

## A PROCESS TO RECOVER PLASTICS FROM OBSOLETE AUTOMOBILES BY USING SOLVENTS AT AMBIENT PRESSURE\*

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### INTRODUCTION

Recycling of the metal content of obsolete vehicles has been actively pursued since the 1950s [1]; today, obsolete automobiles are the single largest source of scrap iron. They contribute over 25% of the 36 metric tonnes (40 million short tons) of ferrous scrap recovered annually by the secondary metals industry and used in the production of finished steel products. They also contribute over one million metric tonnes (1.1 million short tons) of nonferrous metallic scrap a year for recycling. For each ton of metals recovered, about 500 lb of nonmetallic residue or waste is co-produced. Auto shredder residue (ASR) is a very heterogeneous mixture of solids and liquids. Table 1 lists most of the materials that are commonly present in the ASR. Figure 1 shows the relative concentration of the major constituents.

We have developed and tested in the laboratory a three-step process to separate thermoplastics, and other potentially recyclable products, from ASR [2]. The process involves a drying step followed by a mechanical separation step to concentrate the thermoplastics by separating the polyurethane foam and the fines, which are mostly metal oxides and other inert materials that are smaller than 0.62 cm (0.25 in.) in size. The concentrated plastics stream is then treated with organic solvents at ambient pressure and elevated temperatures to dissolve the desired plastics. The basic process is described in detail in Reference [2]. The salient features of the process are described below.

### THE ARGONNE ASR-RECYCLING PROCESS

The Argonne process consists of three steps: drying, mechanical separation to concentrate the plastics, and solvent extraction of the plastics. The drying process is by indirect heating (i.e., steam coil) only. Flame or sparks could potentially set the material on fire. Drying at lower temperatures will minimize the evaporation of organic species along with the moisture, thereby avoiding a potential environmental problem that may require scrubbing or wastewater treatment.

The mechanical separation of polyurethane foam and fines (< 0.62 cm in size) from ASR is necessary for many reasons. First, the foam can be recovered as a potential product. Second,

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the plastics in the remaining fraction can be concentrated (this results in smaller and less expensive equipment for the solvent-extraction operation and in lower solvent losses because fewer nonplastic materials that can absorb solvent [foam] or be wetted by it [dirt] will be present). Third, the presence of the fine, nonplastic particles will contaminate the extracted plastics unless excessive and costly filtration of the fine particles from the solution is performed. The mechanical separation was accomplished in the laboratory by using a fluidized column fitted with screens [2]. In the design of a 200-lb/day pilot plant, the plan is to use a trommel combined with a modified air classifier. Tests were conducted on several types of commercially available full-scale separation equipment. The trommel was selected because of its acceptable performance, moderate cost, and widespread use in the shredding industry.

An evaluation of the plastics-rich stream that remained after the separation of the foam and the fines, identified acrylonitrile-butadiene-styrene (ABS), polyvinyl chloride (PVC), polypropylene (PP), and polyethylene (PE) as potential candidates for recovery and recycling. ABS was targeted because of the high market value of the virgin resin and because of its good solubility characteristics in several mild organic solvents at low and moderate temperatures. PVC was selected because its chlorine content could be an obstacle if the stream is to be processed for its energy or chemical value (incineration, pyrolysis). In addition, reasonably clean PVC can also be used for making numerous products with flexible specifications. PVC, however, is susceptible to degradation upon thermal cycling; among the first signs of degradation is the appearance of a blackish color. PP was targeted for recovery because it is present in large quantities and its use by the automotive industry is on the rise. Moreover, because it is soluble only at high temperatures, it can be recovered with little contamination, except for the PP, which dissolves under very similar conditions. At this point, the economic values of PE and PP are not sufficient to justify their separation.

To minimize the contamination of the recovered plastics, the first step in the extraction process was to use a mild solvent (such as hexane) to extract the automotive fluids (see Table 1) without dissolving the targeted plastics. The "oils" recovered in the process have heating values between 16,000 and 178,000 Btu/lb. However, the hexane also extracts the PCBs that may be present in the ASR.

After the "oils" are extracted, the extraction of the plastics at ambient pressure was tested by using two methods. In the first method, selective solvents were used to extract individual plastics in series [2]. In the second method, a solvent was used to dissolve all of the plastics of interest, and then the mixed plastics were separated by using different solvents. Each method has advantages and disadvantages. For example, in the first method, the ABS and the PVC can be recovered without being exposed to the high temperature required for the recovery of PP and PE. However, the extraction steps occur in large reactors. In the second method, only one extraction has to be done in a large vessel. The separation of the mixed plastics can be conducted in smaller reactors. In addition, the second method enables more efficient cascading of the heat between the stages to minimize the energy requirement of the process. All of the plastics will, however, be exposed to the high temperature and will experience a higher number of thermal cycles. Therefore, the potential degradability of some of the products is higher. Products generated by both methods are under evaluation. The economics of both methods is also being studied.

Figures 2, 3, and 4 are the infrared spectra of recovered ABS, PVC, and PP/PE samples, respectively.

### PROCESS ECONOMICS

Table 2 summarizes the key parameters used in and the results obtained from a preliminary economic study that we have recently completed. The results indicate that a three-year payback is realistically possible. This study assumed that the plant will charge no tipping fees for accepting the ASR and will pay no fees for the disposal of the nonmagnetic fines. It was, however, assumed that the recovered oil will be disposed of as a hazardous waste. No revenues were assumed for the material left after the extraction process is completed, even though it has a heating value of about 3,000-5,000 Btu/lb and is virtually dry, PCBfree, and nearly chlorine-free.

### CONCLUSIONS

The work done so far on the process demonstrated that the process is technically feasible and potentially economical. The process uses all commercially available equipment, even though it can benefit from a better system for the mechanical removal of foam and fines. The economic competitiveness of the process is dependent on the market value of the recovered foam and the recovered plastics.

### REFERENCES

- [1]. Jody, B.J., and E.J. Daniels, "Automobile Shredder Residue: Treatment Options", Hazardous Waste & Hazardous Materials, Vol. 8, Number 3, pages 219-230, 1991.
- [2]. Daniels, E.J., B.J. Jody, and P.V. Bonsignore, "Alternatives for Recycling of Auto Shredder Residue", the Journal of Resource Management and Technology, Vol. 29, Number 1, pages 14-26, March 1992.

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Table 1. Composition of ASR

Recyclables	Energy Value*	Inerts
Thermoplastics	Gasoline	Glass
Foams	Brake fluid	Dirt
Fibers	Engine oil	Sand
Metal chunks	Transmission oil	Gravel
Rust	Grease	Moisture
Wires	Wood chips	
	Thermosets	
	Rubber	
	Tar	
	Paper	

\* Heating value is about 2,500-7,000 Btu/lb.

Table 2. Economic Analysis of the Argonne  
Plastics-Recycling Process

Item	Description/Value
Plastics product form	Pellet
Process type	Precipitation
Raw material source	ASR
Feed (MM PP)	183
Plastic output (MM PP)	25
Capital investment (MM)	7.5
Operating pressure (atm)	1
Costs (cents/lb)	
Variable	11
Fixed	8
Subtotal mfg. cost	19
Depreciation (20%)	5
Charge for ROI + wk cap	6
Netback Req'd (ex SAR)	30
Annual Realization (MM\$)	+1.6*
Payout time (yr)	3

\* Value is determined on the basis of assumed values for the recovered materials of \$0.25/lb for foam and PVC, \$0.05/lb for PP&PE, and \$0.40/lb for ABS.

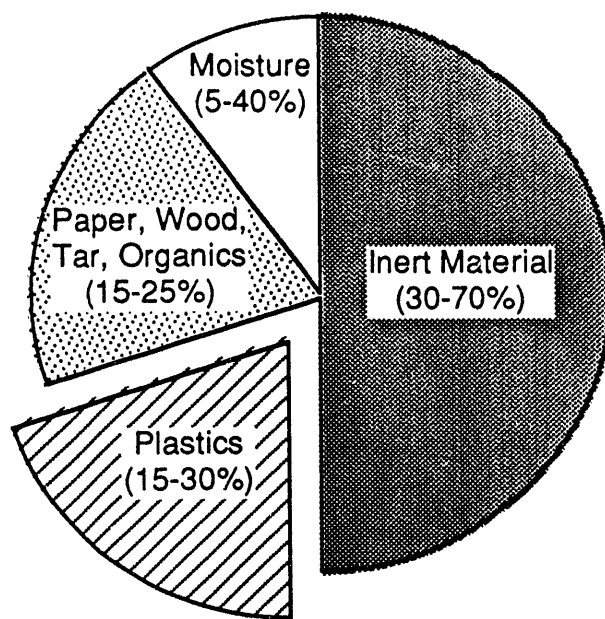


Figure 1. Approximate Composition of ASR

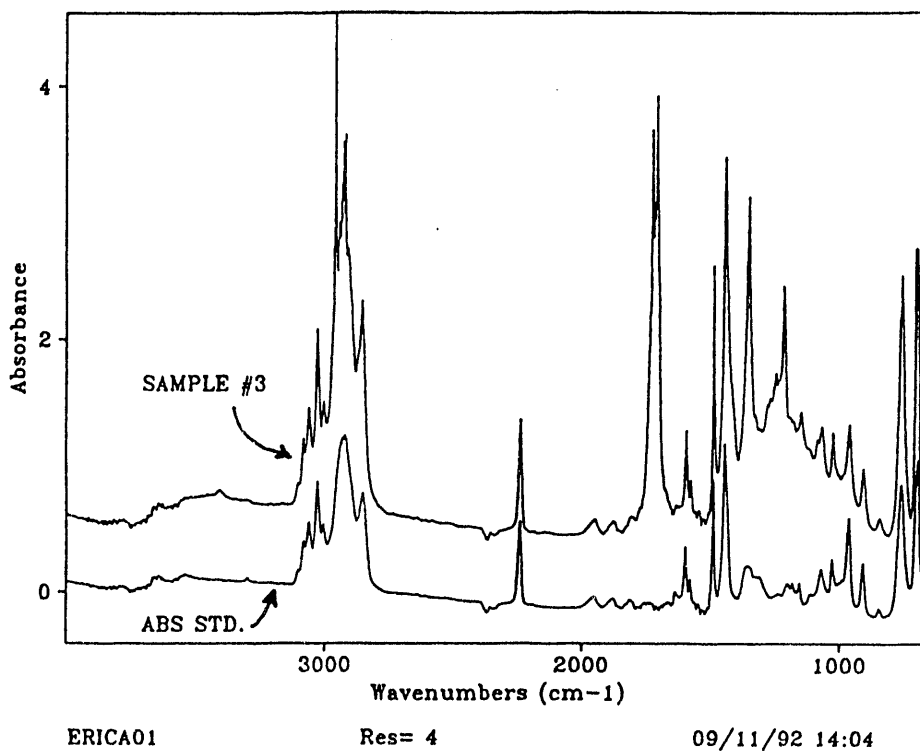


Figure 2. Infrared Spectra of Recovered ABS and Commercial-Grade ABS

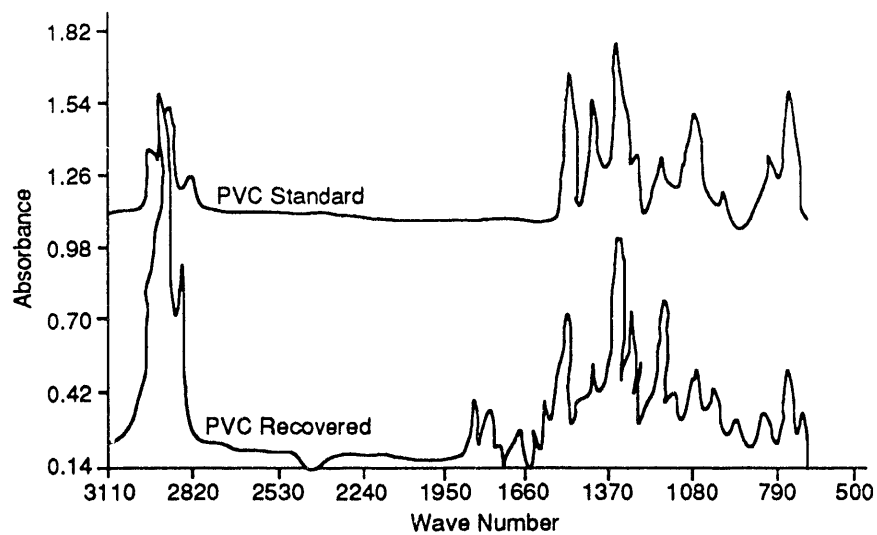


Figure 3. Infrared Spectra of Recovered PVC and Commercial-Grade PVC

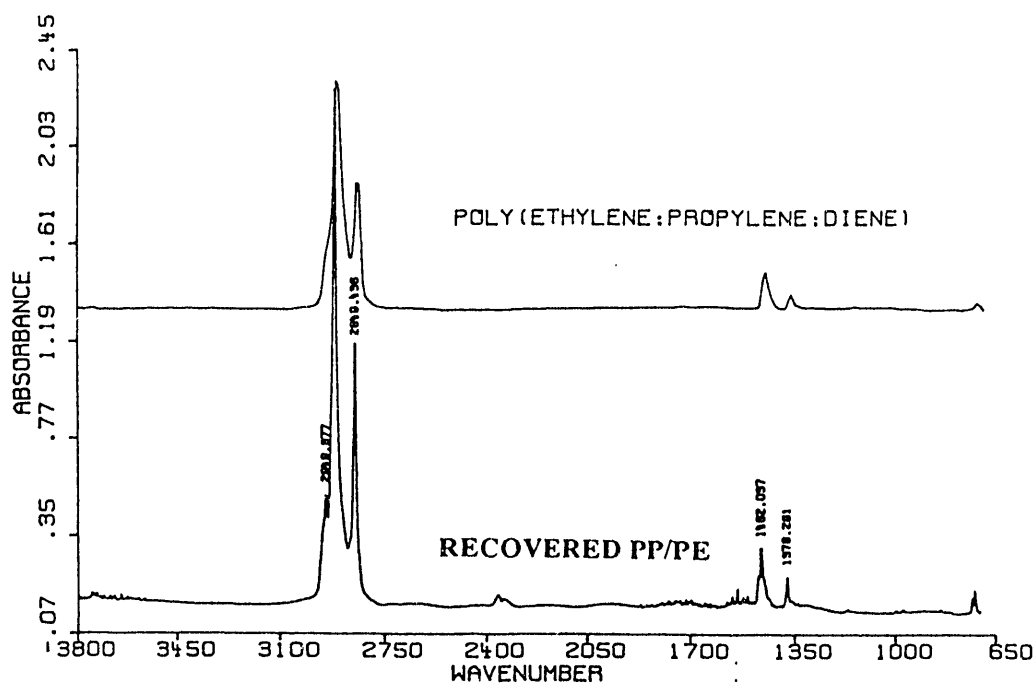


Figure 4. Infrared Spectra of Recovered PP/PE and PP/PE-Diene

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