Plastics Recycling Technical Assistance Report

RECYCLING TECHNOLOGY ASSISTANCE PARTNERSHIP ReTAP

AN AFFILIATE OF MANUFACTURING EXTENSION PARTNERSHIP™

PLASTICS RECYCLING
TECHNICAL ASSISTANCE REPORT

FINAL REPORT

PREPARED FOR:

CWC
A division of the Pacific NorthWest Economic Region (PNWER)
2200 Alaskan Way, Suite 460
Seattle, WA 98121

March 1999

PROJECT CONSULTANTS:

Cascadia Consulting Group
O'Brien & Company
DAK Consulting
LBA Associates

This recycled paper is recyclable

Report No. PL-99-1

ACKNOWLEDGMENTS

CWC is a nonprofit organization providing recycling market development services to both businesses and governments, including tools and technologies to help manufacturers use recycled materials. CWC is an affiliate of the national Manufacturing Extension Partnership (MEP) – a program of the US Commerce Department's National Institute of Standards and Technology. The MEP is a growing nationwide network of extension services to help smaller US manufacturers improve their performance and become more competitive. CWC also acknowledges support from the US Environmental Protection Agency and other organizations.

Recycled Plastic Products, Inc., and Plastics Design and Manufacturing (PDM) were selected for this technical assistance project. Recycled Plastic Products, Inc., manufacturers and distributes a line of recycled plastic fencing products, and PDM is a custom molder, which provides molding services to Recycled Plastic Products. CWC would also like to thank the contract molding facility, Techworks (located in Denver, CO)

TABLE OF CONTENTS

Page

APPENDICES

EXECUTIVE SUMMARY

The goals of this project were to provide hands-on technical assistance to selected Colorado businesses and to demonstrate the effectiveness of recycling extension services to those businesses. Two separate technical assistance projects relating to plastics recycling were undertaken as part of the Industrial Partnership Program (IPP): 1) using recycled plastic flake in an extrusion molding process; and 2) using recycled plastics in an injection molding process. This report presents the results and evaluation of these efforts.

The first project provided support to a manufacturer in using recycled plastic flake as a substitute for pellets, with the aim of helping to develop and expand the potential market for locally produced clean-washed HDPE flake; most, if not all manufacturers in Colorado are currently only manufacturing with pellets.

The product and process for the technical assistance project was a hollow profile extrusion for 1" x 6" and 1" x 8" fence pickets. The extrusion process used an extruder with a water-filled vacuum tank and a pulley. The product was originally manufactured with 100% reclaimed HDPE pellets (Dupont™), with a color and ultraviolet (UV) inhibitor additive.

Testing was performed on two different dates at a custom molder's extrusion molding department. Materials selected for testing included Talco's™ 100% post-consumer HDPE washed flake, and EcoPlast's™ 100% post-consumer HDPE washed flake. It was determined that both products were the same in quality and composition, and therefore, only the Talco product was used for testing purposes.

On the first testing date, samples of 20%, 40%, 60%, and 80% flakes, mixed with the Dupont pellets, were prepared and extruded, both with and without the color additive. The extrusion process and processing parameters were monitored, samples of the extruded pickets were taken for each sample mix, and the quality of each sample mix was observed. The test samples were collected and sent to a testing lab to perform physical property testing. Based on preliminary test results, a second testing with samples of 25%, 30%, and 35% flake mixed with Dupont pellets was requested to better determine the upper threshold of flake content.

Test results indicated that a blend of 25% flake provided a product of acceptable physical and visual quality, and the mix of flakes and pellets could be processed on the existing equipment without any modifications in equipment or process parameters. Additional equipment is required to mix the flakes and pellets at a higher ratio.

This project demonstrated the economic and technical feasibility of using recycled plastic flake in a minority ratio with pellets in a specific extrusion molding process. This increased usage could provide a new market for recycled plastic bottles in Colorado, create new jobs in recycling and processing the flake, and offer a superior cost alternative to more distant national markets for recycled plastic bottles.

The other technical assistance project consisted of two elements: (1) testing the use of recycled plastic in an injection molding process; and (2) conducting a survey of injection molding companies in Colorado about recycling issues.

The testing involved using both injection grade plastics and bottle grade recycled plastics, with the aim of helping to develop and expand the potential market for locally produced, recycled-injection grade plastics. The testing included processing trials of the recycled plastics in an injection molding process and laboratory testing of the recycled-content parts, to determine their strength and melt flow characteristics.

The survey consisted of questions aimed at identifying the market potential and requirements for using recycled injection grade plastics in existing injection molding manufacturing.

The process testing was conducted at a contract molding facility, Techworks (located in Denver, CO), on a total of 13 samples, including recycled bottle grade high density polyethylene (HDPE) flake from two different suppliers, mixed with injection grade virgin

HDPE pellets. The feedstock mixes were tested at 20% flake, 40% flake, 60% flake, and 100% flake.

Processing tests were also conducted on several injection grade plastics samples, including repelletized post-consumer HDPE, repelletized post-industrial polypropylene (PP), post-consumer dairy tub containers in flake form [(mixed HDPE and LDPE (low density polyethylene)], post-consumer HDPE buckets and crates in flake form, and post-industrial PP in flake form. All sample materials were processed in a commercial scale injection-molding machine, using a non-proprietary mold as a testing mold. All material samples were also sent to a testing laboratory for tensile strength, melt index and impact strength testing.

Information provided by the facility indicated that all of the bottle grade HDPE mixes processed adequately with similar processing conditions and times. Both of the repelletized samples (HDPE and PP) also processed sufficiently. Processing results of the remaining samples (with flake from dairy tubs, buckets, crates, and post-industrial PP) were unsuccessful, apparently due to various contaminants in the samples.

The test results indicated that the physical properties of the plastics were within usable ranges for the resin types, and comparable with their virgin resin equivalents. However, significant variation was seen between the recycled HDPE flakes provided by two different suppliers, although both samples were supposedly from post-consumer HDPE bottles. Additional testing of multiple samples over time would be required to determine the variability from suppliers of the recycled plastics tested in this project.

1.0 PLASTICS RECYCLING TECHNICAL ASSISTANCE REPORTS

Two separate technical assistance initiatives relating to plastics recycling were undertaken as part of the Industrial Partnership Project (IPP): 1) using recycled plastic flake in an extrusion molding process; and 2) testing the viability of using recycled plastics in an injection molding process.

1.1 Extrusion Molding Technical Assistance Project

Goals

The goals of the technical assistance portions of the IPP project were to provide hands-on technical assistance to select Colorado businesses and to demonstrate the effectiveness of providing recycling extension services to Colorado businesses.

Selection Criteria

The IPP project solicitation specified that one of the three technical assistance projects should address a plastics manufacturer converting to recycled materials or using more recycled materials in their product. Using this as a guideline, a plastics focus group comprised of plastics manufacturers, suppliers and processors in Colorado was formed. Input was gathered by the group on the most appropriate and effective areas for technical assistance in the local plastics industry. Other criteria was added, including an achievable scope, budget and schedule within the project constraints, and a technical assistance area of focus that would have benefits for plastics recycling in the state.

The focus group suggested and reviewed several possible technical assistance projects, and finally recommended a project focusing on the plastics manufacturing use of recycled HDPE or LDPE in a washed flake form. These resins have some established collection and handling infrastructure already, providing a potential supply of locally generated materials. The project team had already identified several manufacturing companies who used recycled pellet imported from outside of Colorado. A processing system to grind and wash these materials could potentially be economically effective in competition with out-of-state pelletizing operations. The technical assistance project would provide assistance to a selected manufacturer in using recycled flake as a substitute for pellets, with the aim of helping to develop and expand the potential market for locally produced clean washed HDPE or LDPE flake. The processing equipment required to feed flakes could be different than that for pellets, and most if not all manufacturers in Colorado are currently only operating with pellets.

Activities

Based on the recommendations of the plastic focus group, the technical assistance project was designed with the following components:

1. Survey potential manufacturing markets for recycled materials and develop needs/requirements, focusing on HDPE and LDPE, and noting all potential opportunities to use washed flake in substitution for pellets.
2. Create a material testing model to provide samples of washed flake to a selected manufacturer to develop, test, and demonstrate the requirements for using recycled materials in the manufacturing process. A range of usable specification properties could be developed and then tested to validate the specifications.
3. Provide technical assistance on feed equipment requirements, operating procedures for using the flake material, and evaluating the cost-effectiveness of appropriate equipment modifications for the use of flake instead of or in addition to pellets.

Recycled Plastic Products, Inc., and Plastics Design and Manufacturing (PDM) were selected for the technical assistance project. Recycled Plastic Products manufactures and distributes a line of recycled plastic fencing products, and PDM is a custom molder, which provided the molding services to Recycled Plastic Products. The product and process for the technical assistance project was a hollow profile extrusion for 1” X 6” and 1” X 8” fence pickets. The extrusion process used an extruder with a water-filled vacuum tank and a pulley.

The product is manufactured with Dupont 100% reclaimed HDPE pellets, with a color and UV inhibitor additive.

Testing was done on two different dates at PDM's extrusion molding department. Materials selected for testing included Talco's 100% post-consumer HDPE washed flake, and EcoPlast's 100% post-consumer HDPE washed flake. Based on comparisons of the two testing materials, it was determined that they were essentially the same in quality and composition. Therefore, only one material, the Talco product, was used for testing purposes. On the first testing date, samples of 20%, 40%, 60% and 80% flakes mixed with the Dupont pellets were prepared and extruded, both with and without the color additive. The extrusion process and processing parameters were monitored, samples of the extruded pickets were taken for each sample mix, and the quality of each sample mix was observed. The test samples were collected and sent to a testing lab to perform physical property testing.

Based on the preliminary results of the first tests, Recycled Plastic Products requested a second testing with samples of 25%, 30% and 35% flakes mixed with the Dupont pellets, to better determine the upper threshold of flake content. This second testing was conducted at PDM and followed the same procedures as the first testing date.

A telephone survey was developed by the project team and conducted by TechWork. The survey consisted of contacting extrusion molders and asking a series of questions regarding the current and potential use of recycled resins in their manufacturing processes, and the potential for the use of clean flake as a substitute for pellets.

Outcomes

During the first testing date, it appeared that at 20%, the processing system performed near normal (material had to be hand blended), with no problems with the feed system, extrusion operation, maintaining integrity of profile through vacuum tanks, cooling process, puller and chop saw. The product quality was generally acceptable and comparable to the standard product with DuPont pellets. There was some contamination from labels or foreign plastic in all product samples, and some color contamination from foreign plastic in natural-colored samples.

The 40% blend presented problems with process stability. There were no problems with the feed system but the extruder required constant adjustment to maintain part integrity in the vacuum tanks and water bath. The increased flake and foreign particles caused voids in the product, resulting in holes in the product.

With the 60% blend, a stable product could not be achieved even with continued feeding of the material. The extruder was able to melt and blend the material but caused the die to clog and the product could not be pulled through the water bath vacuum tank. After several attempts to stabilize the process, there was no success in getting product through the process.

During the second testing date, it appeared that at 25%, the processing system performed near normal, as with the 20% level. The product had to be examined by the customer, who was to determine whether the quality would be acceptable and comparable to the standard product with 100% DuPont pellets. There was still some minimal contamination from labels or foreign plastic in all product, and color contamination from foreign plastic in natural-colored samples.

During the 30% and 35% mix tests, the processing system performed near normal, with no problems with the feed system, extrusion operation, cooling process, puller and chop saw. The integrity of profile coming out of the die seemed a little more flimsy but no adjustments were made. There was significantly more contamination from labels or foreign plastic causing sink marks, and it was assumed that this would cause the product to be rejected. Color contamination from foreign plastic in natural-colored samples continued.

The customer did not examine the product run in this test, but it would seem from the results of the test, that a blend at 25% would still provide a product of acceptable visual quality. While higher percentage mixes could be processed adequately, visual defects at levels above 25% would most likely be unacceptable. For extrusion products with lower aesthetic requirements, products not extruded using a vacuum tank in the process and/or solid profile products, these factors would not be limiting and higher percentage mixes of flake up to 40% and higher could be processed. Also, based on the custom molder's experience, the use of larger diameter extruders at lower RPM and processing temperature could reduce problems with off-gassing from recycled material, improve processing of flake mixes, and allow mixes of approximately 50%.

Based on the results of the processing tests, the mix of flakes and pellets could be processed on the existing equipment without any modifications in equipment or process parameters. Some additional equipment would be required to mix the flakes and pellets at the desired ratio. This could be done on a batch basis, producing gaylord quantities of the mix for feeding with the existing feed and process equipment. The best process and equipment for this mixing function may be the topic of additional testing and/or technical assistance for this processor, and the costs of this additional equipment would have to be weighed against the economic benefits of using the flake material.

The economic benefits of using recycled flake at a 25% ratio are substantial. At current pricing, including transportation of the flake material from out of state, the flake could provide a $0.05 to $0.10 per pound discount from pellets, including transportation costs to PDM. While this discount could vary, depending on pricing fluctuations, at 25% of all feed material, and a typical processing volume of 80,000 pounds per month, the use of flake could save $1,000 to $2,000 per month in materials costs. These savings, or the discount of flake from pellets could be even greater if the flakes were locally produced, assuming that locally prepared materials would have a reduced transportation cost. From a local market development standpoint, this manufacturer, using clean flake at the suggested levels, could create a demand for up to 240,000 pounds per year for locally produced clean washed flake.

Results from the molders survey indicates that there could be an additional market potential for use of clean flake. Of the 25 companies for which survey results were completed, roughly one-third used HDPE in injection or extrusion molding and about the same percentage used washed flake or clean industrial regrind on a regular basis. Most of these used clean industrial regrind from their own in-house scrap materials. The major concerns with the use of flake from outside sources were consistency of materials, quality of materials and supply of materials. A little less than half of the respondents indicated that they would use technical assistance program services in using new materials such as recycled clean flake in their manufacturing operations.

1.2. Injection Molding Technical Assistance Project

Goals

The goals of the technical assistance portions of the IPP project were to provide hands-on technical assistance to selected Colorado businesses and to demonstrate the effectiveness of providing recycling extension services to those businesses.

Selection Criteria

This is the second technical assistance project dealing with plastics manufacturing, and was included in the project after a technical assistance project focusing on recycled glass materials was not available. As with the first plastics project, in addition to the criteria that the project select a plastics manufacturer converting to recycled materials or use more recycled materials in their product, other criteria were added, including an achievable scope, budget and schedule within the project constraints, and a technical assistance area of focus that would have benefits for plastics recycling in Colorado.

The plastics focus group had suggested a secondary project, dealing with a market survey and technical assistance for the use of post-consumer injection grade HDPE, LDPE, and PP. These resins and packaging types (diary tubs, buckets, crates, etc.) have very limited collection and handling infrastructure in Colorado. Technical assistance focusing on this group of resins could help to open-up collection, processing and re-manufacturing for materials currently not being recovered.

Activities

Based on the recommendations of the plastic focus group, the technical assistance project was designed with the following components:

1. Survey potential manufacturing markets for recycled materials and develop needs/requirements, focusing on injection grade HDPE, LDPE and PP.
2. Provide samples of recycled injection grade materials to a selected virgin manufacturer to test and demonstrate the requirements for using recycled materials in their manufacturing

processes, and provide technical assistance on feed equipment requirements, and operating procedures for using the recycled material.

Sample testing and processing using available molds was performed at TechWorks' facility. Processing tests were conducted on a total of 13 samples, including mixes of recycled bottle grade HDPE (high density polyethylene) flakes from two suppliers with injection grade virgin HDPE pellets, at 20% flakes, 40% flakes, 60% flakes and 100% flakes. Processing tests were also conducted on several injection grade plastics samples, including repelletized post-consumer HDPE, repelletized post-industrial PP (polypropylene), post-consumer dairy tub containers in flake form (mixed HDPE and LDPE-low density polyethylene), post-consumer buckets and crates in flake form (HDPE), and post-industrial PP in flake form. All sample materials were processed in a commercial scale injection molding machine, using a non-proprietary mold as a testing mold. All material samples were also sent to a testing laboratory for tensile strength, melt index and impact strength testing.

Outcomes

Anecdotal information provided by the facility indicated that all of the bottle grade HDPE mixes processed adequately, with similar processing conditions and times. Both of the repelletized samples (HDPE and PP) also processed adequately.

Processing results of the remaining samples were unsuccessful, apparently due to various contaminants in the samples. The post-consumer dairy tub containers in flake form (mixed HDPE and LDPE-low density polyethylene) were extremely runny with a viscosity similar to water. The processor was unable to maintain it in the barrel and it immediately clogged the mold, which required a complete teardown and clean out of the machine. The processor did not clarify if this was a problem with the sample material or inappropriate settings on the injection-molding machine. This sample was not re-tested.

No processing results were provided for the post-consumer buckets and crates in flake form (HDPE).

The post-industrial PP in flake form could not be processed successfully, due to water contamination in the sample. This sample was dried, still had contaminants and clogged the nozzles.

The physical testing results for the HDPE flake and virgin pellet mixes showed increasing tensile strength and impact strength, along with decreasing melt flow as the percentage of recycled flakes was increased. This was because the flakes were from bottle-grade HDPE, which typically has a higher strength and lower, or fractional melt flow value compared to injection grade HDPE. The following table shows typical ranges of melt flow rate, tensile strength and Izod Impact values for different grades of HDPE.

Grade HDPE	Density, g/cc	Melt Flow Rate #g/10 min.	Tensile Strength at Yield, 1000 psi	Izod Impact, Notched ft-lb/in (1/8 in)
Blow Molding Grades	.945 - .961	0.05 – 100	3.3 – 4.4	1.4 – 2.2
Extrusion Grades	.941 - .961	0.1 – 54	2.4 – 3.5	8 – 16
Injection Grades	.942 - .964	0.2 – 100	2.3 – 4.8	1.2 – 1.8

Because the HDPE material blends followed a fairly consistent pattern of increasing strength and decreasing melt flow with increasing percentage of bottle-grade flake, the tests indicated that a predictable strength and melt flow could be obtained from a mix of the recycled bottle-grade flakes and injection grade virgin pellets. Thus, allowing a manufacturer to use the flakes to prepare a feedstock with desired characteristics for a specific application.

The repelletized post-consumer HDPE showed strength test results comparable to that of the post-consumer flake, and a noticeably higher melt flow value. The repelletized post-industrial PP showed low strength for PP resin, and a melt flow similar to the HDPE flake materials. The post-consumer dairy tub containers in flake form (mixed HDPE and LDPE-low density polyethylene) was not tested due to significant contamination of the sample in the form of glass, aluminum and other metal. The post-consumer buckets and crates in flake form (HDPE) tested a low strength value, and the post-industrial PP in flake form tested within the expected range for strength and melt flow.

The test results indicated that the physical properties of the materials tested are within usable ranges for the resin types, and comparable with their virgin resin equivalents. The remaining issue for successful use of these types of materials would be the consistency of supply. Typically, recycled plastics can vary significantly from batch to batch, both in strength, melt flow and color, causing processing and quality problems for manufacturers. Significant variation was seen between the recycled HDPE flakes provided by two different suppliers, although both samples were supposedly from post-consumer HDPE bottles. Additional testing of multiple samples over time would be required to determine the variability of the specific supplies of recycled plastics tested in this project. The following table presents the results of the testing.

Sample Material	Melt Flow Rate #g/10 min.	Tensile Strength at Yield, 1000 psi	Izod Impact, Notched ft-lb/in (1/8 in)
(1) HDPE Talco flake 20%, 80% virgin	13.190	2.970	0.63972
(2) HDPE Talco flake 40%, 60% virgin	6.440	3.210	0.92156
(3) HDPE Talco flake 60%, 40% virgin	5.608	3.290	0.64486
(4) HDPE Talco flake 100%, 0% virgin	0.740	3.635	4.7203
(5) HDPE EcoPl flake 20%, 80% virgin	8.744	3.240	0.64486
(6) HDPE EcoPl flake 40%, 60% virgin	5.608	3.285	1.1241
(7) HDPE EcoPl flake 60%, 40% virgin	4.816	3.315	1.8171
(8) HDPE EcoPl flake 100%, 0% virgin	0.862	3.555	4.61526
(9) PP CPR PP scrap	20.932	4.085	0.39482
(10) Mix CPR dairy tub scrap	No test results	No test results	No test results
(11) HDPE CPR bucket and crate scrap	12.610	2.090	0.28916
(12) HDPE EcoPl repro pellets	6.928	3.815	0.76068
(13) PP EcoPl repro pellets	8.962	2.325	1.3898

Results from the telephone survey indicated that there is the potential for a substantial market for recycled plastics in the existing plastics manufacturing community in Colorado. Twenty-one injection molders and four extrusion molders responded to the survey. Of the respondents, 27% used HDPE and 31% used PP (some used both). Approximately 30% of the respondents used washed flake or industrial regrind on a regular basis, although most used regrind from their own operations. A majority has used recycled plastics in the past, with a wide range of results, from very negative experiences to no problems. About one-third of the respondents stated that they would consider using a technical assistance program, and the needs included help with obtaining a reliable supply of consistent materials, technical information on the properties and procedures for using recycled materials, and assistance in finding markets for internally-generated regrind materials. Some applications, such as medical products and regulated or certified products, would not be able to use recycled materials but many other applications exist which could potentially use some recycled materials.

With a number of plastic injection molding companies located in Colorado, there is the potential for a significant increase in the use of locally generated and produced recycled plastic flake material. This increased usage could provide a new market for recycled plastics in Colorado, create new jobs in recycling and processing the plastics, and offer a superior cost alternative to more distant national markets for recycled plastic materials.

2.0 REPORT ON EXTRUSION MOLDING TESTS

A report on the first extrusion molding testing relating to the plastics extrusion molding technical assistance project was prepared by TechWorks.

Recycled Plastic Products, Inc., and Plastics Design Manufacturing (PDM) were selected for this technical project. Recycled Plastic Products, Inc., manufactures and distributes a line of recycled plastic fencing products, and PDM is a custom extrusion company located in Denver, Colorado, and provides molding services to Recycled Plastic Products. This study was performed on a plastic fence line.

Equipment:	2 ½, 24:1 Akron Extruder High Compression Screw 2 station Maguire Proportional Loader **Note:** There was no screen on the extruder to catch contaminants. Also other equipment in line included 2 or 3 vacuum tanks with "plate molds", a puller and a chop saw.
Product:	1" x 6" board of lumber, 060-070 thick.
Material:	Dupont's Tyvek Reprocessed Pellet, Natural Talco's washed HPDE flake.

The machine was running 100% reprocessed Tyvek pellets and was running good product. The settings were as follows:

RPM:	83 (actual)	125 (max)
AMP:	49	
PSI (head):	700	
Melt Temperature:	405	
Barrel Temp Settings:		
Zone 1 (rear)	370	
Zone 2	360	
Zone 3	371	
Zone 4	380	
Zone 5 (Nozzle)	349	
Zone 6 (Die)	335	

2.1 Procedure

Although there was a two-station proportional loader on the machine, the material was hand-blended because of the flake. Blenders are available that will handle flake and should be considered if the project progressed. Blends of 20%, 40%, 60% and 80% flake-to-pellet were prepared.

The 20% blended natural material was added to the process. This material was run for ten minutes and consistent product was achieved. White color concentrate was added at a 2½% letdown ratio. The process was stable and the following was observed:

	20% Natural	20% w/color
RPM:	83.2	82.7
AMP:	48.2	45
PSI (head)	700	700
Melt Temperature	400	398
Barrel Temp Settings:		
Zone 1 (rear)	369	369
Zone 2	360	361
Zone 3	370	369
Zone 4	382	381
Zone 5 (Nozzle)	348	351
Zone 6 (Die)	335	335

There was evidence of labels and some non-melted pellets. Parts continued to be acceptable to the customer although the contaminants were evident.

After 15 minutes of running this material, the 40% blended material was run.

The following observations were made:

	40% Natural	40% w/color
RPM:	83.1	83.3
AMP:	45.8-46.3	45.7
PSI (head)	700	700
Melt Temperature	398	396
Barrel Temp Settings:		
Zone 1 (rear)	369	364
Zone 2	361	355
Zone 3	370	365
Zone 4	384	362
Zone 5 (Nozzle)	349	350
Zone 6 (Die)	335	335

To raise the amperage draw, the temperatures were lowered by 5% across-the-board. The product was witnessing sink marks and there was difficulty holding the profile. The speed was increased when the temperature stabilized; the RPM's returned to 83. Although the process stabilized, the parts were unacceptable because holes were being blown in the profile where the labels and contaminants were.

Next, the 60% blend was introduced. Stability of the process was lost and the temperatures and screw speed had to be raised to achieve a seal. The RPM's were 105 and then lowered to 96. The die clogged and the process could not be held.

2.2 Observations

- The product was acceptable at a 20% blend, but did not meet specification at 40%.
- Contaminants were evident but did not effect the product at 20%.
- The flake ranged in size from .300 - .700. In a random 1 cup sample, contaminants were found to consist of the following:

  Approximately 7,000 – 8,000 parts
  Contaminants 53 parts
  Labels – 21 parts
  Plastic – 32 parts

This represented approximately ½% foreign particles present in the material. The plastic contaminants appeared to be other mixed bottles and plastic caps. The labels included paper, plastic and printed plastic.

- In addition to poor product characteristics, the process was unstable and unable to run under normal operating procedures.

- Product Quality

  0% Flake – In a 14 linear inch sample the following was found:
  - 0 non-melts
  - 1 black spec
  - no color contamination

  20% Natural Flake – In a 15 linear inch product sample the following was observed:
  - 3 non-melts
  - 7 color disbursements over a 4 ½ section of product
  - Good product stability

  20% Flake with White color
  - 2 non-melts
  - 2 contaminants
  - 1 black spec

  40% Natural Flake
  - 1 non-melt
  - 9 contaminants
  - 2 black specs
  - Poor product quality

  40% Flake with color
  - 2 non-melts
  - 6 contaminants
  - Poor product quality

2.3 Recommendations and Conclusions

It appeared that at 20%, the processing system performed near normal (material had to be hand-blended), with no problems with the feed system, extrusion operation, maintaining integrity of profile through vacuum tanks, cooling process and puller and chop saw. Product quality was generally acceptable and comparable to the standard product with DuPont pellets. There was some contamination in all product from labels or foreign plastic, and color contamination from foreign plastic in natural-colored samples.

The 40% blend presented problems with process stability. There were no problems with the feed system but the extruder required constant adjustment to maintain part integrity in the vacuum tanks and water bath. The increased flake and foreign particles caused voids in the product, resulting in holes in the product.

With the 60% blend, a stable product was not achieved even with continued feeding of the material. The extruder was able to melt and blend the material, but caused the die to clog and it wasn't possible to pull the product through the water bath. After several attempts to stabilize the process, there was no success in getting the product through the process.

Due to the marginal success of the 40% blend and the lack of success with the 60% blend, there was no attempt to run the 80% and 100% blends of material.

Additional studies may be conducted to find the upper limits between the range of 20%and 40%. This would aid in finding the maximum level of recycled-content allowed by the product.

Screw configuration or a static mixer may assist with the non-melts that were found in the product. Additional mixing of the material would eliminate resins that did not have time to melt under normal processing conditions. This could assist in removing them from the product. Accurate metering of the flake in the process would offer stability in the process by insuring precise amounts of material blended. This metering device would be most effective if placed on the throat of the extruder and material introduced directly on the screw. If the material is metered at a separated station and pneumatically conveyed to the machine, consideration should be given to the type of pneumatic conveying that is done. Due to the difference in bulk density of the flake and pellet, separation could occur during the conveying process. The equipment supplier would be able to assist in the evaluation of equipment purchased. Smaller consistent flake size could prove beneficial. With a more consistent material, the screw would be able to mix the material better in the transition and mixing section of the screw and would aid in stabilizing the process. A screen pack with an automatic screen changer may help remove labels in the extrusion process.

2.4 Content Process Optimization Considerations for Converting to Recycled Content

Processes are unique to the material, product, equipment and even the processor. Although there are no set rules, the following guidelines increase the chance of success for the introduction of recycled material.

2.4.1 Material Considerations

- Resins and additives that are to be used with the recycled material need to be compatible. It is recommended that the material be a similar polymer base with like processing parameters.
- Drying recycled material can make it easier to process. When possible, it is recommended that the material be dryed, even when it is not typically hygroscopic.
- The thermal history of the material is an important aspect of processing. It is important to know if the material was sourced from a virgin product (indicating one heat history) or if the source of the product had recycled content in it (indicating multiple heat histories). With shear sensitive materials, this is even more important. If the material experiences excessive heats during the initial processing, it will be more difficult to feed and will impact how the material processes.
- Mixing efficiency of the material is important and should be considered when choosing the type of recycled material to be used. If the material is difficult to mix, a special screw design could be required.
- Equipment and environmental cleanliness is another important aspect for successful implementation of this program. The material should be kept covered and free of contaminants. It is important to understand the cleanliness policies of the material supplier as well.
- Pellet/flake geometry will impact how well the material feeds and runs. When doing a visual inspection of the material, it is important to note the size and shape consistency.

2.4.2 Extruder Hardware Considerations

Extruder Feed Hopper

- Hopper design is important for feeding the material into the extruder. The pitch on the hopper should be steep enough to allow the material to flow freely. Staineless steel hoppers also offer the surface finish that can help flow the material. A material level control or sensor should be in the hopper to alarm an operator should the material stop flowing or run out of material. Dryers at the throat also assist in the processing.

Extruder Feed Throat

- The feed throat of the extruder is another important consideration for feeding the material on to the screw. There are straight and tangential throats and the material being processed will dictate which is most effective.
- With the advent of a grooved or smooth bore at the feed throat opening, some materials such as LDPE have been found to feed better on a grooved feed section while others require a smooth bore.
- The opening of the throat needs to be sufficient to allow the material to feed easily and is dependent on the pellet/flake size and density.
- Cooling at the throat is often done with air, water or glycol. Keeping the material from melting too early in the process will avoid bridging at the throat and allow the screw to feed the material more freely.

Extruder Barrel

- Consideration to the material used on the barrel lining is important when using recycled material. Since foreign particles may be present, it is important to have good wear resistance. Premature wear or excessive clearances between the barrel and the screw will effect how well the machine processes.

- L/D ratio – The barrel should have a long enough L/D (length over diameter) to process the material effectively. It is generally recommend that the L/D range from 24:1 – 32:1 for extruders and 18:1 – 24:1 for injection molding machines. The equipment design may also effect how long the L/D can be.

- Temperature sensing devices are used to sense the temperature in the barrel and indicate how the material is processing. These should be located in 6-12 zones throughout the machine and monitored regularly.
- Heating and cooling on the barrel will keep the process stable. Heater bands and cooling channels should be in good working condition and calibrated regularly.

Extruder Screw

- Extruder Screws should be designed for the material being used. There are many general purpose screws that will process a range of materials. A specially designed screw will offer process optimization and can improve productivity.
- Screw wear should generally not exceed .012-.015. Although some materials are more forgiving, it is recommend that the screw be replaced after excessive wear is detected.

Extruder Drive System

- It is important that the appropriate HP rating be sufficient. Accurate feedback of motor speed should also be available.
- The drive system should be protected from overload should the material viscosity change, causing a problem with the material feed.
- Motor vibration and misalignments should be checked annually.

Extruder Tooling

- The appropriate base material for the tool should be considered for optimizing the life and continued accuracy of the tool.
- The tool should be cleaned regularly and kept in good condition.
- The tool design should consider balanced flow and velocity profile, optimum land length and entrance angle, as well as surface coatings to reduce slip/stick effects.
- The breaker plate geometry should avoid any dead spots where material can hang up and degrade.
- When putting in a screen pack (recommended for recycled materials) it is important to consider the shear and pressure effects it will have on the process. Automatic screen changers are recommended.

- Die position and concentricity are important aspects to the optimization of the process as well.

Water Bath

- The water bath is used for cooling the plastic and aids in consistent product. It is important to have temperature control and proper control of turbulence.
- Cooling rate is important for the crystallization of the material.

Vacuum Sizer

- Temperature and vacuum control are important to maintain the integrity of the vacuum. Appropriate vacuum should be present for the product.
- It is important to seal the tank lid.

Product Take-Off System

- Feedback and tension controls are important for the take-off equipment. This can be obtained through P.I.D. algorithms. The belt puller centerline alignment should be aligned with the die centerline and the belt pressure should be evenly distributed.

3.0 REPORT ON SECOND EXTRUSION MOLDING TESTING

The following is the second extrusion molding testing relating to the plastics extrusion molding technical assistance project and was prepared by Techworks. This study was performed on a plastic fence line.

Equipment:	3 ½, 36:1 Akron Extruder, PAK 350 Two Stage Screw 2 station Maguire Proportional Loader Vacuum tanks. A puller and a chop saw.
Product:	1” x 8” board of lumber
Material:	Dupont’s Tyvek Reprocessed Pellet, Natural Talco’s washed HPDE flake
Purpose:	The purpose of this second run was to take a closer look at what was happening between the 20% and 40% batches that were run during the first testing. There was failure at the 40% level, but success at the 20% level. Closer examination was needed to see where the failure was starting.

Note: It should be noted that this second testing was performed on a different machine than the first testing. The second testing used a machine that was larger in screw, barrel, and throat sizes. All of which affected the processing of this material. The L:D ratio on the screw required higher Amps, as well as, lower Rams, due to the size increase in comparison to the first run. The product was also larger and required a larger die. This information should be taken into consideration when comparing the results from the two different test times.

The machine operated fine and was running 100% reprocessed Tyvek pellets. The settings were as follows:

RPM:	35
AMP:	81
PSI (head):	1400
Melt Temperature:	363
Barrel Temp Settings:	
Zone 1 (rear)	345
Zone 2	351
Zone 3	355
Zone 4	345
Zone 5	350
Zone 6 (Die)	340
Gate	330

3.1 Procedure

Although there was a two-station proportional loader on the machine, the material was hand-blended because of the flake. Blenders are available that will handle flake and should be considered if the project progressed. Blends of 25%, 30% and 35% flake to pellet were prepared.

The 25% blended natural material was added to the process. The material was run until a consistent product was achieved. White color concentrate was added at a 2 1/2% letdown ratio. The process was stable and the following was observed:

	25% Natural	25% w/color
RPM:	35	35
AMP:	80	84
PSI (head)	1500	2000
Melt Temperature	362	362
Barrel Temp Settings:		
Zone 1 (rear)	344	345
Zone 2	350	350
Zone 3	354	355
Zone 4	346	347
Zone 5	349	350
Zone 6 (Die)	340	340
Gate	330	330

After running the completion of the batch of 25% mix through, the 30% batch was started. The following was observed:

	30% Natural	30% w/color
RPM:	35	35
AMP:	86	85
PSI (head)	2250	2000
Melt Temperature	365	362
Barrel Temp Settings:		
Zone 1 (rear)	346	344
Zone 2	350	350
Zone 3	355	355
Zone 4	345	345
Zone 5	350	349
Zone 6 (Die)	343	338
Gate	330	329

After running the completion of the batch of 30% mix through, the 35% batch was started. The following was observed:

	35% Natural	35% w/color
RPM:	35	35
AMP:	84	81
PSI (head)	2000	2000
Melt Temperature	362	361
Barrel Temp Settings:		
Zone 1 (rear)	345	344
Zone 2	350	350
Zone 3	355	355
Zone 4	345	345
Zone 5	351	349
Zone 6 (Die)	339	340
Gate	330	330

3.2 Observations

- The flake ranged in size from .300 - .700. In a random 1 cup sample, contaminants were found and consisted of the following:

  Approximately 7,000 – 8,000 parts
  Contaminants 53 parts
  Labels – 21 parts
  Plastic – 32 parts

  This represented approximately ½% foreign particles present in the material. The plastic contaminants appeared to be other mixed bottles and plastic caps. The labels included paper, plastic and printed plastic. (Data from first run, same gaylord of material was used.)

- Product Quality

  0% Flake – In a 14 linear inch sample the following was found: (Data from the first test.)
  0 non-melts
  1 black spec
  no color contamination

When the following data was collected, a 15 linear inch sample, per percentage, was examined at a distance of 18 inches. Non-melt was a form of contamination and was separated out to show the defects causing sink versus non-sink areas. The non-melt caused sink marks. Therefore, the contaminant numbers do not include the non-melt contaminants.

25% Natural Flake

0 non-melts
0 contaminates
5 color dispersion streaks
5 black specs

25% Flake with Color

0 non-melts
2 contaminates
0 color streaks
7 black specs

30% Natural Flake

6 non-melts
5 contaminants
1 color dispersion streak
2 black specs

30% Flake with Color

7 non-melts
0 contaminants
1 color streaks
0 black specs

35% Natural Flake

16 non-melts
7 contaminants
2 color dispersion streaks
2 black specs

35% Flake with Color

6 non-melts
3 contaminants
0 color streaks
0 black specs

3.3 Recommendations and Conclusions

There was evidence of labels and some non-melted pellets in the non-colored parts. The contaminants were less evident in the colored product. No changes were made to the processing conditions of the extrusion machine at any time through the run. The water temperature did vary between 60 to 85 degrees in the tanks. The product witnessed several sink marks at the 30% and above ratios. There was no problem holding the profile until the 35% mixture. The vacuum was blown at one time due to a through hole in the extrusion.

It appeared that at 25%, the processing system performed near normal (material had to be hand blended), with no problems with the feed system, extrusion operation, maintaining integrity of profile through vacuum tanks, cooling process, puller and chop saw. Product had to be examined by the customer to determine whether the quality was acceptable and comparable to the standard

product with 100% DuPont pellets. There was some contamination from labels or foreign plastic in all products and color contamination from foreign plastic in natural-colored samples.
During the 30% mix test, the processing system performed near normal (material had to be hand blended), with no problems with the feed system, extrusion operation, cooling process, puller and chop saw. The integrity of profile coming out of the die seemed a little more flimsy but no adjustments were made. Product had to be examined by the customer to determine whether the quality was acceptable and comparable to the standard product with 100% DuPont pellets. There was more contamination from labels or foreign plastic causing sink marks and it was assumed that this would cause the product to be rejected. Color contamination from foreign plastic in natural-colored samples continued.

The 35% blend had no problems with the feed system, extrusion operation, maintaining integrity of profile through vacuum tanks, cooling process, puller and chop saw. The increased flake and foreign particles caused more sink marks in the product. A void did cause a hole in the product at one point, causing a break in the vacuum. This was quickly corrected and didn't effect the rest of the process.

The customer did not examine the product run in this test but it would seem from the results of these tests that a blend at 25% would still provide a product of acceptable visual quality. It could also be concluded that larger equipment and product could make it easier to run larger percentages.

3.4 Equipment Suppliers

Equipment should meet the specifications for the material and product being processed. The requirements change by product and need. The following considerations should be made when choosing equipment. Included in this section are reputable suppliers for each of these products (see following page). This list does not include all suppliers, nor is it intended as a recommendation by this project. It is intended only as a reference list. Complete lists of suppliers can be obtained by multiple sources. Some recommended sources are Modern Plastics Encyclopedia, Plastics Technology Handbook, www.plasticsnet.com and the Society of the Plastics Industry.

PROCESSING EQUIPMENT, EXTRUDERS AND INJECTION MOLDERS

FEED HOPPER

Hopper design
Material level control
Drying capabilities

FEED THROAT

Material
Straight/Tangential
Grooved or smooth
Opening (length/width ratio)
Cooling (water/air/glycol)
Inside Diameter (straight/undercut)

BARREL

Material
Iron content (flouropolymer)
L/D
Temperature sensing locations
Heating/cooling
Barrel alignment/barrel support
Barrel wear

SCREW

Appropriate design for the material
Screw tolerances
Radial flight clearances

DRIVE SYSTEM

Appropriate HP rating
Accurate feedback of motor speed
Analog vs. digital vs. servo
Appropriate gear reduction
Overload protection
Vibrations (motor or misalignment)

INSTRUMENTATION/SENSORS

Appropriate pressure transducers
Thermocouples
T/C condition
T/C mounting in well
T/C cold junction compensation
PID Capable temperature controllers
PID/Adaptive Process Pressure Controller
Potentiometer for speed control

TOOLING

Appropriate base material
Appropriate cleaning techniques
Velocity profile/balanced flow
Optimum land length
Optimum entrance angles
Surface coatings
Breaker plate/nozzle geometry
Screen pack assembly
Tooling surface finish
Optimum temperature control
Concentricity/thickness adjustment
Die position

EXTRUDER SUPPLIERS

- Akron Extruders, Inc.
- Cincinnati Milacron
- Conair Gatto Group
- Davis Standard
- HPM
- Wayne Machine and Die

INJECTION MOLDING MACHINES SUPPLIERS

- Cincinnati Milacron
- Demag
- HPM
- Nissei
- Toshiba
- Van Dorn

TEMPERATURE/PRESSURE CONTROLS

- Barber Colman
- DME
- Fast Heat
- IMS
- Industrial Heater
- RJG
- Tempco
- Watlow Electric

AUXILIARY EQUIPMENT

CONVEYING AND LOADING EQUIPMENT

- Colortronic
- Foremost
- Matsui
- Motan
- Novatec
- Process Control
- The Conair Group

METERING AND FEEDING EQUIPMENT

- Accurate
- Colortronic
- Hydreclaim
- Maguire
- Motan
- Novatec

RESIN DRYING

- Colortronic
- Matsui
- Motan
- Novatec
- Process Control
- The Conair Group
- Unidyn

SCREWS

- Cincinnati Milacron
- Davis Standard
- HPM
  New Castle
- Spirex
- Xaloy

BARRELS

- Bernex
- Wexco
- Xaloy

PELLETIZERS AND DICERS

- Cincinnati Milacron
- Davis Standard
- Gala Industries
- Hydreclaim

This is a list of primary equipment used in manufacturing plastic products for virgin and recycled material. Original equipment manufacturers (OEMs) also provide complete packages of equipment.

4.0 REPORT ON INJECTION MOLD TECHNICAL ASSISTANCE PROJECT

The TechCenter at TechWorks is a training facility for the plastics industry and is located in Denver, Colorado. This study was performed on an injection molding press at the molding laboratory.

Equipment:	220 Ton HPM Injection Molding Machine General Purpose Screw with a 23 ounce barrel RJG DartScanner for electronic data collection
Product:	The mold used was an obsolete bezel from an electronics company.
Material:	Post Consumer washed flake.

Notes: The molding machine was setup with cavity pressure transducers in the tool in two locations. One at post gate (just after the nozzle where the plastic enters the mold, and the second at end of fill (the last area in the tool to see plastic during the fill stage of processing). The transducers were hooked up to the DartScanner and data were collected; data included pressure in the cavity. By monitoring pressure in the cavity, pressure can be monitored at the end of fill (a general rule is that if the pressure remains at 3,000 psi at the end of fill, with the same fill time, you can duplicate identical parts regardless of change in material viscosity). This technology introduces a "scientific" approach to injection molding and removes variables in the process which do not have a specific impact on the process.

The advantage of this technology with recycled content material is the ability for the machine (if the machine is load-compensated and not pressure-limited) to duplicate part dimensions regardless of material variation.

4.1 Procedure

The following material was used:

- Talco HDPE flake hand mixed at ratios of 20%, 40%, 60%, 80% and 100%.
- Ecoplast HDPE flake hand mixed at ratios of 20%, 40%, 60%, 80% and 100%.
- 100% HDPE Repelletized.

- 100% PP Repelletized.
- 100% PCR crate and barrel regrind.
- 100% PCR dairy tub regrind.
- 100% PP scrap.

4.2 Observations

- Acceptable product could be made with identical set-ups on the machine for the material.
- Unable to process the PP scrap material because of high levels of contamination content in the material.
- The dairy tub regrind material was extremely runny with a viscosity similar to water. Unable to maintain it in the barrel and it immediately clogged the mold, which required a complete teardown and clean out of the machine.

4.3 Recommendations and Conclusions

- The material processed fairly consistently across-the-board in terms of reasonably acceptable parts. The best parts were seen in the 40%-60% blends of repelletized material blended with virgin.
- The repelletized material processed the best.
- The parts did not require high dimensional tolerances for the purpose of this test but the finish and overall dimensions were consistent.
- Although cycle times were the same for all parts, improvements could be made with a screw designed for PE or PP if this makes sense for the processor. However, the GP screw design was acceptable.
- 25% of the shot size of the barrel was used and there was no burning related to foreign particles in the melt. It is recommend that the barrel size be kept between 35% and 50% of the overall shot to prevent possible degradation due to residence time in the barrel.
- Some contamination was evident but did not pose a problem for this particular job.

- It is recommended that the flake be used with some carrier of virgin material. This would be best achieved with a blender on the throat of the machine for accurate metering. Since the material was fed, no bridging was experienced. However, this would most likely occur if the screw was not designed for flake (deeper feed flights) and it was fed at 100%.
- It is recommended that the supplier dry the material. PP and HDPE are not hygroscopic materials (meaning they absorb moisture naturally) and the moisture in the material was "around" the material and not trapped in the material. This indicated that it was not properly dried after washing at the supplier.

5.0 REPORT FROM TECHWORKS ON PHYSICAL TESTING RESULTS

The following information references the Technical Assistance Project, Injection Molding and Testing, by the Plastics Research and Education Center of Ball State University.

5.1 Process and Test Criteria

Tensile

- Tensile specimen was consistently placed gate down in the jaws of the machine.
- Ejector pins faced away from the operator.
- Speed of pull = 2 in./min.
- Load range = 100,000 psi.
- Thickness = .125 in.
- Width of part = .5 in.
- Gage length = 2 in.
- Machine = Instron, Model #1011, Tensilometer.

Notched Impact

- Test specimen cut in half.
- Impact specimen was of non-gated side, rounded surface up.
- Hammer weight = 8.313 lb. Force.
- Machine = Tinius Olsen, Model #892 (Impact Display Model).
- Machine = Tinius Olsen, Model #92T Impact Testing Machine.

Melt Index

- ASTM D1238 / D1248.
- PE = 190*C, 2.16 kg weight.
- PP = 230 *C, 2.16 kg weight.
- Machine = Tinius Olsen Extrusion Plastometer, Model # AD987.
- Scale = Ohaus, Model # E120.

Processing

- PP = 100 *F Thermolator Temperature.
- PE = 70 *F Thermolator Temperature.
- PP = 430 *F All Zones.
- PE = 410 *F All Zones.
- Machine = Sandretto 60 ton Injection Press, Model # S.7.60.
- Thermolator = Conair Tempro, Model # EC1-DI.
- ASTM Test Bar Mold.

Materials

- Talco's washed HDPE flake.
- Eco Plast's washed HDPE flake.
- Alathon, Lyondell PE Resin, Lot # 614040 H5618 Virgin.
- Eco Plast Repelletized HDPE.
- Eco Plast Repelletized PP CO 8.
- CPR Post Consumer Scrap, PP Flake.
- CPR Post Consumer Dairy Tub Scrap, PP Flake.
- CPR Post Consumer Bucket and Crate Scrap, PP Flake.

The material was shipped to Ball State in weighed-out batches. The batches were not mixed prior to shipment. The mixes were labeled as:

Mix (Material) 1:	20% Talco Flake + 80% Virgin
Mix (Material) 2:	40% Talco Flake + 60% Virgin
Mix (Material) 3:	60% Talco Flake + 40% Virgin
Mix (Material) 4:	100% Talco Flake
Mix (Material) 5:	20% Eco Flake + 80% Virgin
Mix (Material) 6:	40% Eco Flake + 60% Virgin
Mix (Material) 7:	60% Eco Flake + 40% Virgin
Mix (Material) 8:	100% Eco Flake
Mix (Material) 9:	100% CPR Scrap
Mix (Material) 10:	100% CPR Dairy Tub Scrap
Mix (Material) 11:	100% CPR Bucket and Crate Scrap
Mix (Material) 12:	100% Eco Repelletized HDPE
Mix (Material) 13:	100% Eco Repelletized PP CO 8

5.2 Procedure

The test bars were run at the process conditions shown above. Random sampling in this study was conducted as follows. Thirty pieces of each material were produced for each test of the study. Each test category (impact, tensile, etc.) had a bag containing all thirty specimens. The sample size for each category was N=5. Five samples were pulled at random from the bags. These five samples were then used for the testing procedure and the remainders were left undisturbed.

5.3 Observations

- Material 10, the dairy tub scrap, was not suitable for processing due to glass, aluminum and nails found in the regrind.
- By studying the PE, Rank Order Table in Appendix C, it was found that the materials, for the most part, ranked themselves in order by the percentage of regrind (or flake). However, the mixes with large percentages of regrind (flake %) had higher tensile strength results, as well as higher impact strength. The more regrind (flake) the mixes had, the stronger they were in impact and tensile. The repelletized PE mix, which is 100% regrind, was the highest in the Tensile test results and fell mid-range in the melt and impact.
- The higher percentage of PE regrind mixes also had lower melt index readings. The material was harder to push as the regrind percentage (flake percentage) increased.
- The PP Rank Order Table found in Appendix C was harder to interpret and see a pattern because there were only three material batches. The melt index results showed that the Repelletized PP was actually the harder of the three to push, having a lower melt index number.
- The 100% CPR Scrap had the highest tensile of all the materials tested, as well as the highest melt index. However, its impact strength was among the lowest.
- The 100% CPR dairy tub scrap was not processed due to contaminates and therefore could not be tested by tensile or impact. It was tested by melt flow and had a low index rating of 1.864 g/10min, which would rank it third from the bottom.
- The 100% CPR Bucket and crate scrap showed the lowest tensile strength and impact strength of all the materials tested. It did rank in the top three of the melt index results.

5.4 Recommendations and Conclusions

It was surprising that the higher percentage batches were showing higher strengths, since this was not expected. It is possible that the virgin material used was of lower strength than the mixture of regrind that was received. Unfortunately, there is no way to know what brands of PE have been mixed into the regrind.

APPENDIX A:

EVALUATION REPORT

EVALUATION REPORT: SUMMARY OF SURVEY OF COLORADO BASED PLASTIC MOLDERS

1. # RESPONSES FOR:

- Injection Molders: 21
- Extrusion Molders: 4 (sheet =2)
- N/A Calls: 19 disconnected/out of service or don't mold)

2. TYPES OF RESINS USED:

HDPE - 12, LDPE – 6, PP – 14, PVC – 6, ABS - 7

Others:

- All Engineering Grades
- Peek, Ultem, PC, PC/ABS Blends
- Commodity to Engineering Grades
- Nylon
- PETG
- PS
- Commodity through Engineering Grade, Many with Fillers
- PUR, PE, Nylon
- Urethanes and Nylon
- Expanded Polystyrene (Not typical inj. molder)
- PC, PC/ABS Blends, PPE
- Medical Grades, PVC
- PC/ABS, Nylon,
- 200 types, incl. PC, Nylons, & Glassfilled Materials
- Commodities & Engineering Grades
- PC, Acrylic, Peek, PPA, Teflon, PBT
- HIPS and Engineering grades
- Engineering grades, rarely use PS, PE

3. DO YOU USE PCR PELLETS?

Regular - 5
Selected Products - 2
Infrequently – 4
NO - 13
Other comments:

- No and Never Will.
- It's all they run.
- No applications.
- Combination of PCR and PIR varies. Get PCR from Indiana.
- Get regrind from CA, 500,000 lb./month. 80% is PCR.
- Specified for selected products
- Only recompound
- They have a program where their customers return the parts for reuse.
- The FDA frowns on the liabilities of using regrind for medical parts.

4. DO YOU USE WASHED FLAKE OR CLEAN INDUSTRIAL REGRIND?

Regular - 7
Selected Products - 1
Infrequently - 3
No - 12
Other comments:

- Not unless in-house regrind. Job dependent.
- Some in-house flake, rarely.
- Use some regrind, new at molding.
- Run pellets only, sell all regrind.
- Run in house regrind
- No. All pelletized
- Buy to grind, as well as, ground.
- Aren't now, have and still capable.
- Run internal scrap
- Grind own.
- In house
- Don't use flake they recompound their regrind.
- Computer parts that are internally used.

5. HAVE YOU EVER USED RECYCLED MATERIALS, ESP. WASHED FLAKE?

Yes - 14
No - 2
Comments, Yes:

- Had a bad experience. PC repelletized material, parts shattered.
- Use Internal
- It's all they run.
- Customers limit their use.
- In house regrind.
- Tried, had feeder problems.
- Internal.

- Only run internal, have FDA Tracability requirements
- Depends on Product
- Post Industrial
- As long as it meets requirements.
- Limited use do to computer industry.
- Medical products only run virgin. Customer's choice, FDA may have say.
- Own after recompounding.

Comments, No:
- Too color oriented, 90-95% spec. color
- Medical products, design for no regrind. Tracability by lot too difficult with regrind.

6. WHAT ARE YOUR REQUIREMENTS FOR USING RECYCLED MATERIALS?

- Internally generated, max of 25%, per customer, Job by Job, and cost of virgin.
- Conforming, cosmetic, dimension stability, non-contaminated.
- Only use internal.
- Use all in-house generated, also use medical molded scrap (local).
- Don't, they sell 95% of own scrap. They have fast enough cycles to accumulate quantities.
- Must meet virgin specs. and it doesn't.
- Natural material, Melt, density .92-.95
- Rigid PVC, relatively
- FDA 100% tracability back to virgin
- Non contaminated, Low amount of fines.
- The product drives the material usage decisions
- Up to customer.
- Use grindings, don't repelletize.
- Project Dependent, UL Ratings
- Customer's regulate/specify. Selected in design stage.
- Project Specific
- They recompound to out gas.
- Customer calls out specs. If UL Rated then max. of 25% can be used. Like to use min of runner weight. Or even 100% if possible and customer approved.
- Very difficult. Must run the right type of material for the right process. Inj to Inj, Blow to Blow.

7. WHAT ARE YOU EQUIPMENT CAPABILITIES FOR USING RECYCLED MATERIALS?

- Have 5 grinders and a gravometric loader or pre mix.
- Fine
- Fine
- Large grinders.
- Grinder, not set up for contamination or separation of mixed materials.
- Can do.
- No problems, Control of Cleanliness, Throat metering.
- Vacuum loaders, no problems
- No limitations.
- No equipment problems, light colored flake does burn/discolor easily.
- Not sure.
- Have grinder, sell regrind, and do run on non-medical jobs.
- Grief for cleaning by the operators.
- Not limited
- Have beside the press grinders. If blades get dull get problems. Too many fines, poor flakes, non-uniform for feeding problems.

8. WOULD YOU USE A TECHNICAL ASSISTANCE PROGRAM BY THE STATE?

Yes - 5
No - 7
Maybe - 4
Other comments:
- Possibly, depends on what is required of them. They are recycling other materials such as packaging, in house, too.
- No, what are they going to tell me?
- No, Don't know how helpful it would be.
- Probably.
- Can't see using PCR and other recycled, there is no control over and it is too expensive.
- Certainly
- Probably not.
- Doubt it.
- Possibly, I've been talking with Dave Kahl, Yes then.
- Use all they can internally, it is "free money"
- For a PP premold, which must be non-conductive and has no appearance concerns.

- Absolutely Not
- It's possible. Learn more, become better user.
- Would like to see a consortium (collection site) for regrind sellers so material could be sold by volume. Thinks buyers are screwing sellers.
- Not really being used.
- How would it assist? I would need to see value before using.
- In supply of regrind
- Their customers drive them. "hog tied"
- Won't matter, you can't even get companies to run PIR.

9. SPECIFICALLY WHAT TYPE OF INFORMATION OR SERVICES DO YOU THINK YOU MIGHT NEED?

- Information on Resources. A market is needed for mixed regrinds. (Some one in New Mexico is mixing pellets with a binder?) Need a clearinghouse to run internal regrind through, give away, rather than landfilling. Cost / quantities prohibit it
- None, They don't know my product to be able to tell me what I can or can't use.
- Technical Data, Effect on Properties
- Technical Training, Sorting of materials, Testing to determine what type of resin it is.
- New at molding, need knowledge, where to buy materials, spec. regrinds?
- Technical back up, don't have capabilities to do in house.
- Testing, melt, density, elongation, tensile. To determine if "Slip" or contamination. Underwrite or fund to put in a pelletizing line? Need a market here, if enough collected he would buy locally.
- Nothing Specific.
- They sell a lot of sheet yearly. Estimate only getting 15% back. Would like to get more back. Tracability? Don't want it to go to landfill. Current pricing of virgin.
- Only using plastics as a binder. Very little usage. Not applicable. (Coors Ceramic)
- All of the above, mainly to find suppliers
- Specifications are very important, Tech. Data. They run 500-1000 lbs./month.
- Leads into projects using recycled materials
- If a job came up for use then need help.
- Thinks it is a great idea. Go to the OEM, customer/Designer. They would submit a list of customers.
- Show me a benefit to regrind all my scrap. Who will I sell it to? Costs to regrind, no profit.
- Get in at design stage, Educate at the design level. Show cost saving vs. properties.
- They try to lead customers towards reprocessed materials if suited towards project. Some cases they have some input other times none.
- Need a product, extruded lumber, decking, and benches, roofing tiles, extrusion.
- Empak has a processing center in Houston, looking to move it to Colorado, he will be a resource for us.
- Must find a market and need collection facilities.
- Not directly – through FDA, would give material too? Even with extra measure being taken to pull material aside, still couldn't guarantee cleanliness.
- If you could prove to the customer/OEM that a larger % of regrind wouldn't jeopardize the properties. Or more importantly convince <u>UL</u>.

EVALUATION REPORT: RESULTS OF INTERVIEWS WITH EXTRUSION PLASTICS COMPANY PERSONNEL

INTERVIEW WITH GENE PENDERY, PRESIDENT RECYCLED PLASTIC PRODUCTS INC.

The following are the questions and responses from Gene Pendery, President of Recycled Plastic Products, Inc., the manufacturer of the plastic lumber product line we used for testing in the extrusion technical assistance project. His responses are in Italics.

1. Have you decided whether to use washed flake?
   Not yet – still investigating.

2. If yes, can you estimate how much recycled washed flake you might substitute for recycled pellet and/or virgin resin in the next 2 – 3 years?
   Best guess would be to blend 15 – 25% with repro pellets.

3. Would you have been able to decide whether to use washed flake without the test results?
   No.

4. Did the test provide you with sufficient data for you to make a decision on whether to use washed flake?
   Probably.

5. Did the test and equipment recommendations provide you with sufficient data about how washed flake could be used in your system?
   Yes.

6. Would your company have performed the tests without the intervention of this project? If yes, can you estimate the timeline for when you may have done so?
   No.

7. Were you satisfied with your level of involvement in the project?
   Yes.

8. How great of a time commitment was this project for you? Did it require more or less time than you had anticipated?
   About as expected.

9. Prior to this project, have you attempted to find information about alternative feedstocks or other environment-related issues? If so, from what source did you get the information?
   Yes – various suppliers and consultants.

10. State government is considering whether to implement an ongoing technical assistance program. Would you be likely to use such a service?
    Yes.

11. Specifically, what types of information do you think you might need? In what form would you like this information?
    Continuing updates on materials available; equipment to make it work.

12. What other feedback or suggestions do you have about this project?
    Program was well thought out and performed.

INTERVIEW WITH AL CHAVEZ, PDM

The following are the questions and responses from Al Chavez, Extrusion Department manager for the custom molder, Plastics Design and Manufacturing, of the plastic lumber product line we used for testing in the extrusion technical assistance project. As the custom molder, he molds what his customers tell him to, so the first few questions were not applicable. I only asked him the final questions re. the technical assistance project. His responses are in Italics.

1. State government is considering whether to implement an ongoing technical assistance program. Would you be likely to use such a service?
   No, the technical assistance would need to be very advanced, current and applicable for the technology in question. We have in-house technical expertise and do not think the State could provide any expertise beyond ours. The custom extrusion business is very competitive and closed to exchange of information.

2. Specifically, what types of information do you think you might need? In what form would you like this information?
   Product design and extrusion die design for the use of recycled resins, to account for differences in processing behaviors. For example, recycled resins experience more swelling in extrusion process than virgin resins and the die and product design must account for this. Other information might be equipment recommendations to overcome material shortcomings.

APPENDIX B:

PLASTICS PROJECT SELECTION CRITERIA & EVALUATION

APPENDIX B: PLASTICS PROJECT SELECTION CRITERIA & EVALUATION

TO: Kelly Roberts
Amy Smith

FROM: Carol Brown
CWC Project Team

DATE: 4/30/98

RE: PLASTIC TECHNICAL ASSISTANCE PROJECT

Below is an explanation of the plastic technical assistance project and the project assessment and ratings. This project was developed by the attendees at the plastic industry forum and will involve multiple local participants.

PROJECT OVERVIEW:

(1) MARKET SURVEY AND TECHNICAL ASSISTANCE FOR THE USE OF HDPE AND LDPE WASHED FLAKE.

These resins have some established collection and handling infrastructure already, and we have already identified several manufacturing companies who use recycled pellet imported from outside of the State. A processing system to grind and wash these materials could potentially be economically effective in competition with out-of-state pelletizing operations. The processing equipment required to feed flakes is different than that for pellets, and most if not all manufacturers in Colorado are currently only designed, equipped and operated for pellets. Technical assistance activities:

- Survey potential manufacturing markets for recycled materials and develop needs/requirements, focusing on HDPE and LDPE, and noting all potential opportunities to use washed flake in substitution for pellets.
- Create a material testing model to provide samples of washed flake to a selected manufacturer to develop, test and demonstrate the requirements for using recycled materials in their manufacturing process. A range of usable specification properties could be developed and then tested to validate the specifications.
- Provide technical assistance on feed equipment requirements, and operating procedures for using the flake material and evaluate the cost-effectiveness of appropriate equipment modifications for the use of flake instead of or in addition to pellets.

The goal of the project is to demonstrate the feasibility of using washed flake in place of pellets and to document the specific blends and material properties which result. The required equipment modifications will be documented and will include a cost-benefit analysis.

PROJECT ASSESSMENT AND RATINGS:

Feasibility within time and scope of IPP project

1

The project involves a total of 6-8 weeks elapsed time and can easily be accommodated within the project timeframe

Reasonable probability of success

1

Strong level of interest from industry players and clearly expressed need for this information; technical testing facility makes information and results credible and neutral

Ability to institutionalize use of recycled materials

2

This project is a stepping stone to opening up the local markets for washed flake; real world industry application and experience have been shown to be the best "sales" tool; project will identify specific companies who are potential users

Immediate implementation possibilities

2

Project data will allow interested manufacturer to apply the information to their process and determine applicability. However, industry is always slow to embrace change - especially when it involves risk and virgin material prices will impact economics of a feedstock substitution; degree of acceptance is hard to predict

Ability of technical assistance to close market gap- solve problem

2

Pellets have been the industry standard for recycled material yet washed flake can be used in many applications; this project will provide specific material data and a model to help potential end users determine applicability to their manufacturing process and help minimize the risks involved;

Transferability of lessons learned to other businesses

2

Model for material testing and evaluation could be used in the future for testing other plastic resin types and other end use applications.

Visibility of company and project- value for support and funding

2

Actual project participants are small local players but potential range of interested parties could involve some of the larger more influential companies;

Commitment of company leadership-"champion of change"

2

The team of participants are all committed but the nature of the project doesn't lend itself to a single visible leader; the players include material processors, product manufacturers, and the technical engineers at the testing facility;All have a vested interest in the project results

Volume of material utilized
2

Potential volume is very significant but conversion of individual manufacturers will be a slow process; any utilization will be dependent on the development of local wash and flake capacity

High market impact - value of material utilization **3**

Recycled HDPE and LDPE are low value materials; project results could lead to substitution of locally processed flake for out of state pellets and/or local virgin material...all relatively low value; hopefully results will increase total utilization of recycled material by COL manufacturers

OTHER PROJECTS CONSIDERED:

Identify existing users of recycled plastic and collate information on type of resins, quantities, specifications, and ability to accept pellets, flake or other forms for use. Develop information on market potential and processing requirements in an effort to demonstrate economic feasibility of washing and/or pelletizing line investment.

Project might have increased local processing capacity but economies of scale of larger out of state processors would be hard to match. Transportation savings likely offset by lower processing costs. Potential to substitute local processing capacity for out of state material but not necessarily increase volume of material utilized.

Survey companies in Colorado that generate plastic scrap, identify quantity and type of materials, and what problems they have finding markets. The goal would be to increase supply and accessibility of material available for recovery and reutilization. This is similar to efforts underway with EPA/CCEM Waste Characterization project. Multiple steps required to impact actual utilization of any of this material.

Train operators of plastics manufacturing equipment in the use of recycled materials. Often the requirements for the use of recycled materials differ from virgin materials, and operator and product problems result in the discontinuation of the recycled material. Understanding the differences in material handling and system operations can optimize material performance.
This applicability of this assistance would be limited to specific products, types of equipment and processes. The TechWorks Tech Center is well situated to provide this kind of training as part of their curriculum.

Market survey and technical assistance for the use of injection grade HDPE, LDPE, and PP. These resins have limited collection and handling infrastructure. There are some existing regional markets and a large number of injection molders in the state. Technical assistance focusing on this group of resins could help to open up collection, processing and remanufacturing for materials not currently being recovered.
This project was the second priority from the plastic industry forum. It has the potential to open up substantial new markets for recycled plastics in Colorado.

However, the challenge of simultaneously addressing the end user specifications and market barriers as well as the front end collection and supply issues were a bit daunting for a 4 month project. This project had too many pieces that would have to all fall in place before there would be any impact on plastic recycling in CO.

APPENDIX C:

MOLDERS SURVEY FORMS

Injection Molders Survey Form

Company Called:______________________

Hello, this is Sheri Peterson with TechWorks. We are working with the Colorado Governor's Office of Energy Conservation on a project to assist Colorado businesses in using more recycled materials in manufacturing. We are particularly interested in plastics manufacturing and the use of recycled plastics. Would you have time to answer a few questions about your company's potential to use recycled plastics in your manufacturing? (if NO, is there another time or person we could call? If NO, thank you, end survey).

1. Does your company do injection molding? (if NO, thank you, end survey) YES NO

2. What resins do you use for injection molding? (e.g. HDPE, LDPE, others) HDPE LDPE PP PVC ABS OTHERS:____

3. Do you use any PCR pellets, (1) on a regular basis, (2) for selected products, (3) very infrequently? (1) REGULAR (2) SELECTED PRODUCTS (3) INFREQUENTLY

4. Do you use any washed flake or clean industrial regrind, (1) on a regular basis, (2) for selected products, or (3) very infrequently? (1) REGULAR (2) SELECTED PRODUCTS (3) INFREQUENTLY

5. Have you ever used recycled materials? (if NO, why not, what are barriers?) Would you consider using recycled materials (or more recycled materials), if it met your requirements? (if NO, why not, what are barriers?) YES, comments:_________________
   ____
   NO, comments:____

6. What are your requirements for using recycled materials? (e.g. pellets or flake size, contamination level and type, resin type, quantity and delivery requirements, price savings)____
   ____

7. What are your equipment capabilities for using recycled materials? (e.g. feeding system -- vacuum take-up, bulk loading)____
   ____

8. Colorado State is considering whether to implement an ongoing technical assistance program. Would you be likely to use such a service? (why, why not)__________________
   ____

9. Specifically, what types of information or services do you think you might need? (e.g. specs on recycled content products , testing with flake, R&D on new products , tech assistance with equipment upgrades)____
   ____

Extrusion Molders Survey Form **Company Called:______________________**

Hello, this is Sheri Peterson with TechWorks. We are working with the Colorado Governor's Office of Energy Conservation on a project to assist Colorado businesses in using more recycled materials in manufacturing. We are particularly interested in plastics manufacturing and the use of recycled plastics. Would you have time to answer a few questions about your company's potential to use recycled plastics in your manufacturing? (if NO, is there another time or person we could call? If NO, thank you, end survey).

1. Does your company do extrusion molding? (if NO, thank you, end survey) YES NO

2. What resins do you use for extrusion molding? (e.g. HDPE, LDPE, others) HDPE LDPE PP PVC ABS OTHERS:____

3. Do you use any PCR pellets, (1) on a regular basis, (2) for selected products, (3) very infrequently? (1) REGULAR (2) SELECTED PRODUCTS (3) INFREQUENTLY

4. Do you use any washed flake or clean industrial regrind, (1) on a regular basis, (2) for selected products, or (3) very infrequently? (1) REGULAR (2) SELECTED PRODUCTS (3) INFREQUENTLY

5. Have you ever used recycled materials? (if NO, why not, what are barriers?) Would you consider using washed flake (or more washed flake), if it met your requirements? (if NO, why not, what are barriers?) YES, comments:_________________________________
____
NO, comments:____

6. What are your requirements for using washed flake? (e.g. pellets or flake size, contamination level and type, resin type, quantity and delivery requirements, price savings)____
____

7. What are your equipment capabilities for using washed flake? (e.g. feeding system -- vacuum take-up, bulk loading, crammer feeding, screen packs in extruders -- continuous screen changers)____
____

8. Colorado State is considering whether to implement an ongoing technical assistance program. Would you be likely to use such a service? (why, why not)___________________
____

9. Specifically, what types of information or services do you think you might need? (e.g. specs on recycled content products , testing with flake, R&D on new products , tech assistance with equipment upgrades)____
____

APPENDIX D:

MATERIAL TEST RESULTS