ENERGY EFFICIENCY AND
POLLUTION PREVENTION ASSESSMENT
PROTOCOL

in the
POLYMER PROCESSING INDUSTRIES

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Executive Summary

This draft protocol, which was developed from experiences with three New Jersey firms, is intended to be a guide for conducting analyses on resource (energy and raw materials) utilization and pollution (solid waste, air and water emissions) prevention in plastics processing plants. The protocol is written on the assumption that the analysis is to be done by an outside agency-such as a consulting firm, but it also can be used for internal audits by plant teams. Key concepts in this analysis were adapted from Life Cycle Analysis.

Because of the small sample of companies studied, the results have to be considered highly preliminary, but some of the conclusions will probably be confirmed by further work.

1. General Observations

While there were some differences between the studies conducted on these three firms, some important factors were common to all:

(a.) Level of Industry Interest

Based on the experience with the three companies studied, there is significant interest in the plastics industry in finding ways to reduce energy costs, and a general lack of understanding on how to do it. With respect to the other areas of focus for this protocol - reductions in solid waste and air and water emissions, promotion of recycling and designing products that have reduced environmental impact - the level of interest is spotty and much lower. However, manufacturers will usually have at least one significant problem in these additional areas that will require analysis. It is probable that increasing attention to environmental issues, sparked by such things as the ISO 14000 registrations, will stimulate interest in all manufacturing operations that impact on the environment.

(b.) Role of the Local Utility

In all three cases, the local utility was interested in participating in the studies and made important contributions. Any program of this sort should seek to obtain maximum assistance of the local utility; the probabilities are high that the utility will want to participate.

(c.) Value of an Integrated Analysis

It was apparent from the programs at the three companies that there are significant efficiencies if the studies on resource utilization and pollution prevention are done as an integrated package rather than done separately. Not only are there efficiencies in working from a common data base and avoiding duplication of measurements, but also ideas are developed when integrated studies are done that would likely not have come about with separated studies.

(d.) Planning

Since the studies are to be done by teams of specialists, including plastics process engineers, product designers, environmental engineers and public utility personnel, it is vital that the team members devote adequate time in the beginning in developing a good plan, and that this be done with participation of plant personnel.

2. Elements of the Analysis

Using concepts from Life Cycle Analysis, the protocol attempts to do what amounts to a total energy and material balance around the manufacturing operation, with particular emphasis on the energy consumed in all of the operations. The analysis can be organized in individual modules, which,

although they can be done separately as discrete studies, are more efficiently done as a package. The modules are:

(a.) Primary Process Energy

This area focuses on the major pieces of processing equipment that are unique to the kind of manufacturing operation being carried out: injection molding, extrusion, blow molding, etc. In general, this is the single largest area of energy consumption in the plant.

(b.) Auxiliary Process Energy

This area includes items of equipment that are involved in the production of goods, but are not necessarily unique to the kind of process being conducted. Typical items of equipment that fall into this category are hopper driers, chillers, air compressors, granulators and mixers, etc. This area is usually significant but less important than primary process energy.

(c.) Non-process energy

This covers all energy consumption not directly related to production of goods; for example: plant heating and air conditioning, lighting, etc. It is in this area that help from the local utility is most valuable.

(d.) Solid waste

This topic includes all of the solid material that leaves the plant that is not salable product. Involved are identifying and quantifying the solid waste streams, finding ways to reduce them, and finding outlets for the materials other than landfilling or incineration. Frequently, markets for recyclable plastic waste can be found that the plant personnel are not aware of.

(e.) Air emissions

In general, the processing of thermoplastics generates very little in the way of emissions to the air, and those that are generated are generally not toxic. Nevertheless, plastics processing operations usually require permits involving air emissions. Sometimes problems of odor or dust arise that need to be addressed, even if operations are within guidelines of the permits.

(f.) Water emissions

Emissions to water in plastics processing are virtually nil, and are included in the protocol for sake of completeness. The principal use for water in plastics is for cooling and normally does not come in contact with the product. However, on occasion hot polymer is extruded into a water bath, and potential for contaminating the water exists. Any of this cooling water that is ultimately discharged should be tested for contaminants.

(g.) Product design issues

Various factors in the design of a product or of the mold used to make it can influence the ease with which the product can be recycled, the amount of scrap generated when the product is made, and the environmental issues related to the choice of resin and additives specified for the product.

3. Guidelines for Report Preparation

The protocol anticipates that two types of reports might be written for a given company assessment: one for internal use by the company, and one for external use, where the results might be disclosed to the industry or to the

public. Guidelines are given that guarantee company confidentiality, as well as making generalized information available to outside sources.

4. Plans

Near term prospects for extending and improving this protocol are possible through the New Jersey Manufacturing Extension Partnership, a cooperative program between the state of New Jersey and the National Institute for Science and Technology.

5. Costs

The amount of effort required for the analysis by the audit team is on the order of 20 ± 5 man-days. An equivalent amount of time will be needed by company personnel; somewhat less time by utility personnel.

6. Benefits

Typical savings are 10-20% of energy costs. Energy costs in plastics processing average about 3-4% of revenue; so a company with sales of \$50,000,000 might save over \$200,000 a year from this program. Additional savings could accrue from reduced scrap or increased recycling. The benefits from analyzing air and water emissions and producing "environmentally friendly" designs are harder to quantify, and will come from marketing advantages associated with an increasing world-wide interest in products and processes that have minimal negative impacts on the environment.

1.0 Introduction

This protocol was developed from studies at three New Jersey plastics firms and is intended to be used as a guide for carrying out energy efficiency and pollution prevention assessments in small and mid-sized plastics firms. As additional firms are studied, the protocol will be expanded and improved. Ultimately, it should be possible for it to be used in studies on firms in other manufacturing industries.

The logic of combining energy efficiency and pollution prevention assessments is based on the concepts developed in Life Cycle Analysis (LCA). LCA is a discipline that has been under development for the last 15 years or so that considers all of the energy and material flows over the life cycle of a product, assesses their impact on the environment and addresses ways to make improvements. It is a "cradle-to-grave" study beginning with the generation of the raw materials involved, through product manufacture and use, and finally with the product's discard, recycle and ultimate disposition. This technique has been widely applied in making decisions on which of several alternatives is preferable when environmental factors are taken into account. When used as a management tool in product development and production these tools are often referred to as "Product Life Cycle Management" or "Life Cycle Thinking".

One section of an LCA on a plastic product is the manufacturing step in which a plastic pellet is converted into a plastic item ready for sale. In this section, all of the material and energy consumed in the manufacture is accounted for, as are the solid waste generated as well as the air and water discharges. This protocol addresses how to go about making those studies.

In this protocol, primary emphasis is placed on items dealing with energy efficiency. This is because 1) it gets plant managers interested and involved, 2) energy consumption is the principal area in plastics manufacture that has an adverse effect on the environment and 3) it provides a good point of departure

to do the other studies on product design, air emissions, wastewater and solid waste. In mid-sized and small plants, the managers usually have a good idea of what their raw material costs and utilizations are, and also understand their labor costs and how to control them. Energy, however, is another matter. It is not so large a factor that it demands their continued attentions, its use is dispersed throughout the plant with no single source dominant and it is hard to control. Plant managers know that energy costs are not trivial and worry about how to handle them. It is for this reason that the plant managers in these three New Jersey firms were willing to be "guinea pigs" for this study.

2.0 Life Cycle Analysis Concepts

The objective of Product Life Cycle Management is to provide people who make, use or dispose of plastics and other products with a method to help understand how their decisions and actions involving those products affect the utilization of resources (energy and raw materials) and generation of pollution (waste products discharged to the air, water or the earth). It can be helpful in determining how to design a product, run a manufacturing plant or choose between products made from different raw materials (plastics, glass, paper, etc.).

The Product Life Cycle Management concept, shown schematically in Figure 1, Page 3 indicates that at each stage in the production, use and disposal of a product, energy and materials are consumed and waste products are generated. It also shows potential for reduction of solid waste through product reuse or recycling. It highlights the importance of product design, where key decisions are made that affect resource utilization and pollution generation throughout the system.

The idea that choices between product alternatives should be made on a system basis came into prominence in the "energy crisis" of the 1970's. At that time, there was much debate on the most attractive fuel source for the U.S. - oil,

Figure 1

Process Flow of Life Cycle Management

coal, shale, nuclear or various "sustainable" resources such as solar or biomass. Alcohol from grain was promoted as an alternative to gasoline from petroleum. But as studies proceeded, the complexities of the problem became apparent including the level of energy consumed in production of fuels. As environmental issues became increasingly important in the 70's and 80's, the systems approach developed for energy analysis was adapted to include waste generation as well. A formal method called Life Cycle Analysis was developed with the Society for Environmental Toxicology and Chemistry (SETAC) playing a leading role.

A formal LCA has three stages: 1) Inventory Analysis, during which all of the energy and material flows are identified and quantified, 2) Impact Assessment, during which the environmental impacts are highlighted and their magnitudes assessed and 3) Improvement Analysis, during which remedial alternatives are explored. A full blown LCA is costly and time-consuming. Alternatively, in many cases it is not necessary to do a complete Life Cycle Analysis in order to get insight into a problem; frequently, just structuring the Process Flow of Life Cycle Management will provide the insight needed.

The ideas of Life Cycle Analysis, which have been called Life Cycle Thinking, are being used in decision-making. These ideas are being felt in product design, the emerging "Design for the Environment". Designers are also learning how to design for product disassembly, and to select materials whose production is environmentally benign. LCA concepts are part of regulations that guide purchases by various federal agencies. Global consensus is being developed and is being promoted by the International Organization for Standards and its ISO 14000 series of voluntary standards, which include elements of LCA as important components.

The important ideas from Life Cycle Analysis that are involved in developing this protocol are:

- (a) Making an inventory of all the material and energy flows in plastics manufacture

- (b) Assessing the impact of the waste discharges
- (c) Identifying operational improvements
- (d) Considering how product design features might change to effect improvements

3.0 Benchmarks

One of the early tasks in the program was to establish benchmarks to use in evaluating how much room for improvement was reasonable for the three companies in the initial study.

The information needed is not readily available, so benchmarks were constructed by consolidating information from a number of different sources. The most useful of these were 1) the DOE-funded database maintained by the Office of Industrial Productivity and Energy Assessment at Rutgers University, 2) Facts and Figures of Plastics Industry, published by the Society of the Plastics Industry, 3) Guide 55: Extrusion of Thermoplastics Pipes and Profiles, published by the British Plastics Federation, 4) an unpublished study on Energy Consumption in the Plastics Industry done for the American Plastics Council by the Polymer Processing Institute at Stevens Institute of Technology and 5) various proprietary publications by the Electric Power Research Institute (EPRI) which can be accessed through local public utilities.

From these sources, the following picture emerges:

- a) Relative to all manufacturing the plastics fabrication industry is more energy intensive, and a higher percentage of the energy consumed is electricity.

Rutgers OIPEA Database

• Number of companies	4,733
• Number of plastics fabricators	361
• Energy consumption (% of sales)	
Plastics	2.5
Other manufacturers	1.7
• Electricity/total energy (%)	
Plastics	90
Other manufacturers	70

- (b) A little more than half of the energy used in plastics manufacturing is used for the primary processing machinery (injection molders, extruders, etc.); the balance is for lighting, heating, cooling and auxiliary process equipment.
- (c) For the medium sized and small plastics processor, the energy costs are comparable in magnitude to the manufacturer's operating margin. A 20% reduction in energy consumption could make the difference in determining whether a small processor survives or not.
- (d) The average processor consumes about 0.4 kWh/pound of plastic processed.
- (e) Some typical examples of energy costs in plastics processing, expressed as percentage (%) of dollar sales are:
• Injection molding	3.5
• Blow molding	3.6
• Extrusion-pipe	2.3
• Blown Film	4.4
- (f) A typical distribution of energy, by percentage (%), in a pipe extrusion operation is:

• Screw motor	39
• Material drying	7
• Auxiliary heat	7
• Other auxiliaries	17
• Chillers	20
• Lighting	10

In assessments of plastics processing operations the above benchmarks are useful in gauging company operations with industry norms. They also highlight the operations where the greatest potential for savings exist.

4.0 Assessment Elements

The protocol presented in this report was based on the assessment of extrusion processing operations, but is adaptable for other plastics processes. A general schematic of a typical plastics processing facility is illustrated in Figure 2, Page 8. In plastics processing by extrusion, injection molding or blow molding, a plastic resin (termed a thermoplastic) is heated to a melt stage in the processing machine, formed into a shape and cooled to the solid state; all on a continuous basis. The solid thermoplastic can be recycled in that it can be reheated to the melt stage and reformed.

The primary processes utilize various auxiliary equipment items (most of which employ electric motors) to accommodate the material, the processing machine or other manufacturing steps. Typically, a plastic processing machine will have a resin dryer, cooling water provided by a chiller and a granulator to regrind process scrap for reuse. Additional equipment utilized in processing include mixers, air compressors and items for post finishing operations. The life cycle assessment of auxiliary items includes the equipment efficiency, studies of which are available from other sources¹

¹A Self-Assessment Workbook for Small Manufacturers, A "Best Practice Manual," 1.0 Rutgers, the State Univ. of NJ

Figure 2

Typical Processing Equipment

The assessments that this protocol are designed to produce are:

1. Industry-specific, focusing on plastics processing.
2. Comprehensive, covering all activities that affect resource utilization and pollution generation, including the design of the product being manufactured.
3. Intensive, probably requiring at least 10 man-days of effort and involving a team of three or more members, including plastics, power and environmental specialists.

Plants that have been ISO 9000 or 14000 certified will find the assessments easier to do than plants that have not.

Similarly, plants that have participated in the Department of Energy's Energy Analysis and Diagnostic Center (EADC) program will find the information from that program useful in these assessments. (About 400 plastics processors in the U.S. have been involved in the EADC program to date.)

The protocol for an effective facility assessment is based on the concept of an umbrella or bubble (Figure 3, See page 10) over the entire manufacturing site. From this concept, five assessment elements (Figure 4, See page 11) are identified for the facility analysis: Planning, Process Energy, Non-Process Energy, Waste Streams and Product Design. Of the five elements, planning is the most important element since it sets the stage for the other assessment elements.

4.1 Planning

In order to produce a high quality and useful assessment at a reasonable cost, the first priority is to develop a comprehensive plan for the program. The planning effort, including periodic reviews, could be on the order of 20% of the total time spent on the assessment. Key elements of the planning program are:

Figure 3

Facility Bubble Concept

Figure 4
Facility Assessment Elements

1. Developing relationships between plant personnel and the assessment team.
2. Setting goals and budgets.
3. Securing the participation of the utility involved.
4. Assembling relevant data on plant operations.
5. Developing work assignments between team members, plant personnel and utility representatives.
6. Scheduling periodic progress reviews.

The plan should be put in writing and distributed to the people concerned. Gantt charts or similar time-line representations should be used wherever possible.

The planning phase of an assessment encompasses a number of steps which necessitate that the facility management understand the scope of the effort. They must agree to actively participate by providing needed information, facility access and assistance during the assessment activities. It also includes the active involvement of the utility providing the plant's power. The assessment planning developed is illustrated in Figure 5 (See page 13).

The initial planning action developed by the team is an "assessment definition" which defines 1) the type of facility to be studied and 2) the scope of the assessment contemplated. This action is followed by "resource definition" which outlines the assessment manpower needed, designates a team leader and the equipment needed to conduct the assessment. When defined, one or more facilities can be contacted to arrange for an introductory visit to discuss participation in the assessment. Arrangements are made by either telephone or by letter, preferably through a known staff member within the company.

The introductory "facility visitation" is accomplished by two or more individuals from the team, one of which is the identified team leader. The visit will present the objectives of the assessment, describe the resources to be utilized, the needs of the assessment team and the level of participation required by the facility staff. The anticipated benefits to be derived and specific issues will also be discussed.

Figure 5

Assessment Planning Process

During the visitation, it is important to agree upon the objective and extent of assessment to be conducted. If limited by the availability of manpower, facilities or financial resources. It is essential to establish a priority list of energy related equipment and waste stream areas to be assessed along with the deliverables to the client.

A "facility agreement" by the company's management to participate will necessitate that a company profile and other survey forms be completed. The forms include an overview of company capabilities and equipment as listed in Tables 1-8. The agreement will also include a declaration of confidentiality by the assessment team regarding the proprietary aspects of company operations.

Prior to the actual scheduling of the assessment, it is necessary to obtain detailed technical information and data on plant equipment, operations and practices for both the energy and environmental interests. The preliminary information and data will be provided by the company staff by completing the forms provided by the assessment team. The forms reflect what is needed for an effective assessment, although it is expected that a good percentage of the information will not be available. The forms will have two benefits: 1) the company will be advised of the technical data needed to assess and improve business operations and 2) when completed will identify the lack of data on hand by the company staff.

Table 1 provides the assessment team with an overview of company operations. Table 2 contains the needed plant energy data, to be compiled in conjunction with the local utility representative, to assess the energy use and means to conserve same. Tables 3-5 contain the detailed data for primary and auxiliary equipment utilized in the facility. Tables 6-8 contain information and data needed to assess the waste streams.

Following the receipt of the completed survey forms from the facility, each will be reviewed and the team will plan a visit to allow general protocols to be brought into focus for the site. The visiting group of experts will consist of a team leader, a process expert (e.g. extrusion, injection molding, etc.), an environmentalist, a site

energy specialist and one or more members of the electric utility technical and marketing staff. Additional specialists to participate in the assessment will be identified at the initial meeting.

After a general discussion of plant operations, a review of the survey forms and a plant tour, a program plan will be developed. The plan will include an "assessment schedule" for the actions agreed to by all parties. Emphasis will be placed on minimizing the impact of the assessment actions on the company production and plant operations.

The team leader is responsible for the overall assessment and will be the focal point in all facility matters. The facility management will also identify a staff member as the company's point of contact.

4.2 Electrical Power Utility

The utilities are active participants throughout the facility assessment (Figure 5). The electrical power utility plays an important role in the planning phase due to the high use of energy in plastics processing and the complexity of determining power distribution and consumption as noted in Table 2. Also, the utility normally has a company representative who services the processing facility and is usually aware of power consumption issues. During the assessment planning phase, the utility representative and support staff are identified.

The goals of the assessment team, i.e., power conservation, are discussed with the utility representative to assure the most effective analysis of energy usage. Additional topics considered early in the program are discussed in the following paragraphs.

4.2.1 Utility Contract

The contract between the utility and the company is discussed during the planning phase as well as the availability of the detailed computerized records maintained by the power utility. The information needed by the assessment

team, as outlined in Table 2, is to be developed by company and the utility. The utility is requested, with the approval of the company, to provide the needed information and data.

4.2.2 Utility Services

Discussions during the utility interactions should include the services available to the company. These include special programs which can conserve power, reduce power cost or enhance the power supply. The programs may include:

- Identification of special customer needs
- High efficiency HVAC equipment rebates
- Power quality assessments for surges and low voltage
- Power curtailment programs
- Load studies of electrical distribution system
- Power factor and frequency variation evaluations
- Installing emergency backup systems
- Electric motor efficiency studies with suggested payoff periods
- Process technology alternatives
- Energy surveys

4.3 Process Energy Analysis

Process energy is energy consumed in the actual manufacture of product. It normally is 65 - 85% of the total energy used in a plant, and so is the source of the largest potential savings and should be the major focus of the assessment. Achieving a good analysis of the process energy normally requires the services of at least two specialists - a plastics process engineer and a representative of the local utility.

Process energy can be subdivided into two categories: primary and

auxiliary. Primary process equipment are the machines that melt and shape the products - injection molding machines, extruders, thermoformers, etc. Auxiliary equipment are machines that handle and treat the feed and the products: conveyors, grinders, chillers, etc. Primary process energy is usually 60% or more of total process energy.

The measuring equipment needed to make the assessments is readily available. The principal unit is a data acquisition system (DAS) which consists of a personal computer (PC), with data acquisition and analysis software, watt transducers and current transformers (CTs). The PC needs 8-16 channels, depending on the plant size, to record voltage, amperage and power factor. The watt transducers and CTs are best installed on a permanent basis to enable continuous energy monitoring. Also, needed is an electrical phase meter reader.

For plastics processing a high precision pyrometer is needed, coupled with a melt thermocouple. Additionally, a feed stock thermocouple and flow meters for water and gas streams are essential for an overall systems energy assessment.

In conducting energy assessments, two things are evident: 1) not all of the information data requested in Tables 1-5 is likely to be available and 2) at any site, specific data needs pertinent to the plant systems need to be obtained. From this starting point, however, the specific data requirements for the operations at a specific site can be generated with the cooperation of plant personnel. These issues will be treated below in the specific sections on primary and auxiliary equipment.

In assessing energy consumption, leading to energy conservation, the protocol must include the utility servicing the facility. Power usage, power demand and power quality issues are paramount in effective energy conservation. Active participation by knowledgeable utility company personnel and plant management people in the early plant discussions is essential.

4.3.1 Primary Equipment

The analysis of a plastic processing line requires a study of the overall system from drying the plastic resin to product takeoff. The intent is to:

- Identify inefficient equipment and operations
- Modify procedures for more efficient operation
- Take advantage of low rate power use periods
- Replace inefficient equipment

The power consumed and the efficiency of equipment operations is determined by conducting a thorough energy balance including heat transferred to cooling water and heat losses to the surroundings. For extrusion processing, thermal blankets are used to minimize the heat losses.

The general approach is to identify the team participants, meter the processing equipment and analyze the data collected and recommend improvements. The protocol details for this approach are as follows:

(a) Team formation and planning

- Identify the utility and processor participants
- Define the purpose, analysis techniques and responsibilities
- Identify equipment and obtain nameplate data
- Review plant layout and operational procedures
- Obtain pertinent power rate schedules from the utility
- Identify the availability of instrumentation to measure power usage
- Categorize power consumption for primary and auxiliary equipment
- Plan and schedule the metering of all identified equipment

(b) Metering of equipment

- Train processor's personnel in use of recording equipment

- Set up recording wattmeters to determine total plant power requirement
- Set up recording wattmeters on a typical operating unit
- Record power requirements over a period of time to include start-up and steady operation
- When possible, measure total power required by the primary processing unit and simultaneously measure the power required by the individual motors in the line
- Record total kWh and peak kW demand (average kWh over 15-30 minute interval) for a one month period
- Record total kWh and peak kW demand of a primary processing line
- Identify major contributor to power consumption, e.g. extruder drive motor
- Conduct a total energy balance for the product produced
- Record total kWh and peak kW demand for other equipment in primary processing line
- Record total kWh and peak kW demand for auxiliary equipment
- Determine chilled water usage in primary processing line
- Record equipment operating hours and pounds of product produced during study

(c) Analyze data and recommend improvements

- Study each primary operating unit to characterize power requirements versus the amount of product produced
- Suggest energy cost reduction through scheduling to take advantage of low rate periods
- Discuss energy usage management to reduce peak demand charge

- Suggest conservation by more efficient operation, e.g. reduction of preheat times, more efficient sequence of operations and improvement in operating procedures to reduce downtime
- Adding insulation to reduce ambient heat losses
- Replacement of inefficient equipment
- Capturing excess heat and funneling it for other use

The above protocol includes the use of auxiliary equipment in the operation of the primary processing equipment. Each piece of auxiliary equipment needs an individual evaluation to determine if each is operating at peak efficiency.

4.3.2 Auxiliary Equipment

All equipment that is not directly involved in the melt processing of the polymer is included in this category. Typically, each thermoplastic processing facility will use chiller systems, compressed air systems, resin blenders, air dryers, granulators and post processing equipment to support the primary items. Each utilizes an energy source to operate with the level of energy demand dictated by the operation.

Each piece of equipment is operated as needed to support the primary equipment (e.g., an extruder) as well as other plant needs. Their efficient use is very important in energy conservation measures. The data required for the equipment are listed in Tables 4 and 5. Additional general and specific data needs will be listed under the separate equipment sections to follow.

The general data needed are:

- Start-up/shut-down procedures for the operating cycle and utility peak periods
- Actual power consumption as a function of time and process load
- Control system for partial loads and non process operating periods
- Approach to handling seasonal demand changes. (e.g. impact of cold weather)

- Comparison of overall system efficiency relative to design and to current best practice
- Motor efficiency (as a function of load if possible)
- Power factor and any cost impact
- Control of product use (e.g. compressed air flow)
- System configuration details, including instrumentation.
- Electrical connection diagram
- Nameplate data on all motors, electrical heaters, and fuel users
- Visual inspection of the system

The initial step will include any obvious waste in energy use. To assist in the elimination of waste, a brief general questionnaire is given below. The questions below are aimed at identifying waste sources:

- Is the intensity level of utility the minimum need for the job (e.g., is 120 psig air used when 50 psig would do)?
- Is the consumption measured?
- Are the set points checked regularly?
- Are there visible/audible leaks in the system?
- Are lights and machines turned off when not in use?
- Is a small part of a load setting the intensity level of the entire system?
- Are machines idled or run at low load just to keep them running?
- Is the cooling water too cold in winter?
- Is there a seasonal changeover program?
- Is there a day to night changeover program?
- Are historical practices reevaluated periodically?
- Are burner settings in combustion device checked periodically?
- Is everybody too busy?

4.3.2.1 Chillers

Chiller systems generally produce either a glycol water or pure water product in the temperature range of 35-45°F. The chiller will consist of one or more refrigerant compressors (connected in series, parallel or some mixture of these on the refrigerant), a refrigerant condenser to reject heat to the atmosphere (air or water cooled), a throttle valve, a control system and a product pump(s). The chilled water may be used in extruder cooling jackets or inside screws, but rarely contacts the plastic directly. Usually an intermediate heat exchanger cooling another coolant (water) is interposed between the chilled solution and any product. Thus, the specified additional data needed to evaluate the chilled water use are as follows.

- Chilled water (solution) temperature as a function of time and throughput
- Compressor and pump power used as a function of time and throughput
- Condenser coolant use or power consumption as a function of time and throughput
- For each chilled water exchanger; the chilled water outlet temperature and flow rate, the process side (or machine) inlet and outlet temperatures, and flow rate of applicable coolant
- A comparison of chiller duty versus total power requirement

In evaluating these data it will be important to determine whether a less expensive coolant could have been used in place of the chilled water in any application during all or part of the year.

4.3.2.2 Air Compressors

Air compressor systems generally come in three parts: 1) the compressor itself (generally a screw or reciprocating machine), 2) the compressor cooling

system and 3) an after cooler to condense moisture for the air stream. Often the systems are purchased as a skid mounted package and have minimum instrumentation. In addition to the general data listed in Table 4, the following specific information is needed.

- Variation of compressor power with throughput and integrated consumption over the data period related to process loads
- Total air flow rate corresponding to power measurements and integrated over the data period
- Coolant flow inlet and outlet temperatures and air inlet and outlet temperatures
- Disposition of coolant in summer and winter
- Air flow to major uses and pressure at each
- Amount of water removed in the dryer
- Power consumption in cooler and dryer as a function of throughput

4.3.2.3 Evaporative Cooling Water Tower

These devices operate by cascading warm cooling water over some sort of packing in contact with a counter current air stream. The water is cooled to near the wet bulb temperature of the air by evaporation. The evaporation causes buildup of solids in the recirculated water , requiring a purge. The organic content of water normally requires chemical treatment. The detailed data required to evaluate tower performance are:

- Cold water inlet and outlet temperatures and flow rate
- Wet bulb temperature of the air
- Blow down flow rate and water analysis for critical component
- Fan horsepower over the data period
- Water pump(s) horsepower over the data period
- Control valve pressure drops in cold water system

4.3.2.4 Air Coolers

These devices cool a process fluid by blowing ambient air over the outside of cooling tubes containing the fluid. The outside of the tubes are usually covered with some sort of extended surface (fins) to increase heat transfer. The additional data required are:

- Approach temperature of process fluid to air temperature a function of load, time of day and season
- Fan horsepower as a function of time during data period
- Influence of any performance enhancers, e.g., water spray
- Process fluid flow rate and temperature differential

4.3.2.5 Combustion Devices

There are a myriad of potential combustion devices and a variety of fuels, although natural gas and heating oil are most widely used. Both contain low amounts of sulfur, allowing low stack temperatures. The additional data request to evaluate these devices are:

- Stack temperature and oxygen concentration. Very low oxygen concentration may require a carbon monoxide measurement
- Visual inspection for air leaks into the combustion chamber and heat exchange sections
- Large devices may require additional oxygen measurements in other sections, e.g., radiant, convection, etc.

4.4 Non-process Energy Analysis

Non-process energy is all of the energy involved in maintaining the facility: lighting, heating, air conditioning, ventilation, as well as off-sites operations, such as garages, water treating facilities, etc. Typically, it is 15 - 35% to the total energy consumed. While it is smaller than process energy consumption,

savings are often more easily achieved, such as changing thermostat set points, using more efficient light bulbs, etc.

Some utility companies still have special incentive programs supporting some energy efficiency improvements among their customers. These programs are disappearing due to pending regulation. Higher efficiency in lighting, HVAC, and motors are typical. Help with the installed cost and/or rebates on energy costs are common incentives. In addition, some utilities have incentives for plant expansions. The protocol provides an opportunity for many of these programs to be reviewed and implemented as desired. As deregulation approaches, these services may be modified by the individual utilities and guidance is provided by Turner² who discusses energy management of common building utility requirements.

Most plants do not have the internal metering needed to segregate utility consumption for lighting and comfort conditioning. With help from the utility (e.g., degree day history) an estimate of the consumption can be made. If the non-process energy use is not available, it may be determined by difference between total power and the process power measurements.

An approach to an assessment of non-process power includes:

- Subtraction of identified process and auxiliary utility loads from the total for the various operating and non-operating periods
- Compare winter and summer power consumption from the above calculation
- Identify all users of fuel and power for comfort conditioning
- Compare winter and summer fuel bills taking into account utility degree days information

² Energy Management Handbook, Third Edition, Wayne C. Turner, Fairmont Press, Inc., GA

Small differences in rather large numbers may make this process difficult but can also lead to guidance in locating additional meters.

4.5 Waste Stream Analysis

The waste streams involved in this section include all of the material leaving the plant that is not salable product: solid waste (plastic scrap, waste paper, etc.) and air and water emissions.

Plants that manufacture thermoplastic products do not generate much pollution when compared to most manufacturing processes. Solid waste sent to landfills or incinerators rarely exceeds 2% by weight of total throughput. Emissions to the air and water from processing polyethylene, polypropylene and polystyrene are negligible, and the little that is produced is innocuous. Polyvinyl chloride has the potential for producing some pollutants, particularly (1) if the polymer contains plasticizers and (2) if recommended processing temperatures are exceeded. Also, the emissions, which can contain hydrogen chloride and phthalate plasticizers, can be irritating. But even in this case, emissions are low and easy to control. However, in these assessments, it is important to check that all necessary permits have been obtained and that spot checks be made to make sure operations are within prescribed limits.

This part of the assessment will require at least two specialists - an engineer with knowledge of solid waste disposal practices including recycling and one or two environmental engineers.

Equipment for on-site, waste stream evaluation includes a particle counter and an air sampler, used for air emissions only. For water and solid waste analysis, samples are taken and evaluated in the laboratory.

The particle counter is capable of sampling the air, determining the particle size and recording the data on-site. The air sampler, however, will require the sample to be returned for laboratory evaluation of the chemical constituents and quantity.

Both water and solid material samples are analyzed for chemical

constituents and quantity in the laboratory. The solid waste constituents are leached out, typically in a water solution, for evaluation.

Pollution outputs in thermoplastics processing facilities consist mainly of gaseous emissions (including airborne particulate matter), with wastewater, solid waste and hazardous waste of lesser concern. The important points that must be considered in executing this protocol include:

- The purpose of the assessment is to improve the overall environmental performance of plastic manufacturing facilities and not to perform an environmental compliance audit
- The protocol is targeting small manufacturing facilities of limited resources
- The plastics manufacturing industry has not been regulated heavily in the past and may be fearful of over regulation
- The facility managers/owners may not understand the difference between environmental regulatory compliance and pollution prevention practices
- The facility managers/owners must be assured that some business benefit will result from this assessment

The environmental assessment protocol consists of four distinct steps:

Identification of Current Practices: The purpose of this step is to identify how the facility is currently handling their environmental affairs. The issues range from overall philosophy to employee awareness, incentives, training, waste management plans, recycling and pollution prevention policies, floor practices and regulatory compliance.

(a) **Evaluation of Current Practices:** This step involves a thorough evaluation of all current practices related to environmental issues including adequacy inventory practices, process mass balances, pollution prevention

measures, culture and management and training programs. This evaluation is performed on the basis of data collected in step (a) above.

(b) Improvement Analysis: This step entails an analysis and development of alternatives aimed to improve the current practices in the facility. This may entail the employment of qualitative and quantitative methods for obtaining missing data and the development of pilot programs to try out the implementation of new alternatives.

(c) Improvement Recommendations: This step entails the formulation of specific recommendations and implementation plans for achieving better environmental performance.

4.5.1 Air Emissions

Primary gaseous emissions are in the form of point source releases discharge discharged into the atmospheric air by means of stacks. Emissions in thermoplastic processing are well below the national average of all industries in the U.S.

Decentralized HVAC exhausts are the primary vehicle of emissions. Airborne particulate matter represents a potential non-specific pollutant. Depending on their size airborne particulates can be transferred at a considerable distance from the source by advective air transport. Gravitational settling (dry deposition) and atmospheric precipitation (wet deposition) are the primary mechanisms for contamination of downwind land and water resources.

The steps involved in assessing air emissions can be summarized as follows:

- Examination of permitting and compliance requirements (centralized vs. specific equipment permits, air emission limits, etc.)
- Identification of primary emission (VOCs, particulate matter, etc.)

- Identification of primary and secondary point source releases (i.e. Stack, HVAC system)
- Air pollution control devices (type, function and capacity)
- Quantification of point source releases
- Fate and transport issues associated with point source emissions
- Identification of process and practice specific fugitive emissions
- Quantification of fugitive emissions
- Identification of pertinent monitoring parameters and monitoring schedule
- Analysis of monitoring data
- Fate and transport issues associated with fugitive emissions
- Occupational health Implications
- Existing personnel training in waste minimization/pollution prevention practices
- Identification of waste minimization/pollution prevention opportunities
- Recommendations

4.5.2 Wastewater

Contaminated wastewater streams represent another concern of the plastics industry. Of the EPA estimated 10,260 plastic molding and forming plants approximately 18.5 % have wet processes with direct or indirect discharges. Major water demanding activities include: 1) heating or cooling of plastic products, 2) cleaning of plastic products and production equipment, and 3) finishing of plastic products.

During molding and forming operations heating or cooling water comes in direct contact with raw materials or products for heat transfer purposes. In such operations contaminants may be transported from the plastic matrix into solution thus contaminating the water stream. Most facilities claim that contamination of heating or cooling water is so small that makes discharge

permits unnecessary. There is not much literature to substantiate or confront these claims, although presence of the bis(2-ethylhexyl)phthalate has been reported in facilities processing plasticized polyvinyl chloride(PVC).

Cleaning water includes water used for cleaning product surfaces as well as process equipment. Conventional [biochemical oxygen demand (BOD), oil and grease], total suspended solids (TSS), pH, non-conventional chemical oxygen demand (COD), total organic carbon (TOC) and priority pollutants (total phenol, phenol, zinc) can be transported into cleaning water streams at treatable concentrations.

Finishing water is used to improve the palatability of the final plastic product. TSS and a variety of phthalates (bis(2-ethylhexyl) phthalate, di-n butyl phthalate, dimethyl phthalate) are common pollutants identified in finishing water streams.

The steps involved in assessing wastewater streams are described below:

- Data collection (water bills, sewer charges, etc.)
- Permitting and compliance requirements
- Identification of contaminants of primary concern
- Identification of potential wastewater generating processes and practices
- Open- and closed- water utilizing loops with associated water consumption
- Quantity/quality of generated wastewater streams
- On-site treatment facilities (description of processes and related efficiencies)
- Monitoring and analysis schedule
- Data analysis
- Existing waste minimization/pollution prevention practices and associated personnel training

- Waste minimization/pollution prevention opportunities
- Recommendations

4.5.3 Solid Waste

Solid releases are an additional concern of the plastics industry. Solid releases include pellets, granules, and powders. Other formulations of plastics used as raw materials, for intermediate or final plastic products, are often lost as floor sweepings during various handling operations. Although reuse of such materials is to the best interest of plastics industries, contamination of these materials with other impurities makes wasting an effortless alternative. The same is applicable for finished end products if care is not exercised to avoid contamination of cutoff and other scrap pieces. Although most plastic products are chemically inert, uncontrolled release to the environment by means of wind or runoff transport may cause harmful effects to sensitive ecosystems. In most plastics facilities solid releases are collected by solid waste contractors and are subsequently either incinerated or disposed off to landfills. Pollution prevention opportunities are ample for this waste stream and can result in measurable savings for the industry.

The steps involved in assessing solid waste materials can be summarized as follows:

- Data collection (floor plans of raw materials and products storage areas, types/quantities of raw materials and products, waste disposal contracts and bills, etc.)
- Permitting/compliance requirements
- Identification of primary and secondary solid waste disposal practices and associated contractors
- Quality and quantity of solid waste associated with raw materials (empty containers, packaging waste, defective raw materials, etc.)

- Identification of process (size reduction, blending, extruding) related solid waste and associated quantity and quality of process scrap
- Existing recycle/reuse practices and associated quantities
- Identification of practice (floor sweeping, cleaning, packaging, etc.) related solid waste and associated quantity and quality
- Quantity and quality of office waste
- Existing recycle and reuse practices and associated personnel training
- Development of a solids mass balance
- Waste minimization/pollution prevention opportunities
- Recommendations

4.5.4 Hazardous Waste

The Environmental Protection Agency (EPA) has defined hazardous waste as those with chemical activity, toxicity, explosivity, corrosivity or other characteristics which can cause damages to health and/or the environment. The EPA lists those chemicals which are known to be harmful; the existence of which is the basis for concern.

Hazardous waste can be generated in plastics processing facilities either in the form of chemicals used in primary process operations or in secondary activities such as cleaning and degreasing. For thermoplastic processing, hazardous materials are typically additives as pigments, plasticizer or other modifiers added to the base polymer. Use of hazardous ingredients is generally avoided because of their known harmful nature. Also, characterized as hazardous are solvents used to clean equipment, mixing and blending vessels and other appurtenances, and petroleum products used in equipment operations.

The steps involved in assessing hazardous waste materials can be summarized as follows:

- Data collection (permits, regulatory requirements, TSDF contracts and bills, etc.)
- Identification of processes utilizing hazardous materials
- Identification of practices utilizing hazardous materials
- Hazardous materials inventories
- Process related hazardous chemicals generated (type, state, and quantities)
- Practice related hazardous chemicals generated (type, state, and quantities)
- Existing waste minimization/pollution prevention practices and associated personnel training
- Waste minimization/pollution prevention opportunities
- Substitution of a less hazardous chemical
- Recommendations

4.6 Product Development

Many of the environmental issues involved with a plastic product are set when the product (and associated tooling, etc.) are designed. For example, the design includes such factors as the nature of the plastic to be used (thermoplastic or thermoset); polyolefin or PVC, etc); the intended use of the product (re-usable or single-use), etc. Also, tooling design can influence the amount of scrap generated and regrind needed.

All of these factors and more are dealt with in an emerging discipline called "Design for the Environment" (DFE). Once a designer begins to think about how the design decision made can effect the environment, incorporating DFE principles in design is relatively straightforward. In these assessments, the design of the product being produced should be reviewed by a plastics engineer familiar with DFE. The effect normally is between 0.5 and 2.0 days

unless a complete redesign is necessary.

The protocol used in assessment of overall life cycle management for a product is complex and extends from the materials manufacturer, to product manufacture to the final disposition after use (Figure 1). For product manufacture, the considerations in the assessment will vary depending on the responsibility for product design and the selection of the materials and manufacturing processes.

Initially, it is necessary to determine the responsibility of the processor in the product design followed by discussions with the processor using questionnaires (Table 9 and 10). The discussions will ascertain the basic knowledge of life cycle principles in 1) the development or design of the product and in the processing of plastics and 2) and how these principles are implemented in daily operations as outlined in the following paragraphs.

4.6.1 Product Design

In concurrent engineering practices, the product developer is responsible for the overall product design, materials selection, the processing interface and consumer satisfaction. The questionnaire listed in Table 9 contains a protocol to evaluate the 1) developer's understanding of life cycle management principles and 2) the extent of influence the product developer has in waste management related to plastics processing and post consumer use. If the processor participates in the development of the product or is the developer, the protocol also requires a response to the questionnaire.

Included in product design issues are the energy conservation and pollution prevention issues associated with processing operations, product packaging and its disposal, and the disposal of the product at the end of its useful life. The protocols for pollution prevention presume that for each issue there is an acceptable, cost effective solution. The assessment protocol should address the availability of solutions to environmental issues.

4.62 Plastic Utilization

Effective utilization of plastic materials in product manufacture requires planning for the acceptance of the virgin plastic, the expectation of product nonconformance to specifications and the excess plastic fragments that is a normal part of the process. The assessment protocol of a facility, illustrated in Figure 6 (See page 36), focuses on the practices of handling plastic scrap.

The handling of plastic scrap and/or regrind can take paths which allow for its reuse, the sale as regrind, or direct disposal into waste disposal repositories. The protocol emphasizes overall materials inventory control and disposition. The protocol should establish whether the least costly route is taken and if it is weighed against potential environmental problems.

5.0 Guidelines for Report Preparation

The assessment reports that this protocol is designed to produce have two main objectives.

- (a) Internal: The report is to help plant management to reduce costs, to improve plant operations, and to address issues relating to the impact of the plant's operations on the environment.
- (b) External: The report is also to be used to add to the growing body of information on the impact of plastics processing on resource utilization and pollution prevention.

To meet objective (a), the report must be concise and specific, describing current operations quantitatively, identifying potential savings and operating improvements, and where possible, suggesting solutions.

To meet objective (b) an addendum or summary report must be produced that meets the following criteria:

Figure 6

Plastic Materials Utilization

- It must be coded so that the individual plant and company cannot be identified
- Data must be summarized and presented in a standardized form so that it can be combined with data from other firms in a master data base
- Plant management must sign-off that the results are valid

5.1 Internal (Items for Plant Management)

(a) Description of Work Done

This section should contain information on what measurements were made, how they were done, and the level of effort employed.

(b) Findings and Analysis

This section should describe what was learned about plant operations, including any analysis made of the data.

(c) Appendices and References

This section should include background and explanatory material, and also direct plant management to relevant literature that would help in the event that they wish to continue further work.

5.2 External (Items for Disclosure to Outside Sources)

This should be a supplement to the Internal report that will enable the information obtained to be made useful to the industry at large, which will not damage the assessed company short term, and long term, by increasing overall industry efficiency, should be a benefit. The major items in the report should be:

- Summary data tables, showing energy and electricity consumption per pound and per sales dollar, scrap rates, company operating data, etc.

- Summary of conclusions and recommendations
- Any important references and appendices

6.0 Plans

Future activities on this program have two components:

(a) Implementation of Current Findings

Even though the development of this protocol is still in its infancy and draws on a very narrow data base, there are prospects for using and extending it within the framework of existing budgets and programs in the State of New Jersey.

Subject to review of its management, the New Jersey Manufacturing Extension Partnership (NJMEP), a joint program of the State of New Jersey and the National Institute of Science and Technology, plans to assign manpower to introduce the protocol to New Jersey plastics firms and test its acceptance.

Also, in the event that the program with NJMEP proceeds, an attempt will be made to integrate these operations and the data produced with the on-going activities in Energy Conservation and Pollution Prevention funded by the Department of Energy and centered at Rutgers University in New Brunswick, New Jersey.

(b) Extending and Improving the Protocol

The program just completed barely scratched the surface on the work that needs to be done. Key additional tasks are:

- Additional assessments in extrusion and compounding
- Inclusion of other plastics processes, particularly injection molding, thermoforming, and blow film injection moldings, thermoforming, blow molding and blow film manufacture.

- Extension to industries other than plastics
- Funds for (b) are not now available. Should program (a) proceed, funds for (b) will be sought from a number of sources, including the DOE, EPA, Society of the Plastics Industry and the Electric Power Research Institute.

Table 1

Facility Profile Information

General:

- Facility Name
- Location
- Standard Industrial Code (SIC)
- Number of years in operation
- Number of employees
- Total sales (\$/yr.)

Operations:

- Operating shifts per day (# and hr.)
- Days of operation per week
- Type of operations (extrusion, thermoforming, etc.)
- Plastics processed (PVC, PS, PE, etc.)
- Quantity of plastics processed (lb./yr.)
- Products manufactured

Plant Facilities:

- Number of buildings
- Total plant floor area (sq. ft.)
- Total process area (sq. ft.)
- Total storage areas (sq. ft.)
- Total office area (sq. ft.)

Energy Consumption:

- Electrical power consumed (kWh/yr.)
- Electrical power demand (average kW/month)
- Electrical power cost (\$/yr.)
- Other energy costs (Type and \$/yr.)

Equipment Capabilities List:

- Primary process equipment (Type, number and size)
- Auxiliary equipment (Type, number and rating)

Table 2

Plant Energy Supply and Load Data

Electrical Power

- Total plant load (voltages, power factor and transformer locations)
 - Maximum, minimum (kW)
 - Split among process equipment, heating, lighting and HVAC,
 - Share of total plant energy cost resulting from electricity
- Utility contract details
 - Rate schedule
 - Description of utility peak and off-peak periods
 - How demand charge is defined (ratchets, etc.)
 - Copy of load management plan
 - Energy charge, fuel surcharges, taxes
 - Power factor requirements and charges
 - Utility incentives (discounts, rebates, etc.)
 - Seasonal factors
 - Special conditions (Curtailment, real time pricing, etc.)
- Power self generated by plant or third party
 - Description of system (thermal and power load)
 - How controlled and integrated with utility supply
 - Capacity Utilization
 - Limitations
 - System service factor(percent downtime and back-up)
 - List of electrical loads: supply voltage, kva, power factors, and operating cycles

Combustion Processes

- Fuels used, percent sulfur, costs, source, rate schedule
- Share of total energy costs
- List of combustion devices and fuel consumption
 - Stack/exhaust temperature
 - Percent oxygen in exhaust
 - Combustion air preheat
 - Process/water side temperature range (or steam conditions)
- Rate schedules, incentives and penalty clauses

Table 3

Primary Equipment Description and Information

Extruder System:

- Make and model
- Screw size (dia, L/D)
- Throughput (lb./hr nominal)
- Type of operation (profile, sheet, etc.)
- Extruder drive (Hp, v, a, pf) efficiency
- Motor (takeoff, gear pump, etc.: Hp, v, a, pf) efficiency
- Heaters (barrel, die: kW)
- Plastics processed
- Operating procedures (start-up, running and shut-down)
- Equipment startups per week
- Product changes per week
- Average percent of capacity run (max. %, min %)
- Status of equipment during shutdown
- Description of system and products produced

Injection Molding Machines:

- Make and model
- Shot size (oz ps)
- Tonnage
- Motor (Hp, V, a, pf) efficiency
- Equipment startups per week
- Product changes per week
- Average percent of capacity run (max. %, min %)
- Status of equipment during shutdown
- Description of machine and products produced

Other:

- Make and model
- Rating parameters
- Motor (Hp, V, a, pf) efficiency
- Equipment startups per week
- Product changes per week
- Average percent of capacity run (max. %, min %)
- Status of equipment during shutdown

Plastics processed:

- Supplier
- Grades

- Specifications

Table 4

Auxiliary Equipment Description and Information

Equipment Types:

- Dryers
- Chillers
- Evaporative cooling towers
- Air compressors
- Granulators
- Blenders
- Heat exchangers
- Conveying systems
- Other

General Equipment Data (all items):

- Make, model and nameplate data
- Motor specifications (HP,A,V)
- Operating procedures (start-up, running and shut-down)
- Control system to meet load and seasonal changes
- Design system and motor efficiency for process loads
- Power factor and cost impacts
- Control of product use (e.g. compressed air flow)
- System configuration details (including instrumentation)
- Electrical connection diagram

Table 5

Specific Auxiliary Equipment Requirements

Chiller Systems

- Refrigerant, product material (e.g., water, glycol-water) and design temperature
- Number of compressors, control scheme, series, parallel or mixed lineup
- Condenser type, cooling medium, design temperatures
- Product pumping arrangement
- List of product uses and flows to each
- Design kW/ton refrigeration at design temperature

Air Compressors

- Design discharge pressure and temperature
- Product cooling system details, medium, exhaust temperature and disposition of coolant
- Air dryer system details and specifications
- List of air uses and flow rates to each

Dryers

- Drying medium, inlet temperature and purity specifications
- Inlet and outlet product water content
- Source of energy and control system

Evaporative Cooling Systems:

- Total flow rate of cooling water
- Type (e.g. recirculating or once through, contact etc.)
- Design cooling water temperature, actual temperatures, seasonal variations, approach to air wet bulb temperature
- Water pump power, driver type
- Fan power, driver type
- List of exchangers and types, along with process and utility side temperatures for each and water flow rates for each
- Description of chemical treating scheme and cost

Air Cooling Systems

- Air flow rates, exhaust temperatures
- Power source, consumption
- Type (contact, extended surface, heat pipe, etc.)
- Seasonal changes in fan operating practices

Table 6

Air Emissions Information and Data

General

- Is an inventory of air emission sources available for the facility?
- Are process diagrams showing emission points available?
- Are air flow rates available for each emission point/source?
- Are emission rates computed or measured?
- Are there any air emission permits required for the facility (state, local)?
- Is the facility in compliance with air permit requirements?
- Is there any air monitoring program required for the facility?
- Is air monitoring taking place?
- Is annual emissions reporting required?
- Does the facility use any ozone depleting substances?
- Is the facility using solvents or other degreasing agents that are potential source for hazardous air pollutants?
- Are any emissions capture or control devices used in the facility?
- Are any emission control devices required by facility permits?

Emission Sources (to the atmosphere)

- List types (Vent, Stack) of air emission sources
- Estimate discharge rate per type (scf/min)
- List air pollution control devices (type, and capacity)

Emission Sources (indoors)

- List indoor air pollution sources
- Estimate discharge rates per source
- List air pollution control devices (type, and capacity)

Air Quality Monitoring

- Air Emissions Permits (Permit Number)
- Programs implemented to reduce overall process emissions

Table 7

Wastewater and Solid Waste Information and Data

Wastewater

- Identify water supply source
- What is the total water usage (gpd):
- Determine quantity (gpd) of water used in process areas (open loops)
- Determine quantity (gpd) of water used in process areas (closed loops)
- Determine quantity (gpd) of water used for cleaning/washing
- Does the facility have wastewater discharge permit(s)
- Does the facility have a wastewater treatment plant on site? If yes, describe wastewater treatment method.
- What is the total amount of wastewater discharged (gpd)?
- What is the wastewater discharge method?
- Does the facility have a wastewater monitoring program ? What are the parameters monitored?

Solid Waste

- General
 - Does the facility have a solid waste minimization program in place?
 - Does the facility recycle process scrap materials?
 - Is process scrap reused in house?
 - Is process scrap shipped to any other facility for reuse?
 - Are recycled plastics used in the facility as raw materials?
 - Is material balance for each process stream?
 - Is an overall material balance performed facility wide?
 - Is any scrap generated from composite materials processing?
 - Is processed scrap blended with virgin raw material before reprocessing?
 - Does the facility keep records of polymeric materials being shipped out as waste?
 - Does the facility keep records of solid waste shipped out (other than polymeric materials)?
 - Does the facility recycle packaging materials?
- Solid materials
 - List polymer type and quantity processed
 - List other raw materials
 - List raw materials waste (related to operational practices)
List process scrap materials (type and quantity)
 - List process scrap materials re-processed on-site and/or shipped off-site for reprocessing (type and quantity)
 - List process scrap materials shipped out as waste (type and quantify)

Table 8

Hazardous Waste Information and Data

General

- Does the facility generate any liquid hazardous waste?
- Does the facility generate any solid hazardous waste?
- Does the facility have a written hazardous material handling plan?
- Does the facility have a written hazardous waste minimization plan?
- Does the facility have a hazardous material reuse/recycling plan?
- Does the facility have a current hazardous materials substitution plan?
- Does the facility treat any hazardous waste on site?
- Does the facility use solvents for cleaning equipment?
- Does the facility use more than one type solvent for cleaning equipment?
- Does the facility have any vapor collection/treatment devices to minimize VOC emissions from solvent cleaning operations?
- Does the facility keep an inventory of all hazardous materials purchased?
- Does the facility keep records of individual hazardous wastes from point of generation to disposal?
- Do R&D activities in the facility generate hazardous solid or liquid wastes?
- Are hazardous wastes disposed of in accordance with federal and state regulations?

Hazardous Materials Used in Production

- List of hazardous materials used
- Estimated quantity used

Other Hazardous Materials Used (not process related)

- List of hazardous materials used
- Related use of materials

Hazardous Waste Shipped for Disposal

- List type and quantity of liquid waste shipped
- List disposal facilities used

- List other solid waste (packaging, office, etc.)

Table 9

Life Cycle Product Design Issues

Product Life Cycle Management

- Understanding overall product life cycle management concepts
- Considerations as part of the product development requirements
- Consideration of environmental issues during product design
- Development staff familiarity with of de-manufacturing concepts
- Consideration for the disposal of the product following it useful life
- Guidance by material suppliers on post consumer use of materials

Product Design

- Development group responsibility for choice of product materials
- Customer influence on the selection of product materials
- Influence of environmental issues on product and process materials used
- Awareness of material ingredients (fillers, colorants or other additives)
- Awareness of ingredients known to environmentally harmful
- Planning actions for post consumer use or disposition

Processing

- Responsibility for specifying methods of processing for the product
- Awareness of the energy used for processing methods to be used
- Awareness of the process scrap levels generated for processing methods
- Consideration for reuse of scrap with the raw material in the product
- Alternatives for the use of scrap if not acceptable for the product
- Material suppliers guidance on reuse or disposal regrind
- Responsibility for specifying the method of packaging the product

Plastic Scrap Utilization

- Consideration for disposition of plastic scrap waste
- Cost considerations in minimizing material waste
- Environmental considerations in minimizing material waste
- Consideration given to the disposal of product packaging following use

Table 10

Life Cycle Manufacturing Issues

Product Life cycle management

- Understanding overall product life cycle management concepts
- Considerations made as part of the product process requirements
- Consideration of environmental issues during process development
- Guidance by material suppliers on post process use of materials

Product Design

- Role of the processor in the choice of product and process materials
- Awareness of material ingredients (fillers, colorants or other additives)
- Awareness of ingredients known to environmentally harmful

Processing Procedures

- Role of product developer in specifying manufacturing processes
- Capability for secondary processes (painting, coloring, or labeling)
- Identification of process scrap levels to be generated in processing
- Consideration given to reuse of process scrap prior production
- Role of processor in specifying the method of product packaging
- Consideration given to the disposal of the packaging materials after use
- Types of other process materials used in manufacturing
- Existence of raw material inventory with current quantities specified

Plastic Waste

- Identification of scrap to be discarded as waste prior to production
- Provisions for disposal of scrap waste prior to the planned production
- Considerations for recycling or selling of waste materials