

## E. Post-Shred Materials-Recovery Technology Development

*Principal Investigator: Edward J. Daniels*

*Argonne National Laboratory (ANL)*

*9700 S. Cass Ave., Argonne, IL 60439*

*(630) 252-5279; fax: (630) 252-1342; e-mail: edaniels@anl.gov*

*Technology Area Development Manager: Joseph A. Carpenter*

*(202) 586-1022; fax: (202) 586-1600; e-mail: joseph.carpenter@ee.doe.gov*

*Expert Technical Monitor: Philip S. Sklad*

*(865) 574-5069; fax: (865) 576-4963; e-mail: skladps@ornl.gov*

### *Participants:*

*This project is conducted as part of a Cooperative Research and Development Agreement (CRADA) among Argonne, USCAR's Vehicle Recycling Partnership<sup>1</sup>, and the Plastics Division (formerly the American Plastics Council) of the American Chemistry Council.*

### *CRADA Partner Principal Investigators:*

*Michael Fisher, American Chemistry Council, (703) 741-5599, e-mail: Mike\_Fisher@americanchemistry.com*

*Gerald Winslow, VRP, DaimlerChrysler Corp., (248) 512-4802; e-mail: grwx@DCX.com*

*Claudia Duranceau, VRP, Ford Motor Co., (313) 390-0504; e-mail: cdurance@ford.com*

*Candace Wheeler, VRP, General Motors Corp., (586) 986-1674; e-mail: candace.s.wheeler@gm.com*

*This project is conducted as part of the CRADA among Argonne, USCAR's Vehicle Recycling Partnership, and the*

*Changing World Technologies is cost-sharing on the evaluation of its thermal depolymerization process.*

*The Polyurethanes Recycle and Recovery Council (PURCC) is also participating and cost-sharing on the evaluation of the Troy Polymers, Inc., polyurethane glycolysis process.*

---

*Contractor: Argonne National Laboratory*

*Contract No.: W-31-109-Eng-38*

---

### **Objective**

- Develop technology for the cost-effective recovery of materials from post-shred residues.

### **Approach**

- Characterize shredder residue from a number of sources to determine composition variability.
- Conduct bench-scale and large-scale process/technology tests to benchmark technology.
- Build and operate a pilot-plant for the separation of shredder residue to produce recovered materials for market evaluation and to provide "control" samples of materials for testing of alternative technologies, as appropriate.
- Conduct cost and performance analyses of alternative technologies to establish the business case for the technologies and to identify technology gaps.

## Accomplishments During this Reporting Period (FY 2006)

### Mechanical Separation of Shredder Residue

- Ran one 10-ton production campaign (fractions supplied to commercial equipment vendors for performance verification).
- Initiated engineering design for full-scale bulk-separation system--three process options in collaboration with a major shredder operator.
- Obtained budgetary quotes from vendors for major equipment.
- Confirmed performance of commercial equipment (including shredder and granulator) with field trials by vendors/Argonne of the as-is shredder residue and of the fractions generated in the Argonne pilot-plant.
- Designed, built and tested physical rubber separation system.
- Conducted preliminary investigation of costs and performance of commercial color sorters, electrostatic separators, and infrared (IR) sorters for removal of wood and rubber (also evaluated relative to plastics separation).

### Froth-Flotation Process for Recovering Plastics

- Ran first campaign of the middling plastics fraction.
- Recovered a 60% unfilled acrylonitrile-butadiene-styrene/polystyrene (ABS/PS) concentrate and a 50% filled ABS concentrate from the middling plastics.
- Upgraded the filled ABS concentrate from 50% to 70% and defined process conditions to further upgrade this fraction to 90%.
- Defined process conditions for separating and recovering unfilled ABS and PS from the unfilled ABS/PS concentrate, to greater than 90% and 85%, respectively.
- Defined process conditions for separating and recovering an 85% polycarbonate (PC)-ABS/PC alloy from the middling plastics fraction.

### Other Accomplishments

- Completed testing of Troy Polymer, Inc.'s (TPI's), glycolysis process for conversion of polyurethane (PU) foam to polyol initiators. Over 1,200 lbs. of foam were used, and over 100 gallons of polyol initiators were produced.
- Conducted pilot-scale testing of Changing World Technologies' (CWT's) thermal-depolymerization process for converting shredder residue to fuels. Pre-processed shredder residue from another shredder has been evaluated and shipped to CWT for further testing.
- Completed a large-scale plastics-separation test at MBA Polymers Inc. using a plastic concentrate produced by Salyp's mechanical separation system.
- Completed testing of the VW-SiCon plastics-separation process.

## Prior Accomplishments

### Argonne Pilot-Plant

- Construction of the pilot-plant at Argonne was initiated in FY 2003 and was completed in FY 2004. The pilot-plant consists of two major parts: a mechanical separation facility and a wet separation/froth-flotation facility.

### Mechanical Separation Facility

#### FY 2005

- Ran four 15-ton production campaigns.
- Conducted complete materials loss analysis on all runs.

- Modified the bulk-separation operation resulting in an increase in polymer yield in concentrate from 40% (runs 1-2) to over 90% (runs 3-4).

#### FY 2004

- Completed construction, shakedown and start-up of the bulk-separation facility.
- Ran six (6) 5-ton trial campaigns, 4th quarter.

#### FY 2003 3<sup>rd</sup> quarter

- Initiated construction of bulk-separation facility.

#### Froth-Flotation Process for Recovering Plastics

#### FY 2005

- Conducted trials on gravity tables, mineral jigs, and a kinetic-density separator in the U.S. and Europe primarily for removal of wood and rubber.
- Conducted bench-scale research on settling velocities and density distributions of actual shredder-residue polymers including the wood and rubber.
- Ran a production campaign of the base process with shredder-residue polymer concentrate to yield three polymer fractions; the polyolefin fraction, middling plastic fraction, and the heavies plastic fraction.
- Developed a two-stage, wet-separation process for removal of wood and rubber from the recovered polyolefin fraction.
- Upgraded the polyolefin fraction, recovered 5000 pounds of polyethylene/polypropylene (PE/PP) product essentially free of wood and rubber.

#### FY 2004

- Completed construction and shakedown with electronics plastics, 2nd quarter.
- Redesigned and modified materials-handling equipment.
- Ran a shakedown campaign with shredder-residue polymer concentrate.

#### FY 2003, 3<sup>rd</sup> quarter

- Initiated construction of froth-flotation pilot-plant.

#### Other Accomplishments

- Conducted bench-scale tests and in a five-gallon reactor of Troy Polymer, Inc.'s (TPI's) glycolysis process for conversion of polyurethane (PU) foam to polyol initiators.
- Conducted bench- and pilot-scale testing of Changing World Technologies' (CWT's) thermal-depolymerization process for converting shredder residue to fuels.
- Completed large-scale tests of Salyp's "thermoplastics-sorting" technology by using residue from two European locations and one U.S. location as feed materials.
- Developed an Excel-based process cost model that incorporates two primary modules for the recovery of automotive plastics: the first module includes the unit operations required for recovering a plastics concentrate from shredder residues, and the second module includes the unit operations required to recover selected plastics from the mixed plastics concentrates.

### **Future Direction**

- Efforts in FY 2007 will be as follows:
- Bulk Separation of Shredder Residue
- Complete engineering designs (3 process options) of bulk-separation system to include equipment specifications, equipment cost, operating requirements, and utility requirements (design basis 20 ton/hour, 1-shift, 2-shift, 3-shift).

- Conduct cost analysis including sensitivity of the cost of polymer concentrate as a function of: 1) yield per ton of shredder residue, 2) value of the by-products (ferrous, non-ferrous, and foam), 3) cost of utilities, 4) cost-of-capital, etc.
- Conduct performance trade-off and cost analyses of color sorter for wood and rubber removal vis-à-vis Argonne physical rubber separation and wet-wood separation; specify preferred process (dry or wet) for separation of wood and rubber from the polymer concentrate.

#### Froth-Flotation Separation of the Plastics

- Upgrade the filled ABS concentrate from 70% to greater than 90%.
- Upgrade the unfilled ABS and PS from the unfilled ABS/PS concentrate to greater than 90% and 85% respectively.
- Recover an 85% PC-ABS/PC alloy concentrate.
- Define process conditions for upgrading the PC-ABS/PC alloy concentrate to 90-95%.
- Initiate engineering designs of the froth-flotation process to include equipment specifications, equipment cost, operating requirements, and utility requirements (design basis 8 ton/hour of polymer concentrate, 1-shift, 2-shift, and 3-shift).
- Initiate development of a predictive simulation model for determining appropriate separation operating and solution conditions that can affect gravity and froth-flotation separation of selected polymer materials for separation and recovery of polymers from a shredder-residue concentrate.
- Development of bench-scale experimental design to provide requisite empirical data for the predictive simulation model.

#### CWT's Thermochemical Process for Producing Hydrocarbon Liquids

- Complete the 2000-lb sample run. Evaluation of the CWT technology will be completed and recommendations for path forward will be made.

#### Evaluation of Emerging Technologies for the Rapid Identification and Sorting of Plastics

- Evaluation of the applicability of color sorters and IR sortation technologies for further refinement of selected process streams from the Argonne physical separation and froth-flotation processes will be completed in FY 2007.

In FY 2007, evaluation of the following technologies will also be completed and recommendations for path-forward will be made.

- TPI's hydrolysis/glycolysis process for producing polyol initiators.
- VW-SiCon technology for separation of shredder residue.
- MBA Plastics separation technology.

## **Summary**

The objective of this project is to develop technology for the cost-effective recovery of materials from post-shred residues. Research will provide data essential to establishing a business case for sustainable recycling of automotive materials from post-shred residue. Technologies specific to the recovery of materials from post-shred material streams are being evaluated and demonstrated to determine their commercial viability. The performance (e.g., yield, purity, efficiency, and cost) of these emerging technologies will be

determined to enable the development of an integrated process for recovering materials from shredder residue.

Research has been completed on the Salyp process and on Argonne's physical separation process. Testing of the VW-Sicon and of the MBA Polymers processes were completed in FY 2006 and final reports will be prepared in FY 2007. Research is ongoing on the Argonne froth-flotation process, the Changing World Technologies (CWT) process, and the Troy Polymers process.

### **Characterization of Shredder Residue**

Over 90 tons of shredder residues from five shredders were processed in Argonne's mechanical separation plant. Table 1 shows the composition of the different fractions that were produced. We observed:

- Large variations in non-plastic materials (e.g., fines, metals, rubber and wood) and
- Less-significant variation in the composition of the plastics fraction.

The mass fractions of the polymer concentrate separated from different shredder residues showed little variation, and the weight percent (wt%) of the polymer concentrate recovered from eight runs totaling 80,000 lbs of shredder residue from a given source conducted over a six-month period was reasonably consistent (41%, 26%, 36%, 39%, 45%, 37%, 43% and 45%.; average 40%). The composition of the different polymer concentrates was similar (Figure 1).

### **Argonne Pilot-Plant**

Argonne's pilot-plant consists of two major facilities: a mechanical separation facility and a density/froth-flotation facility. The pilot -plant is used to:

1. Recover materials from shredder residue,
2. Conduct process improvement studies
3. Generate design and scale-up data
4. Produce samples of recovered materials for market evaluation,
5. Define the effectiveness of alternative separation technologies and systems, and
6. Serve as a user/demonstration facility.

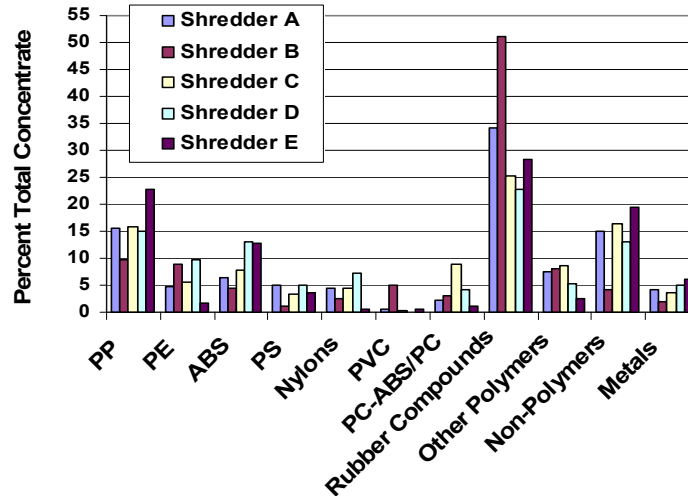
### **Mechanical Separation Pilot-Plant**

The mechanical separation facility processes raw shredder residue to yield a polymer concentrate, ferrous and non-ferrous concentrates and other fractions. Initially, the average yield of polymer concentrate recovered was only 17% of the weight of the shredder residue. The recovery of the

**Table 1.** Streams produced by mechanical separation of an average shredder residue.

	Shredder Residue	Oversized Heavies	Oversized Foam rich	Fines +	Ferrous Rich	Non-Ferrous Rich	Lights	Polymer Concentrate
Weight (lbs)	40,000	2,148	756	17,640	656	1,468	1,968	10,044
PP	1,075	0	0	0	17	33	129	897
PP (filled)	403	0	0	0	0	0	9	393
ABS	763	0	0	0	5	9	13	737
PE	941	0	0	0	9	18	85	830
HIPS	261	0	0	0	4	8	15	234
Nylon	379	0	0	0	4	9	19	347
PVC	512	0	0	0	0	0	0	511
PPO	139	0	0	0	0	0	4	135
PC-ABS	151	0	0	0	0	0	1	150
PC	212	0	0	0	0	0	12	200
Other Plastics	597	0	0	0	1	0	17	579
Rubber	4,505	20	0	0	6	172	61	4,246
PU	273	3	0	0	1	23	9	237
Wood	239	0	0	0	0	0	0	239
Metals	2,911	1,117	0	0	590	954	0	249
Foam, Fiber and others	21,320	1,008	756	17,640 +	19	241	1,597	59
Moisture	5,320	0	0	0	0	0	0	0
Total	40,000	2,148	756	17,640	656	1,468	1,968	10,044

+ Fines are material smaller than 0.25 inch in size and also contain some polymers and metals.  
HIPS = high-impact polystyrene. PVC = polyvinyl chloride. PPO = polyphenylene oxide.



**Figure 1.** Composition of polymer concentrates from different shredder residues.

polymers in the polymer concentrate was also low (40–70%) for the different source materials. A loss analysis was undertaken including quantification of polymers in each of the fractions that are generated in the bulk processing of shredder residue.

On the basis of this analysis, process modifications were made, and some of the fractions were reprocessed. As a result, the yield of polymer concentrate more than doubled. The analyses also indicated that the recovery of polymers larger than 6 mm in size targeted for recovery in the polymer concentrate was over 90%.

The polymer concentrate included high and varying amounts of wood and rubber. Wood was about 1–4 wt%. In Figure 1, the wood is included in the “non-polymers.”

**Separation of Wood and Rubber**

Trials were conducted by using commercially-available air aspirators, classifiers, air-gravity tables, and mineral jigs to remove wood and/or rubber from the polymer concentrate. This equipment did not yield satisfactory results. Conventional sink/float techniques did not work either. Trials using modified wet-separation approaches ultimately yielded a set of conditions to remove almost 100% of the wood and over 90% of the rubber with a nominal loss (~ 5%) of the plastics. This approach was integrated with the froth-flotation facility.

A dry process has been tested at Argonne, at a rate of up to 100 lb/hr of polymer concentrate, for separating the rubber in the polymer concentrate from recovered plastics concentrates. The process has been able to separate over 75% of the rubber and produce a rubber fraction containing less than 10% of non-rubber material. Further testing and scale-up of the process is on-going.

**Froth-Flotation Pilot-Plant**

This facility includes six continuous stages for the separation of targeted plastics from the polymer concentrate. A shakedown of the facility was conducted using 4,000 lb of post-consumer electronics and appliance mixed plastics and by using a mixture of colored plastics. These trials confirmed the effectiveness of the basic system.

Over 20,000 lbs of polymer concentrate from shredder residue have been processed in this facility. The recovered fractions include PP/PE, filled ABS and an unfilled ABS/PS concentrate. These are described below.

**Recovered PP/PE Fraction:** More than 5,000 lbs. of an unfilled PP/PE fraction that is over 95% PP/PE have been consistently produced. It contains less than 0.2% wood and less than 4% rubber. The recovered PP/PE has properties similar to those of some commercially-available PP materials. The recovered unfilled PP/PE product constituted about 5%–6% of the starting shredder-residue weight.

Table 2 summarizes the recoverable unfilled PP/PE and other plastics from 10,000 pounds of typical shredder residue.

**Filled ABS Fraction:** Filled ABS that has a specific gravity between 1.07 and 1.1 was isolated by the basic froth-flotation process as an ABS concentrate, Table 2. It contains 50% ABS, 20% rubber, 10% rigid urethane rubber, 8% PPO, 3% filled PP and 9% of other materials. Processing of this fraction to remove the wood and rubber increased the ABS concentration to 70% and reduced the rubber and urethane concentrations to 3% and 2%, respectively. When this material was blended with virgin ABS at 10% and 25% recovered material, the properties of the blends were slightly different from the properties of the virgin ABS. Laboratory tests have established process conditions to increase the ABS concentration to over 90%.

**Unfilled ABS and PS:** A fraction containing unfilled or slightly filled ABS, PS and PPO (43% ABS, 22% PS, 7% PPO, 12% rubber, 7% wood, 5% filled PP and 4% other materials) was produced by the basic process. This fraction is being used to

recover the unfilled ABS and the PS/PPO. Laboratory tests defined process conditions to separate this fraction and produce fractions with over 90% ABS and over 85% PS/PPO.

**PC-ABS/PC Alloy:** Work is ongoing to isolate an ABS/PC-PC fraction. Laboratory tests produced a PC-ABS/PC fraction having a combined concentration of over 85%.

**PVC:** Recovery of these fractions leaves behind a fraction made of high specific-gravity materials. Rubber constitutes over 50% of the total and metals about 5%. After the rubber and the metals were separated, a PVC fraction having over 50% PVC and rich in glass-filled nylons can be produced.

**Rubber:** Recovered rubber concentrate was also evaluated by rubber recyclers. It was determined that the presence of thermoplastics in the rubber improves certain properties of the recycled rubber when used to make construction products (such as roofing shingles). The Argonne dry rubber separation process has been able to increase the rubber content of this fraction to over 90%.

**Table 2.** Composition of an average polymer concentrate and recovered polymer fractions.

	Polymer Concentrate	PP/PE Product	ABS Product	ABS/PC Product	Rubber Product	HIPS/ABS Concentrate	Mixed Plastics	Mixed Stream*
Weight (lbs)	10,044	1,736	141	108	689	856	1,203	5,311
PP	897	827	0	0	0	0	63	7
PP (filled)	393	0	0	0	11	43	194	146
ABS	737	0	105	2	0	365	176	88
PE	830	787	0	0	10	12	21	0
HIPS	234	0	2	0	0	186	25	21
Nylon	347	0	5	0	0	5	42	296
PVC	511	0	0	0	3	0	123	385
PPO	135	0	13	1	0	62	21	37
PC-ABS	150	0	0	6	0	0	0	143
PC	200	0	0	85	1	0	19	94
Other Plastics	579	0	9	2	2	12	8	547
Rubber	4,246	90	2	9	628	104	263	3,149
PU	237	21	4	2	18	0	96	96
Wood	239	0	1	0	17	66	146	8
Metals	249	0	0	0	0	0	0	249
Foam, Fiber and others	59	10	0	0	0	1	5	42
Total	10,044	1,736	141	108	689	856	1,203	5,311

\* Rubber and metals are to be recovered from these streams

In summary, we have recovered the unfilled polyolefins as a potentially useable product, and isolated the filled ABS, unfilled ABS/PS, PC-ABS/PC and PVC into more manageable fractions. The objective now is to produce enough of these materials to determine their physical properties and conduct mold tests when warranted.

A 2000 lb/hr, continuous, flotation module has been designed and is being built. Testing of this module will provide valuable and necessary information for designing and building the first commercial plant.

### **Development of a Process Flowsheet**

A process conceptual design for a 20 ton/ hr mechanical separation system has been developed. The key steps in the process include 1) a de-stoner to separate bulky components such as metal chunks and 2) a screen separator, such as a trommel, to separate pieces larger than 3 inches. This contains most of the foam as well as fabrics, tire-rubber pieces and some plastics, 3) a shredder to size reduce the material to 1 inch, 4) a vibrating screen or a trommel to separate “fines” that are smaller than ¼ inch, 5) a magnetic separator to recover ferrous metals, 6) an eddy current separator to recover non-ferrous metals, 7) a granulator to size-reduce the material to about 3/8 inch and 8) an air classifier to remove “lights” from the granulated material. Tests, using shredder residue, were conducted to evaluate the cost, performance and maintenance requirements of various equipment that was proposed for the conceptual design. The cost of a plant having a design capacity of 20 tons/hr of shredder residue is estimated, based on quotes from manufacturers, to be under a million dollars.

### **Processing of Polymer Concentrate at MBA**

Salyp built a mechanical separation system that started with Argonne’s original mechanical separation system. Salyp added an optical sorter to remove wood and a plastics-washing system that also separated heavy polymers from the polymer concentrate. Salyp’s starting shredder residue also contained substantially less rubber and wood than the U.S. residue. It was decided to test the Salyp plastics concentrate using the MBA process. MBA processed the material on its pilot lines in Richmond, CA. Five materials grades were recovered: 1) Polyolefin “A”, 2) Polyolefin “B”,

3) filled PP, 4) ABS and 5) HIPS. The total yield of these products was estimated to be about 48.5% of the plastics-rich fraction. This yield is approximately 88% of the amounts of these plastics predicted from characterization of the feed material. The products were characterized and extruded on a small laboratory extruder, molded and tested. The purities and properties of the recovered plastics were reported to be “encouraging” and it is expected that most of the products could be used in some type of durable-good applications without modification. MBA also compounded modified versions of the recovered ABS and HIPS to enhance their properties. Their properties are being evaluated.

### **Changing World Technologies (CWT)**

CWT has developed a thermal-conversion process that converts organic material into high-hydrocarbon oil. CWT built a pilot-scale apparatus to process a mixed shredder-residue waste stream. A 1/16-in. screen was used to separate the fines (~36% by weight). About 700 lbs. of the remaining material were processed along with 80 lbs. of tires and 1,700 lbs. of used motor oil. Thermal- cracking tests of the produced hydrocarbon fuel were performed. The products were hydrocarbon oil (84%), a fuel-gas (10%), and a solid carbon product (6%). Distillation of the oil generated gasoline (12%), diesel (32%), heavy hydrocarbon oils (15%), and (3%) as gas.

The products were analyzed to determine the fate of the inert solids and contaminants. Polychlorinated biphenyls (PCBs) in the input shredder residue was 21.8 ppm. PCBs in the products including the hydrolysis oils, cracked oil, distillates, hydrolysis water, wash water, and char were below the detection limits. This indicated that PCBs degrade during the CWT process.

Several heavy metals were found in the heavy-oil dissolver. Heavy metals decreased gradually in liquid output materials from the thermal-conversion processes. Cracked oil and distillates contained only traces of one or two metals. No measurable concentrations of heavy metals were found in distillate-cut #3. The char contained significant amounts of several metals and their salts.

The heavy oil from the dissolver contained about 3,200 parts per million (ppm) of total chlorine.

Chlorine decreased in the organic output products. No chlorine was found in the light distillates (Cuts #1 and #2), and only 14 ppm were found in the heavier distillate-cut #3 and 11 ppm in the distillate bottoms.

Bromine was found in the heavy oil from the dissolver (~135 ppm). No bromine was found in the output liquid products. Bromine was found in char (87 ppm).

The tire-rubber sample used with the shredder residue contained 17,200 ppm of sulfur. Total sulfur in the motor oil used in the dissolver was 1,600 ppm. Sulfur in the cracked oil was 621 ppm, and 2,696 ppm in the treated hydrolysis oil. This indicates that sulfur compounds degraded in the process.

The cracked oil contained 0.06% of ash and the treated hydrolysis oil contained 0.7% of ash.

A pre-processed organic fraction (about 2,000 pounds) derived from shredder residue has been characterized and shipped to CWT for next trials.

### **Troy Polymers Glycolysis Process (TPI)**

TPI has developed a process for the conversion of mixed polyurethane (PU) foams into polyol initiators. Bench-scale testing demonstrated the technical feasibility of the process. Clean mixed foam and dirty foam from shredder residue were converted to polyol initiators at yields of about 88% and 72%, respectively. Commercially-available activated carbons reduced the concentration of PCBs in the products to < 2 ppm.

The process was scaled up in a 5-gal reactor. Over 1,200 lbs of foam separated from shredder residue have been processed, and over 100 gal of polyol initiator have been produced. By using optimized reaction conditions with diethylene glycol and potassium hydroxide, the yields were increased to over 90%.

Twenty gallons of the polyol initiator, (equivalent weight 163), was propoxylated and two lots of polyols were produced (equivalent weights 354 and 173). The recycled polyols were also tested in

making rigid foams. The recycled polyols were more reactive in that they required less or no catalysts, and had better flame resistance than the foams made with virgin polyols.

Initial economic analysis of the process to produce polyol initiator indicated that the glycolysis process is potentially economical.

### **Recycling of Fines**

As more lightweight materials are used in future vehicles, the amount and value of fines (<0.25 in.), which presently constitute about 50% of the weight of shredder residue, will increase. Therefore, recycling the fines is necessary to increase the recyclability of future vehicles.

Argonne conducted preliminary tests to recover metals and polymers from these fines. The results are summarized below.

1. The polymer concentrate recovered from the material in the 2-6 mm size range was 21 wt% of the starting shredder residue, or ~50 wt% of the weight of the fines fraction.
2. The composition of the recovered polymer concentrate is shown in Table 3.
3. 20 wt% of the plastics had specific gravity < 1.

**Table 3.** Composition of the 2-6 mm fines.

<b>Fraction</b>	<b>Weight % of Polymer Concentrate</b>
Rubber	52.1
Plastics	18.6
Non-Ferrous metals	8.3
Wood	6.7
Fibers	6.1
Foams	2.6
Ferrous metals	1.8
Glass	0.9
Others	2.9
<b>Total</b>	<b>100.0</b>

Evaluation of the plastics and the metals in this material will be conducted to decide if they should be recovered.

Trip Allen, a consultant to the Plastics Division of the American Chemistry Council, also conducted tests on 300 pound samples of fines (smaller than about 1 inch). In these tests, shredder residue was screened using a 7/8-in. (2.2-cm) screen. The material that passed the 2.2-cm screen was processed to yield organic- and inorganic-rich products. A combination of hydrocycloning, screening, rising current, wet tabling, magnet, and grinding technologies was utilized to give ferrous and non-ferrous metal, organic, and inorganic/sand separations at four different size distributions. Economic modeling of the process showed that recovery of the metal and sand may be viable.

### **Publications**

1. *Scale Up Study on Converting and Recycling Shredder Residue Into a Fuel Oil*, Winslow, G.R. Appel, B.S., Adams, T.N., Simon, N.L., Duranceau, C.M., Wheeler, C.S., paper # SAE-2006-01-1580.
2. *Recycling of Polyurethane Foams Recovered From Shredder Residue Via Glycolysis Process Into Polyurethanes*, Sendijarevic, V., Sendijarevic, I., Mayne, K., Winslow, G.R., Duranceau, C.M., Simon, N.L. Wheeler, C.S., paper # SAE-2006-01-1579.
3. *Chemical Recycling of Mixed Polyurethane Foam Recovered from Shredder Residue into Polyurethane Polyols*, Sendijarevic, V.; Sendijarevic, I.; Winslow, G.R.; Duranceau, C.M.; Simon, N.I.; and Wheeler, C.S., SAE paper # 2005-01-0850.
4. *Recycling Shredder Residue Containing Plastics and Foam Using a Thermal Conversion Process*, Winslow, G.R.; Appel, B.S.; Adams, T.; Simon, N.I.; Duranceau, C.M.; Wheeler, C.S.; and Sendijarevic, V., SAE Paper #2005-01- 0848.
5. *Advanced Separation of Plastics from Shredder Residue*, Winslow, G.R., Simon, N.I., Duranceau, C.M., Williams, R., Wheeler, C.S., Fisher, M., Kistenmacher, A., and VanHerpe, I., SAE Paper No. 2004-01-0469.
6. *Recycling Automotive Shredder Residue and Plastics Using the CWT Thermal Process*, Winslow, G.R., and Adams, T., Proc. of the 10<sup>th</sup> Annual Global Plastics Environmental Conference (GPEC), Detroit, MI, February 18, 2004.
7. *Screening Study to Evaluate Shredder Residue Materials*, Winslow, G.R.; Wheeler, C.S.; Williams, R.L.; Duranceau, C.M.; Simon, N.L.; and Schomer, D.R., SAE paper # 2004-01-0468.
8. *Processes for Recycling the Non-Metallic Portion of Obsolete Automobiles*, Jody, B.J., Daniels, E.J., and Pomykala, J.A., Jr., U.S. Environment-2003 On-Line Conference, July 14-25, 2003.
9. *Cost Effective Recovery of Thermoplastics From Mixed Scrap*, Jody, B.J., Pomykala, J.A., Jr. and Daniels, E.J., Materials Technology, Volume 18 Number 1, March 2003, pp 18-24.
10. *Separation and Recovery of Thermoplastics From Mixed-Scrap Plastics*, Pomykala, J.A. Jr., Jody, B.J., Daniels, E.J., and Greminger, J., Proc. of the 9<sup>th</sup> Annual Global Plastics Environmental Conference (GPEC), Detroit, MI, February 26-27, 2003, pp 7-16.

---

<sup>i</sup> One of the formal consortia of the United States Council for Automotive Research (USCAR) set up by the “Big Three” traditionally U.S.-based automakers to conduct joint pre-competitive research and development.