PLASTIC DRUM INSTITUTE

The Plastic Drum Institute Research Program on the Environmental Attributes of Plastic Drums

Including Executive Summaries of PDI Research Reports:

The Plastic Drum Reuse Study

The Real World Refill Test

The Resin Reconditioning Study

The Recycled Drum Performance Test

The 55-Gallon All-Plastic Drum Reuse Study

PLASTIC DRUM INSTITUTE

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Plasti-Drum

Resin Manufacturers

American Hoechst Corporation
Chemplex Company
Exxon Chemical Company
Soltex Polymer Corporation

PLASTIC DRUM INSTITUTE COMITTEES

REUSE COMMITTEE

Bill Newton, Chairman	Allied Chemical Corporation
Ronald Kostka	Advanced Chemical Technology
Frank Becker	American Hoechst Corporation
Jon A. Packard	Chemplex Company
Dan Barber	Container Corporation of America
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John P. DeManuelle	Exxon Chemical Company
Jeff Ames	Owens-Illinois, Inc.
E. Fogle	Soltex Polymer Corporation
Herbert Galer	U.S. Steel Products

TECHNICAL COMMITTEE

Matt Smith, Chairman	Owens-Illinois, Inc.
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Frank Becker	American Hoechst Corporation
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Earl Lind	Container Corporation of America
E. Robert Byrne	Eastern/Plastics Division
Bill Cary	Hedwin Corporation
Dave Thornburg	Phillips Chemical Company
Dan Torno	U.S. Industrial Chemicals
Herbert Galer	U.S. Steel Products

I. REPORT DIGEST

A. Objectives

The purpose of this study was to determine the ability of drum washing to neutralize an all-plastic drum from the previous lading packaged in order to safely reuse the drum in subsequent service.

B. Sponsorship

The Plastic Drum Institute (PDI) sponsored the reuse study in conjunction with the Chemical Packaging Committee of The Packaging Institute. A committee composed of container fabricators, polymer producers, and chemical producers and shippers planned the project.

C. Conclusions

Tests examining the effect of various ladings on the container material indicate:

1. The laundering process was, in general, successful, efficient. effective and had no adverse effects on the drum;

2. Minimal residue from previous ladings remain in the laundered drums. For example, the maximum residue remaining in the drums for the products tested under the titration procedure was less than 0.017% of the weight of the laundered drum.

D. Recommendations

The Plastic Drum Institute recommends that the Chemical Packaging Committee, the Petroleum Packaging Committee. and the National Barrel & Drum Association assemble a Task Group to examine the following questions:

1. Is the residue remaining in the laundered plastic drum at an acceptable level to chemical shippers?

2. What is the optimum method to be used in the laundering process?

II. REPORT DETAIL

A. Background

Reusability of all-plastic 55-gallon drums has been a subject of discussion since the first such drum was introduced in the United States in 1972. The market introduction followed the development of high molecular weight high- density polyethylene in Western Europe, the subsequent commercialization of the resin in the United States, and the availability of large-capacity molding machines. Since that time, over eight (8) million all-plastic drums have been used successfully in the United States.

All-plastic drums are formed either by blow molding high molecular weight high-density polyethylene or by rotationally molding a copolymer cross- linkable high-density polyethylene.

The all-plastic drum has brought to the chemical industry a new concept with numerous advantages: economies of acquisition, lower freight costs through reduction in tare weight and, where product and distribution systems permit, lower warehousing costs due to the drums ability to be stored outdoors. Its chemical resistance enables safe and efficient shipment of corrosive chemicals, food products, photographic chemicals, pharmaceuticals, and reagent solutions.

Plastic drums reusability is of interest by virtue of the drum's materials of construction which offer shippers additional economy through multiple trip use. Such use requires appropriate refurbishing to neutralize the container from the previous lading and to restore the overall appearance.

It was precisely the prospect of reuse that prompted the Plastic Drum Institute to initiate a test program in conjunction with the Chemical Packaging Committee of The Packaging Institute.

The Plastic Drum Institute is one such group. Its members are container fabricators and polymer producers.

A committee representing container manufacturers, polymer produce r s, and shippers of chemicals selected ladings for the test program. Refer to Table I, pages 11-12.

B. Test Procedures

The ladings chosen for testing represent the class of chemicals normally packaged in industrial plastic shipping containers. They cover a wide range of permeation rates and were selected in consultation with the chemical shippers.

The periods selected for lading storage were three months and six months. These time

frames reflect experience levels encountered by drum shippers in the normal distribution cycle and good test practices for determining packability.

The laundering process involved nine steps: two caustic rinses, three exposures to live steam, and several rinse cycles. The laundered drums were then drained and vacuumed dry.

Unfilled drums were also subject to the storage and washing procedure and used as controls.

Sections for analysis were prepared by dissecting the drums into specific top, side and bottom specimens. These specimens were then ground into a fine mesh for study.

The laboratory procedures used in the study were designed to measure the amount of material retained in the polyethylene after the laundering process or to determine changes in the polyethylene caused by exposure to the lading.

The procedures can be divided into two groups; chemical and physical test methods. The chemical methods measure the amount of material retained in the polyethylene or chemical attack on the polyethylene. The physical methods measure changes in the mechanical properties of the polyethylene caused by exposure to the chemical.

A brief description of these procedures is as follows:

Chemical

1. **Titration** - A procedure used to quantitatively measure the amount of ac1_d or base (caustic) extracted from a given amount of polyethylene. This amount is then calculated as ppm retained by the polyethylene. A basic assumption is that the chemical is completely extracted into the test solution.

2. **Infrared** - This procedure measures the chemical change in the polyethylene by comparing the "fingerprint" (IR spectrum) of exposed polyethylene to unexposed polyethylene. In this case, oxidation and changes in vinyl saturation are measures of chemical attack. The procedure can also be used as a qualitative tool to determine if chemicals are present in the polyethylene.

3. **Liquid Chromotography** - This procedure is used to measure the amount of product absorbed by the polyethylene. The polyethylene is extracted and the resulting solution analyzed by LC. The results are compared with standards prepared from the chemical in question. Again the assumption is made that the extraction is complete. The procedure was only applied to three of the test ladings.

4. **Gas Chromotography** - This procedure is similar to Liquid Chromotography in that it is a separation procedure which identifies materials by comparison with standards. In this case, only those components which can be volatilized are analyzed. The drum sample is heated in a nitrogen atmosphere and the resultant mixture, nitrogen plus volatilized lading, is analyzed by GC. The amount of product absorbed by the polyethylene is then estimated.

   GC analysis was applied to five of the ladings. Again, the assumption is made that the absorbed lading is completely removed by the analytical procedure employed.

   An extraction procedure was applied to one lading (SAE oil) with the extract analyzed by GC and the amount retained in the polyethylene calculated.

Physical

1. **Flow Rates** - This refers to the Melt Flow Rate (ASTM D 1238- F) commonly referred to as HLMI (High Load Melt Index) when speaking of the high molecular weight high-density polyethylene drum resins. The Melt Flow Rate is the amount of material that flows through a. 0825 in. diameter in 10 minutes when at a temperature of 190°C and a pressure of 432 psi. It is reported as grams per 10 minutes. Changes in Melt Flow Rate can be caused by degradation cross-linking or the lubricating effect of absorbed chemical.

2. **Density** - The density is a physical property of a material which relates its mass to the volume it occupies. Density is usually reported as grams per cubic centimeter (g/cm3). This procedure was applied to all the drums in the test program. Changes in density can occur through product absorption or chemical attack of the polymer. In the current study the annealing procedure used may have driven off some absorbed ladings.

3. **Tensile Properties** - The tensile properties were measured by ASTM 0638. These are the tensile yield strength, yield elongation. Break strength break elongation which are basic mechanical properties of a material such as polyethylene.

   The tensile strength is the force per unit area to cause yielding or failure of the material and is given in pounds per square inch (psi). The elongation is the percentage that the material elongates or stretches at yielded or break.

   Changes in tensile properties can be an indication of degradation or product absorption. In the case of degradation, the polyethylene may become brittle,

tensile strength remains the same or increases slightly while the elongation to break decreases markedly. Product absorption may show a plasticizing effect. Tensile strength decreases and elongation increases. Absorption at low levels may also show a stiffening effect.

C. Test Results[1]

TEST METHOD

Lading	Titration	IR[2]	LC	GC	MFR[3]	DEN.	Tensile[4]
10% Igepal	NA[5]	-0.1	0.02%	NA	+0.9	-	-57.5, +5.0
SAE 40	NA	-0.1	0.44%	NA	+0.8	.957	-10.3, -15.9
Methanol	NA	+0.1	NA	+[7]	+0.5	.946	-3.6, -10.7
MEK	NA	-0.2	NA	+	+0.2	.952	+0.8, +8.7
Acrylic Acid	173 ppm	-0.3	NA	+	+1.6	.950	-0.3, +64
Acetic Acid	77 ppm	-0.5	NA	+	0	.944	+10.7, -42.2
Sulfuric Acid	1 ppm	-0.2	NA	NA	-0.9	.951[8]	+3.1, -31.9
Sodium Hydroxide[9] - A	50 ppm	+0.2	NA	NA	NA	.933	-2.9, -3.4
B	1 ppm	-0.2			+0.2	.937[10]	-11.3, -25.0
Hydrogen Peroxide	NA	-0.3	NA	NA	-0.8	.954	+4.5, -7.4
Tbutyl Hydroperoxide	NA	-.0.1	0.43%	NA	-11.3	.953	+6.0, -44.4

1. Results are for 6 month washed drums.
2. Change in vinyl groups per 2000 C.
3. MFR Change in units g/10 min.; increase+, decrease-. For melt flow rates in the range of 5g/10 min., a change of 0.6g/10 min. is insignificant. For rates in the range of 11g/10 min., a change of 2g/10 min. is insignificant.
4. 1st figure change in tensile yield strength, 2nd figure change in ultimate elongation. Both are given as percentage change from control washed sample. Results for side wall samples only were used. A change of ± 10% in tensile yield strength is deemed insignificant.
5. NA - Not applied for this lading.
6. 6 mo. non washed.
7. + indicates chemical present after laundering.
8. 53 mo- washed.

9. A. = Rota Molded Drum.
   B. = Blow Molded Drum.
10. 6m non washed wts. 951.

D. Observations

During the drum reuse project, we made the following observations:

1. The water used to wash the drums may have become contaminated during the wash cycle.
2. There are also manufacturing process variables to consider.
3. lgepal is a very active stress crack agent for polyethylene. It is normally used in the ASTM Stress Crack Test. Although satisfactorily removed in the laundering process, it did have an effect on tensile properties, as expected.

PLASTIC DRUM INSTITUTE

The Real World Test

THE PDI REAL WORLD TEST

While the Plastic Drum Institute, its members, and others participating in this study have made their best efforts to provide reliable and accurate information, they individually and collectively disclaim all warranties, expressed or implied, including the warranties of merchantability and of fitness for a particular use. For a complete understanding of the study, it should be read in its entirety. Specific manufacturers' instructions should be consulted relative to the reuse of 55-gallon all-plastic drums for particular commodities.

PDI REAL WORID TEST

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Shell Oil Company
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The Dow Chemical Company

Plastic Drum Fabricators

Container Corporation of America
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Reconditioner

Bakerstown Container

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Institute of Packaging Professionals *
Chemical Packaging Committee (CPC)
Petroleum Packaging Committee (PPC)
National Barrel and Drum Association (NABADA)

*The merger of the former Packaging Institute/International with the Society of Packaging Professionals.

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TECHNICAL COMMITTEE

John DeManuelle Chairman	Exxon Chemical Americas

RE-USE SUBCOMMITTEE

Jerry Geyer	Container Corp. of America
Ed Gunn	Hunter Drum Ltd.
Andrew Campbell	Eastern/Plastic Division

ANALYTICAL PROTOCOL SUBCOMMITTEE

John Bergerhouse	Quantum Chemical Corp. and USI Division Chairman
Jimmy Parr	Exxon Chemical Americas
Earl Lind	Container Corp. of America
Don Peters	Phillips 66 Company
Ken Shaw	The Dow Chemical Company

INTRODUCTION

In 1983 the Plastic Drum Institute (PDI) issued a report entitled "The 55-Gallon All Plastic Drum Reuse Study." That report concluded:

- Ladings did not affect the structural integrity of the plastic drums.
- Reconditioning did not affect the structural integrity of the plastic drums.
- Minimal residue from previous ladings packaged remained in the reconditioned drums.

The significance of this residue to the chemical and petroleum packaging industry was broadly discussed within the PDI.

As a result of these discussions, the PDI proposed a task force in conjunction with the Petroleum Packaging Committee (PPC) and the Chemical Packaging Committee (CPC) of the Institute of Packaging Professionals and the National Barrel and Drum Association (NABADA) to develop a second study to include the evaluation of shippers responsible for the purity of packaged ladings. The task force recommended a program outline which the PDI agreed to coordinate. This program has become known as the "Real World Test."

OBJECTIVES

The primary objective of the "Real World Test" was to establish the suitability of 55-gallon all-plastic drums, which had previously seen service with another lading, for the storage and shipping of a second lading.

The criteria for acceptability were the quality control analyses performed by the shippers upon their ladings following three months storage in the used containers.

A secondary objective was to reconfirm the results of the 1983 study regarding the integrity of all-plastic drums following service and reconditioning. The test criterion was a water-filled drop test.

A further objective was the determination of the residual second lading absorbed into the polyethylene drum wall and remaining after reconditioning. Five testing laboratories produced and performed analytical procedures on sections cut from walls of the test drums.

CONCLUSIONS

The results of the "Real World Test" reconfirmed:

- Ladings did not affect the structural integrity of plastic drums.
- Reconditioning did not affect the structural integrity of the plastic drums.
- Minimal residue from previous ladings packaged remained in the reconditioned drums.

And finally it was determined that:

- Most shippers concluded that reconditioned plastic drums were acceptable for the ladings used in the study.

SUMMARY

The "Real World Test" involved the filling and storage of seventy-two 55-gallon high density polyethylene containers with six selected ladings. The ladings were chosen by the joint Task Force as representative of classes of products currently shipped in all-plastic containers. The six ladings chosen by the joint Task Force were:

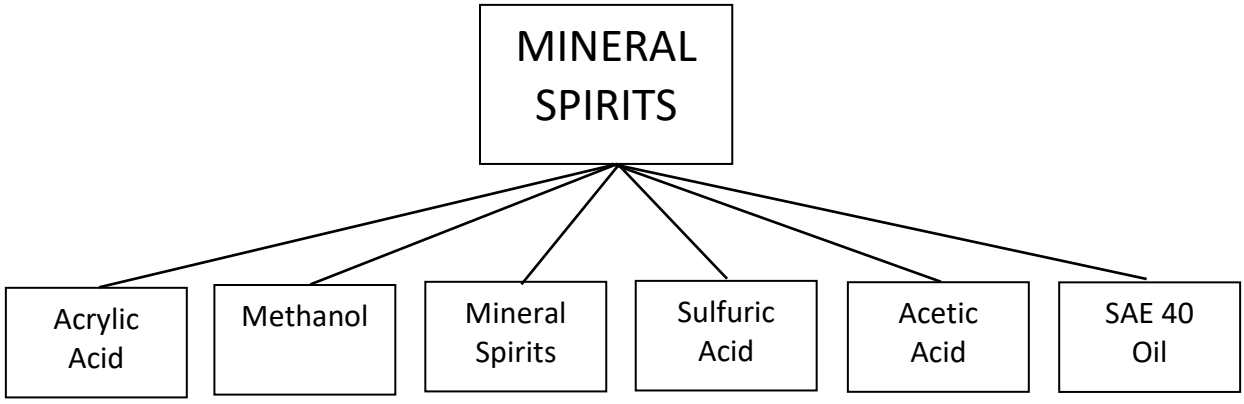
Methanol
Mineral Spirits
Acrylic Acid
Acetic Acid
Sulfuric Acid
Motor Oil

For the first phase of this test, twelve containers were filled with the ladings.

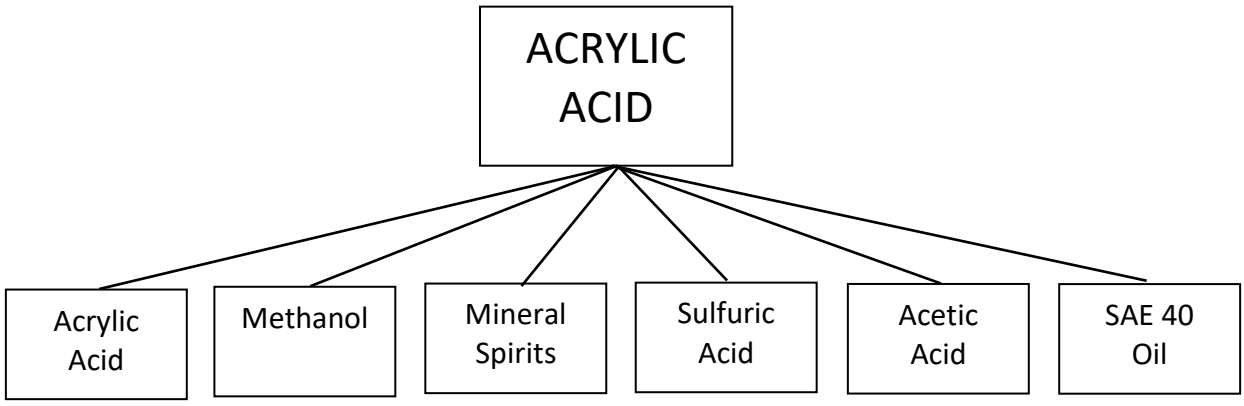
Before storage, the ladings were analyzed as a base reference. After the storage period of three months, the ladings would again be analyzed to determine what effect, if any, the storage in plastic containers had on the product in question.

After three months storage at the shippers'/fillers' facilities, the drums were emptied and sent to the reconditioner where the drums were cleaned using normal procedures for plastic drum interior, exterior and closure and, were submitted to final inspection.

The next step involved twelve drums from each product being disbursed to the various other products and filled.
The chart below illustrates the 12 drums with Mineral Spirits being apportioned to the other chemicals in the test program.



The following chart illustrates the apportionment of Acrylic Acid. This same procedure would be conducted with the remaining 4 chemicals until all 72 drums were in their proper categories.



After filling, the drums were stored by shippers/fillers for a period of three months. Before and after the three month storage period, the ladings were again analyzed for possible contaminates. Comments of the shippers/fillers concerning these assay results determined the suitability of reused drums for service with each lading.

After emptying the second lading, the drums were returned to the reconditioner and were again cleaned following normal procedures for plastic drums.
The drums were subjected to flat-side drop at an ambient temperature from a height of six feet. The drums were divided into sets pertaining to the second lading and forwarded to five

laboratories while they developed techniques for quantifying the residual second lading absorbed into HPDE. The laboratories were asked to determine the residual second lading in sections cut from the drum walls. Lading concentrations were reported as an average value for each lading and as a function of the first lading.

Further, for drums that contained the same lading in both fillings, the laboratories determined a residual lading gradient by dividing the drum wall cross section into thirds (inner, middle, and outer) and performing the analysis on these sections.

The PDI Real World Test Part II

The Resin Reconditioning Study

The Plastic Drum Institute

www.plasticdrum.org

PDI REAL WORID TEST

The Resin Reconditioning Study is part of an ongoing industry study on the reuse of plastic drums that once contained hazardous materials. No part of this study should be used to determine compliance with any part of the Department of Transportation's Hazardous Materials Regulations. While the Plastic Drum Institute, its members and the study participants have attempted to conduct this study using industry-accepted test methods, use of a method does not warrant the validity of a particular method.

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Plastic Drum Fabricators

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Resin Manufacturers

Fina Corporation
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Novacor Chemical, Ltd.
Phillips 66 Company
Quantum Chemical Corporation

Reconditioners

National Container Services Inc.
Restoration Plastics Inc.

Plastic Drum Institute
Technical Committee

John Bergerhouse, Chairman	Quantum Chemical
Don Belcher	Dow Chemical
D'Jaris Richardson	Fina Corporation
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Earl Lind	Russell-Stanley
John Malik	Sonoco Plastic Drum

INTRODUCTION

Two prior Plastic Drum Institute (PDI) reports have been issued on studies of HOPE drums to determine their ability to be reused and the effect of lading contamination. These studies were written up as the following reports:

In 1983 the PDI issued a report entitled "The 55-Gallon All Plastic Drum Reuse Study." Its main purpose was to investigate whether the lading or reconditioning of the plastic drum affect- ed the structural integrity of the plastic drum for a second use. It was found that the lading or drum reconditioning did not affect the structural integrity of the plastic drum. It was noticed that minimal residue from the previous ladings packaged remained in the reconditioned drums. This residue was broadly discussed and prompted a second study.

The PDI issued a second report in 1990 that was entitled "The Real World Test." This study was to establish the suitability of 55-gallon all-plastic drums, which had previously seen service with another lading, for the storage and shipping of a second lading. The primary objective was acceptability of the ladings determined through quality control analysis upon the ladings after a three month storage in used containers. A secondary objective was reconfirmation of the results from the 1983 study regarding the integrity of the all-plastic drums following service and reconditioning. A third objective was the determination of the second lading absorbed into the polyethylene drum wall and remaining after reconditioning.

The results of this second study reconfirmed that minimal residue from previous ladings pack- aged remained in the reconditioned drums. Most shippers concluded that the reconditioned plastic drums were acceptable for the ladings used. Also reconfirmed was that the ladings and reconditioning did not affect the structural integrity of the plastic drum, as seen in the 1983 study.

DISCUSSION

It was shown in the "Real World Test" that 55-gallon all-plastic drums can be successfully reused in selected secondary service. A possible conclusion to the life of a polyethylene drum would be as a recycled material going into a totally unrelated application. As the recycled polyethylene currently available goes through a special cleaning process, above and beyond that used to recondition a drum for secondary use, it is reasonable that an investigation be made into continuing the PDI work to measure the amount of residual lading detectable after the polyethylene has been subjected to such a process.

OBJECTIVES

The primary objective of the "Resin Reconditioning Study" was to quantify the residual of six selected ladings remaining absorbed into the HOPE used to make a drum after both a drum reconditioning step and the treatment of the resin through a typical post consumer polyethylene plant.

A secondary objective was to conduct investigative work into the usefulness of a Microtox® test that could determine toxicity level of the residual lading in the high density polyethylene (HOPE) drum samples during the various stages of the study. This test consisted of leaching the drum samples to try and remove any residual ladings in them. The leachate was then mixed with the pure Microtox® reagent. The Microtox® reagent is a living bacteria which emits light. If the lading or concentration of the lading from the leachate is toxic to the living bacteria, then some of the bacteria will perish. The amount of light emitted will, therefore, be reduced. An instrument measures the light and a relative value is reported on the toxicity of the sample.

CONCLUSIONS

The results of the "Resin Reconditioning Study" showed:

- Residual lading absorbed into the HOPE of the drum could be reduced for some of the ladings through the drum reconditioning, secondary flake washing and repalletization steps.
- The Microtox® test was able to give some measurement of toxicity and changes in toxicity during steps of the cleaning process.
- It is believed that failure in the Microtox® test does not mean it precludes recycling of the tested drum sample.

SUMMARY

The Real World Test - Part 2, "Resin Reconditioning Study" involved obtaining in-service drums with six ladings. The ladings were similar to those used in the "Real World Test". The ladings were

Hydraulic Oil	Acrylic Acid
Acetic Acid	Sulfuric Acid
Mineral Spirits	Methanol

The drums were emptied of their contents and sent to a drum reconditioner where the drums were cleaned under normal procedures for plastic HDPE drums.

As a next step the drums were then granulated into a flake. The flake was sent to a pilot reconditioning system where the flakes were washed in a secondary operation for further possible removal of residual lading that absorbed into the HDPE.

After this secondary washing step the flakes were sent to a facility for repalletization.

Samples which had been saved at several step of the cleaning process were forwarded to four laboratories for analytical testing of levels of residual lading in the samples. Physical property testing was also conducted on the HDPE to determine if any loss in properties was observed. Also at this time some of the samples were forwarded to a laboratory to conduct a Microtox® test to determine its ability to be used for testing of toxicity of residual lading and differences in level of toxicity of the various stages of the cleaning process of the study.

The PDI Real World Test Part III

Drum Performance with Recycled Content

The Plastic Drum Institute
www.plasticdrum.org

DRUM PERFORMANCE WITH RECYCLED CONTENT

I. INTRODUCTION

Three prior Plastic Thurn Institute (PDI) reports have been issued on studies of High Density Polyethylene drums to determine their ability to be reused, the effect of lading contamination and ability to clean residual lading from used drum recycle resin. These studies were written up as the following reports:

In 1983 the PDI issued a report entitled "The 55-Gallon All Plastic Thurn Reuse Study". Its main purpose was to investigate whether the lading or reconditioning of the plastic drum affected the structural integrity of the plastic drum for a second use. It was found that the lading or drum reconditioning did not affect the structural integrity of the plastic drum. It was noticed that minimal residue from the previous ladings packaged remained in the reconditioned drums. This residue was broadly discussed and prompted a second study.

The PDI issued a second report in 1990 that was entitled "The Real World Test". This study was to establish the suitability of 55-gallon all-plastic drums, which had previously seen service with another lading, for the storage and shipping of a second lading. The primary objective was acceptability of the ladings determined through quality control analysis upon the ladings after a three month storage in used containers. A secondary objective was reconfirmation of the results from the 1983 study regarding the integrity of the all-plastic drums following service and reconditioning. A third objective was the determination of the second lading absorbed into the polyethylene drum wall and remaining after reconditioning.

The results of this second study reconfirmed that minimal residue from previous ladings packaged remained in the reconditioned drums. Most shippers concluded that the reconditioned plastic drums were acceptable for the ladings used. Also reconfirmed was that the ladings and reconditioning did not affect the structural integrity of the plastic drum, as seen in the 1983 study.

In 1993 the PDI issued a third report entitled "PDI Real World Test Part 2 - Resin Reconditioning Study". The PDI was interested in investigating the ability to recondition the High Density Polyethylene for a recycle material from plastic drums taken out of service. The drums were cleaned under standard drum reconditioning, ground into flake, the flake was washed in a secondary washing operation that is typical of post-consumer polyethylene recycle plants and then repelletized. The primary objective of this study was to then quantify the residual ladings remaining absorbed into the High Density Polyethylene at various step during the cleaning and repelleting process.

A secondary objective was to conduct investigative work into the usefulness of a Microtox test that could determine toxicity level of the residual lading in the High Density Polyethylene during various stages of the study.

II. DISCUSSION

The work conducted by PDI to date has shown that plastic drums can be successfully used in packaging various products without detriment to performance properties of the drum due to effects of the lading, primary or secondary, or cleaning processes. Also after the plastic drums have come to the end of their service life that the drums can then be ground up and the resin cleaned so that it can be recycled into a secondary application.

At the present time HM 181 standards state the following: ''No used material other than production residues or regrind from the same manufacturing process may be used." This prohibits the use of drum recycle resin back into the production of new drums for service. Therefore, the PDI determined that an investigation into the feasibility of incorporating drum recycle resin back into new production 55 gallon plastic drums would be done. A program was developed with the following project steps:

- Material Procurement
- Material Preparation
- Drum Production
- Drum Testing

MATERIAL PROCUREMENT

An equal number of drums which had contained the following seven ladings were selected for use in this study:

- Apple Juice
- Sulfuric Acid
- Sodium Hydroxide
- Alcohol based flavor compound
- Hydrogen Peroxide
- Surfactant
- Biocide

The above lading.5 were chosen to represent a cross-section of the majority of drum types available. MSDS sheets for all regulated products are included in Appendix A. In order to ensure a consistent flow rate for the recycled resin, drums were also selected based on the knowledge of the flow properties of the original resins used by each drum manufacturer. All drums were produced with high density, high molecular weight polyethylene ASTM D1248, Type ill , Category 5. Drums were selected to ensure a recycled product with a high load melt index of 3 - 5 dg/min.

MATERIAL PREPARATION

All drums were washed by Recycle, Inc. using a wash procedure which conforms to the EPA guidelines for triple rinsing. Drums were flaked and blended into 5 boxes containing l_Q00 lb. each. A composite sample was taken from each box for flow rate testing to ensure that the target flow rate range was met. The data are provided in Table 1. Oxygen induction time measurements were also taken to determine whether additional stabilization would be required during the pelletization of the flakes. It was determined that the resin was adequately stabilized. Corrosivity testing was also conducted to ensure that there would be no machine damage in processing this material. The tests showed the material to be non-corrosive. A headspace GC-MS analysis was conducted on the drum recycle regrind and drum recycle repelletized resin. Test results for both the corrosivity testing and the headspace GC-MS analysis are provided in Appendix B.

The boxes containing the flaked material were sent to Custom-Pak Extrusion to be pelletized. The material was pelletized for improved processing during the drum production trials. Material was then sent to Hunter Drums Ltd. for drum production trials.

DRUM PRODUCTION/TESTING

It has been shown in previous studies by the PDI that the physical properties of the plastic drum are not significantly altered through multiple reconditioning.5. It has also been established that only minimal residual lading remains in the polyethylene. The primary objective of this study was to demonstrate that recycled polyethylene taken from used plastic drums could be used in the manufacture of new drums. Also that these drums would be capable of passing performance testing as set out in HM 181.

The drum test program was conducted in two parts. In test I, drums were produced with a wide range of recycled content. The primary purpose for this test was to determine the feasibility of producing drums with various levels of regrind and in addition the effect on primary drum properties such as ESCR and stack performance. Following the success of test I, it was decided to conduct a second test in order to produce a set of drums for passing all HM 181 performance testing. Current legislation includes mandates for certain consumer packaging of up to 25%

recycled content. It was decided to conduct a full scale test to produce drums with 30% recycled content for complete testing.

TEST I

Drums with five percentages of drum recycle regrind (0, 10, 25, 50, 100) were produced during a one-day production trial at Hunter Drums Ltd. The virgin resin used to blend with the drum recycle regrind was a nominal 3.5 HL:MI, high molecular weight, high density polyethylene from Novacor. The drum style produced for this trial was the Polycon 210 Liter Tight Head Drum. Observations were made of all critical processing conditions. Slight process changes due to the addition of the recycled material were adjusted for using routine production procedures. There was no change in the temperature settings, cycle time or throughput. A record of the weights and dimensions for every drum set was also recorded. A summary of bung dimensions and average drum weight are included in Tables 2 and 3, respectively. Drums with each of the five regrind levels were sent to TEN-E Packaging Services, Inc. for ESCR and 28-day stack testing. Drum ESCR testing was performed according to AS1M D5571 and 28-day stack testing was performed in accordance with the Department of Transportation's Title 49 CFR Section 178.606. A summary of the test results are shown in the Table 4. A complete test report is included in Appendix C, which also includes flow rate and density values as well as wall thickness profiles and weights measured on each drum set. All drums, including those produced with 100% of the recycled material, passed the ESCR and 28-day stack testing.

TEST II

Drums with 0% and 30% recycled content were produced during a one-day production trial at Hunter Drums Ltd. The virgin resin used to blend with the drum recycle regrind was a nominal 3.5 HL:MI, high molecular weight, high density polyethylene from Novacor. The drum style produced for this trial was the Polycon 210 Liter Tight Head Drum. Drums produced with O and 30% recycled content were sent to TEN-E Packaging Services, Inc. for complete performance testing. A summary of the test results are shown in the Table 5. A complete test report is included in Appendix 4. Drum testing was conducted in conformance with the Department of Transportation's Title 49 CFR for packing group II. Drums produced with 30% recycled drum resin passed all performance tests.

III. CONCLUSIONS

- Recycled material from various drum ladings can be successfully handled through grinding and repelletization.
- Recycled material could be manufactured into new drums at up to 100%.
- Drum ESCR and 28-day stack performance was maintained with up to 100% recycled content.
- Drums produced at a chosen recycled content of 30% passed all UN performance testing for packing group II.

Table 1

FLAKED MATERIAL FLOW PROPERTIES

BOX	FLOW RATE (dg/min), (190/21.6)
1	5.0
2	4.7
3	4.8
4	4.5
5	4.9

Table 2

BUNG DIMENSIONS

DRUM	COARSE THREAD DIAMETER VERTICAL (inch)	COARSE THREAD DIAMETER HORIZ. (inch)	OUT OF ROUND	FINE THREAD DIAMETER VERTICAL (inch)	FINE THREAD DIAMETER HORIZ . (inch)	OUT OF ROUND
0% RECYCLE	2.38	2.40	0.02	2.22	2.24	0.02
10% RECYCLE	2.38	2.40	0.02	2.23	2.23	0.00
25% RECYCLE	2.39	2.40	0.01	2.22	2.24	0.02
50% RECYCLE	2.37	2.40	0.03	2.21	2.22	0.01
100% RECYCLE	2.38	2.37	0.01	2.22	2.24	0.02

Table 3

DRUM WEIGHT DATA

DRUM		DRUM WEIGHT (KG)	FLASH WEIGHT (KG)	TOTAL WEIGHT (KG)
0% RECYCLE	AVERAGE	10.22	1.96	12.19
	STAND. DEV.	0.02	0.03	0.03
10% RECYCLE	AVERAGE	10.21	1.93	12.13
	STAND. DEV.	0.01	0.02	0.02
25% RECYCLE	AVERAGE	10.24	1.98	12.22
	STAND. DEV.	0.03	0.05	0.05
50% RECYCLE	AVERAGE	10.26	1.90	12.16
	STAND. DEV.	0.02	0.02	0.03
100% RECYCLE	AVERAGE	10.16	1.90	12 .06
	STAND. DEV.	0.03	0.05	0.06

Table 4

TEN-E TEST RESULTS
FROM SEPTEMBER 30, 1994

	100 % Virgin 0%PCR	90 % Virgin 10% PCR	75 % Virgin 25%PCR	50 % Virgin 50% PCR	0 % Virgin 100% PCR
28 DAY STACK TEST Specific Gravity: 1.8	3/3 Passed	3/3 Passed	3/3 Passed	3/3 Passed	3/3 Passed
ESCR (days) 10% lgepal, 10% rated capacity, 2 psi internal pressure, 50°C					
Drum 1					
Drum 2	21	12	18	16	21
Drum 3	21	18	21	23	21
	18	20	14	No Failure	25

Table 5

TEN-E TEST RESULTS
FROM
MARCH 24, 1995

	100 % Virgin 0%PCR	70% Virgin 30%PCR
DROPS 1.5M, -18°C		
Diagonal Top Chime	3/3 Passed	3/3 Passed
Flat On Side	3/3 Passed	3/3 Passed
LEAK PROOFNESS Test Pressure 20 Kpa	3/3 Passed	3/3 Passed
HYDROSTATIC PRESSURE Test Pressure 100 Kpa	3/3 Passed	3/3 Passed
28 DAY STACK TEST Specific Gravity: 1.8	3/3 Passed	3/3 Passed
VIBRATION TEST	3/3 Passed	3/3 Passed
DYNAMIC CQMERESSIQN	3/3 Passed	3/3 Passed
ESCR (days) 10% lgepal, 10% rated capacity, 2 psi internal pressure, 50°C		
Drum 1	13	21
Drum 2	16	13
Drum 3	15	15