Plastics Institute of America, Inc.
A Non-Profit, Educational, and Research Organization

*Proceedings*
*Technology Exchange Program*

RECYCLINGPLAS III—Conference

# PLASTICS RECYCLING AS A FUTURE BUSINESS OPPORTUNITY

May 25–26, 1988
At the Mayflower Hotel
Washington, D.C.

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# INTRODUCTION

This past May 25 and 26, 1988, Recyclingplas the third annual two-day conference on "Plastics Recycling as a Future Business Opportunity" was held in Washington, DC.

Sponsored by the Plastics Institute of America in cooperation with the U.S. Department of Energy, this event has become a premier forum for exchanging ideas and information on a subject that has aroused nationwide interest as well as concern.

This year's conference was somewhat unique in that it brought together speakers from various sectors of the recycling business who shared with us their experiences in an emerging plastics recycling business.

International speakers and attendees demonstrated the technological progress made in other countries.

And now the proceedings of that very special conference have been compiled into a 177-page report that should be required reading for anyone concerned with this technology. The proceedings represent a passport to worldwide developments and an opportunity to profit from the experiences of a global plastics community.

Plastics recyclers continue to reach for new levels of sophistication in both understanding the problem and mastering the technology. "Plastics Recycling as a Future Business Opportunity" is without question the most comprehensive and significant conference on the subject. We believe these published proceedings will be just as informative and valuable.

Sincerely,

William Sacks
Executive Director

Michael J. Curry
Program Chairman

## Plastics Poem

I'm plastic and I'm fantastic.

I'm made from oil and the chemist's toil.

The products which to you I bring
Make me the King
Of materials which are light and strong.

So, what is wrong
With my one-time use
When recycling could end this abuse
Of plastic which can be more than one-time
fantastic.

Recycling of me can and will be
But how do you collect and process my variety.

Plastic chemistry can differ significantly
And this inhibits co-compatibility.

Think up ways to keep me clean
Use your intelligence and invent the means
Plastic recycles that can be seen.

But, much must be done, if it is to ring true
That plastics can be reused, too
Along with paper, metals and glass.

Plastic is fantastic and it also has class.

**Composed and Delivered by Bill Mitchell**
**LRL Recycle, Racine, Wisconsin**

## INTRODUCTORY REMARKS

## WORLDWIDE RECYCLING TECHNOLOGY: A PATENT PERSPECTIVE

Dr. Raymond Z. Naar
General Electric Company
(chairman) Plastics Institute of America, Inc.

Ladies and Gentlemen:

This is the third Technology Exchange Conference on Plastics Recycling organized by the Plastics Institute of America with support from the Department of Energy. The fact that it is the third, coupled with another significant increase of the number of registrants, attests to the timeliness of the topic and the quality of the presentations. It is also a tribute, we believe, to PIA's efforts on plastics recycling, efforts very much in line with PIA's objectives as a non-profit, educational and research organization. These objectives are:

a) To support plastics education at the college level, and for the working professional.

b) To promote university research in polymer science and engineering.

c) To provide a long-range technological focus in key areas involving plastics.

PIA membership includes Industry, Academic Institutions and Government Research Institutions. The PIA is administered by an Executive Director, with a Board of Trustees as the policy-making and governing body.

EDUCATIONAL ACTIVITIES: The PIA was the first institution to recognize the plastics education needs of the working professional. We, therefore, initiated, some 20 years ago, 2-4 day courses on polymer science, processing and applications, taught by academic and industry experts. Thousands of attendees have taken our courses while other institutions have since followed our lead. The curriculum is regularly updated, and currently consists of some 20 courses.

Five years ago, PIA recognized the need to bring together technical and business people in the fast growing field of plastics food packaging. We therefore initiated the FOODPLAS conferences -- a forum where the latest developments and future needs of this industry segment are discussed.

In addition to serving the plastics industry, the above activities provide PIA with net income which we devote to supporting our university research programs.

RESEARCH ACTIVITIES: The PIA supports graduate students in universities doing research in polymers and plastics. In the past academic year, we supported research in 15 U.S. Universities. The support often takes the form of partial fellowship grants. Some 180 graduate students have benefited from PIA support in the last 25 years. We focus our support to areas we see as critical to the future of the plastics industry. For example, 8 years ago, we were among the first to recognize the plastics recycling challenge, and with the help of funds available to us by the DOE, we supported university research in this area. The results of that research are now available in a two-volume publication.

LIAISON ACTIVITIES: PIA serves as a liaison organization between industry, education and government; because of PIA's close connection to both industry and academia, government agencies often look to the PIA for guidance in matters of policy as providing an objective viewpoint.

Every other year, PIA publishes a catalogue of plastic education offered by U.S. Universities -- courses, faculty, ongoing research; informative to both industry and government this survey is another illustration of our liaison role.

## WORLDWIDE PLASTICS RECYCLING FROM A PATENT VIEWPOINT

In a field as relatively new as plastics recycling, technology and business opportunity go hand-in-hand. Successful recycling businesses are based on recycling processes that are technically and cost effective. Business growth in turn, spurs more efforts in technology which leads to innovation and servicing of new markets.

We are seeing this technology→ process→ market cycle in full swing right now. One of the important indices of technical evolution is the intensity of patent activity. At last year's Recyclingplas Conference I gave you an overview of the worldwide patent activity on recycling. I had then compiled the number of patent applications on plastics recycling in the major industrial countries. The search was based on the Derwent Patent Service, which offers a sophisticated system of computerized patent retrieval. I searched for issued patents or applications open for examination, on the topics of "Polymers Recovery Process" or "Polymers Recovery Equipment" or "Use of Recovered Polymeric Material". My first slide, a repeat from my presentation of last year, shows that some 90% of all the polymer-related recycling patents filed worldwide were authored by organizations in the seven key countries listed in the slide. Since then, I have taken a closer look at those patents to better understand the key thrusts and project into the future the direction of technology in this active field. This is still work-in-progress, and I propose to give you today a status report. For purposes of this meeting, I reviewed some 450 patents published in 1986, 1987, and the first two months of 1988; as earlier mentioned these cover recycling of polymers i.e.

they include plastics, rubber, and textiles as well (Slide 2). In addition to being an index of worldwide activity, they are also a source of potentially useful technology, since the inventions may be practiced by the patentee or licensed to interested parties. Looking at this large patent population, I sought to devise a rational classification system to highlight the key technological thrusts: what is the invention (is it a process? is it a product use?) and what type of recycling does it address (primary? secondary? etc.). The results in matrix are shown on Slide 3. It is seen that the bulk of the patents address secondary recycling, and are mostly concerned with product rather than equipment and processes. However, there is a significant number of patents, mostly process-related, addressing tertiary recycling. As to primary recycling, many of the patented inventions deal with making use of side- or waste-streams in a particular manufacturing operation. The message is clear: perhaps because of existing perceptions, recent emphasis is on finding other applications for already used products.

The patent review is being extended to earlier years (at least back to 1980) and a more thorough analysis, based on country of origin, breakdown of technology trends in key subcategories, etc. will be carried out. However, to give you a flavor of some of the inventions I ran across in this phase of the work, I list a number of examples in Slides 4 through 11. In each case, I indicate the patent assignee, the country where the patent first issued, the patent number, and a brief descriptive title. These illustrations will give you I hope an appreciation for some of the recent technology.

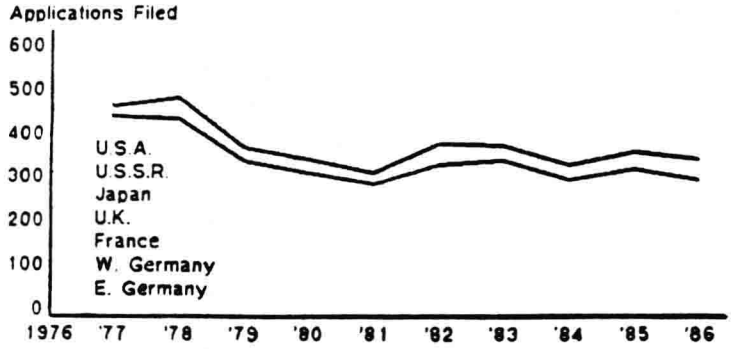
Clearly, there is a significant ongoing global technical effort, and much to be gained from international technological exchanges such as this meeting.

The PIA is happy to be hosting this Conference and hopes that those of you who did not know of our activities will now become our good friends. We encourage all of you to become members.

SLIDE 1

## Polymer Recycling Patents

**Worldwide Totals vs 7 Top Countries**




SLIDE 2

**WORLDWIDE PATENTED RECYCLING TECHNOLOGY**

- Reviewed 1986-1987-1988 (2 Mo.) — 450 References
- Includes Plastics, Rubber, Textiles
- Index Of Worldwide Activity
- Source Of Useful Technology - License
- Classification System: What Is The Invention, For Which Purpose

# WORLDWIDE PATENTED RECYCLING TECHNOLOGY

| CLASSIFICATION SYSTEM | Process | | Product | |
|---|---|---|---|---|
| | 1. Equipment | 2. Equipment - - Process | 3. Process - -Product | 4. Product |
| I. Primary Recycling (Waste Streams) | 2 | 4 | 22 | 18 |
| II. Secondary Recycling | 4 | 25 | 96 | 87 |
| III. Tertiary Recycling (Pyrolysis) | 5 | 18 | 31 | - |
| IV. Quaternary Recycling | 5 | 10 | 7 | 2 |
| V. Other (Unidentified Preliminary) | 38 | 15 | 14 | - |

SLIDE 3

## WORLDWIDE PATENTED RECYCLING TECHNOLOGY

EXAMPLE: EQUIPMENT

- Extrudaids Ltd — Gr. Brit. — 2,171,952
  Plastics Extruder With Separate Feed & Metering Sections - Allows Differential Drive To Accomodate Non Uniform Feed e.g. Scrap Plastics
- SMS Mech. Syst. BV — Netherlands — 8500016
  Apparatus For Crushing Waste Plastics Bottles - Has Rollers With Recess For The Bottle Neck & Sensors Selecting The Neck & Triggering The Rollers

SLIDE 4

## WORLDWIDE PATENTED RECYCLING TECHNOLOGY

EXAMPLE: SURFACE MODIFICATION

- Moscow Fine Chem. Techn. — USSR — 1,310,404
  Treating Polystyrene Particles With Sulfur-Contg. Reagents To Improve Physical Properties
- Lapickij — W. Germ. — 3,617,902
  Modifying Polyethylene - By Treating Melt With Organo-Silicones And Ultrasound Producing Cavitation
- Air Products & Chemicals — U.S.A. — EP-231,918
  Polymer Powder Modification With A Mixture Of Reactive Gases - Followed By Incorporation In Polymer-Forming Liquid

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## WORLDWIDE PATENTED RECYCLING TECHNOLOGY

EXAMPLE: TERTIARY RECYCLING

- Texaco, Inc. — U.S.A. — 4,644,019
  Terephthalic Ester Polyols From Recycled PET & Ethoxylated Alkyl Phenol, For Urethane/Isocyanurate Foams
- Klubyshev Polytechnic — U.S.S.R. — 1,265,189
  Styrene Recovery By Depolymerization Of Polystyrene Production Waste - Using Mixture Of Steam & Hydrogen Combustion Product From Dehydrogenation Of Ethylbenzene
- Inst. Chimice Bucuresti — Romania — 89,671
  Polyols Obtained By Catalytic Alkoxylation Of Waste Polyurethane Foams - Using Alkylene Oxide & Amine Catalyst

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## WORLDWIDE PATENTED RECYCLING TECHNOLOGY

EXAMPLE: PYROLYSIS

- Union Rhein Braunkohlenwerke — W. Germ. — 3,616,785
  Fluidized Bed Hydrogenation - Recovering Hydrocarbon Oils And Removing Halogens As Hydrides
- Brown Boveri & CIE — Switz. — EP-226,895
  Hydrocarbon Pyrolysis (Tires, Plastic) Recycling The C4-Rich Gas Stream To Increase Yield Of Aromatics

## WORLDWIDE PATENTED RECYCLING TECHNOLOGY

EXAMPLE: APPLICATIONS

- Dasurat Enterprises — U.S.A. 4,616,055
  Porous Irrigation Pipe With Improved Porosity Uniformity - By Extruding Rubber Particles Of Controlled Particle Size In Thermoplastic Binder
- Texaco Inc. — U.S.A. 4,574,143
  Amine Curing Agent For Epoxy Resin - Contains Degraded Waste PET Which Functions As An Extender For The Epoxy
- Teplotechna — Czech. 8503233
  Water Proofing Material From Atactic Polypropylene And Reclaimed Plastics - Can Impregnate Fibrous Support To Make e.g. Roofing Tiles

SLIDE 8

## WORLDWIDE PATENTED RECYCLING TECHNOLOGY

EXAMPLE: APPLICATIONS

- Uniroyal Goodrich — U.S.A. — EP-256,294
  Preventing Accumulation Of Combustible Organic Vapor In Closed Container (Esp. Oil Tanker) - By Contacting Vapor With Vulcanized Rubber
- Luthner Metall-Recycling — West Germ. — 3,516,261
  Plastics Or Rubber Granulate From Old Cables - Used As Horse Riding Track Material, Road Grit Or Concrete Filler
- T. Fukashiro — Japan Kokai 1986 123,693
  Foamed Polystyrene Granules As Soil Additive For Agriculture - Soften The Ground, Retain Heat, Do Not Rot

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## WORLDWIDE PATENTED RECYCLING TECHNOLOGY

EXAMPLE: BOTTLES/PACKAGING

- Stamicarbon (DSM) — Netherlands 8600627
  Removing Labels And Base Cups From Bottles - By Immersion In A Liquid Bath At Disorientation Temp. Of Plastic And Mechanically Separating
- Owens - Illinois — U.S.A. 4,599,131
  Apparatus Removing Labels From Plastic Container - Has Converging Heated Roll Series Followed By Wire Brush Rolls
- Dow Chemical — U.S.A. 4,647,509
  Thermoformable Multilayer Structure - Comprises Gas Barrier Layer And Polyolefin Polystyrene Blended With Scrap In Second Layer

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## WORLDWIDE PATENTED RECYCLING TECHNOLOGY

EXAMPLE: UNCOMMON APPPLICATIONS

- Genyo KK — Japan Kokai 1987 156,158
  Weakly Magnetic Material For Growing Plants - From Reclaimed PET Tape, Gamma Ferrite & Olefin Resin
- Marpac Industries, Inc. — U.S.A. 4,678,617
  Convert Plastic Bottles Into Building Blocks - Heat & Remold Bottles Maintaining High Internal Pressure

# "NEW APPLICATIONS AND MARKETS FOR RECYCLED PLASTICS"

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Research Funded by:
The Plastics Recycling Foundation/Center for Plastics Recycling Research
Ohio Department of Natural Resources, Division of Litter Prevention & Recycling

Research Goals:

This research project was directed at gaining an improved understanding of new product opportunities, markets and the economics associated with the emerging plastics recycling business. Goals include investigating potential new products and markets for recycled plastics and developing an electronic database on the plastics recycling industry.

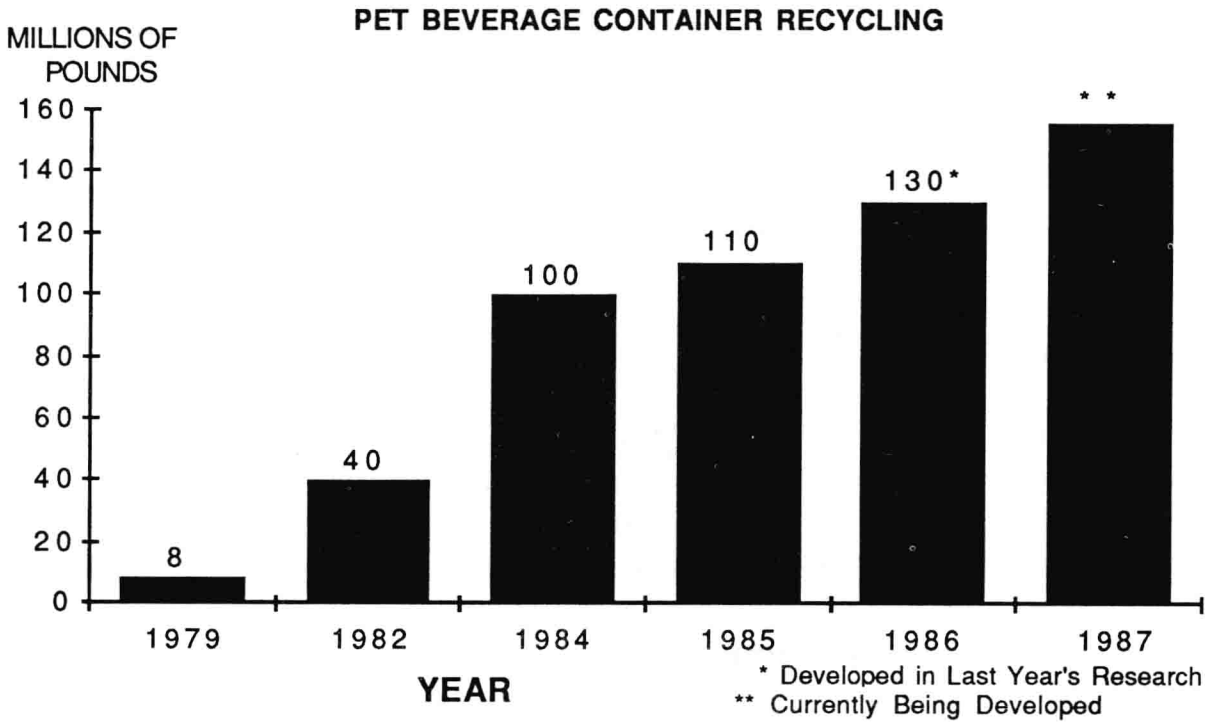
Research was performed in conjunction with other plastics recycling research projects funded through The Plastics Recycling Foundation/Center for Plastics Recycling Research. As part of this research, companies have been contacted to determine interest in utilizing recycled plastics in manufacturing products. Questionnaires have been sent to recyclers to determine quantity, products and types of plastics being recycled. Information is entered into a personal computer database which allows efficient and convenient access. Physical testing is being performed to better understand performance of plastic lumber applications.

## Market Supply

The supply of raw materials for plastics recycling is an ever increasing quantity. Last year over 57 billion pounds of plastics were sold in the U.S. These sales volumes were obtained from Modern Plastics, Jan., 1988 and the Textile Economics Bureau, Inc., Roseland, NJ. Polyethylene (high and low density) was the dominant resin with a total of over 17 billion pounds or about 30% of the total plastics sales. Polyester resin for nontextile products accounted for 1.8 billion pounds or 3.15% of the total. Polyester used in textiles accounted for another 3.5 billion pounds or 6.1% of total plastic sales. Polyethylene and polyester are the dominate plastics currently used in recycling post consumer plastics. These billions of pounds of thermoplastics offer recycling opportunities. Reuse of thermoplastics will reduce raw material costs to manufacturers and reduce the burden caused by plastics on the solid waste stream. Recent price increases for plastic resin will provide further incentives for recycling plastics.

## History of Recycling Post Consumer Plastics Scrap

In the beverage industry aluminum containers were quickly recognized as being a valuable material which should not be discarded. About 20 years ago the aluminum companies initiated recycling programs. Aluminum cans are well-known as being recyclable. Glass bottles have been mass produced since the turn of the century and are being recycled into new containers. The plastic beverage container, made of polyester (PET) and polyethylene, was introduced nationally in 1978. Recycling began almost immediately through the efforts of small entrepreneur recyclers. These early plastic recyclers recognized the intrinsic value of this hi-tech polymer. In 1979, only one year after the plastic PET bottle's introduction, eight million pounds of bottles were recycled. This poundage of recycled beverage containers grew to 40 million pounds in 1982 and by 1985, an estimated 110 million pounds of bottles were being recycled. In 1986, this research estimated that 130 million pounds of PET beverage bottles were recycled. Deposit legislation on soft drink containers in 9 states influenced this rapid growth. Recycling legislation aimed at reducing solid waste is expected to continue the growth of plastics recycling along with other materials. The following graph, shows the rapid increase in recycling plastic beverage containers.



Polyester (PET) is the plastic being recycled most as post consumer scrap in the United States. Wellman, Inc. was identified as being the major recycler in this area. Results show that present markets for recycled PET are fiberfill, unsaturated polyester, polyols for rigid urethane foam, strapping, engineering plastics and extruded products. New applications, such as thermoformed products and textiles/geotextiles offer additional opportunities to utilize post consumer plastic scrap.

In 1987, there were 740 million pounds of PET used in manufacturing soft drink containers. Estimates showed that there exists a potential market for 500 million pounds of this material in non food applications. Since only 130 million pounds are currently being recycled, this market is far from being saturated. A 10% penetration into the PET textile would alone represent approximately a 350 million pound market since filament yarn, staple and tow made from virgin PET markets is over 3.5 billion pounds.

### HDPE Recycling

Total sales of HDPE in 1987 was in excess of 7.8 billion pounds. Market research shows that a potential market of an estimated 440 million pounds could be developed to utilize recycled HDPE. Major potential markets for HDPE are soft drink basecups, plastics lumber, containers, drums pails and various types of pipes. Currently only about 52 to 58 million pounds per year of HDPE have been identified as being recycled. Markets identified for recycled HDPE are listed below.

**MARKETS FOR HDPE PRODUCTS**

**AGRICULTURE**
- Drain Pipes
- Pig and Calf Pens

**MARINE ENGINEERING**
- Boat Piers (lumber)

**CIVIL ENGINEERING**
- Building Products
- Curb Stops
- Pipe
- Signs
- Traffic-Barrier Cones

**GARDENING**
- Flower Pots
- Garden Furniture
- Golf Bag Liners
- Lumber

**RECREATIONAL**
- Toys

**INDUSTRIAL**
- Drums/Pails
- Kitchen Drain Boards
- Matting
- Milk Bottle Carriers
- Pallets
- Soft Drink Basecups
- Trash Cans

**TOTAL VOLUME**
52.3 Million lbs. recycled in 1986

## Mixed Plastics

Plastic scrap often is collected as a mixture of many types of plastics. Separation of this mixture into its various plastic components would be costly. It is possible to process the mixed plastics into noncritical product applications. This type of mixed plastics recycling has already begun in Europe and Japan. Products with high volume which could be manufactured from mixed materials are being identified. Lumber substitutes for miscellaneous outdoor furniture, posts, and farm structures are ideal markets. Many items have been mentioned by ART/Europe (Advanced Recycling Technology S.A. Ltd.) and are listed below.

**AGRICULTURE**
- Barrier Retainers
- Duck Boards
- Electric Fences
- Erosion Control Timber
- Fruit Tree Supports
- Gates
- Horse Stalls
- Markers
- Pig and Calf Pens
- Poultry Construction
- Vine Stakes
- Ranch Fences
- Tree-guards

**MARINE ENGINEERING**
- Beach Erosion Control
- Boardwalks
- Boat Docks
- Coast Erosion Protectors
- Dock Side Fenders
- Fishing Boat Wear Plates
- Lobster Traps
- Pier Impact Protectors
- Rub Rails
- Sea Walls
- Trawler Net Rollers

**CIVIL ENGINEERING**
- Barriers
- Bearing Pads
- Fences
- Road Delineators
- Traffic Direction Posts

**RECREATIONAL**
- Flower Pots
- Flower and Tree Boxes
- Golf Course Walkways
- Park Benches
- Picnic Tables
- Playground Equipment
- Sand Box Kits
- Stadium Seating
- Storage Bins

**INDUSTRIAL**
- Car Stops
- Fencing
- Flooring
- Footings, Posts, and Sill Plates
- Highway Construction
- Loading Dock Rails
- Markers
- No-load Grating
- Pallets
- Pipe Racks
- Planks
- Sign Posts
- Slab Separators
- Stair Treads
- Traffic Barriers
- Truck Flooring
- Wire Racks

**GARDENING**
- Compost Enclosures
- Fences, Gates, Enclosures
- Garden Boundary Retainers
- Landscaping Timbers
- Retainer Walls

**New Product Testing**

Manufacturing processes and product durability are areas that require further investigation. Preliminary testing results are being gathered to better understand the limitations associated with using recycled plastic resins. Testing has been performed on test samples of 2x4's manufactured from mixed plastics. A series of nail and screw pull-out experiments shows plastic lumber to behave quite differently than wooden lumber. These types of tests are required in order to better understand potential applications.

Nail pullout tests were performed on wood and recycled plastic specimens to compare their nail holding strength. The specimens were cut out of 8 feet (2x4) construction members. Actual dimensions of the specimens were: 1 1/2" x 3 7/16" x 8'. Nails used have a diameter = 0.15". Nail penetration was 1 1/2" throughout the tests. Results of these tests show that mixed plastics hold nails approximately 40% better than typical wood when nails are perpendicular to the grain. When nails are driven parallel to the grain, wood significantly loses by approximately 50% the ability to hold nails while plastics maintain relatively the same retention capability. However, this advantage of recycled plastic lumber is rapidly lost at elevated temperatures of approximately 149 °F [65 °C].

| | Room Temperature | Heated 65 °C Water Bath | % Loss in Strength |
|---|---|---|---|
| **Wood** Maximum Pullout Force-lbs | 112 lbs | 116 lbs | 3.2% |
| **Plastic** Maximum Pullout Force-lbs | 157 lbs | 88 lbs | -43.7% |

Conclusion:

Wood retained much of it's strength while being heated in a water bath. Recycled plastic lost 43.7% of its nail holding strength due to the same conditions. Consequently, utilization of lumber made from recycled plastics must be carefully evaluated regarding the environment in which it will be used in order to avoid inappropriate applications.

## Continuing Research - Searching for Potential Markets

The challenge of reprocessing post-consumer waste is becoming the concern of all plastic processors and therefore it is necessary that informational networking be increased. The electronic database also developed in this research contains the names of contacts in the plastics industry. This database will prove to be a valuable asset for future research work. With regards to identification of potential products, many companies were found through surveying the Thomas Register. There were 470 pages of listings devoted to firms involved with plastics, not all of these necessarily being processors. These 470 pages contained approximately 12,000 listings. A filtering system was implemented to bring the number of contacts down to a workable number. Criteria used in the filtering system is as follows:

1. Thick walled products (greater than 1/8" thick) - thick walls are necessary due to the possibility of having impurities.
2. Non-food item - in order minimize recycling costs.
3. Color independent - mixed plastics can alter the color required.
4. Company size greater than $20 million sales - the size of the company was used to help focus on companies that would have the greatest consumption of plastics.

Utilizing the above criteria, contacts were made with 191 companies and/or divisions of which 78 have responded. Of these, 30 are regarded as worth pursuing for new product applications. Results of this survey were put into the database. The synergies of these communication links will enhance future research efforts. This systematic market survey initiated last year is simultaneously being performed along with electronic database development on plastics recycling activity nationally .