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Assessment of the Polymers and Resins Industry's Hazardous Waste Source Reduction Planning Efforts

California Department of Toxic Substances Control

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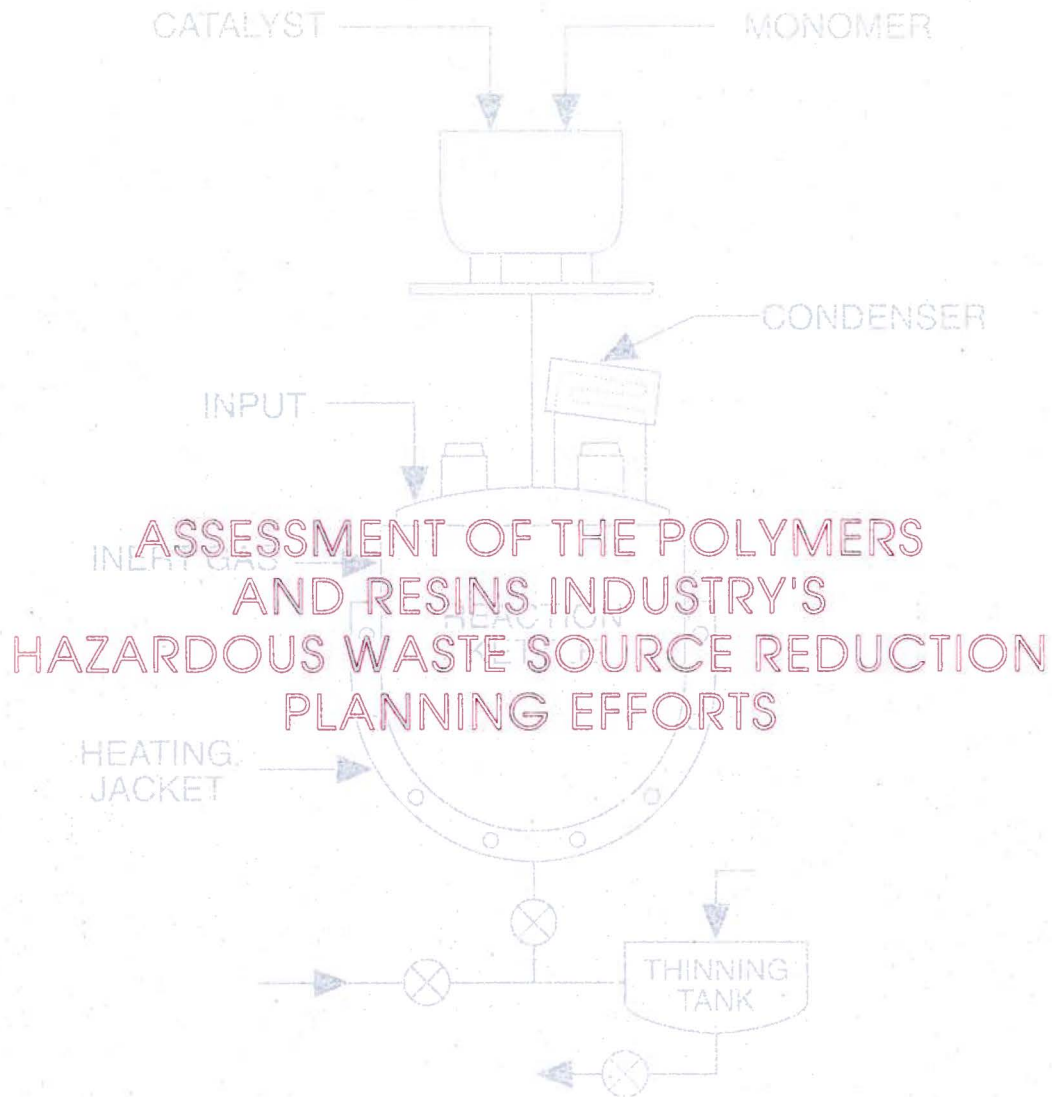


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ASSESSMENT OF THE POLYMERS
AND RESINS INDUSTRY'S
HAZARDOUS WASTE SOURCE REDUCTION
PLANNING EFFORTS

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RESIN MANUFACTURER'S HAZARDOUS WASTE SOURCE REDUCTION
PLANNING EFFORTS**

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GOLDEN GATE UNIVERSITY

Prepared by David Weightman

**State of California
Department of Toxic Substances Control
Office of Pollution Prevention and Technology Development**

February 1996

This report was prepared by David Weightman under the direction of Alan Ingham and Kim Wilhelm, Source Reduction Unit, Office of Pollution Prevention and Technology Development. Cover by Stan Lau and David Weightman.

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DISCLAIMER

The mention of any products, companies, or source reduction technologies, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products, companies or technologies.

REPORT OVERVIEW

This report summarizes the results of the Department of Toxic Substances Control's (DTSC) assessment of the polymers and resin industry's source reduction planning efforts, as mandated by the Hazardous Waste Source Reduction and Management Review Act of 1989 (Act). The assessment of the polymers and resin industry in California is based upon a review of documents produced by a sample of facilities in the state. It includes information on the sources and types of hazardous waste generated by this industry and describes some of the steps taken to reduce the quantities or hazardous characteristics of waste generated in their operations. In addition, three case studies are featured as practical examples to show how source reduction practices benefited particular facilities.

The Act requires the Department to select at least two categories of generators by Standard Industrial Classification (SIC) code every two years for evaluation. This evaluation consists of reviewing documents prepared by facilities which are subject to the Act because of the quantity of hazardous waste generated at their sites. Select facilities were visited to better understand and describe their operations and waste management practices. The Act requires hazardous waste generators to evaluate options for decreasing the quantity, or the hazardous characteristics, of hazardous waste routinely generated in their operations.

The polymers and resins production industry, also known as the synthetic plastics industry, was chosen as one of the targeted categories of generators for review of their 1991 source reduction documents prepared under the Act. The primary Standard Industrial Classification (SIC) code represented is 2821 (Plastics materials and resins). To a smaller extent, other SIC codes represented in the report include 3087 (Plastics, foam products), and 3086 (Custom compound purchased resins).

The three basic manufacturing activities within this industry include polymer production, compounding, and resin processing. This report primarily focuses on companies engaged in polymer production and compounding. However, five companies whose source reduction planning documents were reviewed for this report make plastic reinforced composites. Several of the firms referred to this material as "pre-preg". Pre-preg production involves compounding or custom blending resins and then impregnating a substrate material such as fiberglass with the resin mixture. The impregnation step in producing plastic reinforced composites is, for the purpose of this report, considered a processing function. Otherwise, processing generally involves using customized resins to form molded or laminated products. While some of the facilities assessed for this report process resins, the primary activity of the majority involves production and/or compounding resins/polymers. Customized or compounded resins generally are marketed in the following forms: pellets, powders, liquid emulsions, adhesives, or coatings/sealants.

A total of 36 companies were requested to submit their source reduction planning documents for evaluation. Thirty-one reviews were completed for this report. Among the 36 companies, two had closed operations, and three were deemed not to be subject to the Act. In addition, responses to the letters requesting that documents be submitted revealed that three of the remain-

ing 31 companies (still operating and subject to the Act) did not complete source reduction documents in 1991. These three facilities have since completed documents using 1992 and 1993 as baseline years for reporting purposes. In addition to reviewing 31 sets of source reduction planning documents, DTSC staff visited eight of these facilities.

Although the variation in processes and products within the synthetic plastics industry makes it hard to identify a "largest" wastestream, the Plan review indicated that the most consistently generated wastestream at these facilities was contaminated solvents; in most instances, solvents were contaminated with resin. Liquid solvent-resin waste containing substances such as styrene, acetone, 1,1,1-trichloroethane (1,1,1-TCA), and methylene chloride were generated from activities such as reaction vessel cleaning; excess solvenated resin from treater pans (composite plastics manufacturing only); flushing raw material or product transfer pipes or storage tanks; general equipment and parts cleaning; and, filter screen cleaning.

The identified source reduction measures to reduce solvent-resin waste included finding more efficient ways clean equipment, adjusting cleaning frequencies, better waste segregation to allow for longer use of solvent solutions, improved batch scheduling to minimize the need to clean and flush product or raw material transfer lines, and in a few cases, equipment redesign and cleaning solution substitution.

Another dominant wastestream was waste resin (in liquid or solid form). This waste was generated because; excess product was made that could not be sold or reused; polymerization reaction processes were incomplete; contaminated raw materials were used that lead to the production of off-specification product; samples could not be reused; product was removed in filtering; and, product was removed when build-up was removed from storage tanks.

Measures reported to reduce this wastestream included altering batch production scheduling to better sequence compatible products, adding dedicated product transfer lines and storage tanks, reworking excess product or samples back into batches, making equipment improvements, better waste segregation, and improving procedures to inspect and store incoming raw materials.

Contaminated or spent oil was another frequently reported waste stream. Typically, the oil was described as being contaminated with vapors containing water, monomer, solvents, additive substances, or some combination of these substances. The sources of waste oil included vacuum pumps, reaction vessel heat transfer coils, and leaks and spills.

Measures taken to reduce this wastestreams included installing sealless pumps, installing pumps using a different sealing fluid, using a different type of oil or other internal lubricant, and improving equipment maintenance schedules.

Among the companies that produce batch thermoset resins such as alkyds, polyesters, epoxies, and phenolics; polymerization reaction process condensate was often reported as the single largest quantity wastestream. However, some of the companies that generate this wastestream did not measure it at the source or report it in their source reduction plans. When not reported, generators tended to believe that this by-product from the condensation polymeriza-

tion reaction was not a wastestream for source reduction planning purposes. Some generators mistakenly assumed this because the wastewater condensate was inherent to the production process, or because the condensate was treated and discharged to the local POTW under established parameters for wastewater discharges.

Condensate (the portion which could not be routed back to the reaction vessel for reuse) was frequently directed to a separation tank for solvent recovery. The remaining substance, mostly water, was either treated and discharged to the sewer, or incinerated. In some cases, the condensate was captured and reused in later batches of similar or lower grade products. In one case, a company installed a filter which removed enough impurities to make the water usable in subsequent batches of similar product. Two companies altered ramp temperature times in order to increase the efficiency of reaction to reduce reaction condensate waste. One company is in the process of installing water treatment/purification equipment that will enable condensate wastewater reuse in boilers and cooling towers (see case study three for details).

A last major wastestream generated by these facilities was bags, drums, and containers which became waste when they were emptied of product. Many companies made significant gains in reducing these wastes. Some companies were able to switch to ordering liquid supplies in returnable totes rather than disposable drums, other firms worked with suppliers to order supplies in bulk, and some companies found that they could use liners to prevent bulk bag contamination. Better waste segregation also helped reduce these wastestreams.

In addition to the above wastestream-specific source reduction measures, several companies implemented administrative measures such as employee incentive and training programs, waste tracking and logging procedures, and computerized inventory monitoring. Also, three companies indicated that they had achieved waste reduction via discontinuing or reformulating products. The reformulations included the use of less toxic additives or pigments, or the elimination of heat-sensitive additives which contributed to the generation of off-specification resin wastestreams.

Section IV of this report provides concise summaries of what various companies in the polymer/resin industry have done to implement wastestream-specific source reduction measures. Section V presents case studies which describe in detail the costs and benefits associated with implementing a variety of source reduction measures at three facilities.

In conclusion, information from the submitted documents, and supplemental contacts with facility personnel, revealed that between 1989-1994, the reviewed facilities identified and implemented source reduction measures. Seventy-five percent of the companies achieved reductions in the amount of hazardous waste manifested from their sites. Total hazardous waste manifested from these facilities decreased by 27 percent when comparing individual baseline data with 1994 data.

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I. BACKGROUND

The Hazardous Waste Source Reduction and Management Review Act of 1989 (SB 14) applies to businesses that generated over 12,000 kilograms (13.2 tons) of hazardous waste, or 12 kilograms of extremely hazardous waste, in 1990. The law requires generators to prepare documents which reflect their efforts to identify, and then implement feasible methods for reducing the quantity and/or the hazardous characteristics of hazardous waste routinely generated in their operations. The first set of source reduction documents was due September 1, 1991. Documents are to be completed every four years thereafter, provided that the above threshold is exceeded in the "reporting year". The reporting year is the year which immediately precedes the year in which the documents are required to be completed. For example, the most recent SB 14 documents should have been completed by September 1, 1995, for wastes generated in 1994 (the most recent reporting year)

To comply with the Act, generators must prepare a Source Reduction Plan (Plan), a Management Performance Report, summaries of the Plan and the Report, and a Progress Report. The Plan must include information about the facility's operations and provide waste generation data for the reporting year. The Plan must also include a list of potential source reduction alternatives for "major" wastestreams that are routinely generated, and describe the company's evaluation of the alternatives. Major wastestreams are those that exceed five percent of the total weight of routinely-generated hazardous wastes.

Using specific criteria to evaluate a source reduction measure's feasibility, such as amount of reduction, technical feasibility, economic viability, and effect on workplace health and safety; the Plan must describe the rationale for choosing or rejecting measures for implementation. The generator must then specify a timetable for implementing feasible source reduction options. Finally, the Plan must contain technical and financial certifications to ensure that the documents were prepared with the oversight of those responsible for day-to-day operations, and an owner or operator who has the authority to commit financial resources necessary to implement the Plan.

The Management Performance Report (Report) discusses wastestream generation and management, and describes source reduction measures and other changes in waste management practices that have been made since the baseline year. As with the Plan, the Report must also contain technical and financial certification statements.

The purpose of the Progress Report is to track, on a biennial basis, the percentage of waste reduction achieved for the site's major wastestreams, normalized to account for changes in throughput (or other relevant factor(s)). Companies subject to SB 14 satisfy the Progress Report requirement by using Form GM from their U.S. Environmental Protection Agency Biennial Hazardous Waste Report.

The Act requires the Department of Toxic Substance Control (DTSC) to select at least two categories of generators by Standard Industrial Classification (SIC) code every two years and request that selected generators submit documents for review. The review process involves

sending request letters to generators via certified mail (see appendix A). Upon receipt of the letter, generators have 30 days to send copies of their documents to DTSC. Once the documents are received, they are reviewed for completeness (see appendix B) using checklists found in the Department's source reduction guidance manual. Following the completeness review, a comment letter is prepared and sent to the generator to inform of any revisions necessary to comply with the provisions of the Act. In cases where there are major deficiencies or omissions, the Department asks generators to revise and resubmit the documents.

In addition to monitoring compliance, a primary purpose of the Department's review is to obtain and share information regarding successful source reduction measures. Information collected from the documents is disseminated through factsheets, presentations, and reports (such as this one) to generators with similar operations, and other interested parties.

DTSC selected the polymers and resins industry (primarily represented by SIC code 2821) as one of the targeted industrial categories to review during 1994 and 1995. An initial list of companies within this classification was assembled using data from the 1992 Toxics Release Inventory database. Additional companies were identified using data from the U.S. EPA 1991 and 1993 Hazardous Waste Reports. The Department's manifest tracking database was also used to check the records of plastics and resins companies listed in the California Manufacturers Register. To the Department's knowledge, the 31 facilities reviewed for this report represent a majority of plastics and resins facilities in California that are subject to SB 14.

In the State of California's waste management hierarchy, source reduction is given the highest preference in hazardous waste management. The purpose of planning and implementing source reduction strategies is to minimize the generation of hazardous waste and thereby minimize the need to control it after generation. California's Health and Safety Code defines source reduction as:

- Any action which causes a net reduction in the generation of hazardous waste; or
- Any action taken before the hazardous waste is generated that results in lessening of the properties which cause it to be classified as hazardous.

Furthermore, the Act clearly states that source reduction does not include any of the following:

- Actions taken after a hazardous waste is generated.
- Actions that merely concentrate the constituents of the waste to reduce its volume or that dilute the waste to reduce its hazardous characteristics.
- Actions that merely shift hazardous wastes from one environmental medium to another environmental medium.
- Treatment

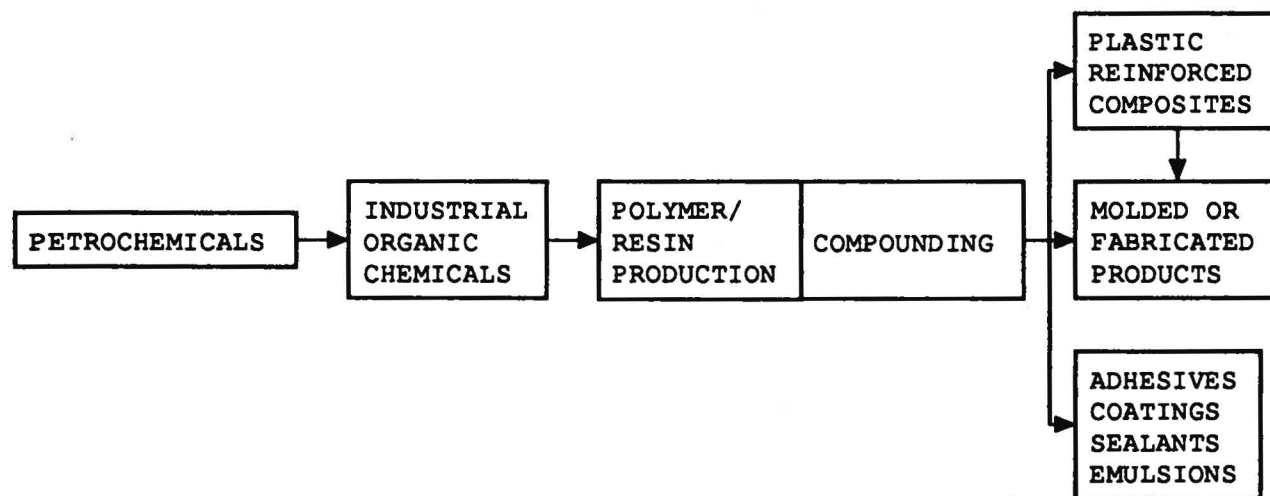
The primary purpose of this report is to provide information regarding hazardous waste source reduction activities implemented by polymers and resins industry facilities. Therefore, discussion of reuse or recycling practices is very limited.



II. INTRODUCTION

This report examines the hazardous waste source reduction practices of California polymers and resins manufacturing firms. The facilities assessed for this report, listed on Table 1 on page 8, are grouped by the primary polymers and resins categories that they formulate, and the end use or intermediate products which they market. In the broader picture, polymers and resins (also known as "synthetic plastics") is a subset of the chemical manufacturing industry. This subset is directly linked with three upstream industries: raw material extraction, raw material refining and industrial organic chemical production. The raw materials used to make polymers and resins, i.e., monomers and chemical additives, originate from the distillation of energy resources including natural gas, coal and petroleum. Manufacturing sectors within the industry include polymer formation (production), resin compounding, and plastics/resins processing. Processing, not the focus of this report, generally involves using resin pellets, sheets, reinforced composites and other intermediate polymer products to form end use products using specific processing methods. Diagram 1 illustrates the progression from basic petrochemicals to finished plastic products.

DIAGRAM 1. PROGRESSION FROM BASIC PETROCHEMICALS TO FINISHED PLASTIC PRODUCTS



Adopted and modified from "Industrial Process Profiles for Environmental Use: Chapter 10A- Plastics and Resins Processing Industry." Radian Corporation. July 1985. McLean, VA.

Polymer production (formation) involves forming long chains of molecules by using specific raw materials with specific polymerization reaction methods. Typically, polymerization begins with an exothermic reaction initiated with heat and catalysts. Process variables such as time, temperature, and pressure are carefully controlled. (more detailed description of production

(formulation) and compounding is provided in the following section).

Compounding involves modifying a polymer/resin to provide the final product with attributes suitable for a particular use. This manufacturing phase can occur just before or during the processing operation, or partially during production (formulation) and partially during processing. It includes steps such as adding pigments for color, adding fillers to increase strength or lower cost, adding plasticizers (which act as lubricants), adding hardening agents that control curing rates, or adding other agents to obtain characteristics such as flexibility, opacity, impact strength, adhesiveness, or fire resistance, among many other possible characteristics.

The production (formation) and compounding methods used to make polymers/resins are functions of the form in which the plastic substance is needed. For example, resins can be produced in a liquid form for use as an adhesive, or formulated for use in spray coatings, lacquers and varnishes, and paints. The same resin type can be formed as a powder to be used to make a molded or casted product.

Polymers/resins produced by the synthetic plastics industry fall into one of three primary categories: thermosets, thermoplastics, or elastomers (or elastomeric thermoplastics). Thermoset resins undergo chemical change during polymerization. In a fully cured, or fully polymerized state, thermoset molecules are cross-linked. This means that the molecules are permanently insoluble and infusible. Prior to reaching this state they are typically produced as intermediate products (which represent a stage of polymerization). These intermediate products are sometimes referred to as A-stage, or B-stage resins. These terms indicate a degree of chemical/molecular bonding in the substance, which affects how the polymer/resin can be modified. In general, A-stage resin is soluble and fusible (melttable), while the B-stage resin is insoluble and only partially fusible. Some examples of thermosets include unsaturated polyesters, epoxies, phenolics, and rigid urethane resins.

Unlike thermosets, thermoplastic resin molecules are unlinked. In their cured state thermoplastics can be softened by heating or hardened by cooling. Because of this characteristic, pre- or post-consumer recycling is possible. Aside from being melttable, most thermoplastics resins are soluble in specific solvents. Some types of thermoplastic resins include: polyvinylchloride, polystyrene, acrylics, and polyamides. These resins are frequently used to make consumer product packaging.

The third broad category of synthetic resins is elastomers, sometimes referred to as elastomeric thermoplastics. As implied in the name, elastomers are elastic in their cured state. They stretch and compress to varying degrees at ambient temperatures depending upon the amount of stress (force) applied. Examples of elastomers include synthetic rubbers, chlorinated polyethylene, acrylonitrile-styrene-butadiene, and acrylates. A common example of an elastomer product is polyurethane foam, a material used in furniture cushions and bedding materials.

The largest group of facilities reviewed for this report produce intermediate thermosetting (non-fusible and non-soluble) resins, in powder form, liquid form, or as adhesives. Source reduction documents were also reviewed for companies that polymerize and extrude thermoplas-

tic resins used in molded products, facilities that make reinforced composites used in laminated materials, and two facilities exclusively engaged in compounding resins. Lastly, documents were reviewed for two manufacturers of rubberized products and for one facility that manufactures polyurethane foam.

Distinctions between groups of facilities based on the primary resin/polymer categories (described in subsequent paragraphs) are important. Different types and quantities of hazardous waste are generated among polymer/plastic manufacturers depending upon products made. Some source reduction measures have potential application in a broad range of polymer/resin manufacturing facilities. Other measures may only apply to facilities making certain categories of plastics because of distinct processes and wastestreams.

For example, thermoset polymers, when compared to thermoplastic polymers, are extremely specific in their constituents and form; like recipes designed to please an individual's palate. Because of this, thermosets are more limited than thermoplastics in possible input substitutions related to product formulation. In addition, thermoset polymers often generate reaction process wastewater. This wastewater starts as a condensate which forms when vapor exhaust from the polymerization reaction cools to a liquid. Thermosets are also usually produced on a batch-by-batch basis. With thermoplastic polymers, reaction process wastewater is typically not generated. Instead of becoming wastewater, the condensate is returned to the reaction vessel during the polymerization reaction. In addition, thermoplastics are usually made in a continuous production process.

The batch production process common to thermosets can complicate attempts to correlate waste generation with production throughput. Batch sizes can range from a few hundred pounds to hundreds of tons. Equipment cleaning, which often generates liquid solvent-resin waste, may be necessary between batches regardless of batch sizes and total facility production. In addition, producing a large number of products (characteristic of batch production operations) affects the amount of excess (waste) product generated which also may not be related to total production throughput.

Table 1, organized by plastics category, lists the companies reviewed for this report, each company's primary manufacturing activities, and the polymer or primary resins/products made at each facility. The SIC code which represents most of the companies included in this report is 2821 (plastics materials and resins). Facilities were identified from information contained in the 1992 Toxics Release Inventory database, and from waste quantity information in the Department's 1990 manifest records.

There are literally thousands of intermediate and end-use products produced from the three types of polymer categories described above. These products affect a broad range of industries. The expansion of polymers and resins production into these industries, is due to several factors: increased use of plastics as a substitute material for glass and metal products, development of new products, and increased sophistication in plastics processing methods and polymer chemistry. Some of the primary industries affected by the expanded use of polymers include electronics, aerospace, textiles, furniture, household products, automobiles, and the packaging

TABLE 1. SB 14 COMPANIES - PLASTIC CATEGORIES, MANUFACTURING FUNCTIONS, AND RESIN TYPES/PRODUCTS

Company	Produce ⁽¹⁾	Compound ⁽²⁾	Process ⁽³⁾	Resin(s) or Product
Thermoplastic Resins				
American Polystyrene	x	x		Polystyrene
Amoco Foam Products		x	x	Polystyrene
BASF Corporation	x			Polystyrene
Tenneco Packaging Corp.	x	x	x	Polystyrene
Dow Chemical	x	x	x	Polystyrene, styrofoam
Heller Performance Polymers		x		Polyvinyl chloride, polyethylene
Keysor Century	x			Polyvinyl chloride
Thermoset Resins				
Alpha Owens-Corning	x	x		Polyesters
Ashland Chemical	x			Polyesters
Engineering Polymer Solutions	x			Polyesters, alkyds, ureas
McWhorter Technologies	x	x		Polyesters, alkyds
Reichhold Chemicals, Inc. - Azusa	x			Polyesters - facility not in operation
Reichhold Chemicals, Inc. - Oxnard	x			Polyesters
Silmar Resins of Interplastic Corp	x	x		Polyesters
Courtaulds Aerospace-Berkeley	x	x		Amine hardeners, epoxies/ureas/ polyurethane
CIBA - Geigy	x	x		Epoxies, amine hardeners, ureas
Fiber - Resin Corp. - Chatsworth	x	x	x	Epoxies, polycarbonates, hardeners
Neville Chemical	x	x		Epoxies, base epoxies
Rhone-Poulenc	x	x		Epoxies (ceased epoxy production in July 1995)
Dow Chemical	x	x		Epoxies
Courtaulds Aerospace - Mojave	x	x		Formaldehyde amines, epoxies, polyesters
Georgia Pacific - Ukiah	x	x		Phenolics, ureas
Georgia Pacific - Sacramento	x	x		Phenolics, formaldehyde-based compounds
BP Chemical Company		x	x	Composites, - plastic reinforced materials
Cytec Engineered Materials		x	x	Composites, - plastic reinforced
Hexcel Corporation - Livermore		x	x	Composites, - plastic reinforced materials
Fiberite Corporation		x	x	Composites, - plastic reinforced materials
Newport Adhesives and Composites		x	x	Composites, - plastic reinforced materials
Rohm & Haas of Delaware Valley	x			Acrylic latex emulsions
Elastomeric Resins				
Rubber Urethanes		x	x	Rubber urea cast products
Mitchell Rubber Products		x	x	Rubber compounds/products
Polycom - Huntsman		x		Acrylonitrile-butadiene-styrene
Foamex, Ltd.	x	x	x	Polyurethane foam

⁽¹⁾Produce - make polymers or copolymers

⁽²⁾Compound - modify or custom blend polymers/resins to achieve particular attributes, or make nonstructural products such as adhesives, coatings, etc.

⁽³⁾Process - use intermediate polymer/resin products to form structural end use products

industry.

Because polymers are used in such a wide variety of industries, changes in the economy can noticeably affect production output in the polymers and resins industry. The economic recession of 1991-1993 is a case in point. A number of polymer/resin firms decreased production because of depressed market demand during the recession. Other polymer manufacturers were affected by downsizing occurring in the aerospace industry due to decreased orders associated with reduced national military spending. Some of the firms assessed for this report relied heavily on aerospace companies as markets for their products. Because of the economic recession, the aerospace industry decline, and other factors, between 1990 and 1994 some polymer/resin firms went out of business or consolidated, while others increased production due to reduced competition in the market.

Among the 36 firms included in the initial SB 14 review, three ceased operations and another is planning a shutdown of one of its facilities.

Other firms assessed for this report were bought by other companies, and some changed product lines. Several firms also noted that they had received products and materials from other facilities in the U.S. that had closed; some of these products and materials had to be disposed as hazardous waste.

It has not been possible, based upon the information provided in the source reduction documents, to determine an overall percentage decrease in waste generation that reflects industry-wide progress due to source reduction practices. Most of the documents did not normalize waste generation data to account for production throughput changes or other factors, such as receiving waste from other facilities, when estimating waste reduction due to source reduction. However, it appears that most facilities instituted source reduction measures. Manifest data shows a 27 percent reduction in waste shipped off-site by these facilities between 1990 and 1994. In future planning efforts by this industry, more effort should be made by individual facilities to normalize waste reduction figures/percentages. Data normalization should account for relevant factors that impact waste generation (other than source reduction) and allow for an accurate assessment of waste generation decrease due to implementing source reduction measures.

III. OVERVIEW OF MANUFACTURING PROCESSES

This section provides a general description of processes that are used by the synthetic plastics manufacturing industry to make polymers (condensation and addition polymerization), modify polymers (compounding), and to make plastic reinforced composites. The methods described below, in actual practice, contain many variations. These descriptions represent information that has been provided in SB 14 source reduction planning documents, and gathered from conversations with facility personnel. In plastics manufacturing (and also processing), there are many cases in which production process details/methods are unique to a facility or company and are considered proprietary because these methods may provide competitive market advantage. In the final analysis, the polymerization and/or compounding methods used by a facility are functions of the form of the polymer/resin, the quantities made, and the chemistry of the polymer compound's raw materials.

The general process used to produce polymers, or co-polymers (polymers compounds made with more than one monomer) starts when specific chemicals, monomers, catalyst, additives and/or solvents are charged into a reaction vessel, sometimes referred to as a "kettle". The mixture is then heated using a heat transfer fluid, such as oil or water, that is contained within a jacket of coils inside or outside the kettle. Typically, excess air is removed from the vessel by vacuum and excluded during the reaction by using a pressurized gas such as nitrogen. As the substances in the vessel react, long chains of molecules called "polymers" are formed. This process is called polymerization.

A. POLYMER PRODUCTION

Thermosets. Facilities that produce/formulate thermoset polymers typically describe the initial reaction phase as "condensation" polymerization. During the reaction, a condensate is formed when unreacted and partially reacted monomers and additives, in combination with water molecules released in the reaction, vaporize, cool, and then collect in a condenser or series of condensers. This condensate, if not recycled in the process, becomes a wastewater by-product. Thermoset polymers are typically produced on a batch-by-batch basis and the product developed in the reactor is usually not fully polymerized ("cured"). As discussed earlier, the partially cured condition of the process stream allows the substance to be modified, subject to its specific chemical makeup and polymerization stage. Once removed from the reaction vessel(s), this process stream may undergo viscosity adjustment; usually, this means the mixture is diluted with solvent. The mixture may also be filtered to remove contaminants.

Thermoplastics and Elastomers. Although not all products are produced using reaction vessels, (polyurethane foam is an example) facilities that formulate thermoplastics and elastomers typically describe the reaction phase as "addition" polymerization. Generally, addition polymerization involves one type of monomer species and is begun by using an initiator which activates monomers by breaking a double bond between atoms. The reaction phase is often a continuous process that may take place in a series of reactors. As with thermoset polymerization reactions, chemical reactions between the process ingredients in the vessel do not reach 100%

efficiency. As a result, some additives and reactant substances, combined with water, pass through (are vacuumed off) the reaction process partially altered or unaltered, as vapor. However, unlike thermoset reactions, the vapor does not usually become wastewater once it has been condensed and collected. Condensed vapor from the reaction is either reused directly in the reaction, or is collected and used as a makeup ingredient for later batches. Partially-reacted particles remaining in the process stream may generate waste when the product is filtered.

In some polymerization reactions, chemically complex reactants and additives in the polymerization vessel undergo side reactions which create low molecular weight polymer. This off-specification polymer is sometimes referred to as "dimers" or "trimers", depending on the number of molecules in the polymer chain. This low weight polymer, including any unreacted and partially-reacted process additives drained from the vessel, generates waste. Although a portion of the reject low weight polymer may be reusable within the product batch, the unusable portion can sometimes constitute a significant wastestream.

It is important to note that addition or condensation reaction polymers can be produced via several methods. These polymerization methods include solution, mass, suspension, and emulsion, or some combination of these. To a large extent, the polymerization method used to produce a polymer is a function of the form of the final or intermediate product. However, for purposes of this report, it is more important to note that process variables in polymerization reactions can affect the amounts or toxicity levels of waste generated. Some of the key polymerization reaction variables include heating ramp times for process mixtures, peak temperatures, cooking (reaction) time, the degree to which vacuum and agitation is applied to the process stream, catalyst(s) pH level, and the rate at which catalyst is added to the mixture.

B. COMPOUNDING

In a majority of instances, the polymer formed in the reaction is modified to fabricate a particular product, or to suit the needs of a customer who will use the product for a very specific application. As mentioned earlier, compounding is often a multi-step operation that can occur partially or wholly once the resin has reached a particular stage of the polymerization. Compounding may occur at the production facility, or it may occur as a completely separate operation at a different facility. Polymer compound modification may also be a staged process started during the manufacture of the polymer and completed as the polymer is used in a resin processing operation.

Polymer compounds can be modified in many ways and the methods and equipment available for this purpose are quite varied. Some common ways to modify polymers involve adding fillers to increase strength and lower costs, adding plasticizers to facilitate use of the intermediate product in processing operations such as molding or casting, adding pigments for color, adding fire retardants to achieve ignition resistance, and adding stabilizers to prevent degradation due to exposure to chemicals, light or moisture.

A typical compounding operation starts by mixing proportions of polymer and additives in mixing vessels, blenders, or hoppers. In the mixing vessels, the polymer, in dry, paste or liquid form, is pre-blended with additives until the polymer and additives obtain a homogeneous mix. In some instances, blending occurs in several stages. The particular blending technique(s) used (as reflected by the equipment involved) may depend upon the polymer being modified and formulation additives being used. After the initial blending, some mixtures are then filtered. Resin mixtures then undergo fusion as a result of the application of heat and/or shearing action, during which other additives may be incorporated into the polymer's matrix. With thermoset resins heat and shearing action must be carefully controlled to prevent premature curing. After the mixtures' ingredients are incorporated and homogeneously dispersed, the mix is then shaped depending upon how it will be used in processing operations. Typically this involves discharging the polymer to pelletizers, dryers, or processing equipment. The final shape generally takes the form of sheets, granules, pellets, or powder, depending upon the application.

Thermoset compounds, in an uncured state, either A-stage, or B-stage, are frequently used to form paints, sealants and coatings, adhesives, or molding powders. Thermoplastic resins are often extruded as sheets, rods, or pellets. Pellets are typically remelted as feedstock for injection, thermoforming, or blow mold processes.

C. PLASTIC REINFORCED COMPOSITES

Pre-preg, is a plastic resin reinforced material which is a primary product made at five facilities reviewed for this report. Pre-preg is an intermediate product sold as rolls of resin-impregnated material. The resin in the material is only partially cured (B-stage); therefore, the material is flexible. The material to be impregnated with resin is purchased by the pre-preg manufacturing facility in the form of a woven sheet/cloth or mat, or unidirectional fiber, wound on rolls. This material is called the "substrate". The substrate is commonly made out of substances such as glass, graphite, or Kevlar®. After the substrate material is pre-impregnated with resin, it is typically cut to specific widths and stored in cool conditions to prevent the resin from further curing. This intermediate product is then used by fabricators (e.g., laminators) who shape the material and complete the curing stage of the resin. Although both thermosets and thermoplastic resins can be used to make composites, thermosets such as alkyds, polyesters, epoxies, and phenolics were the resins most commonly reported.

There are two dominant processes used in pre-preg production described in the SB 14 documents: solvent-based, and hot-melt coating. In both processes, thermoset resins, which are purchased in A-stage form (partly soluble, partly fusible), are first mixed with a solvent (grosser), an activator, pigments, fillers, and other additives. The mixing vessels used for this operation range from small to large sizes, depending on the batch. The mixing process continues until a specific viscosity and mix uniformity is reached. This may take several hours to complete. If the mixture is not used promptly, it is placed in cold storage to prevent further curing.

Solvent based impregnation. There are two variations of the "solvent-based" impregnation process; one in which the resin is pumped to a "treater" or dip pan within a vertical tower, and

another in which strands of fiber are meshed onto a roll coated with resin adhesive.

In the tower, resin in the treater pan at the bottom of the unit is dissolved in solvent. A reservoir, sometimes called the "bean pot" feeds solvent to the treater pan to precisely adjust the specific gravity of the resin coating mixture. As the substrate (sheet) is unwound from its roll at a given speed, it is dipped into a resin mixture within the treater pan. This dipping may occur multiple times. A second dip pan may be used, depending upon the product being made. Each time the sheet is dipped in the resin solvent mixture, it is run through rollers (set at a specific gap), which mesh the resin mix into the sheet. Then the impregnated sheet passes through one or more oven drying zones. Oven drying cures the material to a B-stage (insoluble and partially fusible) condition. Solvent vapors that are emitted during the oven drying process are exhausted to a thermal incinerator, or they may be condensed in a air cooling chiller. The resin -impregnated material is then cut to size and wound onto rolls. As noted, this process converts A-stage resin to the B-stage (insoluble and partially fusible).

In a variation of the solvent-based impregnation process, strands of fiber are unwound from a creel and fed into a machine that meshes the fiber into a resin adhesive coated roll. Solvent from the coated roll soaks into the fibers as the fibers mesh with the roll. Simultaneously, release paper is applied to the two sides of the impregnated sheet, which is then wound into rolls.

Hot melt impregnation. Hot melt impregnation uses heat to control the viscosity of the resin mix used to impregnate the substrate in lieu of solvents. In the hot-melt coating method, rolls of substrate are fed as a continuous web to a machine that contains a dam filled with resin. This particular machine's line speed, roll gaps, temperature settings, and the resin mixture's specific gravity are controlled by a line operator. The sheets are impregnated when the rollers mesh resin into the fabric sheet, while release paper is added to one side of the roll so that it may later be unwound.

IV. WASTESTREAMS AND SOURCE REDUCTION MEASURES

This section contains a discussion of the types, quantities, and sources of hazardous wastes generated by the 31 facilities assessed for this report. Source reduction measures that were implemented to reduce waste quantity or toxic characteristics are also summarized. Although some of the source reduction measure descriptions include quantitative data, more detailed information regarding waste generating processes, implementation costs, cost savings, and waste reduction quantities is presented in Section Five. Section Five presents case studies which describe in detail the background, the costs, and the benefits associated with implementing a variety of source reduction measures at three facilities.

The most typical source reduction measures cited in the reviewed documents involved making raw material substitutions, or changing the methods, used to accomplish production and operations related tasks. To a lesser extent, some facilities reduced waste by upgrading equipment (making capital improvements), and a number of firms briefly discussed making administrative changes. In many instances, the critical information relating to the criteria used to decide what measures to implement was only generally discussed, or was not documented in the Plans. These Plans would have more value to the Department for technology transfer purposes had this information been included. For the facilities, including information such as implementation costs, waste reduction quantity estimates, and economic benefits in the documents provides a written record with baseline information. Baseline information can be used to determine the accuracy of assumptions and monitor progress towards reaching future waste reduction targets or goals.

Polymer production, modification and processing operations generate pollution from hazardous and nonhazardous liquid wastes (which include wastewater), solid wastes, and air emissions. The sources and types of waste from any one facility generally depend upon the type and form of polymer(s) made at the facility and scope of production, modification, and processing activity at the site. Polymer form (liquid, solid powder, pellets, etc.) is a function of the type of polymerization reaction (addition or condensation) and the polymerization method(s) used to produce the polymer. There are four types of polymerization methods used in the industry. These methods include mass, solution, suspension, and emulsion polymerization (either separately or in combination). These methods vary in the ways in which process ingredients are added to the reaction vessel (reactor), and the extent to which water and/or solvents are used as ingredients in the reaction vessel.

The different polymerization methods create both hazardous and nonhazardous wastes of varying types, concentrations, and characteristics. For example, solution and mass polymerization methods involve using solvents in the polymerization reaction mixture. Vapor vented from the reaction, which is condensed to a liquid, typically contains solvent and partially-reacted and unreacted process substances. The portion of this liquid condensate that is not recycled in the process becomes a generated wastewater. If it is economically justifiable, some facilities will recover solvent from this wastewater by using separation tanks and/or distillation units. These units generate secondary wastestreams such as solvent sludge and activated carbon filters.

In mass polymerization processes, the conversion level of monomer(s) to polymer/copolymer

is typically lower than with solution, suspension, and emulsion methods. As a result, greater amounts of low molecular weight polymer may result. If not recycled in the process, these low-weight polymers may become off-specification waste. In suspension polymerization, water is charged to the reactor vessel to disperse monomer and transfer heat to the mix, which increases the rate of chemical reactions. Once the conversion level of the process mix is reached, and following the discharge and cooling of the process stream, the beads of polymer are typically dewatered and then dried. Dewatering generally produces a nonhazardous wastewater. After dewatering, the polymer may be dried in ovens or in a centrifuge. Vents from the ovens or centrifuge may be sources of particulate waste and/or volatile organic compounds.

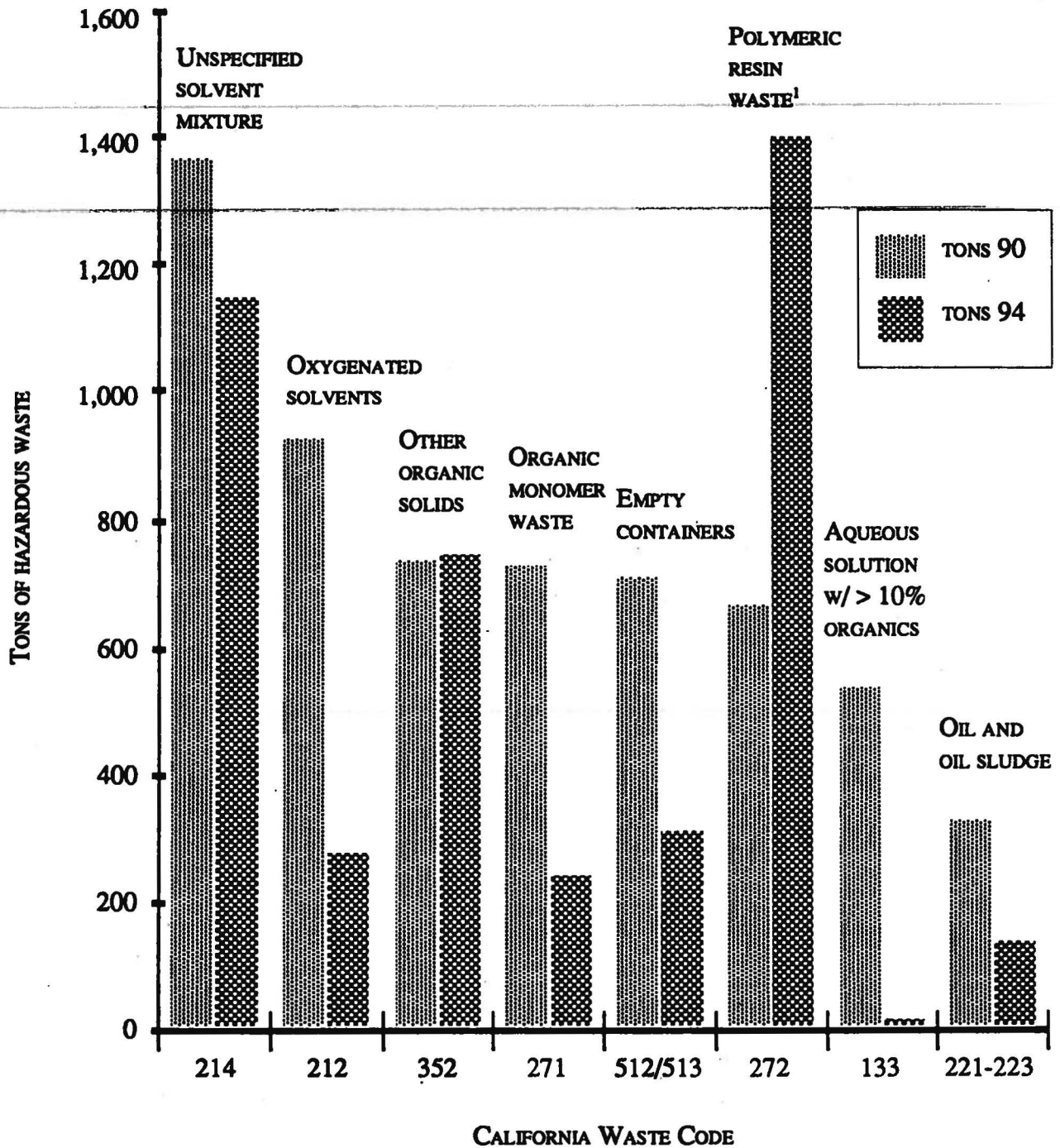
Figure 1 compares the eight largest manifested waste categories generated in 1990 with the manifested amounts of the same waste categories in 1994 (by the 31 facilities). The largest quantity waste type category, California Waste Code (CWC) 134 - aqueous solution with total organic residues < 10 percent, is not shown on the chart because only a small quantity of this waste type was manifested. Most waste categorized as CWC 134 was managed by on-site treatment and then discharge to a Publicly Owned Treatment Works (POTW). In addition, the majority of waste classified as CWC 134 was generated by two facilities.

Figure 1 indicates that solvents or solvent-containing wastes were the largest quantity manifested wastes generated by these 31 sites as a group during 1990. In the SB 14 documents solvent wastestreams were reported under CWCs 211, 212, 213, and 214. However, the largest quantity of solvent wastes were reported under CWC 214 - unspecified solvent mixture (22.7%, by weight, of the largest eight manifested wastestreams) and CWC 212 - oxygenated solvents (15.4% by weight of the largest eight manifested wastestreams). Twenty of the 31 firms reported solvent-containing wastes during the baseline year.

CWC 134, not shown on Figure 1, represents by far, the largest quantity waste type category, (approximately 86,000 tons versus the second largest wastestream by waste code CWC 214 - 1,375 tons) generated by these 31 firms in 1990. However, this waste type was reported by only seven companies in 1990. Two of the seven companies generated 93 percent of the total produced by the seven facilities. A few of the companies that generated wastewater failed to report it in their SB 14 Plans. Therefore the weight quantity of this waste type is probably higher than the data indicates.

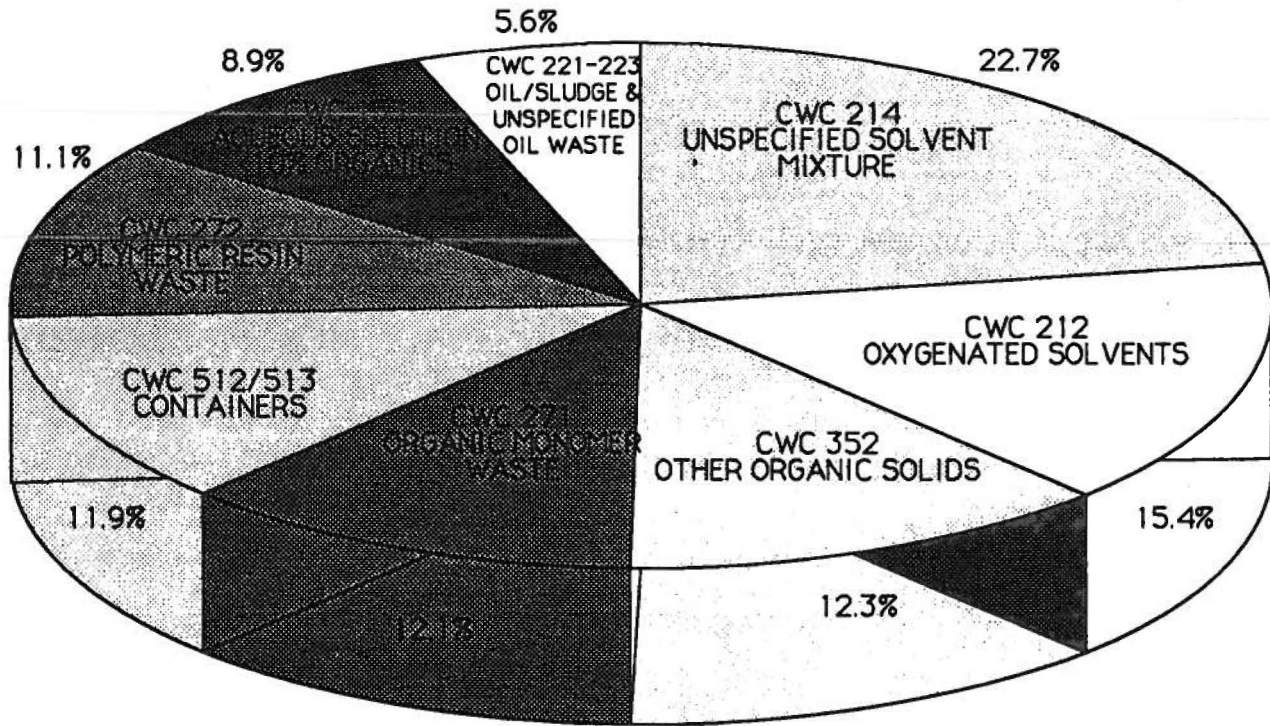
The remaining six largest quantity wastestreams manifested by this group of facilities (1990) in descending order of total quantity and percentage among the eight largest manifested wastestreams were: CWC 352 - other organic solids (12.3%), typically used to classify waste resin, bags, filter media, and carbon from water or air emissions control units; CWC 271 - organic monomer waste (12.1%), which included unreacted or partially reacted process streams containing monomer; CWC 512/513 - empty containers (11.9%), represent empty drums, bags or nylon supersacks of various sizes; CWC 272 - waste resin (11.1%); CWC 133 - aqueous solution with total organic residues 10% or more (8.9%) and, CWC 221, 222, and 223 which included waste oil and oil sludge (5.6%). The relative percentages of each of the eight largest manifested waste type categories during 1990 are shown on Figure 2.

**FIGURE 1. PLASTICS AND RESINS FACILITIES: LARGEST MANIFESTED WASTESTREAMS
WASTE GENERATION BY WASTE CODE, 1990 & 1994**



¹ INCREASE DUE TO ONE FIRM THAT MANIFESTED A LARGE AMOUNT OF CWC 272 IN 1994 THAT WAS MANAGED ON SITE IN 1990

FIGURE 2. LARGEST MANIFESTED WASTESTREAM CATEGORIES BY PERCENTAGE (1990)



CWC = CALIFORNIA WASTE CODE

In a number of instances, 1990 DTSC manifest data differed from the data reported in the SB 14 Plans. This included differences in waste quantity and waste code types. When significant differences were encountered, facility personnel were contacted and asked to review facility records. Changes were made to the data presented on Figure 1, when appropriate, on the basis of additional or updated information supplied by facility personnel.

The remainder of this section discusses waste sources and source reduction measures within the two major categories of generated wastes: liquid hazardous wastes and solid hazardous wastes. Within these categories, polymer and resin manufacturing industry waste types and sources are addressed. Table Two summarizes this information. Following the discussion of each wastestream type and its source(s), source reduction approaches that were implemented or evaluated by particular companies (reviewed for this report) are briefly described. Each source reduction measure description is grouped under one of five categories; input substitutions, process modifications, operational changes, product reformulations, and administrative changes. As previously mentioned, detailed discussions regarding wastestreams, and implemented source

TABLE 2. TYPES AND SOURCES OF WASTE AND EMISSIONS AT POLYMER FACILITIES

Hazardous Waste Categories and Types	Primary Sources of Generation & Source Reduction Measures Page Number Citations
Liquids	
Condensate wastewater containing solvents	Polymerization reactions, air/vapor pollution control equipment, settling tanks (25, 26, and 27)
Spent solvent	Cleaning plant infrastructure and equipment (22, 23, and 24)
Caustic solutions	Equipment cleaning, wastewater treatment (50)
Wastewater - other	Washing and dewatering polymer
Oil	Changeouts of pumps/compressor lubricants; leaking equipment (28, 29)
Excess solvent	Solvent reservoirs in coating operations (21)
Solids	
Waste resin	Off-specification product, low molecular weight off-specification polymer, excess or obsolete product, (32, 33) filtered product, transfer line drainings; using contaminated raw materials, quality control / laboratory sampling wastes
Filter media	Filtering: includes paper, screens, grit etc. (32)
Bags/containers/drums	Emptying raw material and supply containers/bags etc. (32, 33)
Dust/particulates	Drying, flaking, transferring, and bagging polymer
Absorbent/rags	Cleanup of spills and leaks
Waste catalyst and waste additives	Polymerization reaction, expired shelf life materials, material spills. Loading and unloading materials.
Spent carbon	Air and water filters
Scrap material	Resin impregnated materials roll cuttings
Asbestos	Insulating material on pipes and vessels
Laboratory materials	Crushed glass, containers, various excess chemicals and miscellaneous trash
Air Emissions⁽¹⁾	
Volatile organic compounds	Equipment vents, vessel openings, valves, seals, tank vents, resin mixtures or slurries, distillation columns
Dust/ particulates	Polymer drying and bagging operations, loading and unloading materials

⁽¹⁾ Although outside the scope of this report, air emissions can be significant sources of pollution at polymer/resin facilities. As such, they are included in this table.

reduction measures for specific facilities, are presented in three case studies, which comprise Section five of this report.

A. LIQUID HAZARDOUS WASTES

Liquid hazardous waste from polymer production and compounding operations generally includes:

1. Spent solvent or caustic solutions from equipment cleaning
2. Solvent-containing wastewater from the following sources:
 - polymerization reaction condensate
 - air pollution control equipment condensate
 - condensed vapors from vents on storage tanks, extruders, batch mixing vessels, centrifuges, or dryers
 - solvent-contaminated water from liquid ring vacuum pumps
3. Used oil

The sources and source reduction measures implemented to reduce the quantity or toxicity of wastestreams are discussed below.

1. SPENT SOLVENT WASTES

As previously mentioned, the second largest quantity waste type and most consistently generated liquid hazardous waste at the 31 sites assessed for this report was spent solvents. Cleaning plant infrastructure and equipment was listed as the major source of this wastestream. With few exceptions, this waste was reported as either CWC 212 - oxygenated solvents, or CWC 214 - unspecified solvent mixture. Solvents, which contain water, hydrocarbons, and alcohols, by definition, function as agents that can dissolve various substances. In a few cases, caustic solutions, (typically with sodium hydroxide) were also reported as being used as cleaning agents.

Specific instances of solvent-based cleaning included washing polymer reaction vessels, flush cleaning product transfer lines and tank trucks, cleaning mixing vessels and other equipment used to mix or blend polymers with additives, and cleaning filter screens, miscellaneous equipment, and tools. Product transfer line and equipment cleaning is often critical to preventing product contamination. This is particularly true at facilities where different resin/polymer types and products are produced and/or compounded (modified). In addition to helping to maintain product quality, cleaning between production cycles also helps prevent contact among incompatible chemical substances that have the potential to react and create health or safety hazards.

a. Source Reduction Measures

Process modifications

Process changes discussed in this report refer to modifications in plant infrastructure or equipment directly or indirectly related to production.

Engineering Polymer Solutions installed dedicated product loading lines for each of the product categories produced at the plant to eliminate a system that used two combination product loading lines. Using two combination lines required excessive line cleaning (generating waste resin product) and flushing (generating spent solvent waste) to remove material that could contaminate incompatible product(s). The new loading lines minimized the need to flush clean lines between loading different products and reduced spent solvent waste generation by an estimated 16,500 lbs annually.

Fiber-Resin Corporation's Chatsworth facility now uses a multi-nozzle spray device to clean the inside of the site's reaction vessel with solvent. This method generates significantly less spent solvent waste than the previous method which involved filling the kettle up to half full with solvent and then letting the solvent vapors clean the inside walls of the kettle.

Hexcel Chemical's Livermore facility (composite plastic products manufacturing) increased the size of a used solvent storage tank that receives solvent from an on-site distillation unit. The storage tank's previous capacity only allowed for small amounts of used solvent to be retained for reuse as an alternative to fresh solvent for cleaning. Also at this facility, a new vertical fabric coating tower was installed. This measure reduced the need to clean equipment between the changeovers in the facility's substrate/fabric coating processes, thus generating less solvent waste.

Hexcel Chemical (Livermore) also purchased a portable wash unit to reduce spent solvent waste and the solvent vapors generated when resin mixing vessels were cleaned. Experiencing only limited success with the unit, the company decided to install a specially designed unit that cleans the vessels without producing fugitive vapors and minimizes solvent use. This unit has a cover (with hoses attached) that forms a seal on the top of the mixing vessel. Solvent is recirculated through the unit while solvent vapors are removed via vacuum. Used solvent is then transferred to a distillation unit. The efficiency of this unit reduced solvent use and also eliminated much of the solvent vapor in the workplace.

Hexcel Chemical (Livermore) also has a small reaction vessel that it occasionally uses to advance the polymerization stage of some of the resins that are used to coat materials. This vessel was formerly cleaned by using a caustic solution. It is now cleaned with a unit that blasts off residue buildup on the inside walls of the reactor with crushed walnut shells. This alternative method of cleaning the reactor has eliminated the spent caustic wastestream at the facility.

Fiberite Corporation, a composite plastics products manufacturer, made several plant improvements to reduce its waste generation. Fiberite installed new (easier-to-clean) resin

mixers, redesigned its treater pans to minimize solvent use, and replaced old piping on some of its process equipment with stainless steel food grade pipe. The new mixer and (easier-to-clean) stainless steel piping reduced the amount of cleaning solvent. As a result, less spent cleaning solvent waste is generated. Redesigning the treater pan, by tapering the bottom of the unit, reduced the amount of solvent resin mixture used to coat substrates and minimized excess solvent resin mixture waste.

Georgia Pacific's Sacramento facility is planning to install a flake filtration system, which should reduce the amount of reject flake which becomes particulate contamination in transfer lines. At periodic intervals, these lines are flushed with solvent to remove the particulates. The reduced particulate build-up resulting from the installation of this system should reduce the need to flush transfer lines and thus reduce spent solvent waste generation.

Georgia Pacific's Ukiah facility has installed some dedicated transfer lines for specialty products to reduce the need to solvent flush lines after making these products before switching production back to its primary product lines.

BP Chemicals installed a transfer pump system that supplies dip pans (used to coat substrates/fabrics, etc.) with solvents and resins from larger batch reservoirs. This equipment minimizes solvent-resin excess (waste) in dip pans. BP also invested in additional dip pans and tanks to allow for equipment swapping as an alternative to solvent-based equipment cleaning between each change in production.

Foamex Ltd., (polyurethane foam manufacturer) reduced spent solvent waste by altering the process it uses to expand polyurethane foam cell size; a production step that occurs prior to curing the final product. A new machine, which employs vacuum and pressure, is now used as an alternative for expanding foam cell size instead of 1,1,1, TCA which functioned as the blowing agent to expand foam cell size.

Operational changes

Operational changes discussed in this report refer to changes in the way in which housekeeping or production support activities are accomplished to increase efficiency and reduce waste generation.

Courtauld's Mojave facility found that when they used a Wiped Film Evaporator (WFE) to remove odors and adjust the viscosity of polymer mixtures, using higher heat levels and slower feed rates significantly reduced the need to use xylene in the process, which reduced the amount of waste xylene produced.

Alpha Owens-Corning reported that it found ways to better schedule the production of similar batches in sequence to reduce the frequency of reaction vessel cleanouts.

Hexcel Chemical's Livermore facility reduced solvent use and solvent resin waste by eliminating one of the dip tanks used to clean small parts and equipment (used in resin coating

operations).Hexcel Chemical also reduced the frequency of recharging solvent in the remaining dip tanks by lowering the freeboard height of the dip tanks to minimize solvent evaporative losses.

At Courtauld's Mojave facility, the plant's coating manufacturing operation has reduced waste spent solvent generation by using pigs to clear excess from the transfer pipelines. The pigs are polystyrene plugs cut to a size slightly less than the inside diameter of transfer pipe. Air pressure pushes the pig through the line. The excess product in the line is wiped from the inside surface of the pipe wall and is pushed ahead of the pig. Recovered material is drained to drip buckets for reuse.

Georgia Pacific's Ukiah facility installed agitators on product storage tanks to minimize the build-up of gelled product inside the tanks. By minimizing the build-up of gelled product, the frequency of cleaning out gelled product was reduced, which minimized the generation of spent solvent waste.

Heller Performance Polymers changed the way in which sludge settling tanks were cleaned out to significantly reduce solvent- containing wastewater generation. Instead of using a vacuum truck and water to remove the material, as was previously done, the tank is now cleaned out by hand and the material is placed in drums; minimal water is used and the company no longer has to pay for the use, and subsequent cleaning, of the vacuum truck. In 1990, when the vacuum truck and water were used, 26 tons of waste were generated in the cleaning process and waste disposal costs were \$22,000. Using the new approach, 1991 waste generation from cleaning the sludge settling tank was only five tons and disposal costs were only \$6,000.

Input changes

This section describes changes that involved using alternative cleaning substances or altering methods or equipment to reduce or eliminate waste.

[Author's Note - It should be noted that, besides waste source reduction, other factors are creating the necessity or the incentive to replace chlorinated solvents and high VOC emitting solvents with alternative substances or non-chemical methods. For example, because the chlorinated solvent 1,1,1,-trichloroethane (used by many facilities in the polymer industry) contributes to ozone depletion, world wide production of this solvent has been banned as of January 1, 1996 under the Montreal Protocol. Also, in California, many industrialized counties are non-attainment areas for an ozone Ambient Air Quality Standard established under the Federal Clean Air Act. To meet this standard, sources of VOC emissions (contributors to ozone formation in the lower atmosphere) in non-attainment areas will likely face increasingly strict guidelines, control measure requirements and regulations. ⁽³⁾]

Alpha Owens-Corning facility replaced methylene chloride as an cleaning agent with styrene; one of its product raw materials. Styrene acts as a solvent when it is used to remove partially gelled polymer from tank wagons. The styrene wash solution is then used to displace virgin styrene monomer (as a substitute raw material) in polymer batch production.

Amoco Foam Products is planning to replace Naphtha, a solvent used for degreasing parts, with citrisolve, an aqueous-based cleaner, which has been successfully incorporated at other Amoco facilities outside of California.

Courtauld's Mojave facility has almost completely eliminated its use of 1,1,1, TCA, (the primary substance formerly used to clean equipment) by replacing it with Di-Basic ester. In some cleaning applications, a polycarbonate cleaning solvent has been successfully incorporated as a substitute for the TCA.

CIBA-Giegy has successfully replaced Methyl Ethyl Ketone and Xylene with a high boiling, very low vapor solvent called Dipropylene Glycol Monomethyl Ether (DGME) in many equipment and parts cleaning operations.

Foamex, Ltd, mentioned in the previous section, has almost completely eliminated the use of the 1,1,1 TCA as a solvent for cleaning plant infrastructure and equipment. Polyol, one of the raw materials used to make foam, is now being used instead of 1,1,1, TCA as a solvent to clean and flush troughs and mixing vessels. The spent Polyol is then used to make an off-specification product which is ground up and used as a bonding agent in other products. The company estimates a \$120,000 dollar a year savings because of reduced raw material purchases and waste disposal costs.

BP Chemical's facility has phased out methylene chloride as a equipment cleaning agent by replacing it with a low vapor pressure solvent manufactured by Orange County Chemical Corporation. This solvent is a mixture of methyl ethyl ketone (MEK) and xylene. Also, in some resin mixing tank cleaning operations (depending on the resin formulation) acetone has been successfully replaced with this solvent, referred to as 1171. The name refers to the South Coast Air Quality Management District's rule 1171 which affects cleaning operations that emit volatile organic compounds.

Reuse and Recycling

Although recycling and reuse are not source reduction practices unless they are accomplished within closed-loop processes, they are beneficial waste minimization practices that can reduce the total waste generated which is released to the environment. The following items are a few examples of reuse and recycling described in the SB 14 documents.

Rhone-Poulenc's facility Plan indicated that the company would convert an existing polymerization tank so that it could be used to store partially spent solvents for reuse in cleaning operations. Neville Chemical's facility uses solvent recovered from its distillation tanks to clean the site's reaction vessels. Some of the recovered solvent is sold off-site as a commercial product.

Cytec Engineering established a process for cleaning its resin mixers using different batches of used solvent. Batches of once-used solvent and twice-used solvent are stored in different tanks. The source of spent solvent used to clean the mixers (given the degree of residue on the mixers) depends on the strength of solution necessary to accomplish adequate cleaning.

2. WASTEWATER

Solvent-containing wastewater generation was reported from two primary sources. The first source was condensation polymerization reactions associated with thermoset polymer production. The second source was air pollution control equipment. Solvents are often included in polymerization reactions. For example, some monomers are solvents. Solvents can also function as carriers, diluents or stripping agents. In condensation reactions exhaust vapor is vacuumed off the reaction vessel and condensed to a liquid that contains solvents and unreacted or partially reacted process ingredients. Unrecycled portions of this liquid produce the wastewater stream.

Solvent-containing wastewater is also generated from air pollution control equipment. This equipment is typically an electrostatic device with precipitating screens, a condenser and a vacuum pump. It is used to capture vapors that are emitted when resin pellets are extruded or melted during compounding or molding operations. From both sources, SB 14 Plans and Reports generally classified solvent-laden wastewater as CWC 134 - aqueous solution with total organic residues less than 10 percent.

The type and concentration of substances in the solvent-laden wastewater affect the economic and technical viability of recovering process substances for reuse, and also determines the methods by which the liquid waste is managed. In most instances, unrecycled liquids that contain solvents and process ingredients were shipped off-site for either disposal or use by fuel blenders. A few of the facilities managed a portion of the reaction process water by on-site incineration. Several firms indicated that on-site settling tanks or distillation units recovered solvent either for on-site use in cleaning operations or offsite shipment to fuel blenders or recyclers. Secondary wastestreams from on-site solvent recovery from wastewater containing solvent included solvent sludge, and spent carbon used for filtering. Two facilities reviewed for this report indicated that the solvent recovered from their production process was sold as a commercial product.

a. Source Reduction Measures

Process modifications

Ashland Chemical evaluated installation of a Distributive Control System which would automate the reactor process and thereby reduce equipment design and column inefficiencies. A Distributive Control System is a computer-controlled system used to control the charging of reactors via sophisticated metering which monitors temperature and pressure during polymerization reactions. Although a five percent reduction in wastewater was predicted, this measure was not implemented for economic reasons.

Dow Chemical's Torrance facility installed a patented air pollution control device to control acetone emissions associated with the production of epoxy resins. This new device replaced a unit which contained a water scrubber. The water scrubber generated a wastestream containing

acetone and water. After the new device was installed, the acetone and water wastestream quantity was reduced by 76 percent.

Operational changes

Neville Chemical's Anaheim facility, which makes phenolic, epoxy, and aliphatic compound resins, instituted source reduction by segregating nonhazardous and hazardous wastewater streams previously mixed in a common collection tank. At this facility, exhaust vapor from the polymerization reaction vessel is vacuumed off to an initial condenser, while uncondensed exhaust gases from the initial condenser are routed to a steam ejector with a second condenser. Condensate from the steam ejector is filtered and routed to the collection tank prior to POTW discharge. Boiler water (blow down) that is periodically drained from the boiler to prevent scale buildup, due to the dissolved solids in the boiler feed water, also was routed to the collection tank. Mixed together with reaction process water condensate streams, the boiler blowdown water became part of the hazardous waste generated at the facility. To reduce the hazardous wastewater generation, the system was reconfigured to redirect the nonhazardous boiler blowdown directly to the POTW, rather than to the common collection tank.

Product reformulation

CIBA-Geigy's Los Angeles facility makes amine hardeners, urea, and phenolic compounds. CIBA-Geigy instituted source reduction by formulating a substitute product to replace one of its amine-based hardeners. The production of this one product had generated significant quantities of wastewater. Producing an alternative product reduced wastewater by approximately 17,500 lbs year.

Ashland Chemical's polyester manufacturing facility studied the potential for substituting propylene oxide as an alternative to propylene glycol to reduce the glycol contaminated water wastestream by 25%. This measure was rejected for safety, economic, and permitting issue reasons.

In-process recycling/reuse

Reichhold Chemical's Oxnard facility reported that a closed loop system, that consisted of a unit that would distill glycol (for in-process reuse) from the water vapor removed from the reaction vessel during the polymerization of unsaturated polyester, would be installed. This measure would have minimal impact upon wastestream quantity, but would reduce the hazardous characteristics of the reaction process wastewater.

Georgia Pacific's Ukiah facility installed a plate and frame filter to remove contaminant solids from reaction process wastewater to allow for water reuse. In a closed configuration, the water is pumped to the filter and then stored in sealed tanks. This system provides an alternative make-up water supply for compatible batches of polymer. Significant waste reduction results were achieved. Before filter installation (1993), monthly water use averaged 131,833 gallons and monthly waste disposal cost (water and solids) averaged \$10,000. During 1994, average

monthly water use was reduced to 52,600 gallons, and average monthly disposal cost (solids only) was \$1,260.

Reuse and Recycling

McWhorter Technologies is currently testing and implementing a system that treats condensate wastewater generated from the production of alkyd and polyester resins. A portion of the wastewater will be reused, and the remainder will be treated and discharged to the POTW as an alternative to on-site incineration. The proposed system combines five different water treatment technologies (see case study number three for more detail).

3. WASTE OIL AND OIL SLUDGE

Waste oil is generated at polymer facilities from leaking vacuum pumps seals, leaks from hydraulic presses and compressors, heat transfer fluid changeouts, and changeouts of oil in vacuum pumps. Oil, contained in coils on reaction vessels, is commonly used to indirectly heat process mixtures to initiate and maintain polymerization reactions. When vacuum pumps draw off volatile vapors or vapors containing reactant substances, oil can be contaminated. When this happens, the oil must be replaced. Steam is often used to clean oil from compressors and other equipment. The water oil/water mixture that is generated typically is collected in on-site sumps. This collected mixture is often routed to an oil/water separator. Oil sludge is a secondary wastestream generated by the oil/water separator.

a. Source Reduction Measures

Process modifications

Ashland Chemical Company's Los Angeles facility reported in its Plan update that they had installed seal-less pumps to replace leaking mechanical seal pumps to reduce oil waste.

Mitchell Rubber Products facility produces blended rubber compounds and also makes high compression rubber products. This facility reduced oil waste by over 50 percent (104 tons in 1990 versus 43 tons in 1994). When normalized to account for production throughput change, which increased by 45 percent from 1990 to 1994, the reduction is even more significant. Waste oil was reduced by overhauling the rams and glands on 15 of the site's 37 high compression presses which badly leaked substantial amounts of oil. The firm also installed an oil collection system to collect some of the oil that escapes when the presses leak. This system also distributes the collected oil back into the rams/glands. The retrofit of the rams/glands also reduced oil changeout frequency by minimizing the need to replace the packing glands in the presses. Each time the packing glands are replaced the press oil must be drained. This oil is not reused due to contamination concerns.

Input changes

Tenneco Packaging, a polystyrene manufacturer, substituted the vacuum pump oil it used in its extruder operation vacuum pump with the oil that it uses as a raw material for producing polymer. Contaminated oil drained from the pump is now used as a feedstock material rather than disposed as waste. For more details, refer to case study number two.

Product reformulation

American Polystyrene Company's Torrance facility reported that waste oil, which constituted 70 percent of the waste generated at the site, was reduced by eliminating a wax additive in its product. The wax additive fouled condensers, and created the need for frequent oil replacement in the vacuum pumps that are used to remove residual styrene vapors from resin as it is melted in the extruder.

Heller Performance Polymers reduced oil waste by using plasticizer instead of oil as the lubricant for dust seals on the site's large mixer. The plasticizer is a non-hazardous material used a raw material ingredient in the facility's compounding operations. This measure reduced annual waste oil generation by 9,200 lbs and reduced annual waste disposal costs by approximately \$10,000.

B. SOLID HAZARDOUS WASTE

The types of solid hazardous waste generated from polymer production and compounding operations generally include:

1. waste resin or polymer
2. other organic solids, which can include:
 - filter bags and filter media
 - contaminated or excess raw materials
 - dust or particulates
 - spent activated carbon
 - scrap cuttings from resin-impregnated composites
 - cleaning rags
3. containers
4. laboratory wastes

The sources and source reduction measures implemented to reduce the quantity or toxicity of these wastestreams are discussed below.

1. WASTE POLYMER AND RESIN

At some polymer/resin facilities, waste resin constituted the largest hazardous wastestream. SB 14 Plans indicated that waste resin sources included quality control product sampling, off-specification and excess product, low weight polymer molecules created within polymerization reactions, and product filtering. Typically this waste was classified as California Waste Code (CWC) 271 - unreacted monomer waste, CWC 272 - polymeric resin waste, and in some cases, CWC 352 - other organic solids. Most frequently, this waste was managed by offsite disposal.

During polymerization reactions, samples are taken to measure the viscosity, pH, and other chemical or physical properties of the process stream. Some firms save samples for up to three years. These samples are then disposed as waste. Some facilities take double samples so that the accuracy of initial product quality tests can be verified. Waste resin is also generated as a result of draining product from process pipelines in order to get representative samples for laboratory testing purposes. Once these materials have been removed from the system, they are often not reused because of contamination concerns.

Another source of waste resin is excess product that can not be sold. Several companies referred to this as obsolete product. The general practice among many firms is to retain excess product to find a buyer or end user (waste exchange). If the excess product is not used within a certain period of time, environmental factors can render it unusable. It is then disposed as waste.

Excess product waste is generated in part because some facilities must produce a large variety of different size orders among customers who seek very application-specific products. While the sizes of various customer orders may range from a few hundred pounds to several tons or thousands of gallons, production parameters may dictate standard quantity batches of product. Excess production generates waste when the material cannot be sold or used through a waste exchange program. Two facilities reported excess/obsolete product (CWC 272 - polymeric resin waste) as their largest wastestream.

Off-specification waste resin can also be generated when contaminated raw materials are used in production. This potential problem dictates that incoming raw materials be properly inspected before use. Sometimes off-specification product waste is generated by employee error that can occur when certain production process variables are manually controlled. For example, manually controlled addition of catalyst to the polymerization reaction can result in errors that produce large quantities of waste off-specification product.

Another source of waste polymer/resin is the polymerization reaction itself. Often referred to as dimers or trimers (simple two or three molecule compounds), these low-molecular weight polymers are by-products that are sometimes formed in the polymerization reaction. The formation of these by-products is typically a function of the complexity of the substances used to form the polymer, or copolymer, and, also, cases in which relatively narrow parameters are required in polymer chain length. In any case, these simple compounds do not meet narrow final product specifications. One firm referred to this waste, the largest wastestream generated at their site, as "process tars".

Some polymers are filtered during resin production. Generally this process removes resin in addition to removing contaminants. Filter-related waste was classified as CWC 272- waste polymeric resin, or CWC 352 - other organic solids, and included filter bags, filter media, filter paper, particulates, and waste resin product.

a. Source Reduction Measures: waste polymer/resin

Process modifications

After six months of successful testing, Ashland Chemical's Los Angeles facility is now installing new stainless steel mesh-screen filters to replace the bag filters that have been used to remove contaminants from polyester products. These filters contain motor driven wipers that wipe the surface of the screen causing contaminant materials to fall to the bottom of the unit. Because these new filters prevent excess resin from gelling inside the units, waste resin/filter bag waste generation is estimated to be only 25 percent of what it was with the bag filters (a 75% reduction in waste). Although each unit costs approximately \$20,000, the payback period for this investment should be less than 2 years.

Engineering Polymer Solutions installed a gas purge system to blow through excess resin from in-line bag filters, which remove contaminants from the intermediate product. Prior to the installation of this system, a significant quantity of product remained trapped in the filters, which resulted in excess resin waste. Engineering Polymer Solutions also reduced waste resin by adding a dedicated line and pump for its polyester line of product. Prior to the installation of this process line, the line had to be cleared of all residual product (non polyester) to avoid contamination of the polyester between production cycles. The dedicated line reduced waste resin by an estimated 89.5 tons annually.

Silmar Resins of Interplastic Corporation is experimenting with the use of hollow bullets in its filtering system. Within the filter, resin goes around the bullets. The space occupied in the filter by the bullet minimizes the resin that was previously trapped in the filter as waste.

Operational changes

Two firms reduced resin product sample waste by eliminating the practice of taking double samples for some of their polymer products where the double sampling was deemed not necessary. Two other firms reduced sample waste by reducing the size of the catch buckets used to collect samples.

Input changes

Georgia Pacific's Ukiah facility replaced the lime catalyst in one of its phenolic resin products, which had required that the product be filtered to remove lime. Eliminating the need to

filter the product reduced annual generation of waste resin by an estimated 25 tons; approximately 15 percent of the waste generated at the plant during 1990.

2. OTHER ORGANIC SOLIDS

By weight, other organic solids, classified as CWC 352, constituted one of the largest wastestream types generated among the facilities reviewed for this report. This waste is generated by sources that include solvent sludge from settling tanks, spent activated carbon from pollution control filtration/absorption units, particulate dust, scrap cuttings of resin-impregnated material, product bags and containers, rags, and contaminated raw materials.

As previously mentioned, liquid solvent mixtures are sometimes waste by-products from polymerization reactions or air pollution control equipment. Solvent sludge is generated in solvent settling tanks and distillation units which separate solvents from sludge and water. Activated carbon-containing filters are often used in conjunction with these units and are also sometimes used in water treatment units. When the carbon becomes saturated it must be regenerated or replaced.

Dried polymers that are scraped off mixing rollers and then flaked or ground for bagging typically generate a dust waste. This operation is often referred to as shaping, which is a step in the compounding of a polymer. Dust can also be generated when polymer is oven dried or dried using a dewatering centrifuge. Dust waste, if of any significant quantity, is typically captured for disposal in a baghouse.

Scrap cuttings of resin impregnated material (pre-preg) left over after the rolls are cut to widths dictated by the customer typically are generated as waste by-products during the production of plastic reinforced composites.

Wastes generated from empty containers that once held raw materials or were used to store intermediate product, and buckets and containers used to collect or store product samples can all become solid hazardous wastes. Bags and small containers were usually classified under CWC 352 - other organic solids, while drums were classified as CWC 512/513 - empty containers more than or less than 30 gallons (not used for pesticides). Other organic solid hazardous wastes can also include contaminated raw materials. Heat, air exposure, and moisture are environmental factors which have the potential to contaminate raw materials or shorten their shelf life. These factors dictate that careful attention be given to the manner and the location where these materials are stored.

a. Source Reduction Measures: Contaminated Raw Materials

Operational change

CIBA-Geigy's facility reduced contaminated raw material waste by using metal covers on the tops of drums that were stored outside. Prior to instituting this measure, drummed material (stored outside) would sometimes become contaminated because rainwater seeped inside the drum because the drum's screw on cap was loose.

b. Source Reduction Measures: Containers

Process modifications

Georgia Pacific's Ukiah facility started receiving many of its raw materials in returnable plastic tote containers instead of 55 gallon drums. Reduction in drum waste was significant, although not quantified. Georgia Pacific's Sacramento facility plans to install a supersack system for bisphenol-A (one of its primary raw materials) to reduce the generation of empty drum waste.

Operational changes

Courtauld Aerospace's Berkeley facility began using plastic liners in pails and fiber drums to avoid contamination of these containers as hazardous waste. Estimated reduction was 23,000 lbs/yr. This company also substituted stainless steel containers for tin-coated steel containers that were used to measure raw materials. The stainless steel containers have a much greater life span and therefore their use results in less waste generation.

Reuse

Silmar Resins Division of the Interplastic Corporation instituted a system in conjunction with its suppliers of diolic-hydrate to return empty bags for reuse. BASF's facility now receives supplies of mercaptan in returnable totes instead of drums. This eliminated the need to wash and dispose many 55 gallon drums (see case study one).

V. CASE STUDIES

The following section includes three case studies which describe production settings, process descriptions, and hazardous waste reduction measures implemented by companies as a result of source reduction planning. Waste reduction and cost data included in this section were provided by each company.

A. BASF

1. INTRODUCTION

The BASF Santa Ana facility manufactures polystyrene pellets. The site's major manufacturing processes include styrene monomer polymerization, and extrusion. Total annual production at the site exceeds 60 million pounds. Two categories of plastic, "Crystal" and "Impact", are formulated. Crystal is used by processing facilities, which extrude and form the material, to make products such as food containers. Impact, which contains a rubber additive, is used primarily in the processing of molded structural items. Within these groups, different variations occur in the polymer process conditions and additives, depending on the needs specified by the customer(s).

BASF's Santa Ana plant achieved a 70% reduction in routinely-generated hazardous waste at a reasonably stable level of production during the period 1989-1994. Source reduction progress was also made prior to 1989. Many of the pre-1989 waste management changes were instituted primarily out of a concern for health and safety and were ideas initiated by plant personnel. Due in part to these changes, this facility has established an exemplary safety record. In line with this record BASF regularly participates in the Occupational Safety and Health Administration's voluntary protection (audit and inspection) program. Of the nation's 6.5 million work sites, the BASF Santa Ana facility is one of only two hundred sites that participate in this program.

BASF's Source Reduction Plan was unusually thorough in the degree of specific information it provided regarding spill prevention procedures, waste control and tracking methods, housekeeping practices, and employee training programs. For example, written procedures are conveyed to all operations personnel regarding the handling, labeling, and record keeping of all hazardous waste drums.

BASF chose 1989 as its baseline year for recording waste generation data and discussing past waste management practices. During that year, approximately 79 tons of hazardous waste were manifested off the site; 55 tons were identified as routinely generated. There were seven different types (identified by waste constituents) of routinely generated wastes listed in the Source Reduction Plan. Four of these were major wastestreams (those greater than 5% by weight of the total). Three of these four were classified under California Waste Code (CWC) 213 - hydrocarbon solvents. The fourth major wastestream was CWC 223- unspecified oil-containing waste. In addition to analyzing source reduction opportunities for major wastestreams, reduction opportunities were also examined for smaller wastestreams. Those wastestreams were CWC 741

(liquids with halogenated organic compounds \geq 100mg/L) and CWC 512 (empty containers containing 30 gallons or more; that contained mercaptan or phosphite raw material additives).

2. PROCESS DESCRIPTION

The first stage of the production process begins at the site when raw materials including styrene, ethylbenzene, and mineral oil are pumped in precise quantities from storage tanks to solution mixing vessels called dissolvers. When Impact polystyrene is being made, rubber, styrene, and ethylbenzene are pre-mixed in dissolving vessels. The dissolved rubber solution is then transferred through a shear mixer prior to introduction to the next dissolving vessel. Additives and additional styrene and ethylbenzene are added at this time. Ingredients used to make batches of Crystal polystyrene are loaded directly into a dissolving vessel and are not pre-mixed. A vacuum is then applied to remove water and other impurities. This process is known as "vacuum distillation". The dissolving vessel is then re-pressurized using nitrogen to minimize oxygen within the vessel.

One dissolving vessel continually mixes ingredients while the other continuously feeds, by pump, to the next process vessel. The process stream is then filtered to remove foreign matter, gel and undissolved rubber particles. This filtering occurs prior to the process mixture's transfer to sequenced reaction vessels in which the mixture is continuously heated and agitated.

A catalyst is added at the beginning of the reaction. Agitation and recirculation of the solution aids in transferring heat from the internal coils within each reactor to the process stream. After the process stream cooks in the first vessel it is transferred to the next vessel. In this next vessel, the polymerization reaction continues; however, the mixture is heated to much higher temperatures. The process stream is then transferred to a static reactor, which heats the mixture to even higher temperatures.

From the static reactor, the process stream is gravity fed to a holding tank via a slide control valve that regulates the flow. The holding tank, which is also heated, provides surge capacity between the continuous flow through the reaction stages, and the variable flow through the devolatilizer and extruder(s). Pumps and lines from the holding tank are also jacketed with hot oil to keep the polymer pumpable. A large gear pump is used to transfer material from the holding tank to the devolatilizer.

In the devolatilizer, unreacted styrene and ethylbenzene are removed by vacuum distillation. The overhead vapor is condensed. This condensate (styrene-ethylbenzene mix) is piped to the storage tank for use in subsequent batches. After devolatilization, the molten polystyrene is pumped through two die heads, where it is extruded into long strands that are cooled in a water bath. The strands are then blown dry, chopped into pellets, screened to remove fines, and then air conveyed to resin pellet storage silos. Each die head is equipped with a pollution control equipment that collects and precipitates vapors emanating from the die head as strands exit to the water bath.

3. SOURCE REDUCTION MEASURES

The following section describes wastestream sources and the source reduction measures that were implemented by BASF

a. Filter Cartridges

After styrene and other additives are mixed in the dissolver, the process stream mixture is filtered prior to being transferred to the first reaction vessel. Expired filter cartridges containing particulates, gels and dirt, etc., comprised 16.5 tons of hazardous waste (labeled CWC 213 in the Plan, but more accurately characterized as CWC 352 - other organic solids) during 1989. When BASF investigated reduction opportunities for this wastestream it discovered that large particulate matter, e.g. undissolved rubber, was the primary factor contributing to frequent cartridge changeout. The filter cartridge was only designed to remove small materials.

To address this problem, a shear mixer was installed ahead of the filters to improve rubber dissolution. This reduced the number of cartridges generated due to filter change-outs. Subsequent waste generation dropped from 32,600 lbs in 1989 to 18,200 lbs in 1990. A follow up measure, implemented in July 1991, involved installing a bag filter upstream of the cartridges to insure the removal of large particles. This measure additionally extended the life of the filter cartridges. Installation costs for the bag filters was \$17,000; annual estimated reduction was 7,000 pounds. The combined annual waste reduction from implementing these two measures was 22,000 lbs. The annual savings achieved by reducing filter cartridge changeouts and disposal costs was estimated at \$45,000.

b. Product Samples

Product samples are taken every hour from the reactor discharge and their properties tested to determine how well the process is being controlled. In order to get a representative sample, the line from which the sample is taken must be purged. Prior to instituting source reduction, the purged material was collected in five gallon metal buckets lined with polyethylene. The purge was mixed with clay absorbent to minimize vapor emissions and then disposed. The new method involves collecting the purge in a polystyrene container which is housed in a specially-designed stand installed beneath the pregraft. After the sample is taken, the container with the purged material is reused as raw material by placing it back into the dissolver. This measure reduced waste by an estimated 25,000 pounds annually. Annual savings from reduced disposal and raw material costs were estimated at \$50,000.

BASF staff also analyzed the viability of minimizing the need for samples by using in-line viscometers. However, necessary testing of this measure was not possible during production. Equipment could only be installed and removed during periods when the plant was shut down. Therefore, working or not, once installed, the viscometer could not be removed until the next scheduled plant shutdown.

Instead of a test during actual operations, the equipment was evaluated by consulting with the vendors who sold a number of different viscometer models. BASF's primary concern was that movement and agitation of the process mixture to avoid "uncontrolled" polymerization, would create build-up of substance on the viscometer's probe and result in false readings. Unfortunately, the vendors could not guarantee the reliability of the viscometer's readings in the event that substance build-up occurred. The only way to determine if the instruments were accurate was to test them during production.

One alternative to shutting the plant down to test the equipment could involve constructing a temporary bypass line in the plant's piping system. This would allow testing while ensuring an uninterrupted process. However, safety considerations eliminated this option. The use of in-line viscometers in this type of plant may enable future waste reduction, but the barrier described above indicates that vendors and plant personnel may need to generate test data that specifically addresses concerns that may arise in specific production settings.

c. Heat Transfer Fluid (oil)

The primary source of waste oil comes from plant shutdowns and start-ups. Several times per year, process operations at the plant shut down in preparation for production changes. When the equipment cools, oil in the heat transfer coils (system) contracts. In order to keep oxygen from getting into the system, additional oil must be added. However, during start-up, the oil expands as the system is heated, and this generates excess oil. Additionally, sections of the heat transfer fluid system are occasionally drained in preparation for maintenance to repair leaks. This procedure generates waste oil, which is not reused for fear of water contamination.

Although the system contained a hot oil expansion tank to handle the expansion and contraction, the tank was not large enough to accommodate all the excess oil, so excess oil had to be drained. Like waste oil from other sources in the system, it was not re-used because of contamination concerns. During 1989, 1,500 gallons of waste oil were generated. After 1989, BASF found a recycler for this oil. In addition, to reduce this wastestream a new larger expansion tank was installed in 1993. Annual waste oil reduction following installation of the new expansion tank was estimated to be 1,200 gallons (approx. 5 tons).

d. Drums

Prior to 1990, the facility received mercaptan, a substance used to control and extend the length of polymer chains during the polymerization reaction, and phosphite, an anti-oxidant which keeps the product from yellowing, in 55 gallon drums. Drums that had contained mercaptan were landfilled after being triple-rinsed and crushed for volume reduction. Drums that had contained phosphite had to be sent off-site for reconditioning. The source reduction evaluation determined that it would be possible to receive mercaptan in returnable tote bins.

Unfortunately, returnable tote bins were not feasible for the phosphite. Prior to using phosphite, it must be heated. This makes the substance expand, requiring that a vent be configured on the totes. The cost of purchasing the totes and the need for an Air Quality Management District permit to approve the vents made this measure economically infeasible. However, by receiving mercaptan in returnable totes one-third of the drum waste at the plant was eliminated. Annual waste reduction was approximately 3,000 lbs, and annual cost savings was approximately \$3,500.

e. Process Condensate with Monomer and Solvents

During the polymerization reaction, differential pressure (DP) gauges are used to monitor pressure as part of process control. Vapor containing unreacted process constituents from the reaction forms condensate in the gauge's capillaries, which then needed to be periodically drained. During 1989, approximately 1,200 gallons (9,000 lbs) of waste condensate were generated from this source. Condensate from the DP gauges began to be reused to minimize this wastestream. BASF subsequently began replacing the gauges with equipment that does not require draining. As of January 1995, five of seven gauges had been replaced, resulting in an annual waste reduction of 3 tons.

f. Contaminated Solvent

As part of the plant's regular maintenance procedures, tools and equipment parts undergo periodic cleaning. During and prior to 1994, a solvent vendor provided BASF with an organic solvent which emits volatile organic compounds (VOCs). This solvent was used as a degreaser in the cleaning operations. After the solvent was used for cleaning, it was manifested and picked up for recycling by the solvent vendor. BASF decided to seek a nonhazardous substitute for the solvent to reduce waste and to reduce worker VOC exposure. In mid 1994, the company invested \$3,800 in a dedicated parts washer that uses hot water and a surfactant solution; this measure eliminated most of this wastestream. Annual estimated reduction from instituting this measure was 650 pounds, with an expected annual savings of \$700.

4. SUMMARY

Between 1989 and 1994 BASF's Santa Ana facility implemented source reduction measures that reduced the quantities of routinely generated hazardous waste by approximately 70 percent (nearly 40 tons annually) from 1989 baseline quantities. Quantified annual savings over baseline costs were approximately \$100,000. During its source reduction evaluation, BASF chose to examine alternatives for each source of waste for both major and non-major routinely generated wastestreams. This approach uncovered a variety of successful ideas which saved thousands of dollars in waste disposal and raw material purchase costs. Source reduction at this facility included input substitutions to replace hazardous substances, process modifications which allowed for closed loop reuse, equipment purchases to increase process efficiencies, and modifica-

tion of inventory purchase and handling methods. Even though many of these individual changes were small, the cumulative result was very significant. The cost savings and improvements in the working environment at the plant far exceeded the effort and resources expended in the planning process and will pay dividends for years to come.

B. TENNECO PACKAGING CORPORATION

1. INTRODUCTION

Tenneco Packaging's facility located in the City of Industry is a three-phase manufacturer of polystyrene food containers. The manufacturing phases include polymerization of polystyrene, extrusion of plastic pellets and sheets, and container molding using thermoforming machines. The primary customers for these containers are the wholesale and retail food distribution industries. The current daily production of plastic, in pellets and thermoformed sheets, is approximately 193,000 pounds. As described below, between 1992 and late 1995 a number of source reduction measures were implemented at this facility, which accomplished waste reduction and savings in operational and raw material costs. Hazardous waste manifest records show that during 1990 the amount of waste manifested from the site was 147 tons. By 1994, total manifested hazardous waste had dropped to 63 tons; a 43 percent reduction.

In addition to implementing source reduction measures, several environmentally beneficial operational changes were instituted at this facility during the last several years. For example, in late 1992 and early 1993 a process modification was implemented that significantly reduced water consumption. Prior to this change, the facility used between 28 and 30 million gallons of water annually. Annual water use is now between 12-14 million gallons. To achieve this conservation, a single pass system that was used to cool polymer strands exiting the extruder die head (into a water bath) was replaced with a continuous flow closed loop system in which water, after being cooled using a heat exchange piping system or in the cooling towers, is reused.

Another change occurred in 1993, when the facility began reusing its own plant scrap by substituting it for virgin raw material feedstock in its polystyrene polymerization process. This is accomplished by directly dissolving the scrap in the tanks holding the styrene monomer. In the initial trial phases of this practice, five percent of the plant's feedstock came from recycled scrap. This quantity is now approximately 12 percent.

2. PROCESS DESCRIPTION

The manufacture of polystyrene containers and pellets begins when liquid raw materials, which include styrene, ethylbenzene, mineral oil and additives, are charged to the first of four closed vessels (kettles). Liquids are supplied in specified quantities using a computer controlled metering system. To begin polymerization, the process mixture is heated using steam heated coils in the receiving kettle. The process is continuous as the mixture flows from one reactor to the other, where it is progressively heated until the proper degree of viscosity and polymerization is reached. The mixture is then filtered with a screen filter.

After filtering, the mixture is stripped of unreacted styrene and ethylbenzene by vacuum distillation in the devolatilizer. Heat from the process stream is captured in a heat exchanger, while condensate is recovered for reuse in the reactor. Unreacted vapor that is not captured as condensate is vented to the atmosphere. After vacuum distillation, the process stream enters the extruder die heads, where it exits as long strands which are then cooled in a water bath. After exiting the water bath, the strands, which dry quickly, are chopped into fine particles in the pelletizer. Pellets are then transferred to storage silos.

The pellets used to make food containers are pneumatically conveyed to a cyclone which ensures that the pellets leaving the cyclone are of uniform size. Dust generated from the cyclones is captured in a baghouse. From the cyclones, the pellets enter hoppers which feed the extruders. Roll stock formed in the sheet extruder then enters the thermoforming machines. In the thermoforming machine, sheet is heated so that it is pliable. The sheet is then forced around the contours of the container mold. Containers exiting the thermoforming machines are then stored in preparation for marketing.

3. SOURCE REDUCTION MEASURES

The following section describes wastestream sources and the source reduction measures that were implemented by Tenneco Packaging.

a. *Vacuum Pump Oil*

When the reactor ion vessel is charged with styrene monomer, which contains stabilization additives, this liquid is transferred from holding tanks to the reactor using a pump that creates a vacuum in the reactor. During this transfer, styrene monomer vapors contaminate the oil in the vacuum pump. At a certain level of contamination, the oil loses its viscosity and must be replaced. In addition, when the pump is shut down, the styrene monomer in the oil begins to polymerize. Left unchecked, this will make the pump seize up. To maintain oil viscosity and avoid possible pump seizure, the pump's oil must be drained daily. Prior to instituting source reduction, this procedure resulted in the generation of four 55 gallon barrels of waste contaminated oil per week.

A review of source reduction options for this wastestream revealed that the viscosity of the mineral oil used to make the polymer was approximately the same as the Tellus 100 oil used in the vacuum pump. The manufacturer of the pump indicated that the mineral oil could be used as a substitute lubricant in the pump. It was decided to implement this measure as a preferable option to purchasing a new pump that used styrene as an internal lubricant. This input substitution enabled the company to engineer a closed-loop configuration in which styrene-contaminated mineral oil is reused as a constituent raw material in the polymerization reaction. This measure resulted in an annual waste reduction of 44 tons, an annual disposal savings of nearly \$50,000, and the elimination of about \$25,000 in annual costs to purchase Tellus oil.

b. Raw Material Losses

An additional source reduction measure at this facility involved reconfiguring the venting system on the three tanks that are used to store styrene monomer. Prior to this reconfiguration, styrene monomer, which vaporizes in the unfilled portion of the storage tanks, escaped to the atmosphere. This problem occurred when the tanks were being loaded with styrene liquid which is transferred from railcars to the tanks through underground pipelines. In addition to vapor losses, hazardous waste was periodically generated when pipelines had to be cleaned out because they became clogged with condensed styrene monomer. Annual loss (emissions) of styrene monomer to the atmosphere was estimated to exceed 94,000 pounds.

Source reduction involved routing the three tank vents to a single exhaust manifold that directs the vapor to a condenser. By pumping a chilled process stream to the liquid side of the condenser, styrene condensate is captured and directed to the third of the three tanks. Although hazardous waste reduction was not quantified, styrene no longer escapes from this source into the atmosphere. The estimated savings in raw material costs are \$28,000 annually.

c. Pump Seal Fluid

A third source reduction measure was applied to the extrusion operation. During operation of the sheet extruder, styrene vapors containing traces of oil and ethylbenzene are released when the feedstock pellets are melted and the liquid plastic goes through the die heads which form sheets for the thermoforming machine. Although the pollution control equipment (an electrostatic precipitator with a condenser) operating in conjunction with a liquid ring vacuum pump, removed the majority of these vapors, the water, which functions as a seal in the pump, became contaminated with styrene and had to be disposed of as hazardous waste. In addition, the accumulation of styrene in the pump seal water caused the pump to wear out. Because of this, the pump had to be replaced several times each year. Contaminated water from the liquid ring pump generated about 55 gallons of wastewater per week, or 10-11 tons annually.

The first attempt to solve this problem involved installing a vapor-absorbing charcoal filter to minimize water contamination and extend vacuum pump life. Although this measure reduced the wastewater to around 14 gallons a week, two expensive 500 lb charcoal filters had to be disposed of as hazardous waste each month. The final solution to this problem was to install a new once-through oiling mechanical pump. Instead of using water as a seal, the once-through pump uses a thin film of oil within mechanical vanes as a seal on the two ends of the impeller shaft. This measure reduced wastewater to approximately 22 gallons (<1/2 barrel) per week, and eliminated filter disposal, which resulted in an annual savings of \$16,000 in hazardous waste disposal costs. The new pump also created savings by eliminating \$15,000 in annual pump replacement costs and \$8,500 in annual charcoal recharge costs. The payback period for this \$65,500 investment was estimated at 2.16 years.

4. SUMMARY

During the last four years Tenneco Packaging's polystyrene manufacturing facility in the City of Industry instituted source reduction measures that reduced manifested waste by 43 percent when compared to 1990 quantities. A large portion of this reduction came from eliminating waste vacuum pump oil generated from a pump used to transfer liquid raw material. The type of oil used in the pump was changed to allow for reuse of the oil as a raw material after it was drained from the pump. Significant reduction also was accomplished by replacing a pump used to capture fugitive vapors in the extrusion operation with a more efficient pump that uses a different sealing fluid. The combined annual waste disposal cost savings from these two measures was estimated to be \$66,000. Raw material and operational costs savings from implementing these measures were estimated to be \$58,000 annually. A third significant source reduction measure reduced styrene emissions by approximately 94,000 pounds per year and saved \$28,000 in annual raw material costs. This reduction was accomplished by configuring three raw material storage tank vents to a single exhaust manifold, and adding a condenser to capture fugitive styrene vapors generated during tank loading events.

C. MCWHORTER TECHNOLOGIES

1. INTRODUCTION

McWhorter Technologies Incorporated, formerly Cargil Incorporated, located in Lynwood, manufactures thermoset alkyd and polyester resins. These resins are used in paints and in molded and laminated plastic items. At the Lynwood site, five reaction vessels are used to polymerize different combinations of monomer and various additives on a batch-by-batch basis. The attributes of any particular process stream depend upon the specifications dictated by each customer. Individual polymer batches made at this facility during the course of a production cycle can typically range in size from a few tons to hundreds of tons.

Among the group of facilities assessed for source reduction practices, McWhorter Technologies was one of the largest quantity generators during 1990. The most significant factor contributing to its waste quantity has been reaction water. This reaction water is generated as a by-product wastestream during the condensation polymerization reaction to produce both types of resins. The firm's 1991 source reduction plan divided this wastewater into two wastestreams (reaction water and by-product solvent) and quantified them separately. Wastewater classified under California Waste Code 214 (unspecified solvent mixture) constituted 82 percent of the 2,663 tons of waste routinely generated at the site in 1990. During 1990, 392 tons of this wastestream was recovered as by-product solvent in a phase separation tank and then manifested off-site. The remainder of the reaction water was handled in an on-site incinerator. In 1994, 371 tons of solvent by-product wastewater were manifested off-site. Overall, because of source reduction, total waste manifested off the site dropped from 874 tons in 1990 to 641 tons in 1994; a 27 percent decrease, even though production throughput was higher in 1994 than 1990.

In addition to making source reduction progress during the last four years, in 1993, McWhorter began a two year study to develop a method to treat (clean) the reaction water so that it can be managed in a less costly and more environmentally sound manner (as discussed below). Two important goals of the project are to recover organic media for reuse and to recover water so that it can be reused in the cooling towers, in certain polyester products, and as wash water.

The decision to find a different wastewater management method (than incineration) was motivated by several factors: a desire to reduce waste; a desire to increase the recovery and reuse of process chemicals; a desire to conserve water and energy; and, a desire to reduce waste management costs. Waste management costs associated with the operation, maintenance, and a pending permit renewal of the on-site incinerator are significant. For example, Dave Kohler, a lead process engineer with the company, estimated that it could cost as much as \$250,000 to gather and document emissions test data that would be required to renew the incinerator permits. The incinerator operates under permits from three different agencies. The U.S. EPA and DTSC permits regulate the incinerator as a fixed treatment unit, and the South Coast Air Quality Management District permit regulates the incinerator as a vapor emissions source.

Treatment and discharge of the reaction water to the publicly owned wastewater treatment facility (POTW) has not been an option for managing this wastestream. One of the primary impediments is that conventional water treatment processes cannot remove the odor that comes from aliphatic and aromatic hydrocarbons within this wastestream. Another impediment is that soluble organics contained in the wastewater exert a high chemical oxygen demand. To deal with these problems, McWhorter is in the latter stages of incorporating a series of treatment technologies to enable reuse and discharge of the wastewater to the POTW (water treatment steps are described in more detail in the source reduction section of this case study). While these treatment steps do not constitute hazardous waste source reduction, in combination, they represent a significant improvement in the company's waste management approach, and they will result in secondary pollution prevention benefits due to decreased water and energy use.

2. PROCESS DESCRIPTION

The production process starts when the primary liquid raw materials are pumped into the reaction vessels. Dry material additives are also included in the initial mix. Supersacks containing the dry materials are hoisted above the vessels and emptied into a manually opened port on the vessel(s). Different materials and quantities are added to the mix, referred to as the "recipe", at different stages during the reaction depending upon the attributes desired in the end product. Reaction times for mixes typically range from eight to 24 hours.

The alkyd mixture contains substances such as oils, xylene, maleic anhydride and other additives. The mixture is heated indirectly with a heat transfer fluid (oil) contained in coils configured in or around the reaction vessels. When the process stream in the vessel reaches the proper viscosity and solids content, it is cooled, and then transferred to a holding tank. In the tank, the process stream is mixed with solvents. Following this step it is filtered through a plate and frame filter. The final step involves transferring the product to drums or storage tanks.

The production process just described for alkyd resins is similar for polyester resins. However, polyester production involves the use of glycol instead of xylene. In addition, polyester is filtered in a bag-type filter instead of a plate and frame filter. Lastly, a packed column, instead of a decanter, is used to separate out water from the reaction condensate as described below.

Process or reaction wastewater is generated during batch production of alkyd or polyester resin as a result of the chemical reaction that produces resin. In order to polymerize the resin to the desired stage (A-stage, or B-stage thermoset), water must be continuously withdrawn from the reaction vessels throughout the process.

During the production of alkyds, xylene is added as a reflux agent to "strip" the water from the reaction as the monomers react to form polymers. Vapor, containing xylene and water, is drawn off the reaction using a seal-less vacuum pump and then run through a series of condensers. The condensate (reaction process wastewater) then goes to a decanter where water and xylene are separated. The xylene fraction is returned to the reaction vessel. During polyester production, the condensate is routed to a packed column which separates most of the glycol from the water. This glycol (a liquid) is then routed back to the reaction vessel.

In both resin production processes (alkyds and polyesters) the water layer that remains (after the xylene or the glycol is separated and routed back to the reaction vessel) is passed to the same storage tank and then to the same separation tank. Because of this configuration, the wastewater streams (water layers) from both resin production processes are mixed together in the separation tank. In the separation tank the combined wastestream water mixture undergoes phase separation due to further cooling. It separates into a non-miscible organic layer and a water layer (containing about 10% organics). The non-miscible organic layer is removed and sent offsite where it is mixed with other combustible liquids and used as incinerator fuel. The remaining wastewater, which contains approximately 10 percent organics, is incinerated on-site. Uncondensed organic vapors produced in the polymerization reaction for both alkyds and polyesters are routed to the on-site incinerator.

3. SOURCE REDUCTION MEASURES

The following section describes wastestream sources and also the source reduction measures that have been implemented by McWhorter Technologies. A description of an innovative wastewater treatment process combination is also included in this section because of its uniqueness and benefit to McWhorter's overall waste management approach.

a. Reaction Process Wastewater

During polyester or alkyd polymerization reactions, reaction process wastewater containing unreacted or partially reacted substances from the polymer recipe is withdrawn in the process. Wastewater from each category of polymer is removed using different methods, although the result is the same; a large quantity of hazardous (ignitable) wastewater is generated. Wastewater

that has been removed from both resin production process reactions feeds to, and is combined in, the same separation tank. In the separation tank, a portion of the wastewater (a solvent layer) is separated out and disposed at an off-site incinerator. The remaining layer, which contains approximately 10% organic solvents and constitutes the majority of the wastewater, is handled in an on-site incinerator. While McWhorter could renew its on-site incinerator permit(s) and continue managing the wastewater in this manner, as previously mentioned, there are several incentives to find a alternative management method.

During a two year study to search for viable wastewater management alternatives, the firm's investigating team concluded that due to the complex nature of the process wastewater chemistry, and the complex nature of the chemical reactions of various water treatment technologies that were tested, no single technology would adequately treat (clean) the process water. A combination of water treatment steps would be needed to adequately remove the combinations of organic species present in the wastewater due to the large variety of polymer recipes formulated at the plant.

McWhorter Technologies has decided to install a system which consists of a combination of water treatment processes (described in the following paragraph). These treatment steps can remove both organic and inorganic chemicals from the wastewater. If successful (the system is currently in a test phase), the treated water can be reused in the facility's cooling towers and for boiler make-up water. Excess water can then be discharged to the POTW. The new wastewater treatment configuration should eliminate the need to use the on-site incinerator. As a result, significant costs savings are anticipated because extensive testing for permit renewal purposes, and longer term upkeep and monitoring of this equipment will no longer be necessary. Cost savings will also accrue because of reductions in solvent (xylene) purchases, hazardous waste disposal quantity, and energy consumption. The environmental benefits will include water conservation, energy conservation and emissions reductions.

The first phase of the project involves separating the two resin production processes at the point at which condensate wastewater is routed to a single storage and single separation tank (creating a combined wastewater stream from both systems).

Because these wastewater condensates were combined in the one separation tank, the non-miscible organic layer (a potentially recoverable xylene based mixture) that was separated in the tank, contained dicyclopentadiene, a contaminant which exhibits a very strong odor. Separating the condensate wastewater streams into different tanks will prevent this contamination of the recoverable xylene mixture. This separated non-miscible organic mixture is now reused in the alkyd production process instead of being shipped offsite for fuel blending. In addition, a portion of the reaction water from polyester production (also in its own dedicated storage and separation tanks) will be reusable because it will no longer be contaminated with substances from the alkyd production process. Reuse of the glycol-based condensate wastewater is feasible in one of the polyester product lines in which water is added as a required component of the initial mix.

In the second stage of the project, each condensate stream (the reaction wastewater not

including the glycol or xylene that has been removed and recycled to the reaction vessel) will undergo pH adjustment with a magnesium hydroxide slurry. The slurry will be supplied using chemical metering pumps, agitators, and a pH control metering system. The use of magnesium hydroxide, unlike sodium hydroxide (commonly used to adjust pH), will produce insoluble forms of organics that can be filtered from the process water. One of the primary problems with using sodium hydroxide on this water is that it leaves water soluble forms of organics in the wastewater. These organics increase the water's chemical oxygen demand.

After pH adjustment, the reaction water will be pumped to a centrifugal filtration system to remove all solids from the water. The water will then be oxidized using a combination of ozonation and ultraviolet light. The final step involves polish filtration using granular activated carbon modified by a proprietary polymer (XU-4032). The estimated cost of the system is \$276,000. Combined annual savings due to reduced disposal, raw material and water consumption costs, and the elimination of testing and maintenance costs associated with the on-site incinerator, are expected to be \$120,600. The payback period for this investment is estimated to be 2.3 years.

b. Filter waste

As a final step in alkyd manufacture, diatomaceous earth is added to the resin, which is then passed through paper media within a plate and frame filter. The previous practice was to clean the filter's presses after every batch to ensure a high resin quality. The cleaning process generated used filter bags, filter papers, and diatomaceous earth containing waste resin. This constituted about 70 percent of the solid hazardous waste generated at the site during 1990 (280 tons of CWC 352 - other organic solids). Source reduction options for this wastestream showed that the frequency of filter press cleanings could be reduced without compromising product quality when compatible batches were filtered sequentially.

A second source reduction measure implemented for this wastestream involved using a pressure-relief filter press instead of the plate and frame filter. This type of filter press directs the resin through screens instead of paper. The screens trap far less product (which would otherwise become waste) than the paper. These two measures reduced the solid hazardous wastestream by 216 tons and saved over \$34,000 in annual disposal costs.

c. Caustic Cleaning Solution

Reaction kettles were previously cleaned using a caustic solution (CWC 122 - alkaline solution without metals). After use, the spent solution was shipped off-site for disposal. Eighty tons of this waste were generated in 1990. Source reduction for this wastestream involved two procedures; one for polyester processes and one for the alkyd process. For the polyester system, glycol is heated and circulated through the kettle as reflux. The used glycol (flowback, or reflux) is reused in the next batch made in the kettle. In the alkyd system, xylene is first refluxed and then steamed at 212° F for six hours. The steam condensate is collected and reused as reflux

solvent. These procedures eliminated the need for a caustic cleaning operation and saved approximately \$18,000 in annual disposal costs.

d. Decanter Solvent

When alkyd resins are manufactured, xylene is used initially as a reflux agent to strip off water as the monomers react to form polymers. The stripped water, which contains residual xylene, is then collected as it goes through a series of condensers. The condensate wastewater then goes to a decanter which separates the water and the residual xylene. The residual xylene is returned back to the kettle and the water is disposed (as previously described). Upon completion of the batch process, decanters were manually drained. After manual draining, residual xylene remaining in the decanters became lost as waste solvent. Procedures were implemented to leave the decanters at 10% full after each batch to not lose the xylene. In cases where the next batch does not require reflux xylene, it is drummed and stored for later use. These procedural changes reduced waste solvent generation by nine percent (37 tons annually) resulting in annual disposal cost savings of \$3,500 and raw material cost savings of approximately \$1,200.

4. SUMMARY

During the past four years McWhorter Technology's Lynwood facility instituted source reduction measures that reduced manifested waste by 27 percent when compared to 1990 quantities. A large portion of this reduction, which occurred even as production increased, was accomplished by reducing filter cleaning frequency and filter media changeouts. These changes were made possible by a combination of careful batch scheduling, and by installing an alternative filter, which contains screens (which generates less waste product) instead of paper media. Another wastestream, caustic cleaning solution, was eliminated by using cleaning agents that are subsequently used as product raw materials, and by instituting new procedures that made the use and recovery of these substances possible. The combined annual savings in waste disposal costs from these two measures was approximately \$52,500. Annual raw material and operational cost savings for the two measures was estimated to be \$3,400.

McWhorter Technologies is also in the last stages of implementing a wastewater treatment process that will prevent secondary pollution by decreasing energy and water use. Reaction water, which is a by-product of the condensation polymerization reaction, will no longer be incinerated. This wastewater will be soon be treated (cleaned) using a combination of processes. The water will then be reused in the site's cooling towers prior to discharge to the POTW. Re-routing alkyd and polyester condensate streams to separate tanks will also eliminate contamination of xylene so that it can be reused at the site. McWhorter Technologies estimates that annual water use will drop from 2,628,000 gallons to 1,878,000 gallons, and that annual cost savings will come from a combination of elimination of maintenance and testing expenses associated with the on-site incinerator, water and energy use reductions, reduced waste disposal, and reduced raw material purchases. The payback period for this \$276,000 investment is estimated to be 2.3 years.

VI. SUMMARY

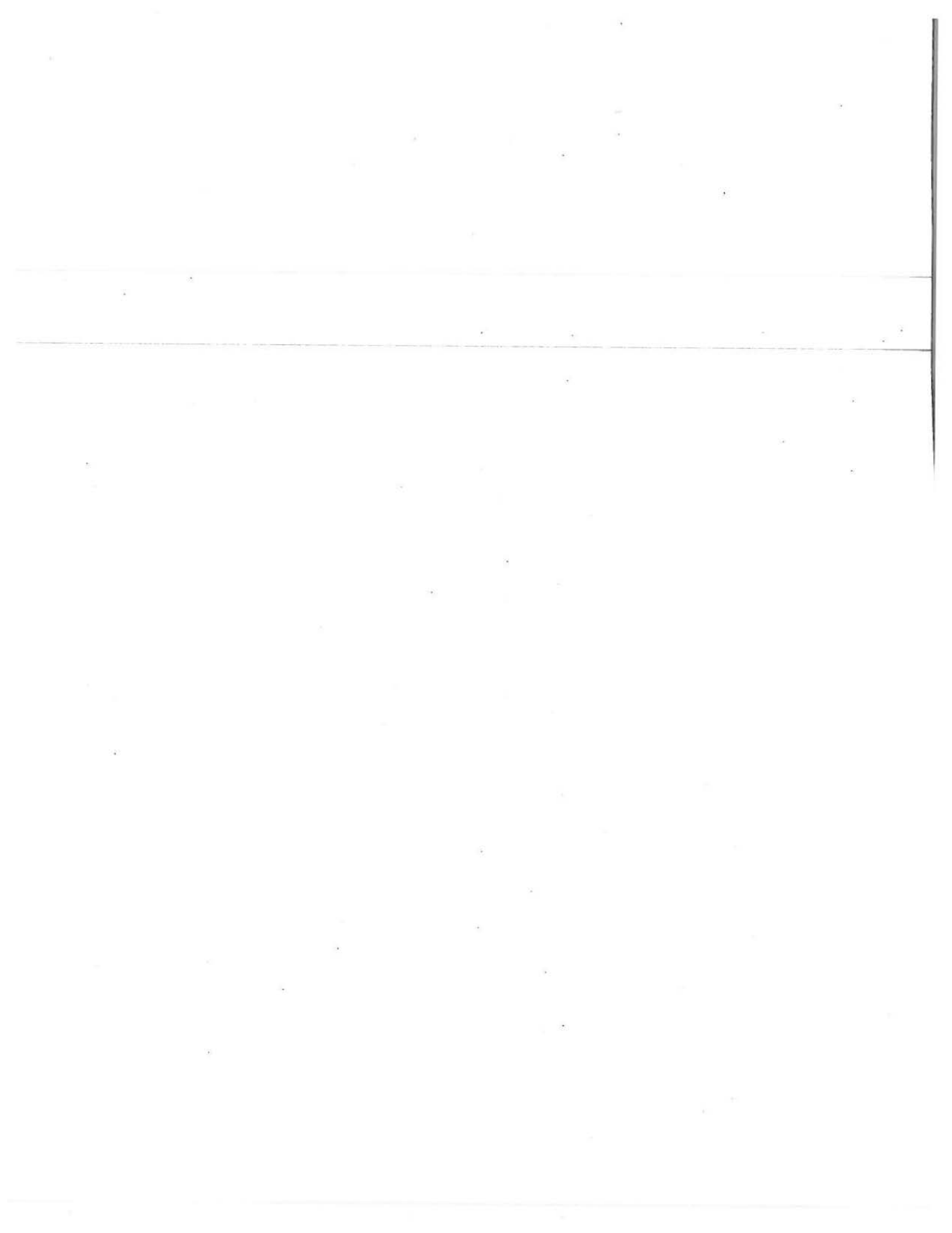
The following summarizes some of the major findings based on the plastics and resins industry source reduction document review:

- A majority of the 31 polymers and resin facilities reviewed for this report prepared source reduction plans and hazardous waste management performance reports in accordance with the provisions of the Hazardous Waste Source Reduction and Management Review Act of 1989. For a number of companies the originally prepared documents had to be revised to meet a minimum standard. Most companies used 1990 as the baseline year to document the types, quantities, and sources of hazardous waste generated at their facilities. Three facilities, which did not prepare documents in 1991, subsequently prepared documents using 1992 or 1993 as the baseline year for planning purposes.
- Waste generation data indicates that the quantity of manifested hazardous waste generated by these 31 firms as a group decreased by 27 percent when comparing 1990 to 1994. Although a variety of factors contributed to this reduction, such as, changes in production throughput and product line changes, source reduction practices clearly played an important role in reducing the quantity of waste generated by these facilities.
- In the polymers and resin industry, waste generation quantity and specific waste types are functions of the scope and integration of activities at any one facility. These activities can include polymer production, compounding or polymer modification, and resin/polymer processing. A significant factor related to waste generation is the large diversity of possible product types and forms. Production and compounding operations generally produce adhesives, coatings, sealants, latex emulsions, elastomeric foam, resin pellets and sheets, and molding powders. Depending upon polymerization method, polymer category, and the final product form, waste produced by these facilities included filter media, wastewater generated by polymer dewatering or washing, condensate from polymerization reactions or air pollution control equipment, waste oil, particulates, rags, containers, waste resin, asbestos, and spent cleaning solvent. Among the entire group of facilities, spent solvent waste was the most frequently generated and largest manifested major (> 5% by weight) wastestream. Plant infrastructure and equipment cleaning was the primary source of this wastestream.
- Another dominant wastestream generated among these facilities is waste resin. Waste resin was generated from sources which included production excess, quality control sampling, production errors, filtering processes, use of contaminated raw materials, and low-weight polymers created as by-products during polymerization reactions. Secondary wastestreams generally included solvent sludge from solvent recovery tanks or distillation units, and activated carbon from air pollution control equipment, or water treatment units. Dominant wastestreams produced by compounding operations included excess or spent solvents, excess product, and wastewater from pollution control equipment. Pre-preg (plastic reinforced composites) manufacturing facilities generated waste spent solvents, waste resin mixes, scrap impregnated material, and, in some cases, wastewater

condensate from pollution control equipment.

- Among the facilities that produced polymers (except a polyurethane foam facility) process ingredients such as solvents, monomers, catalysts, and reactive additives were combined in closed vessels and heat was applied to initiate chemical reactions which produced chains of polymer molecules. This production process can create condensate wastewater which contains solvents, additives and reactants from the process mixture, and also excess product. When generated, reaction condensate wastewater was by far the largest quantity wastestream. Among the group of 31 facilities it was the largest quantity wastestream; however, only seven facilities reported generating this wastestream. Several firms also generated condensate wastewater from pollution control equipment. From either of these two sources, most generators classified this wastestream as CWC 134 - aqueous solution with total organic residues less than 10 percent. For firms that manage this waste through on-site incineration, air pollution control regulations and the expenses associated with permit renewals for on-site thermal treatment units are two factors creating incentives to find alternative management methods.
- Several polymer and resin firms achieved significant waste reductions in solvent and oil waste by using product raw materials as substitute cleaning agents or lubricants to replace substances that became waste after being used. Notable reductions in spent solvent waste generation were also made by firms that upgraded or replaced plant infrastructure and equipment. The infrastructure improvements meant that less solvent was required in cleaning operations. Some equipment replacements eliminated the need to use solvents, while other equipment changes allowed for dedicated processing equipment which reduced or eliminated the need to clean equipment between production cycles. Some firms also discovered more efficient or non-hazardous waste producing methods to clean equipment to reduce or eliminate spent solvent waste. A number of firms also instituted source reduction by replacing high vapor emitting solvents such as 1,1,1, TCA and methyl ethyl ketone with specially manufactured low vapor pressure solvents. For some firms, oil waste reduction was achieved by equipment modifications such as using seal-less pumps, installing in-process oil recycling units, and replacing old parts within equipment. In some instances, oil waste reduction was dramatic.
- Progress was also achieved in reducing waste resin, drums and container waste and waste rags by many of these companies. Measures that were implemented to reduce waste resin included using alternative substances in product formulation to eliminate the need to filter products, adding secondary filtering systems to remove contaminants that created off-specification product, upgrading or replacing filter systems with more efficient units, better scheduling of batch production to sequence compatible products, sampling only when necessary, eliminating double sampling practices for some products with low failure rates, and adding agitation units on product storage tanks to prevent product gelling. A number of facilities reduced container waste by ordering supplies in bulk containers, ordering supplies in bags with removable liners, and using returnable totes for oils and raw materials as an alternative to disposal drums.

- **Many of the submitted documents would have had more value to generators and DTSC for information transferal and as planning tools for hazardous waste source reduction had increased attention been paid to quantitatively estimating the waste reduction, implementation costs, and savings in raw material and disposal costs associated with implementing specific source reduction measures. In addition, generators need to update SB 14 Plans and Reports during the reporting cycle as conditions change, phases of feasibility studies are completed, or as new opportunities arise to reduce waste generation.**



REFERENCES

1. Industrial Process Profiles for Environmental Use. Chapter 10 - The Plastics and Resins Production Industry. Environmental Protection Agency publication number PB 85-245280. pages 1-60. Radian Corporation. McLean, VA. July 1985.
2. Berins, Michael L. Plastics Engineering Handbook of the Society of the Plastics Industry, 5th Edition. 1991.
3. Wolf, K. Alternatives to Chlorinated Solvents in Cleaning Applications. Institute for Research and Technical Assistance. December 1994.
4. Hazardous Waste Source Reduction and Review Plans, September 1991, submitted to the Department (in order of review) by the following:

Tenneco Packaging (formerly called Packaging Corporation of America),

City of Industry

Rohm and Hass, La Mirada

Engineering Polymer Solutions, Commerce

Georgia Pacific, Ukiah

Polycom Huntsman, (formerly G E Plastics), Oxnard

Neville Chemical, Anaheim

Ashland Chemical, Los Angeles

Alpha Owens-Corning Resins, Perris

Fiber-Resin Corporation (formerly Hexcel Chemical), Chatsworth

Dow Chemical, Torrance

McWhorter Technologies (formerly Cargill, Inc.), Lynwood

Newport Composites and Adhesives, Fountain Valley

Hexcel Chemical, Livermore

Silmar Division of Interplastic Corporation, Los Angeles

Keysor Century Corporation, Sangus

Reichhold Chemicals, Azusa

Reichhold Chemicals, Oxnard

Rhone-Poulenc, Los Angeles

BASF, Santa Ana

Cytec Engineering, Anaheim

BP Chemicals, Santa Ana

CIBA-Geigy, Los Angeles

American Polystyrene, Torrance

Georgia Pacific, Sacramento

Courtaulds Aerospace, Mojave

Rubber Urethanes, Azusa

Mitchell Rubber Products, City of Industry

Fiberite Corporation (formerly ICI Fiberite), Orange

Heller Performance Polymers, Visalia

Foamex, Ltd., Orange
Courtaulds Aerospace, Berkeley
Amoco Foam Products, La Mirada

**APPENDIX A.
SAMPLE SB 14 DOCUMENT CALL-IN LETTER**

(916) 322-3670

**Facility Manager
XYZ Chemical Company
123 W. Main Street
Anytown, California 92324**

**HAZARDOUS WASTE SOURCE REDUCTION AND MANAGEMENT REVIEW ACT
OF 1989 - SENATE BILL 14**

Dear Facility Manager:

The Hazardous Waste Source Reduction and Management Review Act of 1989 (SB 14) requires generators that produced over 12,000 kilograms (13.2 tons) of hazardous waste or 12 kilograms (26 pounds) of extremely hazardous waste in 1994, and each reporting year (which occurs every four years), to prepare two documents and summaries of each. Hazardous waste generation includes any RCRA or California-only hazardous waste that is managed by on-site or off-site recycling, onsite treatment, (including wastewater pretreatment), and manifesting offsite.

For the first document, the Source Reduction Plan (Plan), the business identifies all hazardous waste streams at the generator's site and evaluates the major wastestreams for the potential to reduce waste at the source. In the second document, the Management Performance Report, the business describes its hazardous waste management methods and, if applicable, assesses the effectiveness of any changes in waste management methods instituted since 1990 (due to implemented source reduction strategies or other changes in operations).

Under the authority granted in Health and Safety Code (HSC), Section 25244.18, the Department of Toxic Substances Control (DTSC) is hereby requiring that copies of the 1991 Plan and Management Performance Report for XYZ Chemical Company located at 123 W. Main Street in Anytown, California (EPA ID # CAD *****), be sent in for review. Please mail copies

Facility Manager

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of these documents within 30 days of receipt of this letter to:

**DTSC Staff Member
Office of Pollution Prevention
and Technology Development HQ-25
Department of Toxic Substances Control
P.O. Box 806
Sacramento, California 95812-0806**

In addition, pursuant to HSC, Section 25244.19(f), you are required to provide DTSC with a summary of your progress in implementing the measures selected in your Plan. For your convenience, I have enclosed a Progress Summary table with headings reflecting the information you are required to submit. The data you present in the table will be compared to existing information in your Plan. If data is not available because source reduction documents were only recently completed, please note this on the table.

Failure to submit these documents within the specified time frame may result in civil penalties of up to \$1,000 per day as specified in SB 14.

We look forward to your cooperation in this matter. If you have any questions regarding this letter, please contact me at (916) 322-3670. Thank you.

Sincerely,

**DTSC Staff Member
Office of Pollution Prevention
and Technology Development**

**APPENDIX B.
SB 14 PLAN COMPLETENESS CHECKLIST**

- 1) Is your generator's name and address given in the plan? (CCR Section 67100.5(a))
- 2) Is the address the same location where waste is generated?
If no, is there a given address where waste is generated?
- 3) Is the four digit SIC code(s) for the site given? (CCR Section 67100.5(b))
- 4) Are you a small business?
If yes, is a DHS Waste Audit Study Checklist being used?
(If yes see Checklist for content requirements.)
- 5) Is the plan addressing a multi-site operation?
If yes, are all the sites' addresses listed in the plan?
If no, the plan is incomplete.
- 6) Is there a description of your business and waste generating activities in the plan? (CCR Section 67100.5(c))
- 7) Is the length of time your company has been in operations at the present site provided in the plan? (CCR Section 67100.5(d))
- 8) Are the major manufactured products and services you provide described in the plan? (CCR Section 67100.5(e))
- 9) Are the number of employees working for you given in the plan? (CCR Section 67100.5(f))
- 10) Is there a general description of your operations in the plan? (CCR Section 67100.5(g))
- 11) Does the plan identify all routinely generated hazardous waste streams which result from ongoing processes or operations having a yearly volume that exceeds five percent of the total yearly volume of hazardous waste at the site? (CCR Section 67100.5(h))
- 12) Does the plan provide an estimate of the weight, in pounds, of waste generated at the site? (CCR Section 67100.5(i)(1))
- 13) Have you listed the applicable California waste code(s) for each waste stream? (CCR Section 67100.5(i)(2))
- 14) Are the waste generating processes, operations and activities (along with corresponding diagrams) described in the plan? (CCR Section 67100.5(i)(3))

- 15) Do the processes, operations and activities described include a listing of all input materials contributing to the generation of waste? (CCR Section 67100.5(i)(3))
- 16) Is there an evaluation of available source reduction approaches? (CCR Section 67100.5(j))
- 17) Do evaluations for source reduction approaches consider input changes, operational improvements, production process changes, product reformulation, etc.? (CCR Section 67100.5(j))
- 18) Do the evaluation consider the following (CCR Section 67100.5(k))
- Expected change in the amount of hazardous waste generated?
 - Technical feasibility?
 - Economic evaluation?
 - System capacity?
 - System efficiency?
 - Permits, variances, compliance schedules of State, local, and federal agencies?
 - Effects on product quality?
 - Employee health & safety implications?
 - Releases and discharges?
- 19) Does the plan provide information, such as waste stream constituents and concentrations, pertinent to the evaluation of source reduction approaches? (CCR Section 67100.5(l))
- 20) Is there a specification of, and rationale for, each technically feasible and economically practicable source reduction measure(s) being proposed in the plan for implementation? (CCR 67100.5(m))
- 21) Is there an evaluation and, to the extent practicable, a quantification of the effects of the chosen source reduction measures(s) on emissions and discharges to air, water, or land? (CCR Section 67100.5(n))
- 22) Is there a list of alternatives considered but not selected for a detailed evaluation as a potentially viable source reduction approach? (CCR Section 67100.5(o))
- 23) For each alternative rejected, is there a rationale for rejection? (CCR Section 67100.5(o))
- 24) Is there a timetable /schedule for making reasonable and measurable progress towards implementing and completing the selected source reduction measures? (CCR Section 67100.5(p))
- 25) Does the timetable /schedule prioritize processes and wastes for future research, development and source reduction analysis? (CCR Section 67100.5(p))
- 26) Is the plan properly certified? (CCR Section 67100.10))