

**Technical Report #3**

**Feasibility Study:  
Use of Discarded LDPE Shrink-Wrap from  
Boatyards as an Injection Molding Feedstock**

August 1998

# **Feasibility Study: Use of Discarded LDPE Shrink-Wrap from Boatyards as an Injection Molding Feedstock**

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## **Chelsea Center for Recycling and Economic Development Plastics Conversion Project**

August 1998

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## **1. Abstract**

Low density polyethylene (LDPE) shrink-wrap film, discarded after over-winter use for protection of large boats, was demonstrated to be an appropriate and desirable feedstock for the molding of commercial products. Technical barriers to recycling were identified and circumvented, and a concept for portable equipment for in-situ conversion of discarded film to directly usable molding feedstock is presented. In addition to providing a commercially desirable source of feedstock, application of the results of this study should have a major positive environmental impact. An anticipated benefit is mitigation of a serious waste disposal problem experienced by hundreds of boatyards. Additional potential for creation of a new sub-industry to collect, preprocess and transport feedstock is identified.

## **2. Background**

In the course of providing improvement services to local manufacturers, project managers of the Southeastern Massachusetts Manufacturing Partnership (SMMP) identified needs in two disparate industries:

1. Numerous boat builders with boat storage facilities expressed the need for help with disposal of shrink-wrap film removed from boats stored over the winter.
2. SelecTech Inc., in Taunton, MA, uses proprietary injection molding technology for producing robust products from used plastics. SelecTech needed a suitable (preferably local) source of LDPE feedstock. Additional information on SelecTech and their products is available in Appendix A.

In order to test whether both industries' needs could be met through using discarded boat-wrapping film as an injection molding feedstock, SMMP received financial assistance from the Chelsea Center for Recycling and Economic Development through its Plastics Conversion Project. Assistance was granted to characterize the composition variance, condition, and availability of used LDPE shrink-wrap film and to devise means of overcoming barriers-to-use associated with a wet, contaminated, bulky source material. Additional process assistance in shredding, drying, densifying, blending and molding the material was also supported.

### **3. Scope of Work**

This project was structured as a set of four discreet, but temporally overlapping, tasks, followed by generation of this report.

**Task 1:** Characterize source material, identify technical challenges associated with source material supply and acquire samples for testing

**Task 2:** Identify and perform tests to define specific preprocessing requirements – including ratio for blending with other recycled materials if required.

**Task 3:** Perform molding runs to produce commercial product samples

**Task 4:** Identify and recommend appropriate preprocessing equipment and identify appropriate location for preprocessing (at source or at consuming site).

### **4. Description of Work Performed by Task**

#### **4.1 Task 1: Source Material Evaluation**

##### **4.1.1 Boatyards and Boat Storage Facilities**

Over twenty boatyards and boat storage facilities along the Massachusetts coastline from Cape Ann to Dighton were contacted; ‘Yard Managers’ were visited and interviewed in person, if feasible. One of the Yard Managers represented fourteen separate storage facilities in Massachusetts. The vast majority of respondents identified the disposal of shrink-wrap removed from boats in the spring as one of their major operational problems.

##### **4.1.2 Raw Material Description**

The material under study is Low-Density Polyethylene (LDPE) shrink film, used in boat yards to protect boats from climactic and weather damage during storage. Shrinkable film is stretched immediately after formation, and is then chilled to “freeze” the stress. Application of heat induces stress relief, and the material shrinks back toward its as-extruded dimensions. Wholesale suppliers describe the shrink film they supply as “100% virgin resin” in 6 and 7 mil thicknesses, with “maximum UV inhibitors.” The virgin material is purchased in rolls, which vary by length, width and color. The rolls of film available for this project were of several different sizes. The smallest piece was 12’ x 75’ x 0.006” thick, and the largest piece was 40’ x 100’ x 0.007” thick. The colors were white, blue, a mix of blue and white (co-extruded), and clear. By a substantial margin, the predominant color in use is white. This predominance is for two reasons. First, the white film reflects solar infrared energy, as opposed to clear films which “turn the boat into a hothouse”. Second, the white, opaque pigmentation inhibits solar degradation of the boat’s finish. All testing was performed using samples of the white film, which contains titanium dioxide as the white pigment and opaquing agent.

### **4.1.3 Typical Application**

Whenever possible, a single piece of film is used to cover the top and sides of the boat. Splices are sealed with a shrinkable plastic tape. A belt made from glass reinforced draw cord is wrapped (over the film) around below the waterline of the boat and tightened. The film hangs below the cord enough to be folded back against itself to form a 'hem', thereby trapping the cord. Heat is next applied to the doubled film, which bonds the two thicknesses of film together to close the 'hem'. This ensures that the cord will not slip or be pulled off during application of the hull bands. The hull bands are tied to the draw cord, passed under the boat, and then tied to the draw cord on the opposite side. (See Figure 1.) This ensures that the film will not be blown from the boat or removed easily by winter weather, snow loading, or transportation. Once the film is secured, a propane-fired hot air unit is used to shrink the film until it is pulled taut against the boat, thus sealing it against the elements.

### **4.1.4 Wholesale Material Supply**

Dockside Marine of Warwick, Rhode Island, is one of the larger wholesalers of boat wrapping products on the New England coast. The manager of their "Dr. Shrink" program provided a list of their boat protection products, including shrink wrapping film, shrink tape, propane-fired heat tools and strapping materials, as well as a shipping-prepaid bag for recycling. A copy of their product information is in Appendix B.

### **4.1.5 Changes During Use**

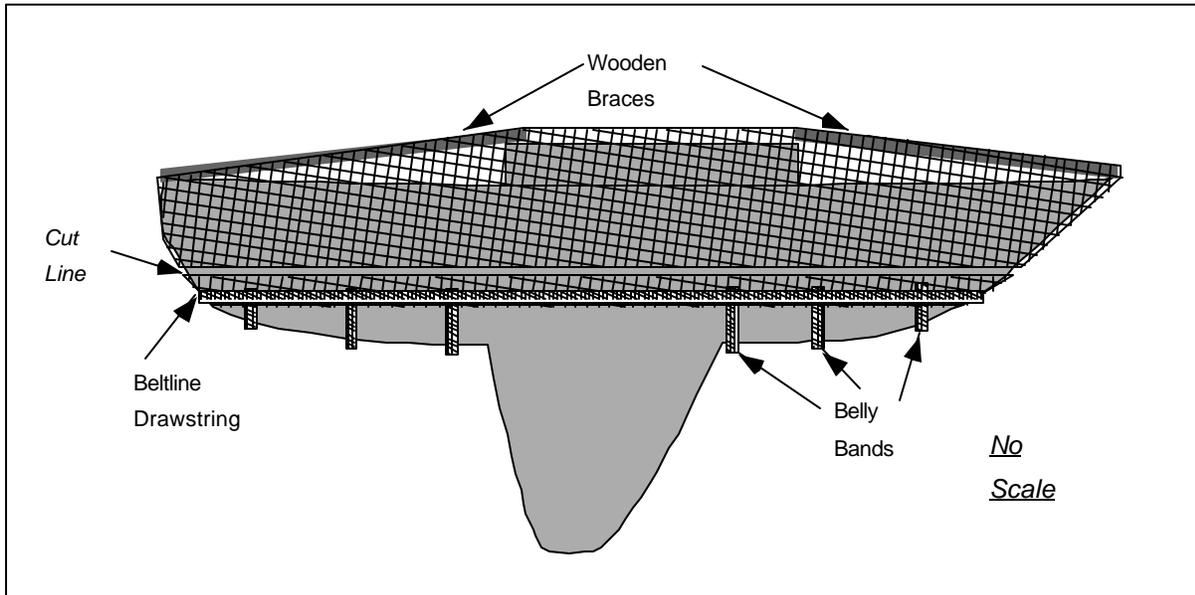
Samples of film ranging from new (on the roll) to "three years' exposure" were examined and collected. Aside from slight yellowing, the latter sample differed from virgin material only by exhibiting slightly increased stiffness and notably reduced tear strength. The predominant changes that occurred in the used film seemed to be due to localized overheating as a result of heat applied to shrink the material to the contours of the boat. In a few extreme cases, holes existed where the film had been overheated while being shrunk.

### **4.1.6 Contaminants Encountered**

Because most samples were retrieved after the area had been deluged with rain, the expected salt spray residue was not observed. As expected, both moisture and soil contaminants were present. Fortunately, the slick and hydrophilic surface of the plastic film sheds water well, and sand is easily shaken off when the surface is dry. One observer noted occasional spatters of paint, but paint did not appear to be a significant contaminant.

All boatyards surveyed use cord or strapping to tie the plastic film around the hull below the waterline (like a drawstring), and for 'bellybands' which attach to the 'beltline drawstring' on opposite sides of the hull and are tensioned underneath to keep the cover snug. A minority of boatyards use a woven thermoplastic cord for this purpose, which can be recycled with the film itself. Unfortunately, the majority of tiedown and strapping material encountered was fiberglass-reinforced strapping tape. Processing of the fiberglass along with the film was not practical with available equipment, so cording/strapping was considered to be a contaminant for purposes of this study.

Fortunately, as indicated in Figure 1, separation of the fiberglass tape from the bulk of the film is easily accomplished by making a cut in the plastic around the boat, immediately above the “beltline drawstring”. When the cut is complete, the fiberglass-filled strapping, including “bellybands,” drop to the ground. When thus separated, items such as tensioning buckles and re-usable strapping can be readily recovered.



**Figure 1**  
**Wrapped Boat with Method for Removing Fiberglass Strapping**

#### 4.1.7 Boatyard Disposal Strategies

As early as March in New England, boatbuilders, marinas, and boat storage facilities start removing the covers from boats. The material is currently rolled up, folded or discarded in a heap for eventual disposal. Several methods are currently employed to deal with the film disposal issue. As described by various Yard Managers, they include:

- “We re-use as much film as we can easily salvage -- and dumpster the rest.”
- “We just put it in the dumpster.”
- “We pre-shrink it (with propane heat guns) and then put it in the dumpster.”
- “We pay to have it hauled *and then* pay to put it in the landfill.”
- “We give it to employees to haul away.”
- “We require the boat-owners to dispose of it.”
- “Re-Bag”: Shipment-prepaid bags for shipping film to recyclers. Cost of bagging materials and labor for a boat longer than 28’ exceeds \$100. (See Attachment B)
- Several Yard Managers along the Wareham to Westport coastline claimed to have minimal problems with disposal because they employ a wrapping/unwrapping service. This service, which operates out of Mattapoisett, provides all materials, wraps the boats in the fall, then returns in the spring, unwraps the boats, and disposes of all waste materials. The owner of this service claimed to be the largest single purchaser of boat wrapping materials along the southern Massachusetts coast.

He employs his own trucks for scrap film disposal, but observed that the bulkiness of the film impairs his hauling efficiency. He is also required to pay a landfill fee of \$20.00 per truckload to dispose of the materials. The owner of this wrapping service expressed serious interest in delivering waste plastic directly to the SelecTech facility in Taunton in lieu of landfilling. He was also actively interested in the concept of a transportable pre-processing unit to reduce the waste film bulk on site and increase his transportation capacity and efficiency.

On the other hand, boatyards in the Cape Ann area reported having used a similar wrapping and disposal service in the past, but had abandoned it because of scheduling problems. It is believed that this was a function of the particular wrapping service's management, rather than a fundamental flaw in the wrapping/disposal service concept.

#### **4.1.8 Logistical Considerations**

Seasonality: One major impediment to using film removed from boats after winter storage is that it constitutes a material supply that is available in reliable volume only over a relatively short time span each year. In New England, weather permitting, boats begin to be uncovered in March, and most boats are uncovered and in the water by Memorial Day. To exacerbate the "peakiness" of supply volume, boats are rarely unwrapped under inclement weather conditions. As occurred during the sample-collection phase of this study, there were extended periods of rainy weather, followed by furious outdoor activity at the boatyards. Consequently, the vast majority of boats unwrapped in May 1998, were unwrapped during two separate two-day "sunny spells".

In order for film to serve as a viable molding feedstock, it must be converted into a densified form that can be stored at the molding facility and used as feedstock on a time schedule dictated by production demands, rather than by vagaries in supply availability. The discussion of transportable, on-site pre-processing equipment below addresses this issue.

Bulkiness: Even with considerable expenditure of labor to roll, fold, or otherwise reduce the bulk of the huge pieces of film removed from large boats, transportation of discarded film is very inefficient. Without further processing to reduce the bulk, storage of the material as a molding feedstock is impractical.

A test was conducted to determine the maximum shrinkage of the material under controlled conditions. The objective of this test was to determine if on-site shrinking of the waste film would enhance the collection of the film by reducing its volume. An oven was set to 350 degrees. A small piece of film 6" x 10" was placed in the oven at 350° F for 2 minutes. The material reduced in size by 70% and then stopped shrinking. This is a good indicator that waste film could be reduced in size on-site and then transported for processing.

Acquisition of Samples: Approximately 350 - 400 pounds of white, LDPE shrink film was collected from two marinas — one on the North Shore and one on the South Shore of Massachusetts. All of the materials exhibited similar amounts of contamination, including sand from the boat yard, rain water, and paint. Most samples still had the fiberglass-reinforced draw cord attached.

Considerable labor was expended by SelecTech to remove the fiberglass cord and to dry the material prior to processing.

The film was very awkward to handle. It was often found in a pile, tangled with several other LDPE film covers. The material was dirty to handle and very difficult to pack. Corrugated “Gaylord” boxes measuring 48” X 48” X 48” (attached to wooden skids) were used for ease of packing. The untreated corrugated cardboard proved to be a dubious choice for transport of wet film. Some samples of the material had been neatly folded after removal, and were easier to handle and pack into the boxes or truck bed. The waste draw cord was the material of choice for tying bundles. There are, as yet, no defined techniques to remove film from boats. Labor is expensive and the boat is obviously the main concern. The film is cut where it needs cutting in order to remove it in the quickest manner. When reclaiming the film, removing the cover by cutting it around the boat, just above the draw cord, would be both desirable and time saving. Commercially available slitting knives designed for operator safety and boat protection have been identified.

Material Overview: As mentioned earlier, the material used in boat yards to cover and store boats is an LDPE material of *fractional melt flow* (melt index). A *melt flow* or *melt index* is the rate at which molten resin flows through a die of a specific length and diameter under prescribed conditions of temperature and pressure. Values of melt flow are reported at prescribed test conditions. Higher molecular weight materials are more resistant to flow. Polyethylene films, like those in the test, are characterized by toughness, near zero moisture absorption, excellent chemical resistance, low coefficient of friction and ease of processing. Low-density materials have a melt index of 0.92 - 0.94. These films are quite flexible, with high impact strength and relatively low heat resistance. Observed shrinkage was 70% by area.

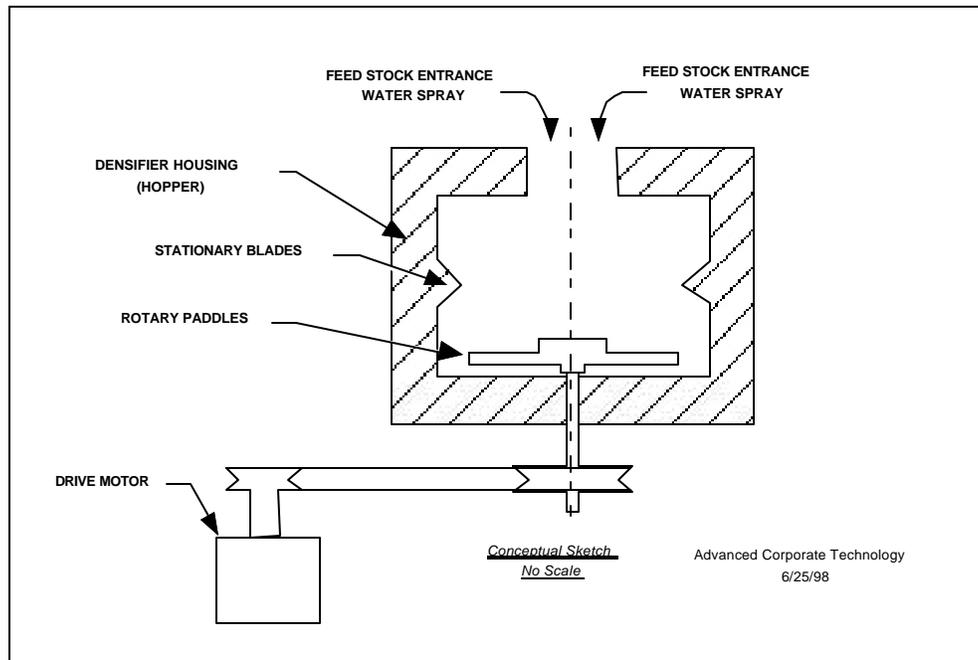
LDPE shrink films are developed using a blown film process. Plastic melt passes through a die that forms it into an annular shape, then air is introduced to create a bubble. The bubble cools the material in the stretched condition. The stretched material is then pinched between rollers to create the film. The bubble diameter varies in ratio between 1:2 - 1:4 times to create the stretched material, as well as orientating the material to improve the properties. The film is cooled in this state of tension. When reheated, the film shrinks back to its relaxed, or annealed, stress-free condition.

## **4.2 Task 2: Preprocessing Experiments**

### **4.2.1 Densifying**

After the waste LDPE shrink film was collected and delivered to SelecTech, several tests were conducted to determine optimum processing conditions to prepare the material for injection molding.

The process that was used to reduce the film to moldable-sized granules is called *densifying*. Densifying is still considered an art when used with water and on older equipment, such as the unit used for this test. (Figure #2)



**Figure 2**  
**Densifier Schematic**

The densifier is round with a flat bottom and has a small opening at the top. The unit can hold about 50 pounds of material at a time. Film is typically fed directly into the densifier housing, or “hopper”. The densifier has rotating paddles at the base of the hopper and stationary blades along the insides of the hopper. The paddles rotate at approximately 200 rpm. For these experiments, the film was carefully fed into the hopper by hand. As the hopper consumes the film, friction between the paddles and the film generates heat and softens the material. The film plasticizes and assumes the texture of hot taffy. Cold water is then introduced into the hopper and instantly hardens the material. The still-rotating paddles shatter the hardening material into moldable sized granules. Granule sizes range from 0.12 to 0.6 inches.

The film tested in the experiment was stripped of its glass-filled, nylon draw cord and all other cord type materials. The first sample was a mixture of material from the two boat yards, and included the contaminants mentioned earlier. The second sample to be densified was exclusively from the boat yard on the North Shore. It was collected immediately following a torrential rainstorm, so it had water on the surface of the film, as well as the other usual contaminants. The third sample had been moisture laden and was air dried before testing. This batch also included similar contaminants.

All samples were then mixed with CO<sub>2</sub> pellets at 0.5%-1%, using an auger blender. These pellets are used as a blowing agent. The blowing agent expands under heat and creates systematic voids just below the surface of the part when injection molded. These voids displace material and a smaller shot can be used. The structural integrity of the part is not diminished but actually enhanced due to the internal structure that is developed.

#### **4.2.2 Results of Preprocessing Tests**

*Sample One:* The material processed very well. The time to densify was 10 minutes. Variation in pellet size was acceptable and produced good feed stock. A “rubber” smell was noticed during densifying; the source of the odor was believed to be the adhesive on shrink tape that was present in small amounts. Neither the adhesive nor other contamination had noticeable effect on the densifying process nor on subsequent molding. Generation of fines (plastic dust) was minimal.

*Sample Two:* This material also processed very well. Time to densify was 12 minutes. The additional two minutes (compared to Sample One) could be due to issues with feeding stock or to moisture still on the surface of the film, as moisture must evaporate before densifying can take place. The moisture had little or no effect on the final product. Fines were minimal.

*Sample Three:* The material processed the same as Sample One. Time to densify was 10 minutes. Variation in pellet size was acceptable and produced good feed stock. Contamination had little or no effect on the densifying or molding processes. Fines were minimal.

#### **4.2.3 Issues and Concerns**

The main difficulty encountered was with feeding the material into the densifier. Hand-feeding film into a small densifier is awkward and time consuming. A larger densifier with feed rolls would reduce the manual effort during this process.

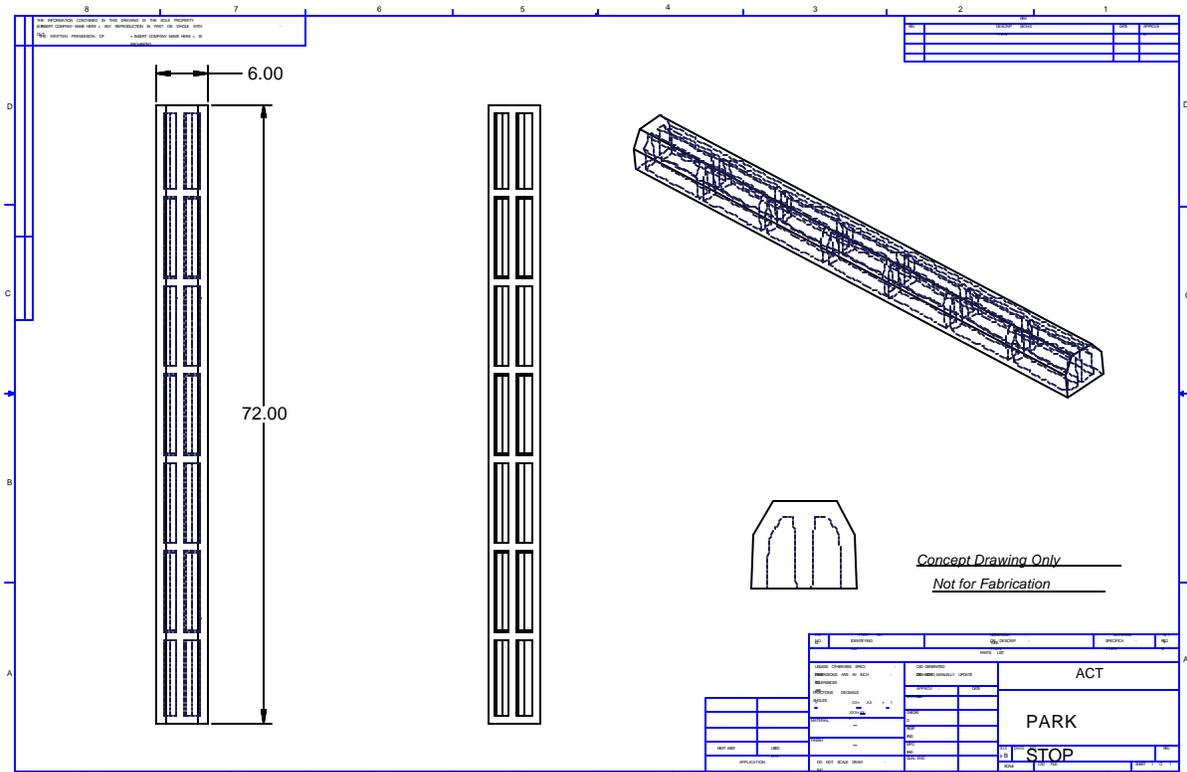
### **4.3 Task 3: Molding of Product**

#### **4.3.1 Process Overview**

The processed LDPE material is fed into the hopper on the molding machine using an auger. The injection molding process at SelecTech is similar to conventional injection molding using a melt, extrusion screw and plunger barrel. Material is extruded through a heated cylinder into an accumulator or injection cylinder. The material is plasticized by the time it reaches the end of the extrusion cylinder due to the heated barrel and shear friction between the screw and material. The plunger barrel is filled with the liquid LDPE, and then the plunger injects the plasticized material into the cavity of the mold through a valve gate or pressure gate. The gate is used to determine shot size. As the material fills the cavity of the mold, back-pressure develops in the cavity and the gate closes at a pre-determined pressure setting and stops any further injection. The correct setting yields a complete part.

#### **4.3.2 Results of Product Molding Tests**

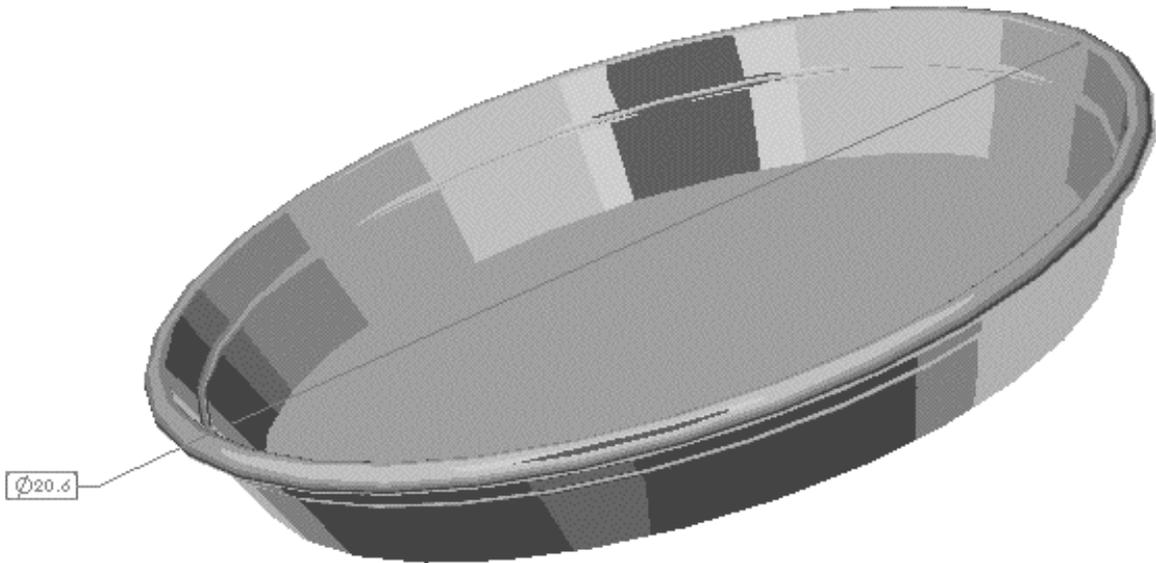
There were two parts manufactured from the densified material – a 24 pound parking stop and a three-pound planter dish (Figures 3 and 4 respectively). A pelletized blowing agent was added to these parts to reduce the quantity of material used. This agent makes up approximately 1% of the shot size.



**Figure 3**  
**Parking Stop Product Drawing**  
 (See photos in Appendix A)

- No virgin LDPE was added to facilitate molding (no blending was required).
- An auger feeder was used to feed material from the Gaylord to the hopper on the molding machine.
- Material feeding resulted in even flow and consistent feed-rate, with no static build up or clumping of material observed.
- The part cycles were 7-8 minutes for the parking stop and 3 minutes for the planter plate. Based on previous molding cycles for these parts and using similar materials and mixes, there were only subtle differences in both parts.
- The parts were well within the quality standards previously set for each part. Sinks or flash were not visible and only minor distortion on the parking stop was found in a non-cosmetic area.
- The parts molded successfully and without problems
- The as-densified film was judged to be a completely suitable molding feedstock.

Since the parts molded were intended to be white, the titanium dioxide pigment in the film provided adequate coloration without any added colorant.



**Figure 4**  
**Planter Dish Product**

## **4.4 Task 4: Equipment Considerations**

### **4.4.1 Background**

Discarded film is currently rolled up, folded or discarded in a heap for eventual disposal. Several methods are currently employed to complete this task: bagging, dumping, loose pickup and delivery to landfills, baling and delivery to the dump, and occasionally saving for reuse from year to year. This section reports several candidate processes for reducing bulkiness for shipment, and describes one in detail (the Portable Densifier Unit) that will improve on recycling boat film.

### **4.4.2 Evacuation**

In this process the film is placed in an airtight bag and sealed. The air is then pulled out of the bag using a vacuum to reduce the volume of the bag and its contents. The major disadvantage to this procedure is that handling will be duplicated, as the material still must be densified prior to molding.

### **4.4.3 Shredding**

In this process, the film is shredded on site and packaged for transport. This process is very labor intensive and also requires the material to be handled at least twice. Unlike the other processes, shredding does not offer compaction and could result in increased volume for shipping.

### **4.4.4 Baling**

This process is similar to evacuation in that the objective is to compact the material prior to shipping. Shredding the material on site may be required prior to bailing it into typically 45 or 90 pound bales. Bails are compact and relatively easy to transport.

#### **4.4.5 Pre-shrinking**

Use of propane-fired hot-air blowers (the same ones used for shrinking the film during wrapping) can significantly reduce film bulk. However, this uncontrolled heating may degrade the plastic to an unacceptable extent.

#### **4.4.6 Densifying**

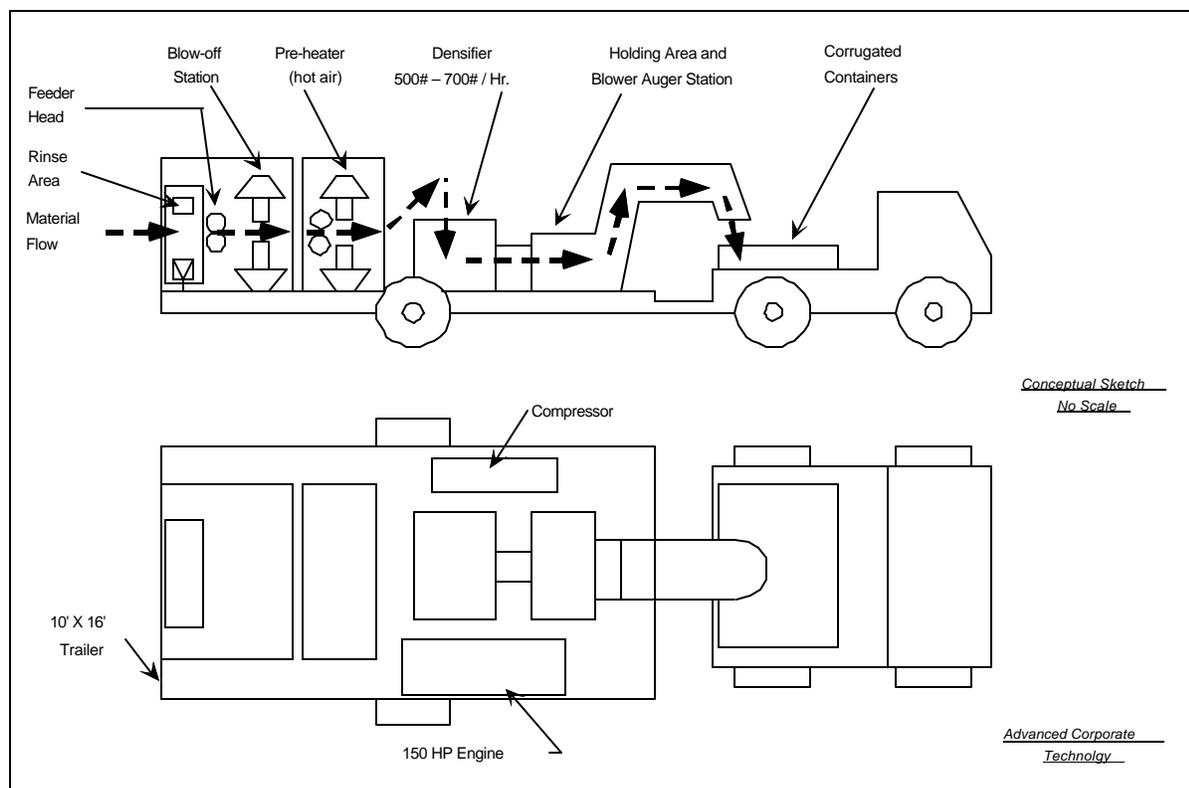
Densifying at the boat yards prior to transporting to molders appears to be the most efficient and cost effective process. Only the desirable product would be processed on-site. (Extraneous materials such as fiberglass cord would be dealt with separately.) Film material would only be handled once. The resulting pellets would provide the densest packaging of film possible. Following is a discussion of a transportable densification system proposed to serve the on-site densification function.

#### **4.4.7 Portable Densifier Unit (PDU) Concept**

During the course of this study, an idea for a portable unit to enable onsite densifying was developed. The proposed PDU (Figure 5) would be capable of producing 500 - 1000 pounds of granulated material per hour. Transportation to marinas could be as simple as a pickup truck with a trailer hitch to pull the portable unit. The densifier would be driven by a gas engine and a 220 AC power generator, potentially driven by the same engine. Supplemental heat could be generated using bottled propane gas.

#### PDU Equipment Description

- a) Blow Off and Feed Rollers - Removes the major contaminants using air and water and controls the film stock feed rate through the preheat roller. The film is rinsed prior to the rollers and then pressurized air blows off remaining contaminants and moisture.
- b) Preheat Roller Feed system – Using forced hot air, the preheater further dries the film before entering the densifier. This will increase the throughput of the densifier.
- c) Densifier -This unit works in the same fashion as described in Section 4.2. The only exception is that energy would be supplied using a gasoline engine and not a electric motor. (Figure 5.)
- d) 150 HP Gas Engine - Supplies the torque and AC power for the compressed air, electricity, heaters, densifier, and roller drives.
- e) Holding Area and Blower Transport – This area of the PDU would store and convey the dry and densified material into corrugated containers on the back of the truck.
- f) Trailer - 10'x16' open stake type would hold all the above mentioned equipment.



**Figure 5**  
**Transportable Preprocessing Station (PDU) Concept**

## 5. Recommendations

The principal focus of this project was to demonstrate the feasibility of injection molding commercial products from used shrink-wrap film. There were disposal, contamination, and logistical issues associated with the material source (boat storage). Of necessity, effort was expended toward identifying and circumventing these issues. In order to capitalize on the positive results of this study, (demonstration that discarded film is a desirable molding feedstock) it is recommended that the following actions dealing with supply-side issues be taken:

1. Seek funding support from organizations that support recycling initiatives.
2. Perform detailed research to determine magnitude of usable film tonnage available within trucking distance of SelecTech.
3. Determine economic variables and gather data to project cost of recycled film as a feedstock.
4. Establish, fund, and perform a project to design, fabricate and test a prototype PDU system.
5. Perform a project to test the practicality and the environmental and economic impacts of a system that integrates PDU use with significant volume production of injection molded products from recovered scrap film.
6. Explore the potential of establishing one or more new business ventures based on use of the PDU system to recover and transport feedstock to SelecTech.
7. Explore the potential of the PDU system for recovering other usable, but low density, plastic scrap that is now uneconomical to transport and re-use.

## 6. Conclusions

Shrink-wrap plastic film salvaged from over-winter boat storage facilities was shown to be a suitable and desirable feedstock for producing commercial products, and conversion from (unblended) salvaged film to commercial product was demonstrated. If technical barriers such as contamination and logistical problems such as seasonality and transport of bulky materials are managed properly, routine use of recovered boat-storage film is technically viable.

## 7. Potential Benefits of Implementing Findings and Recommendations

- a) A major waste disposal problem for the marine industry could be greatly reduced.
- b) A viable new source of injection-molding feedstock will be available.
- c) Significant reduction in landfilling of discarded plastic will constitute a positive environmental impact
- d) Reduction in the volume of petroleum consumed in LDPE production.
- e) A new sub-industry for on-site pre-processing and transport may develop.

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