Froth-Flotation

An Innovative Plastics Recycling Process Developed by Argonne National Laboratory

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Separation and Recovery of Thermoplastics for Reuse via Froth-Flotation

Argonne National Laboratory

Introduction

Consumer durables such as household appliances and automobiles are manufactured from a mix of materials, such as metals, polymers, foam and fiberglass; typically, metals represent more than 75% of the total weight. Consequently, recycling of durables is generally driven by the value of the metal. Over the last 15 years, however, the use of polymers in durables has increased substantially at the expense of metals. Recycling of the polymeric materials has been limited because of the inability to adequately separate selected recyclable polymers from the mix.

Argonne National Laboratory has developed a froth flotation technology that efficiently separates polymers of equivalent densities from each other. The technology was originally developed to separate ABS from HIPS; a mixture of plastics that is typical of that recoverable from obsolete appliances. The basic process has also been successfully applied to recovery of selected plastics from auto shredder residue, disassembled car parts, prompt industrial scrap plastics, and consumer electronics. The technology is both highly selective and effective in that high-purities and high-yields are achieved for the recovered plastics as shown in the attached performance summary of the technology, Attachment 1. The process has been operated at a pilot-demonstration scale and recovered ABS has been successfully injection molded to produce automotive parts, Attachment 2.

This document outlines the basic process and provides an estimate of process economics for the specific application of recovering ABS and HIPS from mixed plastic waste generated in the recycling process for household appliances. The heart of the process is the patented froth flotation process for separating equivalent density thermoplastics. (U.S. Patent No. 5,653,867; issued August 5, 1997, Attachment 3.)

Stage of Technology Development

The technology was initially demonstrated in a batch-scale test to produce 600 pounds of high-purity ABS using an experimental test facility located at Argonne. The quality of the recovered ABS was greater than 99.5% ABS. The recovered material was found to meet the specifications of the recycle market.

A continuous pilot-process with a design capacity of 1000 pounds was designed, built and installed at the Appliance Recycling Center of America's (ARCA) Minnesota facility. The pilot-unit is shown in the Figure 1. The pilot-plant was operated over a six-month period and processed about 50,000 pounds of scrap plastics and recovered more than 10,000 pounds of ABS.

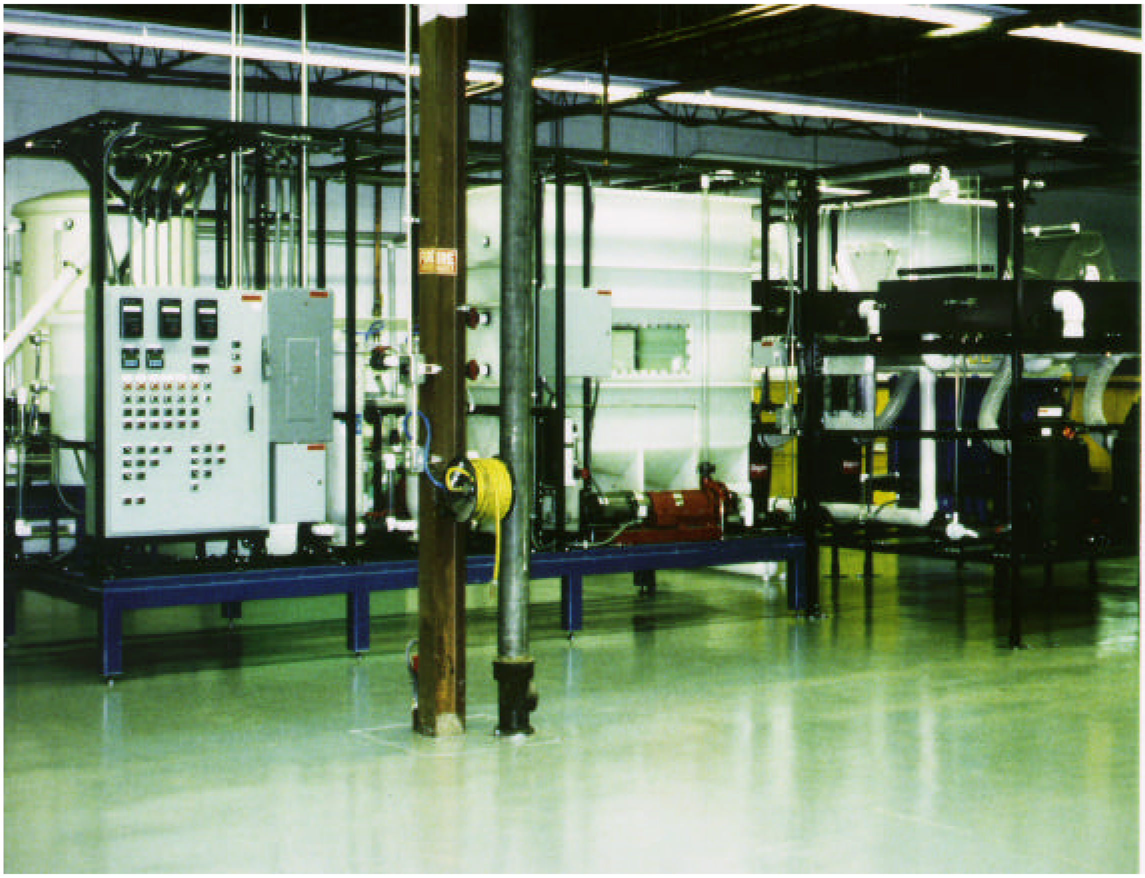

Figure 1. Froth Flotation Stage of the Plastics Separation Pilot-Plant

The photograph shows the froth flotation stage of the three-stage pilot-plant for recovery of ABS and HIPS from the mixed plastic stream generated during the recycling of obsolete appliances. The first two stages, which are not shown, are essentially the same equipment configuration. The first two stages separate the reject material and provide an ABS/HIPS concentrate feed stream to this third stage. From left to right in the photograph, the ABS/HIPS concentrate is fed to a slurry tank located behind the control panel. The slurry is then pumped into the froth flotation tank at the middle-right of the photograph. The ABS sinks in the tank and is slurry-pumped onto a perforated conveyor that allows for recovery of the froth solution. The ABS conveyor system is shown at the right of the photograph. The conveyor system also includes a rinse station and a vacuum dewatering station. The dried ABS is then dropped off the conveyor into a gaylord for shipping. A similar conveyor system, located behind the ABS conveyor is used to rinse and dry the HIPS. Process solutions are filtered and recycled back to the flotation tank.

Description of ARCA's Appliance Recycling Operation

ARCA's approach to appliance recycling is summarized in the block flow diagram shown below. Obsolete appliances are received and partially disassembled in a production line operation. Hazardous materials such as PCB's, CFC's and HCFC's, and mercury switches are removed. The CFC's and HCFC's are redistilled to meet original specifications and are recycled. Mercury switches and PCB's are disposed as hazardous waste. Following removal of the hazardous materials, the appliance hulk is shred in a large hammermill. Ferrous and non-ferrous metal are recovered for recycle. The balance of the material, shown as the reject stream in Figure 2, constitutes about 25 weight per cent of the appliance and is predominantly ABS and HIPS. At present, this material is landfilled.

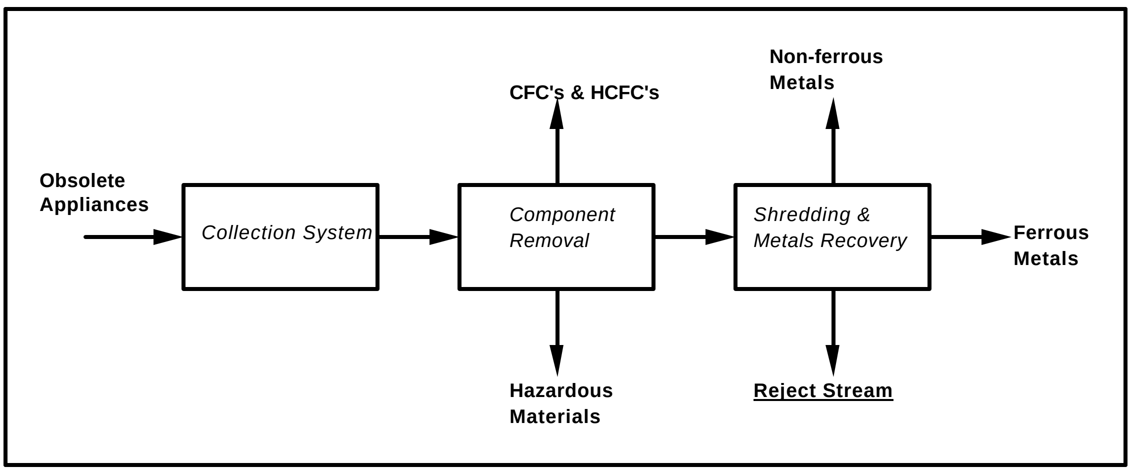

Figure 2. Block Flow Diagram of ARCA's Appliance Recycling Operation

Plastics Separation Technology Description

The reject material from ARCA's operation constitutes the feed material for the separation process for recovering high-purity ABS and HIPS developed by Argonne and ARCA. The typical composition of this material in North America is: ABS, 73 weight per cent; HIPS, 12 weight per cent; rigid foam, 6 weight per cent; and others 9 weight per cent.

The unit operations of the process include: 1) Granulation, 2) First Stage Density Separation, 3) Second Stage Density Separation, and 4) Froth Flotation, as shown in Figure 3.

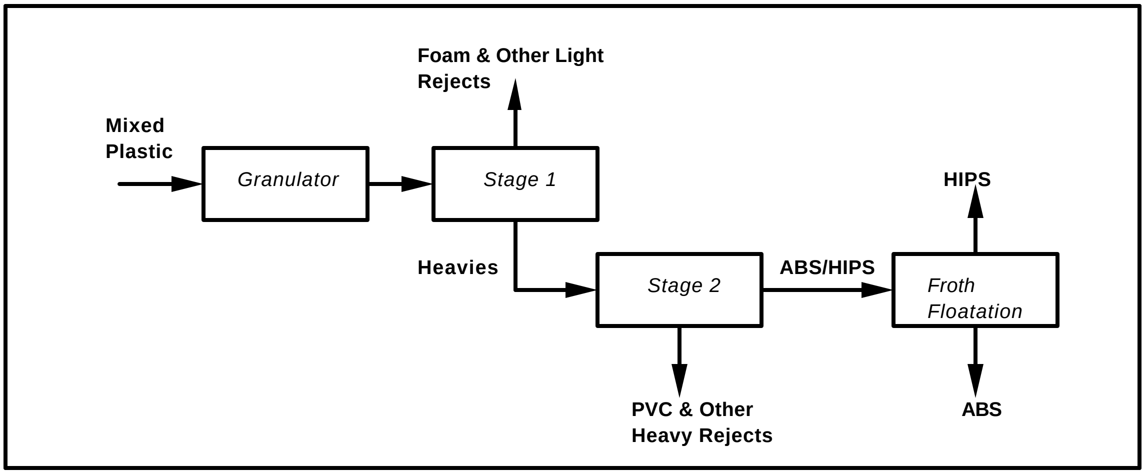

Figure 3. Block Flow Diagram of the Plastics Separation Process

Unit 1 Operation: Granulation

The reject material from the ARCA operations varies in size from about 1 inch by 1 inch up to 1 inch by 6 inches. This material is fed to a granulator to produce a consistent particle size of about 1/4 inch.

Unit 2 Operation: First-Stage Separation

The material exiting the granulator is then conveyed to the first stage density separation tank which contains water and a surfactant with a specific gravity of 1.0. In this tank the lights (e.g. polypropylene, polyethylene, and rigid foams) float. The light materials are rejected from the process and are subsequently disposed of.

Unit 3 Operation: Second-Stage Separation

The heavy material from the first-stage density separation tank is slurry fed to the second-stage density separation tank. The solution in this tank is a brine solution with a specific gravity of 1.1. The heavies sink, and the mixed ABS/HIPS float. The heavies are rejected and are subsequently disposed of. After rinsing and drying, the mixed ABS/HIPS is fed to the final separation step.

Unit 4 Operation: Froth-Flotation

Because ABS and HIPS are incompatible, high-purity separation is required. Both ABS and HIPS have the same specific gravity. Effective separation requires a froth flotation process that can differentiate the two materials based on their respective hydrophilicities. In this stage, the HIPS surface is modified with the use of a conditioning agent such that the HIPS floats and separates from the ABS. Both products are recovered, rinsed and dried. Under the present configuration, only high-purity ABS is recovered. However another froth flotation stage could be added for recovery of high-purity HIPS.

Process Economics

Process economics are estimated on a design basis of 1000 pounds per hour of feed material yielding 700 pounds per hour of recovered ABS for a plant operating eight hours per day and 300 days per year.

The total capital investment is estimated at $500,000 for all unit operations equipment for the plastics separation process including a granulator and a two-stage froth flotation process for recovery of both the ABS and HIPS. The cost does not include contractor's engineering fees, license fees, or taxes and permit fees.

Annual revenues and expenses are summarized In Table 1. As shown, the expected payback on the process is less than one year. For other applications or feed materials, process operating costs are expected to be on the order of $0.12/lb. Actual costs are, however, site and application specific.

Table 1. Annual Earnings Before Interest, Taxes, Depreciation and Amortization

Annual Revenues	
ABS @ $0.40/pound	$672,000
HIPS @ $0.20/pound	48,000
Credit for Avoided Disposal @ $20.00/ton	24,000
Total Annual Revenues	**$744,000**
Operating Costs	
Labor, 4 at $12/hour	115,200
Electricity, 165 kWh/hr @$0.10/kWh	39,600
Chemicals	17,700
Disposal Costs for Reject @ $20.00/ton	4,800
Maintenance, @ 3.5% of Capital	17,500
Total Annual Operating Costs	**$194,800**
Annual Earnings Before Interest, Taxes, Depreciation and Amortization	**$549,200**

To obtain additional information, or to inquire about a license to this technology contact:

Edward J. Daniels
630-252-5279, voice
630-252-1342, fax

edaniels@anl.gov

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Attachment 1: Argonne National Laboratory: Froth Flotation/Plastics Separation Process Performance

Plastic Recovered	Source	Purity, %	Yield, %	Comments
ABS				
	Appliances	>98	88	Pilot Demonstration, 20000 lbs processed
	Electronics	99	84	300 lb batch
	New Car Instrument panels	93[a]	75[a]	10 shredded new car instrument panel shells
	Obsolete Instrument panels	84[a,b]	100[a,b]	shredded obsolete automotive instrument panels
	Auto Shredder Residue plastics	98[a]	62[a]	Plastics from ASR--without surface cleaning
ABS/PC				
	New Car Instrument panels	97[a]	98[a]	10 shredded new instrument panel shells
HIPS				
	Appliances	98	80	Pilot Demonstration, 20000 lbs
	Electronics	99	72	300 lb batch
Polypropylene				
	ASR plastics	98[a]	65[a]	Plastics from ASR--without surface cleaning
Nylons				
	Post Industrial scrap	100	80	Based on 1500 lbs processed

a. Limited number of bench-scale tests to demonstrate technical feasibility. No optimization of conditions was conducted.
b. Objective was to maximize yield subject to purity of 80%.

Attachment 2: Recovered ABS Injection Mold Test

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Post-Consumer ABS Re-used in Auto Parts Test

An injection-mold test using 100% post-consumer ABS confirms the technical feasibility of re-utilizing this material for use in automotive applications. Headlamp "back-cans" (shown in the photos above) were injection molded from post-consumer ABS recovered via Argonne National Laboratory's patented froth flotation process. This process selectively recovers a high-purity ABS (greater than 99.5% ABS) from scrap plastics, thereby preserving the value of the ABS. The ABS for the injection-mold test was recovered from discarded home appliances. Scrap plastics obtained from the appliance recycling process is shown in the extreme right foreground of the lower-left photo. These scrap plastics are granulated, as shown in center of the lower-left photo, and then separated via Argonne's patented froth flotation process. The injection-molded "back can" is then electroplated to provide a reflective finish, and is assembled into the bumper-light assembly (also shown in the lower left photo). This is the first successful test using a 100%-recycled post-consumer polymer material for use in an automotive application.

Contact: Ed Daniels, Manager, Senior Engineer 630-252-5279

edaniels@anl.gov ***Visit our website at: http://pe.es.anl.gov***