is supplied in jacketed totes, so it can be melted as required by connecting steam to the outer jacket. The most frequently-used liquid epoxy resin is bought in bulk and stored in an underground tank on site. The other resins are supplied in liquid form in drums.

Catalysts and Curing Agents. Various catalysts and curing agents are added in the mix batch in very small amounts to promote curing of the resin.

Additives and Modifiers. Additives and modifiers include pigments, flow inhibitors, fillers, fire retardants, surfactants, hardeners and plasticizers. They are also added to the mix resin batch in very small amounts and give the product a certain property as their descriptive names indicate.

Solvents. Solvents are used in large quantities for diluting the resin mix and for equipment cleanup. Acetone, methyl ethyl ketone, and methanol are used most frequently and stored in underground tanks. Other solvents are supplied in drums. The approximate proportion used is 45/45/10 percent acetone, MEK, and methanol, respectively.

Processes

There are five main processes at the plant

- Epoxy resin pretreatment;
- Resin mixing;
- Fabric coating/heat curing:
- Epoxy-contaminated solvent recycling;
- Slitting and rewind.

The storage of raw materials and waste is another major operation.

Epoxy Resin Pretreatment

In this pretreatment step for epoxy resins, the epoxy, catalyst, any fillers, and solvent are added to a reactor and heated to start the resin curing process. The reactor must be washed and rinsed with solvent between pretreatment batches, especially when two consecutive pretreatment batches are different epoxy formulations. After pretreatment, the resin is transferred to the mix tank area by gravity piping.

Resin Mixing

The resin mix instructions contained in Plant A's Resin Mixing Standards give the weight of each chemical in the mix (resin, catalyst, filler, pigment, stabilizer, etc.). the order of addition, time of mixing, and any special instructions or safety precautions. The mix tanks are portable vessels that are transported by forklift to the treater area for processing. The maximum mix is approximately 2,200 pounds, with a resin solids content of approximately 70 percent- Mixing consist-s of combining three to four individually mixed solutions for one to five hours.

It is the mix house operator's responsibility to mix the proper quantity of mix resin for the corresponding fabric yardage requiring coating. Ten percent of the customers allow Plant A to overrun an order by 10 percent and 90 percent allow the order to be underrun by 10 percent. Mixing the exact quantity becomes more critical as the production run becomes smaller. When the run requires only one mix tank batch, mixing the improper quantity for the run will either leave excess solvated resin or require that a small additional mix is made in order to complete the run. If the run is more than one batch all the mixes except the last one do not require exact quantities.

After the mix is made, it is covered and stored in a cool room if it is not to be used right away. Most mixes can be stored for about 14 days at 45^{0}F without adverse affect on product quality.

Plant A runs literally hundreds of possible mix types that are determined by customer requirements. The variety of resin mixes and strict customer quality specifications are two major factors affecting efforts to reduce and recycle wastes at Plant A.

Fabric Coating and Heat Curing

The specific gravity of the resin mix from the previous step must be adjusted by adding solvent at a small reservoir tank upstream of the treater pan. The treater pan holds the resin that coats the fabric. During the coating process, approximately 110 pounds of resin are continually circulated between the reservoir and the treater pan.

The coating process begins by filling the treater pan. The fabric to be coated is loaded onto the unwind shafts. The fabric dips into the pan and then passes between two metering rollers which squeeze the appropriate amount of resin into the fabric. The operator controls the speed of the fabric through the mix pan, the spacing of the rolls, and the final specific gravity of the resin. Improper setting for these parameters can result in offspec material and also a shortage or excess quantity of resin, since the mix quantity was calculated assuming specific values for these process variables. One mix tank of resin is usually sufficient to coat fabric for eight to ten hours.

The coated fabric is then fed to the treater to cure the resin coating at an elevated temperature. The curing heat drives off the solvent, and the solvent-laden air stream is burned in a thermal oxidizer prior to release to the atmosphere. Heat recovered from the thermal oxidizer is used to cure the composite in the treater. The cured composite is cooled before it is wound on the final roll.

Slitting/Rewind

Some products are required in 2-inch widths, so that a regular width product roll is slit into separate rolls of 2-inch-wide tape. Also, if a product roll is soiled or rolled imperfectly during production, the operator marks the damaged section so it can be removed. The good portions of the roll are rewound by the rewind operator.

Waste Generation, Handling, and Disposal

At the end of a run, the resin pan is emptied and cleaned. The leftover solvent resin is disposed of as hazardous waste if it is non-epoxy based, or sent to the recovery still if it is epoxy-based. Plant A has estimated that each cleaning averages 12 gallons of solvent for non-colored resin batches and 30 gallons for colored batches. The cleaning process takes approximately 20 to 30 minutes.

Solvent Recycling

Solvated epoxy resin scrap from the treater process and epoxy-contaminated rinse solvent from the epoxy pretreatment reactor, mixing vat, and resin pan cleanings are recycled through the solvent recovery still. Polyester, polyamide, and phenolic resin or wash solvent cannot be recycled in the still because the fire hazard and runaway reaction risk are too great, Epoxy resin composites account for 70 percent of the Plant A production, so that a large percentage of solvent in scrap resin and from cleaning operations is currently recycled. Recycled solvent can be used for vessel cleanouts in the production of military/aerospace products, but cannot be added directly to the resin mix at the mix house or in the dilution step at the treater. Recycled solvent can be added directly to the resin during processing of Plant A's sporting goods product line, since quality control specifications are not as strict as for aerospace products.

Chemical and Waste Storage

Plant A has a dedicated storage room where the drummed resins, solvents, and drummed hazardous wastes are stored. The site also has areas for empty drum storage and dry chemical storage, finished goods storage, and a warehouse for **raw material fabric storage. Acetone, MEK,** methanol and the most frequently used epoxy **resins** are stored on site in underground storage tanks. Plant A is registered under RCRA as a hazardous waste generator, and accumulates wastes up to 90 days for bulk shipment

Assessment Findings and Recommendations

The assessment team made the following recommendations to help minimize wastes.

- Use squeegees to reduce rinse solvent usage
- Modify resin pan
- Reduce treater pan delivery pipe size
- Reuse rinse solvent
- Recover rinse solvent by distillation

These techniques are described and economics are presented in the subsequent paragraphs.

Use squeegees to reduce rinse solvent usage

A typical economic evaluation of reduction in solvent rinse use using the squeegee cleaning system is summarized in Table A-l. Costs for additional time required for each vessel cleaning, and a one-time operator training program are subtracted from the raw material and disposal cost savings due to reduced solvent usage to give the total cost savings. Total monthly cost savings were estimated at more than $3,700 and the calculated payback period was slightly under one month (Calif. DHS, 1989).

Modify resin pan

The treaters often handle fabrics 32 to 72 inches wide. A pan width 10 inches wider than the fabric is required If fabric is run in a wider pan, solvated resin is wasted. It was recommended that a simple adjustable device be made to fit into the treater pan, so the operator would only have to insert and remove the device as required by the fabric width.

Table A-2 summarizes a typical production match between fabric and treater pan width. The average excess width was 22.4 inches per treater before implementing waste reduction technique. Table A-3 shows an example where the avoidable waste due to excess pan width was 51,500 pounds of solvated resin per year, equal to a raw material and disposal cost savings of $91,700 per year.

Reduce pipe size from mix tank to treater pan

Approximately 8 feet of 2-inch diameter pipe connect the mix tank and the treater tank. At the completion of each run the solvated resin in the treater pan was discarded, along with the resin in the pipe. The flow rate does not justify the 2-inch size, The reason for the 2-inch pipe was that some of the resins are more viscous and require a fairly large pipe size to prevent plugging. Average epoxy resin viscosity is 1000 cp.

The volume per linear foot of 2-inch pipe is 164 percent greater than that of 1 1/2 inch pipe. If the 1 1/2 inch size could be used for the less viscous resins, approximately 1270 pounds of resin per year could be saved for six treaters. The process change would require installation of a parallel run of 1 1/2-inch pipe and valving to allow the operator to select the pipe size for resin delivery based on the resin mix viscosity. The payout period for the system, based on being able to use the smaller pipe one sixth of the time, was 27 months. Table A-4 shows the economic evaluation for the modifications.

Reuse rinse solvent

If the used solvent for non-colored resin batches were stored and reused once instead of being discarded or sent to a recycling still, a substantial reduction in operating costs, raw material costs, and hazardous waste disposal costs could be realized. The operational changes required to realize this opportunity are:

1. Treater rinsing would be divided into two steps: an initial rinse with recycled solvent followed by a final rinse with fresh solvent. The first rinse should be sent to the disposal still or collected for disposal as hazardous waste. The second rinse should be sent to the recycling still or collected, stored and reused.

2. **A** procedure for segregating non-epoxy from epoxy rinse solvents is required, since non-epoxy rinse solvent cannot be recycled because of the risk of a runaway reaction.

Table A-1 Economic Evaluation of Solvent Rinse Use Reduction

In this example, current total solvent use per month is determined from a knowledge of the quantity of non-epoxy solvent (NES) disposed of each month. This known disposal quantity is proportional; since the plant produces 70% epoxy resin-based products and 30% non-epoxy resin-based products, the total amount of solvent rinsate is in the same proportion.

Current solvent use per month

= 16,888 lb rinsate/month x rinses/0.3 NES rinses x gal/0.8 x 8.34 lb

= 8,400 gal/month

Volume of solvent saved @ 25% use reduction

= 2,100 gal/month

RAW MATERIAL SAVINGS (RMS)

RMS	=	2100 gal x 0.45 (acetone) x 0.792(8.32)($0.23/lb)	=	$1,400
		2100 gal x 0.45 (MEK) x 0.792(8.32)($0.365/lb)	=	$2,300
		2100 gal x 0.10 (methanol) x 0.792(8.32)($0.96/lb)	=	$1,300
		TOTAL	=	$5,000/month

DISPOSAL COST SAVING (DCS)

DCS = 2100 gal x 0.3 NES rinse/a; rinse x 0.8 x 8.32 lb/gal x $0.14/lb.

= $590/month

LABOR COST INCREASE (LCI)

LCI = 15 additional minutes/cleanout x 339 cleanouts/month x $22/60 minutes of labor

= $1,865/month

MONTHLY COST SAVINGS (MCS)

MCS = $5,000 + $590 - $1,865

= $3,725/month

OPERATOR TRAINING COST (OTC)

OTC = 15 operators x 8 hours x $22/hour

= $2,700

PAYBACK PERIOD (PP)

PP = $2700/3725 per month

= 3 weeks

Table A-2. Fabric and Treater Pan Width Match

Fabric Width (inches)	Treater Pan Width (inches)	Percent of Production[a]	Excess Inches[b]	Composite Excess Inches of One Treater[c]
32	60	40%	18	7.2
38	78	20%	30	6
50	84	15%	24	3.6
44	84	5%	30	1.5
50	86	9%	26	2.35
60	86	11%	16	1.76
		AVERAGE EXCESS	22.4	

[a] These percentages represent actual fabric width versus pan width from Plant A production records for January through September 1987.
[b] "Excess Inches" is the difference between pan and fabric width, minus the 10-inch clearance required by the machinery.
[c] This column is equal to "Percent of Production" column multiplied by the "Excess Inches" column. For example, the 32-inch fabric width is equivalent to 0.4 x 18 = 7.2 composite excess inches.

Table A-3. Economic Evaluation of Reducing Treater Pan Waste

DESIGN BASIS

No. of treater cleanouts for 9 month period	1369
Average excess per treater cleanout (from Table A-2)	22.4 in.
Wetted cross-sectional area of treater pan[a]	0.22 ft^2
Specific gravity of treater resin	1.1
Waste reduction per excess inch of treater pan	1.26 lbs
Cost of raw material	$1.64/lb
Cost of incineration disposal	$0.14/lb
Investment to modify treater pan	$1000

RAW MATERIAL SAVINGS (RMS)

RMS = 22.4 inches/treater cleanout x 1.26 lb resin waste reduction/excess inch x 1369 treater cleanouts/9 months x 12 mo/year x $1.(
= 51,500 lb/year x $1.64/lb
= $84,500/year

DISPOSAL COST SAVINGS (DCS)

DCS = 51,500 lb/yr x $0.14/lb = $7,210/year

NET SAVINGS = RMS + DCS = 84,500 + 7,210 = $91,710/year

PAYOUT PERIOD = $1,000/91,700 per year = 0.011 years or about 3 days

[a] Assumes a 4" x 8" wetted cross-sectional area

Table A-4. Economic Evaluation of Reducing Pipe Size to Treater Pan

DESIGN BASIS

	2-Inch Pipe	1-1/2-Inch Pipe
Gallons per Lineal Foot	0.1743	0.1058
Total Gallons, 8 Feet of Pipe	1.39	0.85

ASSUMPTIONS FOR ECONOMIC EVALUATION

Additional Gallons/Treater Cleanout	0.54
Treater Cleanouts/Day	6
Operating Days/Year	256
Disposal Cost for Solvated Resin	$0.14/lb
Raw Material Cost for Solvated Resin	$1.64
Resin in Solvated Resin	65%
Specific Gravity of Solvated Resin	1.1
Frequency of Smaller Pipe use	Every 6th Treater (Once per day)

RAW MATERIAL AND DISPOSAL SAVINGS (RMADS)

RMADS = 256 days/yr x 0.54 gal/day x 1.1 x 8.33 lb/gal
= 1,269 lb/yr x $1.78/lb
= $2,258/yr

INVESTMENT REQUIRED

	Quantity	Installed Unit Cost	Installed Total Cost
Pipe	8 feet, 1 1/2" pipe	$550/100 feet	$ 44
Elbows	4	$55/each	220
Tees	2	$ 70/each	140
Valves	4	$ 150/each	600
			$ 1,004
TOTAL COST for 5 treaters			$ 5,020

PAYOUT PERIOD (PP) = $5,020/$2,258 per year = 2.22 years or 27 months

3. Additional storage tanks, pumps and piping would be installed in the treater building, with separate tanks for the non-epoxy and epoxy rinse solvents. Collection of rinsates from the mix vessel and epoxy pretreater at the Mix House would have to be done manually. Rinsate from the final rinsing step using clean solvent should be collected from the treater or Mix House and delivered to the recycled solvent tanks for reuse in the subsequent first rinsing step.

The estimated capital and operating costs for the solvent reuse system are shown in Table A-5, with one-time operator training costs included in the investment. It was assumed that labor costs for bringing the solvent to and from the reused solvent storage tanks in the Treater Room would equal the time now spent getting the solvent from the current tanks and taking it in the drums to the hazardous waste storage area. Based on using 4,280 gallons per month of solvated epoxy resin, this change would reduce the amount of waste solvent incinerated by 1,270 gallons per month. This represents a cost saving of $5,070 per month on raw materials and disposal cost. In addition, the cost of operating the recycling still would be reduced about $1,100 per month. Thus, the total savings would be $6,170 per month. The payout period for the $14,100 investment would be 2.3 months or about 10 weeks

Plant B Waste Minimization Assessment

Plant Description

Plant B uses a mold-based process to manufacture shower stalls, radomes, airport runway markers and bus bumpers. Raw materials used in the manufacture of these products include general purpose (GP) liquid polyester resin, liquid polyester gelcoat resin, catalyst, glass fiber, additives, reinforcing materials, and solvents.

Process Description

The process employed at Plant B consists of a series of steps by which successive layers of various materials are applied to a mold. The first step requires waxing the mold with a mold release agent, followed by spraying the mold with gelcoat to a uniform thickness. The gelcoat forms the surface coating of the product that is exposed when the completed part is separated from the mold. A catalyst is atomized into the gelcoat stream as the resin exits the spray gun.

After the gelcoat has set, the first coat of GP polyester resin and glass roving is applied to the mold. The resin is applied with a spray gun similar to the gelcoat gun, except that the orifice tip is usually smaller, and a chopper attachment is added to &liver glass fiber approximately 1-1/2 inches long into the resin stream. When the first coat has become tacky, the edges of the mold are trimmed, and, if required, reinforcing materials added to the piece.

A second GP resin/glass roving coat is added after the first coat has set. In some cases this second coat is made fire retardant by mixing aluminum hihydrate into the resin batch. After spraying the second GP resin coat, the edges are trimmed of excess resin while the resin is still tacky. Sufficient additional drying time must pass until the resin totally sets, then the finished object is removed from the mold.

Table A-5. Capital and Operating Costs for Recovered Solvent System

CAPITAL COSTS

Item	Quantity	Unit Cost	Installed Cost
Pumps	2	$2000/pump	$4,000
500 gallon tanks	2	$2000/tank	4,000
Pipe and fittings to the 5 treater stations	1500 feet 1/2" pipe	$176/100 ft	2,650
TOTAL CAPITAL COST			$11,400
Operator training			2,700
TOTAL INVESTMENT			$14,100

ANNUAL OPERATING COSTS

Power (2 pumps @ 1hp, running 2 hours per day)	$ 75
Maintenance (5% of capital cost)	570
TOTAL ANNUAL OPERATING COST	$ 645

Waste Generation, Handling, and Disposal

1. Plant B uses an airless spray system for GP resin delivery and has recently installed an air-assisted airless gun for gelcoat delivery. These changes will considerably reduce the generation of wastes.

2. Cleaning operations at the plant generate enough waste solvent to make recycling practical. Plant B has a small batch still, but it does not appear to be used on a regular basis. The still was observed to take approximately 6 hours to recycle 3 gallons of acetone, whereas design specifications indicated the period should have been less than 2 hours. The condenser cooling water flow was set at only l/2-gallon per hour, which seemed low.

Assessment Findings and Recommendations

Improve Recycling Still Operation

The recycling still manufacturer was contacted and questioned about proper operating conditionsand typical causes of malfunction of the unit. The most likely source of malfunction was identified to be the jelling of the heat transfer media. The manufacturer also recommended that the cooling water flow setting should be approximately 30 gallons per hour. The still's heat transfer media was checked and replaced, and the cooling water rate reset according to the manufacturer's instructions. Assuming a cycle time of 7.5 hours, a power cost of 10 cents/KWH and 80 percent recovery of solvent, the cost of recycling acetone at the plant was estimated to be approximately 6 cents per gallon of acetone recovered, compared to $1.80 per gallon for virgin solvent. An annual savings of $2,100 would result from solvent recycling at this plant. No labor cost was assumed in the calculation, since the operation was performed as part of the normal duties of the operator's work&y. Other expenses include disposal of still bottoms, replacement of heat transfer fluid, and equipment maintenance. These operating costs will generally be less than 50 cents per gallon, and some manufacturers claim costs under 20 cents per gallon.

Raise the Mold to Reduce Overspray

Raw material costs for overspray were estimated at $16.10 per shower stall. Based on an average production rate of 10 stalls per day, this loss amounted to $38,640 per year. The assessment team expected that raising the mold would reduce overspray by at least 25 percent, saving $9,660 per year. The total investment for the necessary modifications to the rolling carts which handle the mold was estimated to be $400. These modifications, which could be made with a small capital and labor investment, also requited that the operator use ladders or similar equipment when spraying the top of the object. It was assumed that the labor costs for shooting the objects would probably increase slightly at first, as the operators adjusted to the new situation but no long-term labor difference would result. Based on these estimates, the payback period would be 10 days.

Firm	Waste Minimization Assessment	Prepared By N. Boyer
Site		Checked By
Date	Proj. No.	Sheet ___ of ___ Page 1 of 11

WORKSHEET 1

WASTE SOURCES

Waste Source: Material Handling	Significance at Plant		
	Low	Medium	High
Off-spec materials	✓		
Obsolete raw materials	✓		
Obsolete products	✓		
Spills & leaks (liquids)	✓		
Spills (powders)	✓		
Empty container cleaning	✓		
Container disposal (metal)			✓
Container disposal (paper, plastic)			✓
Pipeline/tank drainage	✓		
Laboratory wastes	✓		
Evaporative losses		✓	
Other			

Waste Source: Process Operations	Low	Medium	High
Tank cleaning			✓
Container cleaning	✓		
Blender cleaning	✓		
Process equipment cleaning		✓	
Gelcoat overspray	✓		
Resin overspray	✓		
Solvent overspray	✓		
Other			

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page 2 of 11

WORKSHEET
2

WASTE MINIMIZATION:
Material Handling

A. GENERAL HANDLING TECHNIQUES

Are all raw materials tested for quality before being accepted from suppliers? ☐ yes ☑ no

Describe safeguards to prevent the use of materials that may generate off-spec product: ______

Is obsolete raw material returned to the supplier? ☐ yes ☑ no
Is inventory used in first-in first-out order? ☑ yes ☐ no
Is the inventory system computerized? ☐ yes ☑ no
Does the current inventory control system adequately prevent waste generation? ☑ yes ☐ no

What information does the system track? OUT OF DATE MATERIALS & LOW STOCK

Is there a formal personnel training program on raw material handling, spill prevention, proper storage techniques, and waste handling procedures? ☑ yes ☐ no
Does the program include information on the safe handling of the types of drums, containers and packages received? ☐ yes ☑ no

How often is training given and by whom? YEARLY - BY HAZARDS CONTROL PERSONNEL

Is dust generated in the storage area during the handling of raw materials? ☐ yes ☑ no
If yes, is there a dedicated dust recovery system in place? ☐ yes ☐ no
Are methods employed to suppress dust or capture and recycle dust? ☐ yes ☑ no
Explain: ______

ws fiber 02

Firm ____ Site ____ Date ____	Waste Minimization Assessment Proj. No. ____	Prepared By ____ Checked By ____ Sheet __ of __ Page 3 of 11

WORKSHEET **3**

WASTE MINIMIZATION: Material Handling

B. BULK LIQUIDS HANDLING

What safeguards are in place to prevent spills and avoid ground contamination during the transfer and filling of storage and blending tanks?

- High level shutdown/alarms ☐ Secondary containment ☑
- Flow totalizers with cutoff ☐ Other ☐

Describe the system: WE TRANSFER SMALL QUANTITIES AND ON RARE OCCASIONS ONLY.

Are air emissions from solvent storage tanks controlled by means of:

- Conservation vents ☐ Absorber/Condenser ☐ Adsorber ☐
- Nitrogen blanketing ☐ Other vapor loss control system ☑

Describe the system: A WATER LAYER TO REMOVE EVAPORATION OF METHYLENE CHLORIDE

Are all storage tanks routinely monitored for leaks? If yes, describe procedure and monitoring frequency for aboveground/vaulted tanks: VISUAL INSPECTIONS AT EVERY USE. DETAILED INSPECTION EVERY YEAR

Underground tanks: N/A

How are the liquids in these tanks dispensed to the users? (i.e., in small containers or hard piped.)

N/A

What measures are employed to prevent the spillage of liquids being dispensed? N/A

Are pipes cleaned regularly? Also discuss the way pipes are cleaned and how the resulting waste is handled:

N/A

When a spill of liquid occurs in the plant, what cleanup methods are employed (e.g., wet or dry)? Also discuss the way in which the resulting wastes are handled: DRY - MATERIAL COLLECTED & SENT THRU NORMAL WASTE MANAGEMENT CHANNELS FOR DISPOSAL.

Would different cleaning methods allow for direct reuse or recycling of the waste? (explain): NO

ws fiber 03

Firm ____ Site ____ Date ____	Waste Minimization Assessment Proj. No. ____	Prepared By ____ Checked By ____ Sheet __ of __ Page 4 of 11

WORKSHEET 4

WASTE MINIMIZATION: Material Handling

C. DRUMS, CONTAINERS, AND PACKAGES

	yes	no
Are drums, packages, and containers inspected for damage before being accepted?	☑	☐
Are employees trained in ways to safely handle the types of drums & packages received?	☑	☐
Are they properly trained in handling of spilled raw materials?	☑	☐
Are stored items protected from damage, contamination, or exposure to rain, snow, sun & heat?	☑	☐

Describe handling procedures for damaged items: DAMAGED PACKAGES ETC. ARE FOUND AT RECEIVING PRIOR TO DELIVERY TO PLASTICS GROUP. AFTER PROPER REPACKAGE, SENT BACK TO VENDOR

Heavy traffic increases the potential for contaminating raw materials with dirt or dust and for causing spilled materials to become dispersed throughout the shop.

	yes	no
Does the layout result in heavy traffic through the raw material storage area?	☐	☑
Can traffic through the storage area be reduced?	☐	☑

To reduce the generation of empty bag & packages, dust from dry material handling, and liquid wastes from cleaning empty solvent drums, has the plant attempted to:

	yes	no
Purchase hazardous materials in preweighed containers to avoid the need for weighing?	☑	☐
Use reuseable/recyclable drums with liners instead of paper bags?	☐	☑
Use larger containers or bulk delivery systems that can be returned to supplier for cleaning?	☐	☑
Dedicate systems in the loading area to segregate hazardous from non-hazardous wastes?	☐	☑
Recycle the cleaning waste into a product?	☐	☑

Discuss the results of these attempts: WE PURCHASE SOME MATERIALS "PREWEIGHED."

Are all empty bags, packages, and containers that contained hazardous materials segregated from those that contained non-hazardous materials? Describe method currently used to dispose of this waste:

CONTAINERS ARE SEGREGATED AND DISPOSED OF THROUGH HAZARDOUS WASTE MANAGEMENT

ws fiber 04

Firm ______ Site ______ Date ______	Waste Minimization Assessment Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page 5 of 11

WORKSHEET
5

OPTION GENERATION:
Material Handling

Meeting Format (e.g., brainstorming, nominal group technique) ______

Meeting Coordinator ______

Meeting Participants ______

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. General Handling Techniques		
Quality Control Check	N	PROGRAM BEING DEVELOPED
Return Obsolete Material to Supplier	N	
Minimize inventory	Y	
Computerize Inventory	N	
Formal Training	Y	
B. Bulk Liquids Handling		
High Level Shutdown/Alarm	N	
Flow Totalizers with Cutoff	N	
Secondary Containment	Y	
Air Emission Control	Y	
Leak Monitoring	Y	VISUAL INSPECTIONS
Spilled Material Reuse	N	
Cleanup Methods to Promote Recycling	N	
C. Drums, Containers, and Packages		
Raw Material Inspection	N	PROGRAM BEING DEVELOPED
Proper Storage/Handling	Y	
Preweighed Containers	Y	
Soluble Bags	N	
Reusable Drums	N	
Bulk Delivery	N	
Waste Segregation	Y	
Reformulate Cleaning Waste	N	

ws liber 05

Firm ______ Site ______ Date ______	Waste Minimization Assessment Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page 6 of 11

WORKSHEET
6

WASTE MINIMIZATION:
Material Substitution
Process Operations

A. MATERIAL SUBSTITUTION

Are any of the formulation and preparation materials used in the plant considered hazardous (e.g., chlorinated solvents)? ☑ yes ☐ no

If so, can other less or non-hazardous materials substitute for the hazardous materials? ☐ yes ☑ no

(example: low styrene resin, non-hazardous solvents, mold release agents and additives)

Have you tried cleaning with emulsifiers instead of solvents? ☑ yes ☐ no

Describe results of any substitution attempts: RESULTS OF USING EMULSIFIERS NOT SATISFACTORY. WE ARE STILL INVESTIGATING MATERIALS

B. PROCESS OPERATIONS

Are dust suppression/collection systems employed during fabrication? ☑ yes ☐ no

Is this dust collected and recycled or reused? ☐ yes ☑ no

Would the installation of a dedicated baghouse or other type of dust collection system allow for reuse? ☐ yes ☑ no

Explain how dusts are handled and the potential for reuse: ONLY SMALL AMOUNTS COLLECTED IN BAGHOUSE NOT PRACTICAL TO INSTALL "DEDICATED SYSTEM"

Use recyclable adsorbent to collect overspray that lands on the floor? ☐ yes ☑ no

Is the adsorbent that is used to collect the solvent and resin oversprays tested for reuse potential and recycled? ☐ yes ☑ no

Decribe results of attempts to reuse adsorbent: N/A

C. CLEANING

Is solvent cleaning done on a once-through basis between process batches? ☑ yes ☐ no

Has solvent cleaning been attempted with a smaller volume of solvent, to reduce overall solvent use? ☑ yes ☐ no

Do you routinely clean equipment before residual resin cures? ☐ yes ☐ no

Describe the results of attempts to use smaller volumes of solvent in repeated cleaning: 90% OF OUR CLEANING IS SMALL "HAND TOOL" SIZE ITEMS. VERY SMALL VOLUMES OF SOLVENTS ARE USED.

ws fiber 06

Firm ______	Waste Minimization Assessment	Prepared By ______
Site ______		Checked By ______
Date ______	Proj. No. ______	Sheet ___ of ___ Page 7 of 11

WORKSHEET
7

WASTE MINIMIZATION:
Cleaning Operations

What methods are used to clean mixing tanks?:

	Solvent-Based	Water-Based
Dry Clean up (rags)	☑	☐
Air Blowing	☐	☐
Solvent Cleaning	☑	☐
Water Cleaning	☐	☐

Explain how these wastes are handled and the potential for their reuse: N/A

To reduce the generation of waste, has the shop attempted to:

Employ vapor recovery systems to reduce solvent air emissions?	☐ yes	☑ no
Equip tanks with wipers to reduce clingage?	☐ yes	☑ no
Employ pressure washers to reduce cleaning solution usage?	☐ yes	☑ no
Reuse cleaning solutions for primary cleaning or as part of a compatible formulation?	☑ yes	☐ no
Equip hoses with spray nozzles to reduce water used for floor washing? (if water-based cleaning agents are used?)	☐ yes	☑ no
Dedicate equipment to reduce the need for cleaning? N/A	☐ yes	☑ no
Use some of the solvent or water that should be added to the formulation to clean the preceding equipment before adding to the mix tank?	☐ yes	☑ no
Segregate wastes so that their reuse potential is increased?	☐ yes	☑ no

Discuss the results of methods employed or attempted: METHYLENE CHLORIDE IS REUSED UNTIL IT IS "SATURATED," THEN DISPOSED OF. WE ARE INVESTIGATING THE USE OF A SOLVENT RECOVERY SYSTEM.

ws liber 07

Firm	Waste Minimization Assessment	Prepared By
Site		Checked By
Date	Proj. No.	Sheet __ of __ Page 8 of 11

WORKSHEET **8**

OPTION GENERATION:
Material Substitution
Process Operation

Meeting Format (e.g., brainstorming, nominal group technique)

Meeting Coordinator

Meeting Participants

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Substitution/Reformulation Techniques		
Solvent Substitution	N	INVESTIGATING
Product Reformulation	N	
Other Raw Material Substitution	N	
B. Chopping/Grinding		
Dust Suppression/Collection	Y	
Dedicated Baghouse	N	
Use Less Cleaning Media	Y	
Test for Reuse Potential	N	
C. Cleaning		
Vapor Recovery	N	
Tank Wipers	N	N/A
Pressure Washers	N	N/A
Reuse Cleaning Solutions	N	
Spray Nozzles on Hoses	N	N/A
Mops and Squeegees	N	N/A
Reuse Rinsewater	N	
Reuse Cleaning Solvent	Y	
Dedicate Equipment	N	
Clean with Part of Batch	Y	
Segregate Wastes for Reuse	N	

ws fiber 08

Firm ____ Site ____ Date ____	Waste Minimization Assessment Proj. No. ____	Prepared By ____ Checked By ____ Sheet ___ of ___ Page 9 of 11

WORKSHEET

9

WASTE MINIMIZATION:
Good Operating Practices

A. PRODUCTION SCHEDULING TECHNIQUES

Is the production schedule varied to decrease waste generation? (For example, do you maximize size of production runs and minimize cleaning by accumulating orders or producing for inventory?)

Describe: N/A

Does the schedule include sequential formulations that do not require cleaning between batches?

If yes, indicate results: NO R & D REQUIRES VIRGIN MATERIALS WE HAVE NO "PRODUCTION"

Are there any other attempts at eliminating cleanup steps between subsequent batches? If yes, results:

B. AVOIDING OFF-SPEC PRODUCTS

Is the batch formulation attempted in the lab before large-scale production?	☑ yes	☐ no
Are laboratory QA/QC procedures performed on a regular basis?	☑ yes	☐ no

C. GOOD OPERATING PRACTICES

Are plant material balances routinely performed?	☐ yes	☑ no
Are they performed for each material of concern (e.g. solvent) separately?	☐ yes	☑ no
Are records kept of individual wastes with their sources of origin and eventual disposal?	☐ yes	☑ no
Are the operators provided with detailed operating manuals or instruction sets?	☑ yes	☐ no
Are all operator job functions well defined?	☐ yes	☑ no
Are regularly scheduled training programs offered to operators?	☐ yes	☑ no
Are there employee incentive programs related to waste minimization?	☐ yes	☑ no
Does the plant have an established waste minimization program in place?	☐ yes	☑ no
If yes, is a specific person assigned to oversee the success of the program?	☐ yes	☐ no

Discuss goals of the program and results: WASTE MINIMIZATION PLAN BEING PREPARED

Has a waste minimization assessment been performed at this plant in the past? If yes, discuss:

ws liber 09

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet ___ of ___ Page 10 of 11

WORKSHEET 10

OPTION GENERATION:
Good Operating Practices

Meeting Format (e.g., brainstorming, nominal group technique) ______

Meeting Coordinator ______

Meeting Participants ______

Suggested Waste Minimization Options	Currently Done Y/N?	Rationale/Remarks on Option
A. Production Scheduling Techniques		
Increase Size of Production Run	N	N/A
Sequential Formulating	N	N/A
Avoid Unnecessary Cleaning	N	N/A
Maximize Equipment Dedication	N	N/A
B. Avoiding Off-Spec Products		
Test Batch Formulation in Lab	Y	
Regular QA/QC	Y	
C. Good Operating Practices		
Perform Material Balances	N	
Keep Records of Waste Sources & Disposition	Y	
Waste/Materials Documentation	Y	
Provide Operating Manuals/Instructions	N	
Employee Training	N	
Increased Supervision	N	
Provide Employee Incentives	N	
Increase Plant Sanitation	N	
Establish Waste Minimization Policy		IN PROCESS
Set Goals for Source Reduction	N	
Set Goals for Recycling	N	
Conduct Annual Assessments	Y	

ws liber 10

Firm ______ Site ______ Date ______	**Waste Minimization Assessment** Proj. No. ______	Prepared By ______ Checked By ______ Sheet __ of __ Page 11 of 11

WORKSHEET
11

WASTE MINIMIZATION:
Reuse and Recovery

A. SEGREGATION

Segregating wastes improves prospects for reuse and recovery.

Are different solvent wastes due to equipment clean-up segregated?	☑ yes	☐ no
Are aqueous wastes from equipment clean-up segregated from solvent wastes? N/A	☐ yes	☑ no
Are spent alkaline solutions segregated from the rinse water streams? N/A	☐ yes	☑ no

If no, explain: N/A

B. ON-SITE RECOVERY

On-site recovery of solvents by distillation is economically feasible for as little as 8 gallons of solvent waste per day.

Has on-site distillation of the spent solvent ever been attempted?	☐ yes	☑ no
If yes, is distillation still being performed?	☐ yes	☐ no

If no, explain: SOLVENT RECOVERY SYSTEM FOR METHYLENE CHLORIDE BEING INVESTIGATED

C. CONSOLIDATION/REUSE

Are many different solvents used for cleaning?	☐ yes	☑ no
If yes, can the solvent used for equipment cleaning be standardized?	☐ yes	☐ no
Is spent cleaning solvent reused?	☐ yes	☑ no
Are there any attempts at making the rinse solvent part of a batch formulation (rework)?	☐ yes	☑ no
Are any attempts made to blend various waste streams to produce marketable products?	☐ yes	☑ no
Are spills collected and reworked?	☐ yes	☑ no

Describe which measures were successful: ______

Has off-site reuse of wastes been considered (e.g. waste exchange services or commercial brokerage firms)?	☑ yes	☐ no

If yes, results: CURRENTLY LOOKING INTO POSSIBILITIES OF USING EXCHANGE SERVICES.

ws liber 11

Appendix B
Where to Get Help
Further Information on Pollution Prevention

Additional information on source reduction, reuse and recycling approaches to pollution prevention is available in EPA reports listed in this section, and through state programs and regional EPA offices (listed below) that offer technical and/or financial assistance in the areas of pollution prevention and treatment.

Waste exchanges have been established in some areas of the U.S. to put waste generators in contact with potential users of the waste. Twenty-four exchanges operating in the U.S. and Canada are listed.

U.S. EPA Reports on Waste Minimization

Waste Minimization Opportunity Assessment Manual. EPA/625/7-88/003

Waste Minimization Audit Report: Case Studies of Corrosive and Heavy Metal Waste Minimization Audit at a Specialty Steel Manufacturing Complex. Executive Summary. NTIS No. PB88-107180

Waste Minimization Audit Report: Case Studies of Minimization of Solvent Waste for Parts Cleaning and from Electronic Capacitor Manufacturing. Executive Summary. NTIS No. PB87-227013

Waste Minimization Audit Report: Case Studies of Minimization of Cyanide Wastes from Electroplating Operations. Executive Summary. NTIS No. PB87-229662.

Report to Congress: Waste Minimization, Vols. I and II. EPA/530-SW-86033 and -034 (Washington, D.C.: U.S.EPA,1986)."

Waste Minimization - Issues and Options, Vols. I-III. EPA/530-SW-86-041 through -043. (Washington, D.C.: U.S.EPA.1986."

Executive Summary available from EPA, CERI Publications Unit, 26 West Martin Luther King Drive, Cincinnati, OH, 45268; full report available from the National Technical Information Service (NTIS), U.S. Department of Commerce, Springfield, VA 22161.

Available from the National Technical Information Service as a five-volume set, NTIS No.PB-87-114328.

* Available from EPA, CERI Publications Unit, 26 West Martin Luther King Drive, Cincinnati, OH 45268. (513) 569-7562.

The Guides to Pollution Prevention manuals*** describe waste minimization options for specific industries. This is a continuing series which currently includes the following titles:

Guides to Pollution Prevention Paint Manufacturing Industry. EPA/625/7-90/005

Guides to Pollution Prevention The Pesticide Formulating Industry. EPA/625/7-90/004

Guides to Pollution Prevention The Commercial Printing Industry. EPA/625/7-90/008

Guides to Pollution Prevention The Fabricated Metal Industry. EPA/625/7-90/006

Guides to Pollution Prevention For Selected Hospital Waste Streams. EPA/625/7-90/009

Guides to Pollution Prevention Research and Educational Institutions. EPA/625/7-90/010

Guides to Pollution Prevention The Printed Circuit Board Manufacturing Industry. EPA/625/7-90/007

Guides to Pollution Prevention The Pharmaceutical Industry. EPA 625/7-91/017

Guides to Pollution Prevention The Photoprocessing Industry. EPA 625/7-91/012

Guides to Pollution Prevention The Automotive Repair Industry. EPA/625/7-91/013

Guides to Pollution Prevention The Automotive Refinishing Industry. EPA/625/7-91/016

Guides to Pollution Prevention The Marine Repair Industry. EPA 625/7-91/015

U.S. EPA Pollution Prevention Information Clearinghouse (PPIC): *Electronic Information Exchange System (EIES)—User Guide, Version 1.1*. EPA/600/9-89/086

Waste Reduction Technical/Financial Assistance Programs

The EPA Pollution Prevention Information Clearinghouse (PPIC) was established to encourage waste reduction through technology transfer, education, and public awareness. PPIC collects and disseminates technical and other information about pollution prevention through a telephone hotline and an electronic information exchange network. Indexed bibliographies and abstracts of reports, publications, and case studies about pollution prevention are available. PPIC also lists a calendar of pertinent conferences and seminars; information about activities abroad and a directory of waste exchanges. Its Pollution Prevention Information Exchange System (PIES) can be accessed electronically 24 hours a day without fees.

For more information contact:

PIES Technical Assistance
Science Applications International Corp.
8400 Westpark Drive
McLean, VA 22102
(703) 821-4800

or

U.S. Environmental Protection Agency
401 M Street S. W.
Washington, D. C. 20460

Myles E. Morse
Office of Environmental Engineering
and Technology Demonstration
(202) 475-7161

Priscilla Flattery
Pollution Prevention Office
(202) 245-3557

The EPA's Office of Solid Waste and Emergency Response has a telephone call-in service to answer questions regarding RCRA and Superfund (CERCLA). The telephone numbers are:

(800) 424-9346 (outside the District of Columbia)

(202) 382-3000 (in the District of Columbia)

The following programs offer technical and/or financial assistance for waste minimization and treatment.

Alabama

Hazardous Material Management and Resources
Recovery Program
University of Alabama
P.O. Box 6373
Tuscaloosa, AL 35487-6373
(205) 348-8401

Alaska

Alaska Health Project
Waste Reduction Assistance Program
431 West Seventh Avenue, Suite 101
Anchorage, AK 99501
(907) 276-2864

Arkansas

Arkansas Industrial Development Commission
One State Capitol Mall
Little Rock, AR 72201
(501) 371-1370

California

Alternative Technology Division
Toxic Substances Control Program
California State Department of Health Services
714/744 P Street
Sacramento, CA 94234-7320
(916) 324-1807

Connecticut

Connecticut Hazardous Waste Management Service
Suite 360
900 Asylum Avenue
Hartford, CT 06105
(203) 244-2007

Connecticut Department of Economic Development
210 Washington Street
Hartford, CT 06106
(203) 566-7196

Florida

Waste Reduction Assistance Program
Florida Department of Environmental Regulation
2600 Blair Stone Road
Tallahassee. FL 32399-2400
(904) 488-0300

Georgia

Hazardous Waste Technical Assistance Program
Georgia Institute of Technology
Georgia Technical Research Institute
Environmental Health and Safety Division
O'Keefe Building, Room 027
Atlanta, GA 30332
(404) 894-3806

Environmental Protection Division
Georgia Department of Natural Resources
Floyd Towers East, Suite 1154
205 Butler Street
Atlanta, GA 30334
(404) 656-2833

Guam

Solid and Hazardous Waste Management Program
Guam Environmental Protection Agency
ITCE E. Harmon Plaza, Complex Unit D-107
130 Rojas Street
Harmon, Guam 96911
(671) 646-8863

Illinois

Hazardous Waste Research and Information Center
Illinois Department of Energy and Natural Resources
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16. ABSTRACT

The fiberglass reinforced and composite plastic industries generate wastes (including air emissions) during fabrication processes and from the use of solvents for clean-up tools, molds and spraying equipment. The wastes generated are: partially solidified resins, contaminated solvent from equipment clean-up, scrap coated fiber, solvated resin streams, and volatile organic emissions. The guide manual presents source reduction and recycling opportunities for reducing these wastes. Suggestions include using substitutes for solvent cleaners, making changes to mixing and application equipment, recovering and recycling solvent, and implementing good materials management and housekeeping practices.

To help companies in the industry identify opportunities for waste reduction at their own facilities, the guide includes a set of worksheets which take the user step-by-step through an analysis of the on-site waste generating operations and the possibilities for minimizing each waste. The guide and its worksheets would also be instructive to consultants serving the fiberglass reinforced and composite plastics industries and government agencies who regulate waste streams generated from these firms.

17. KEY WORDS AND DOCUMENT ANALYSIS

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