

RANDCASTLE COMPOUNDING

The following examples offer insight into our patented single screw Recirculator (page 22) and Elongator (page 23) and offer outstanding mixing advantages:

- Pictures by scale of mixing:
 - Micro to Nano Scale: Pages 6 to 11, 13
 - Macro Scale: Pages 4, 5, 14 to 21
- Comparison to twin screw: Pages 6, 7
- Comparison to single screw mixers: Pages 4, 5, 8, 9
- Index by Filler Type (Including CNTs): Page 2
- Index by Material: Page 3
- Pictures of high/low viscosity mixtures: Pages
- Pictures of de-mixing & re-mixing: Pages 9, 18, 19, 21
- ***Abstracts submitted for Antec 2008: Page 27***
 - RPVC Dry Blend: Single Screw, 180 rpm, 365F Melt, High Output
 - Batch Mixer Scales To Extruder
 - Elongator For Thermally Sensitive Processing

RANDCASTLE COMPOUNDING

Index By Filler Type:

- Color: Page 4 (other examples available)
- 5% 30 to 60 nm ceramic particles: Page 10
- 5% Single Wall Carbon Nano Tubes: 11, 12
- 5% Multi Wall Carbon Nano Tubes: 13
- 12 to 30% 1/8 inch long glass: 14, 15
- 25 to 40% Wood flour: 16, 17
- Unknown Particulate: 19
- 35% Calcium Carbonate: 20, 24, 27

RANDCASTLE COMPOUNDING

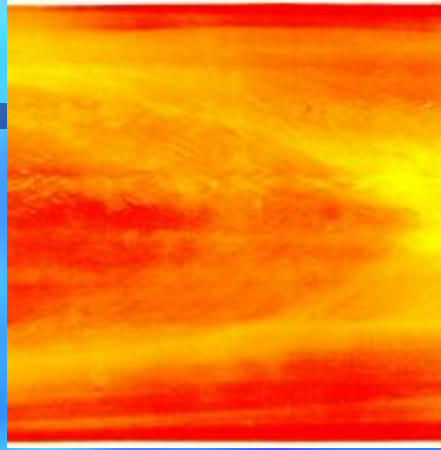
Index By Material, Pages:

- PVC: 4, 17, 18, 25, 26, 27
- PE/Elastomer: 5, 27
- PS/HDPE: 6 to 9, 27
- PMMA: 10, 11
- PC: 12
- Acetal: 13
- PP 14, 21, 27
- LDPE: 16, 27
- Nylon: 19
- Cellulose: 21

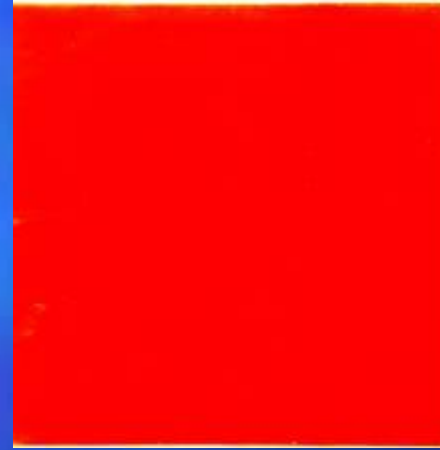
Coloring Vinyl Film

Flexible PVC pellets/0.5% red/0.5% yellow concentrate

UC Mixer



Recirculator



On the left, a conventional mixing section screw (aka Union Carbide mixer or Maddocks mixer) compared to the Recirculator.

Small amounts of color (such as 1%) are even more difficult to mix on small extruders because there are so few pellets per flight. For example, if a 5/8 inch screw (such as made these films) had 300 pellets in the screw, then there would only be 3 color pellets in the whole screw! (Assuming that they entered in a perfectly uniform fashion which, in a typical hopper, they will not.) You would then expect, as the color pellet left the die, high concentrations of yellow and red just as you see in the UC picture. The Recirculator has the ability to reduce such variation greatly—no matter how poor the input mixture.

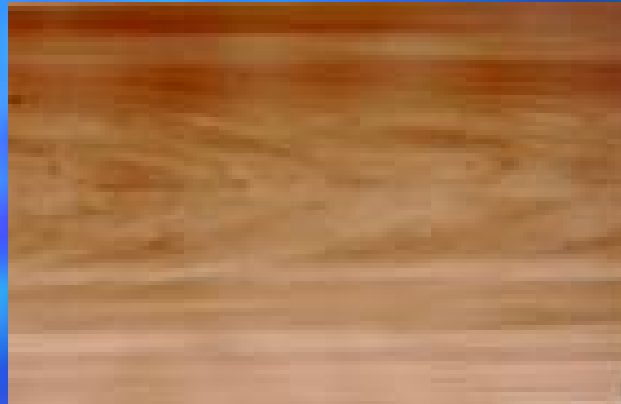
Single Screw Mixer Comparison

10% Elastomer & LDPE

UC Mixer



Double Wave



Recirculator



Left, a conventional mixing section screw (aka Union Carbide mixer or Maddocks mixer), middle a well known compounding screw and on the right, the Recirculator.

Making a TPO (an olefin and elastomer) was thought too difficult for single screw extruders because it was believed that they could not reach sufficiently high critical shear stress. As you can see on the right, the multiple elongational flow fields of the Recirculator are sufficient.

Single Screw vs Twin Screw

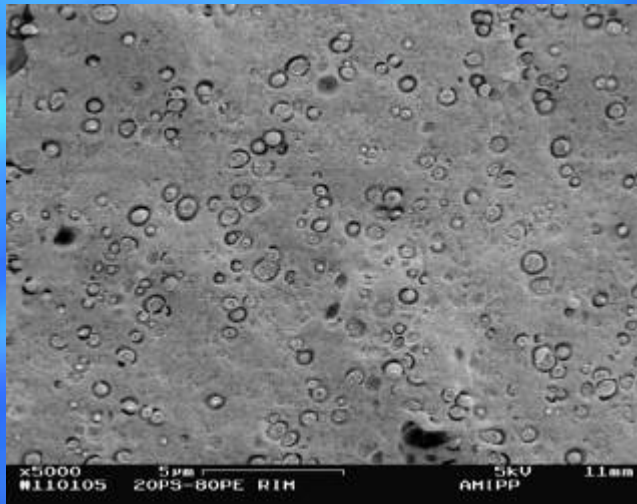
Continuous: 20PS/80PE

Recirculator Single Screw

Twin Screw

~1 Micron
PS Globules

This well studied blend is known to make domains in the 6 to 11 micron range* with a single screw (See Luker, Antec 2007, Ref. 9)

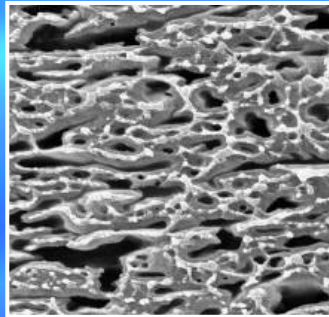


Single screw mixing studies haven't required magnification greater than 400X (most less than 200X). That's all that's needed to see deterioration in the mix quality. Left, the Recirculator magnification is 5,000X with small domains ~ 1 micron—no compatibilizer. Right, twin screw, same scale, processed similar mixture with the similar domains.

Left picture courtesy Rutgers. Right picture, Antec 95, "CO-CONTINUITY AND PHASE INVERSION IN HDPE/PS BLENDS: THE ROLE OF INTERFACIAL MODIFICATION" by Daniel Bourry and Basis D. Favis

Single Screw vs Twin Screw Co-Continuous: 30PS/70PE

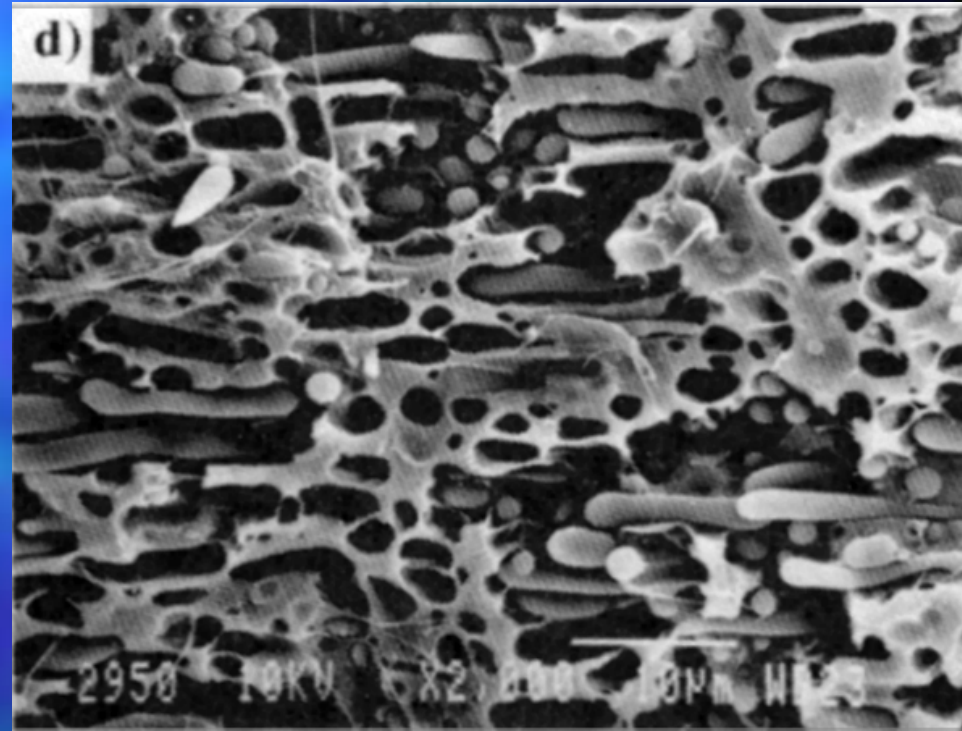
10 microns 



Picture
courtesy
Rutgers.

Single Screw
Recirculator
@ 2,000 X

Note: Material viscosity different.



10 microns 

Twin @ 2,000 X

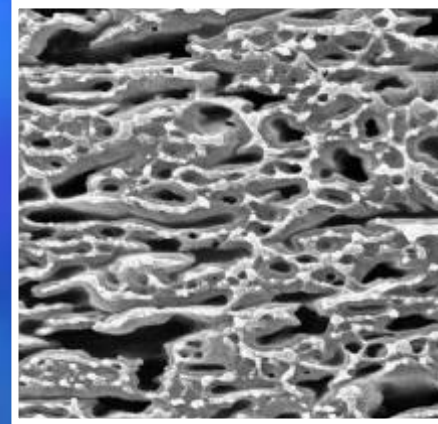
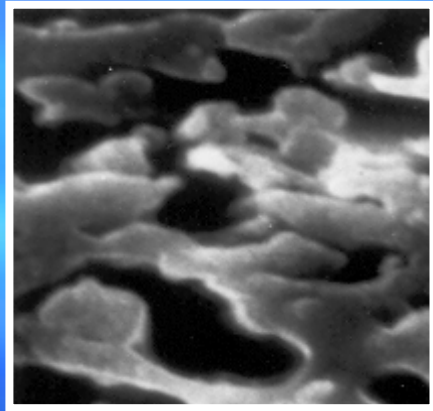
Right picture, Antec 95, "CO-CONTINUITY AND PHASE INVERSION IN HDPE/PS BLENDS: THE ROLE OF INTERFACIAL MODIFICATION" by Daniel Bourry and Basis D. Favis

Single Screw Comparison

Co-Continuous: 30PS/70PE

Classic
"Compounding"
Screw

20 micron
squares



Randcastle
Recirculator
Screw

20 micron
squares

Left, a typical single screw mixture. Right, the Recirculator shows a much finer structure. *Pictures above courtesy Rutgers.*

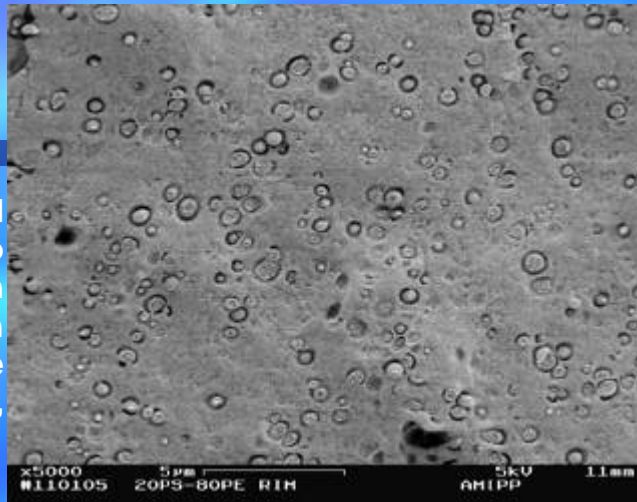
20PS/80PE Molding

Recirculator

Standard Injection Screw

~ 1 Micron
PS Globules

This well studied blend is known to make domains in the 6 to 11 micron range* with a single screw (See Luker, Antec 2007, Ref. 9)



After
Molding
Without
Recirculator

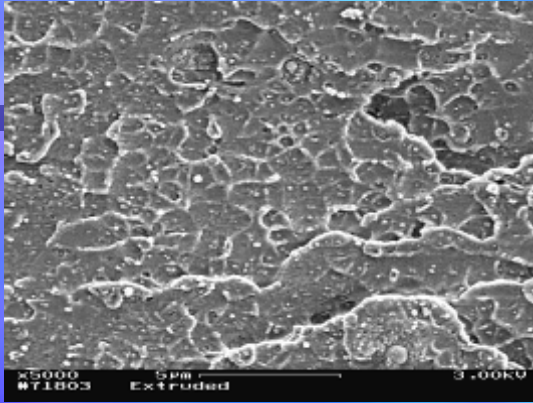
On the left, the ~ 1 micron domains from Recirculator.

On the right, this mixture was injection molded through a typical injection molding screw. Coalescence takes place without the Recirculator and the domains increase about 10 times as seen in the green oval. Soon, we will install a Recirculator molding screw to see if the small domains can be maintained with the Recirculator or, possibly, even mixed within the mold.

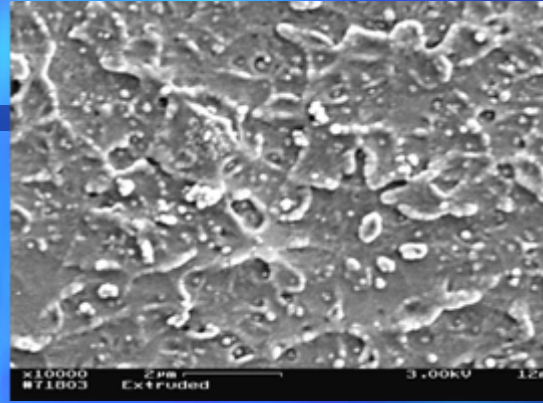
Pictures courtesy Rutgers.

Ceramic Nano-Composites

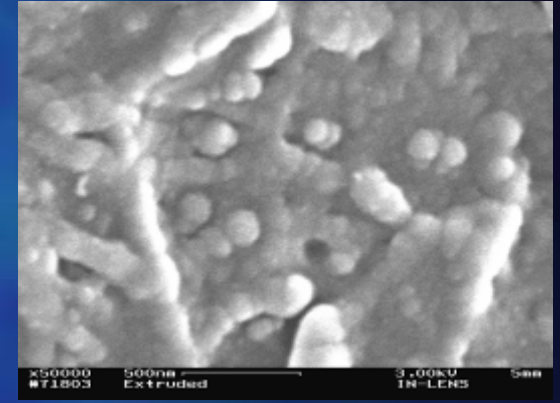
PMMA Pellets & 5% Nano Ceramic 30 to 60 nm



5,000 X



10,000X



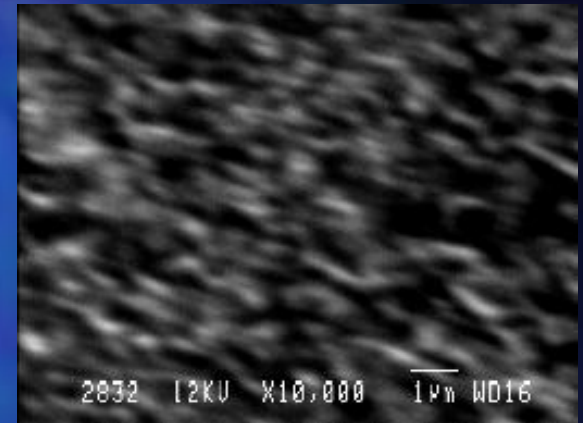
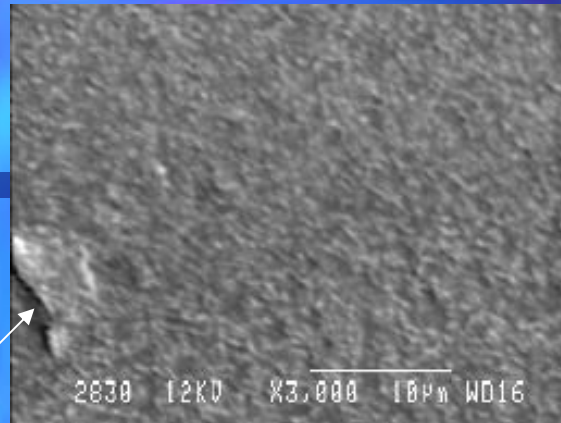
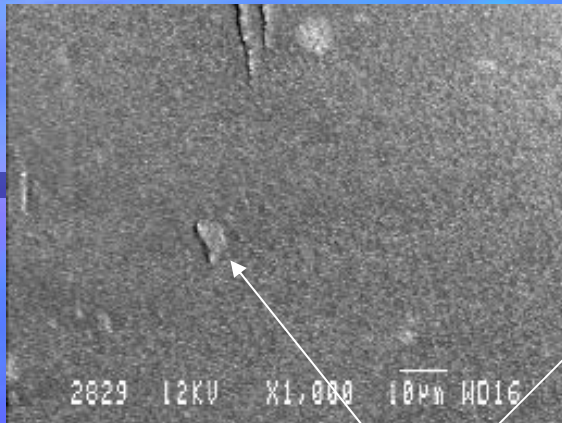
50,000X

Nano compounding is very difficult to accomplish because the particulate is so small compared to a pellet. If a 45 nm ceramic were a baseball, then a pellet would be 3.2 miles high! *That's a tough input mixture!*

These pictures were from a starve fed 5/8 inch Microtruder with three Recirculators rotating at 350 rpm. Even at 50,000X, we still see uniform distribution. This degree of magnification is seldom seen even in a twin where upstream axial mixing (recirculation) does not take place.

Pictures courtesy Rutgers.

5% Carbon Nano-Tubes In PMMA



Contamination

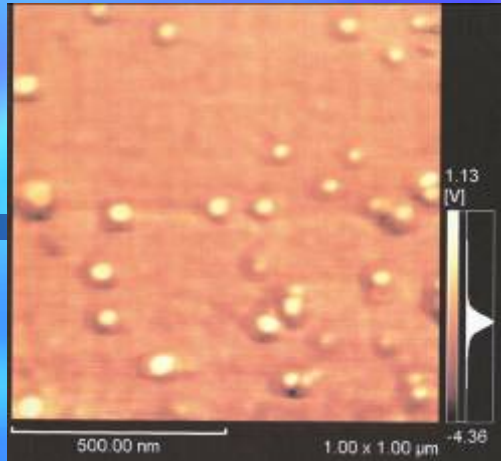
This picture shows untangled CNT's

This sample of 600 grams was processed in Randcastle's 50/1, low output, 4 Recirculator screw, 350 rpm, 5/8 inch Microtruder. We returned 300 grams to the customer in pelletized form.

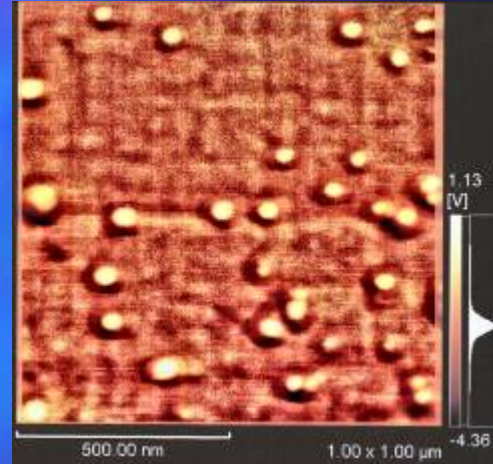
Not only is the mixing quality outstanding, but we are told that even though the customer has twin screw extruders, they have not been able to produce the dis-entangled CNT's in the picture on the right.

2% Carbon Nano-Tubes & PC

100,000 X



100,000 X
(Enhanced)



Everyone is talking about nano compounding but it's very tough to do. Yet, even at 100,000 times magnification (the most magnification we've ever seen in extrusion compounding), the ends of these carbon nano tubes are still separated.

Note that the PC (polycarbonate) was in pellet form which is more difficult to compound than pre-dispersed CNT's in powder.

The picture on the right is software enhanced.

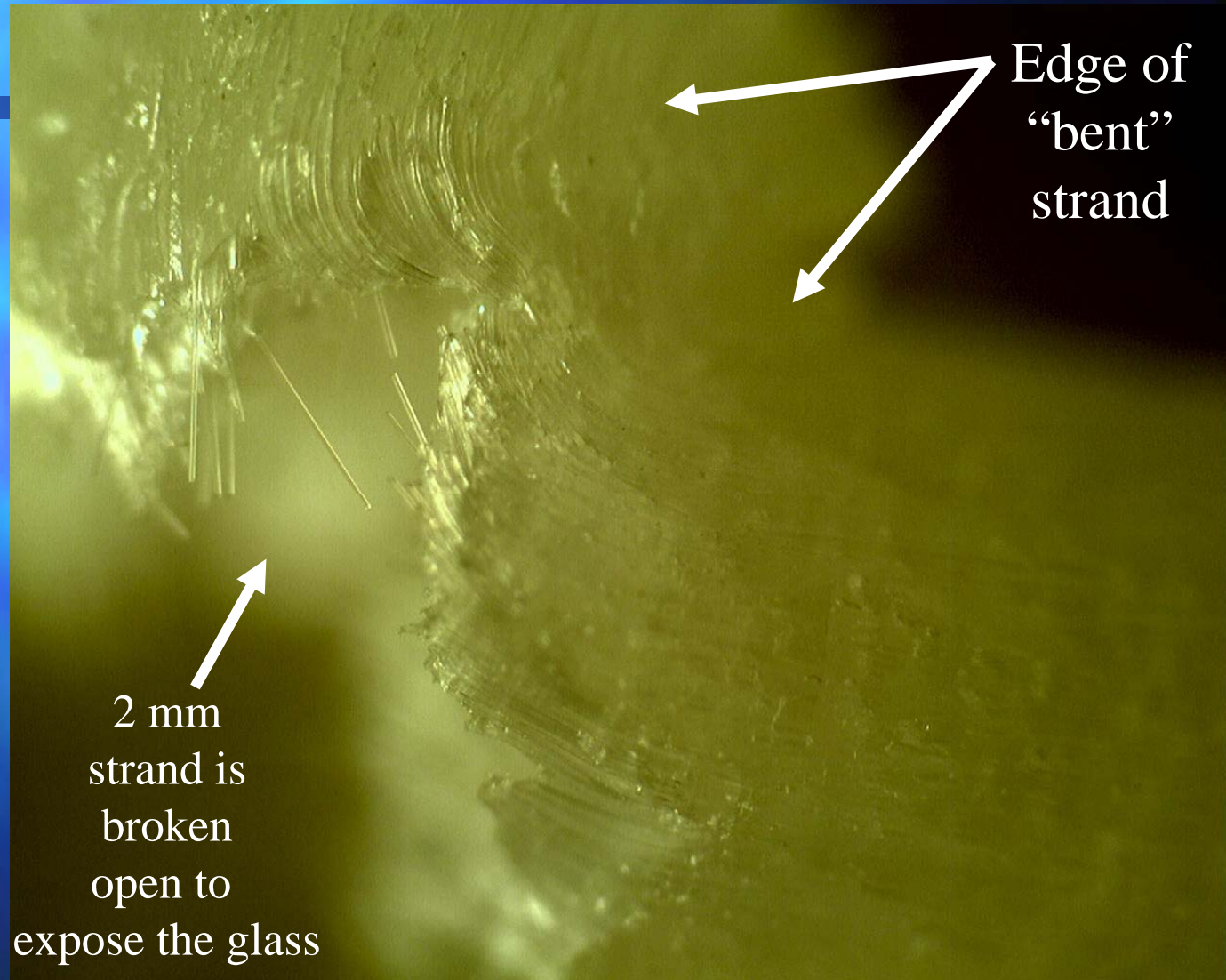
5% Carbon Nano-Tubes In Acetal Conductive to Dissipative Range

Multi-wall CNT's were mixed with acetal pellets in a 36/1 Randcastle Recirculator and pelletized for static dissipation in computer trays. The pellets were injection molded and tested by a large European chemical company under IEC 60093. The range was:

35 to 85 Ohms/sq

30 % Glass Fibers In PP

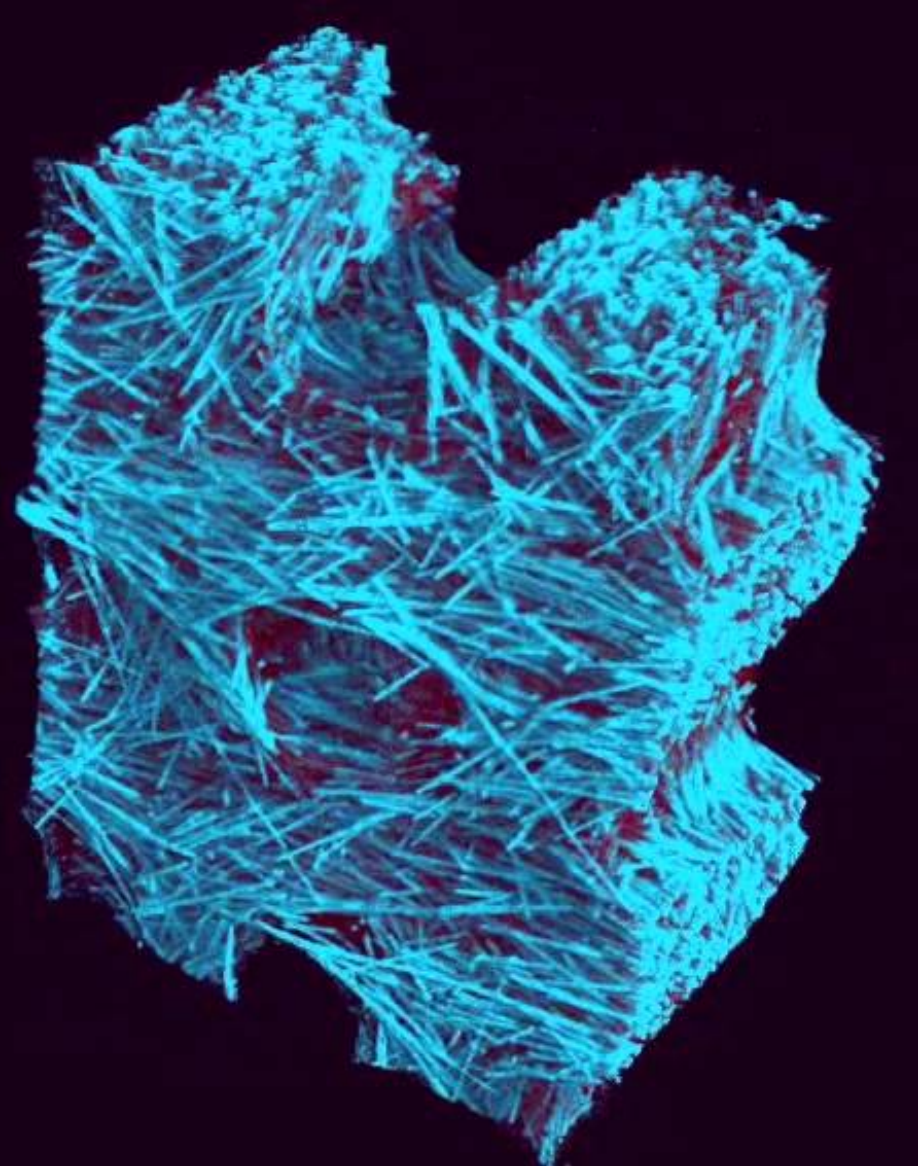
3/16 glass



1 inch Taskmaster, 36/1, double vented

X-Ray Topography

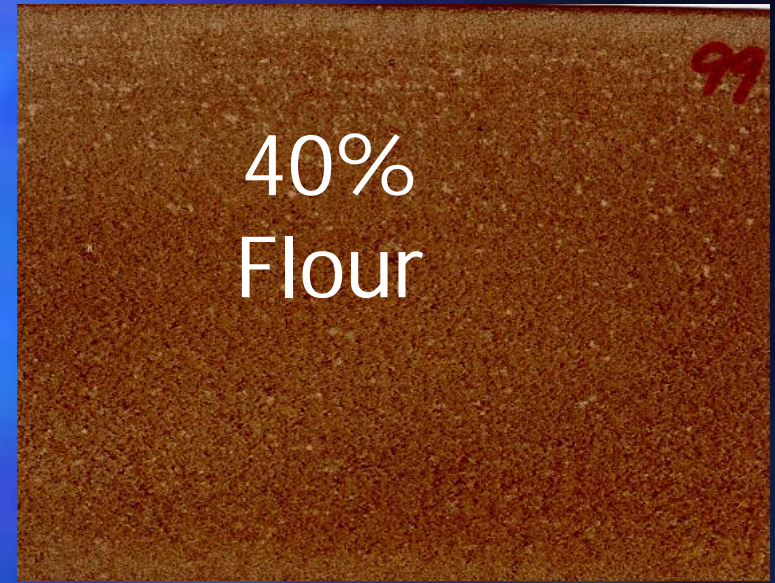
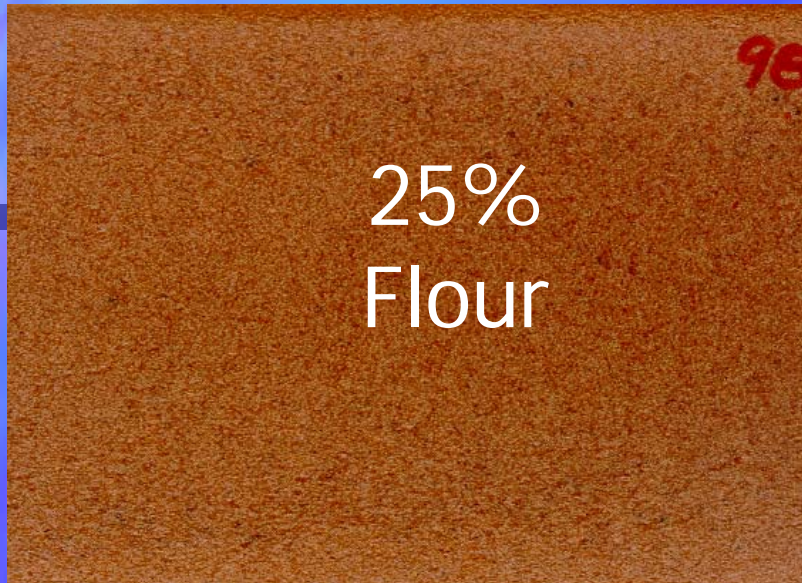
12% Glass/Elastomer



This membrane was compression molded from an extruder strand using the Randcastle Taskmaster, 3 Recirculators, 1 atmospheric vent and overcoating a monofilament.

The glass fibers are remarkably distributed. A short video of the whole movie is available. Note: Most of the polymer (red) is removed from this view.

Wood Flour & LDPE Pellets



Early Recirculator trials mixed a lot of wood directly into sheet. Working with wet wood, we vented off the water in a second extruder.

This was done in a two stage system using the Recirculator to compound and a single screw to degas.

Our newest technology (the Elongator) eliminates the second extruder and vents off the water in a single operation!

Wood Flour & RPVC Powder

100% RPVC Powder

60% RPVC 40% Woodflour
Before Degassing

1" x 0.125 Tensile Bar

1" x 0.062 Tensile Bar



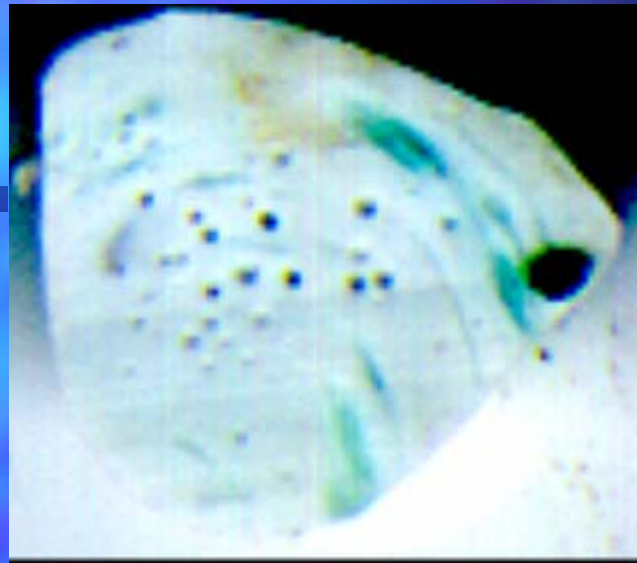
Processing RPVC shows that the Recirculator doesn't degrade even very thermally sensitive materials. The water was vented off in second extruder (see previous slide).

Our newest technology, the Elongator, does it all in one step.

PVC 95/72 Durometer PVC



Barrier Screw
With Mixer



Barrier Screw
With Mixer

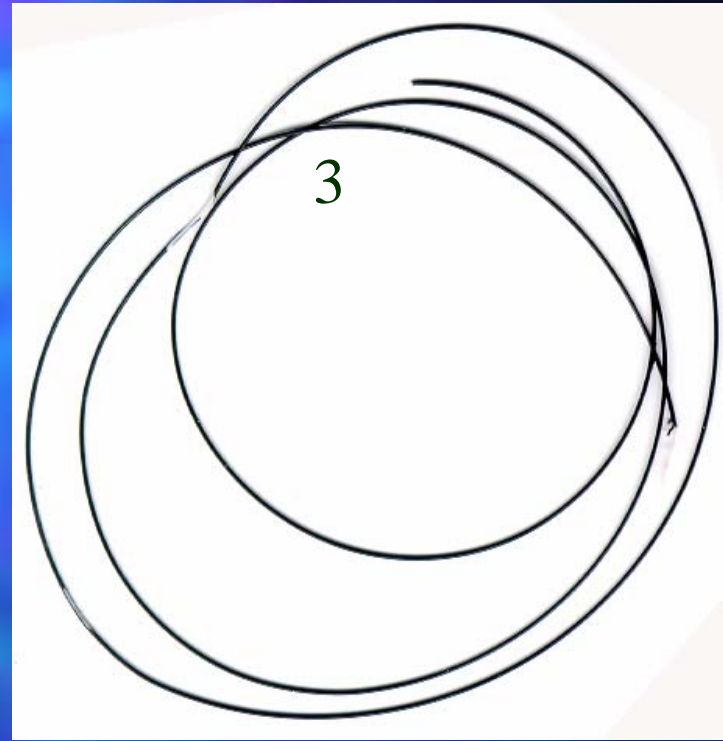


Recirculator

Left and center (cross section), pellets compounded by a 6 inch screw. Left, the more fluid material (white) surrounds the more viscous clear material and makes unsaleable product.

Right, the same material is processed in the Recirculator screw and prevents the problem completely.

Nylon & Filler

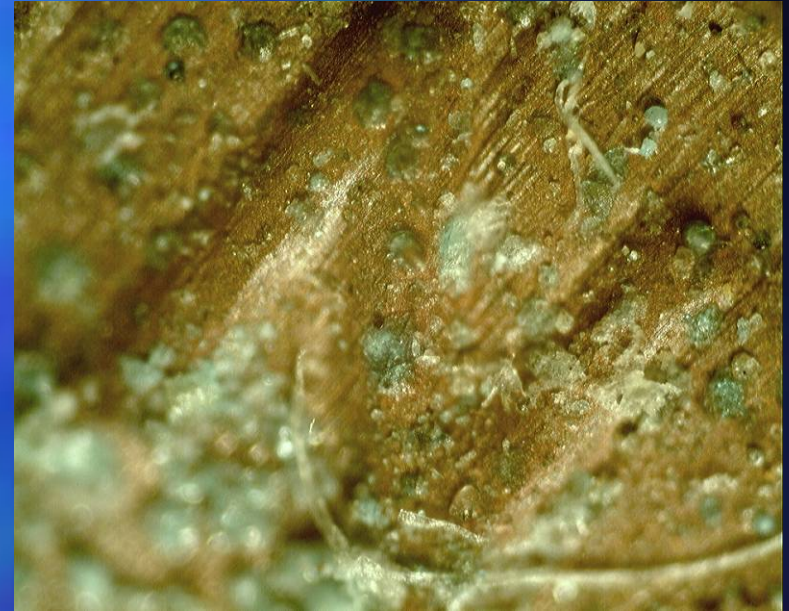


Strand 1 was first compounded by a twin and then extruded in a screw with two spiral UC mixers. The original strand was smooth leaving the twin but agglomerates within the single.

Strand 2 is from the Recirculator from the same pellets. Quite smooth.

Strand 3 is a Recirculator mixed 1 mil coating over monofilament and without agglomeration

35% Calcium Carbonate Powder With PP Pellets: Two Vents



Left, surface microscopy of the strand at 100 times magnification showing no unmixed calcium carbonate (calcium carbonate is white). The surface is smooth and the tones that you see are surface imperfections. This was processed on our Elongator high output vented screw on a 1 inch Taskmaster at 18.4 pph without vent flow. Right, the same magnification of the “N” on a US penny for scale.

Cellulose Pellet Processing, 24/1 L/D

3.5 mil thick films (both films are clear but shaded for contrast)



General Purpose Screw



Elongator

The plasticizer oil forms bubbles with the typical screw, left, but the Elongator keeps the oil mixed to make better film.

Randcastle's Recirculator



Randcastle's Elongator



RPVC Pellets & 15% Calcium Carbonate

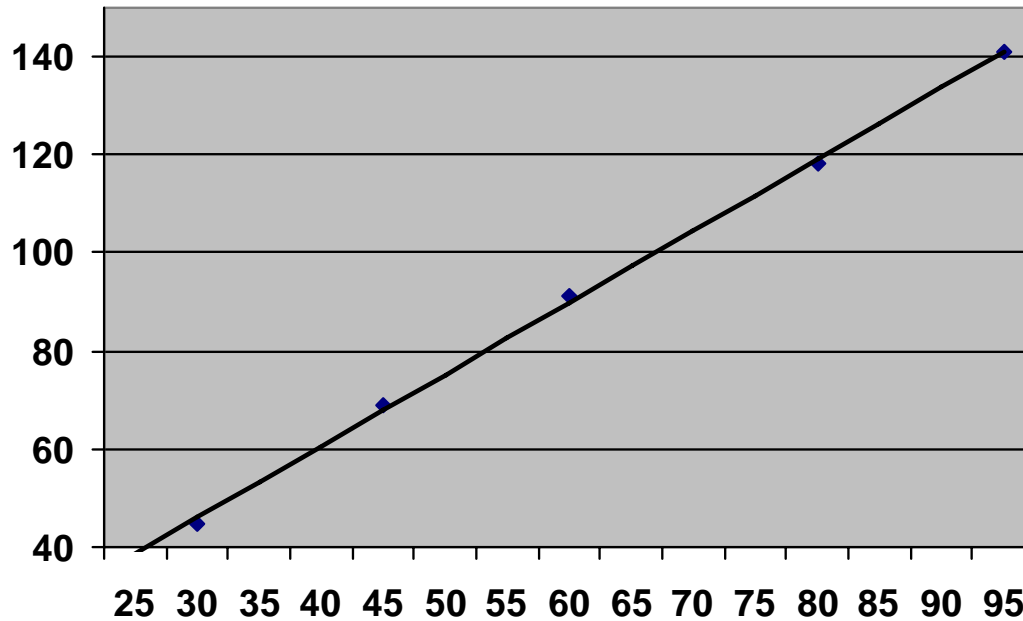


Output RPVC Pellets

1 Inch 36/1 Extruder

Grams/Minute

18.7 PPH



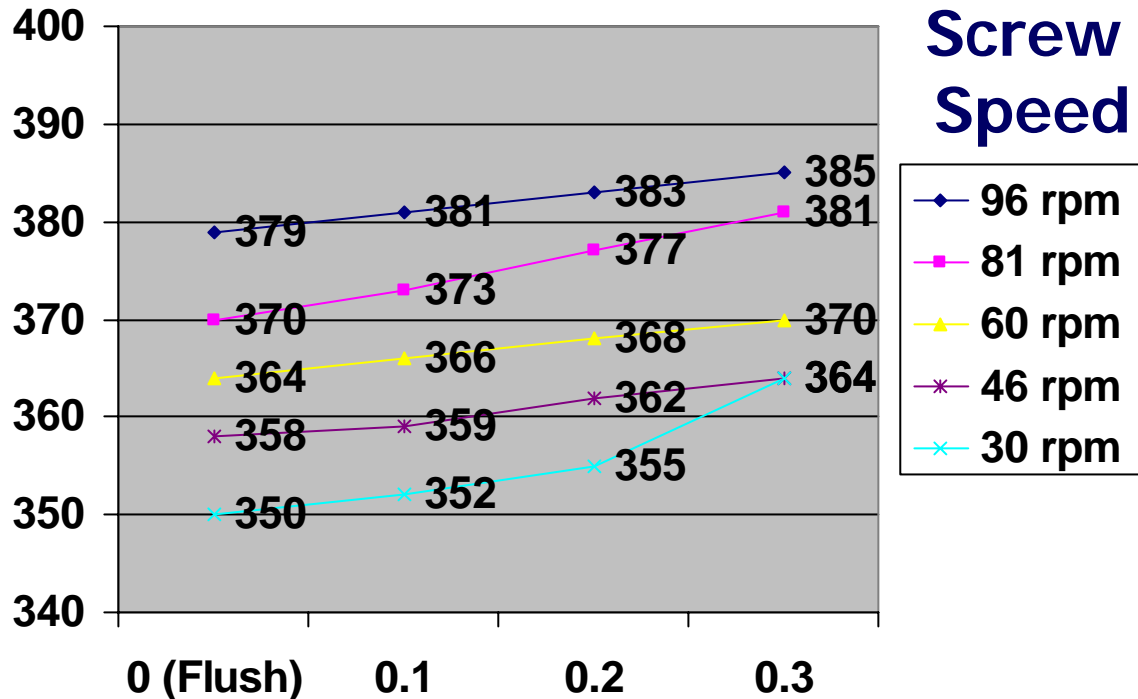
Screw RPM

Since PVC was created, single screws have processed RPVC pellets at about 30 rpm as higher speed degraded the material. This chart shows an output more than three times typical using Elongator technology. See next page for stock temperature.

Melt Temperature RPVC Pellets

1 Inch 36/1 Extruder

Degrees F



Immersion Depth (Inches)
(Through a 1 inch bore)

This chart of stock temperatures refers to the previous output page. The typical recommended maximum stock temperature is 391F (200C). **See page 27 for dry blend!**

NOVEL SINGLE SCREW FOR RPVC DRY BLEND WITH HIGH OUTPUT CHARACTER

*David Lorenc, Randcastle Extrusion Systems, Inc., Cedar Grove, NJ 07009
Keith Luker, Randcastle Extrusion Systems, Inc., Cedar Grove, NJ 07009*

Abstract: It is well known that the single screw extruder (SSE) rpm for rigid polyvinyl chloride (RPVC) dry blends has languished compared to other materials. This paper presents data showing simple processing of RPVC dry blend with a surprising increase in screw speed to 180 rpm and output at only 174 °C.

NOVEL SINGLE SCREW ELONGATIONAL COMPOUNDER FOR THERMALLY SENSITIVE MATERIALS

Keith Luker, Randcastle Extrusion Systems, Inc., Cedar Grove, NJ

Abstract: At Antec 2007, a new single screw compounder with multiple elongational flow fields and upstream axial mixing was described. Called the Recirculator, it was shown an effective compounder of immiscible blends and nano scale. Upstream axial mixing, while particularly useful in some applications, is a potential liability for thermally sensitive materials as they may degrade from extended residence time. A new mixer is presented with similar geometry and that features multiple elongational flow fields. However, it does not have upstream axial mixing. This mixer shows greatly improved processing of thermally sensitive materials. Multi-layer reclaim containing EVOH showed a much broader processing range. Cellulose acetate film degraded on a conventional screw but not on the new design. RPVC pellets were extruded at an extremely high output with an extruder rpm of 96 and a temperature of only 196C.

A NOVEL MICRO-BATCH MIXER THAT SCALES TO A SINGLE SCREW COMPOUNDER

*Keith Luker, Randcastle Extrusion Systems, Inc., Cedar Grove, NJ
Jennifer K. Lynch, Rutgers University
Thomas J. Nosker, Rutgers University*

Abstract: Recently, a simple, extensional flow based single screw extruder (SSE) was developed, incorporating a novel mixing element, the Elongator. Arranging this key compounding element into a micro-batch mixer has yielded similar mixedness of particle-polymer and polymer-polymer systems, as when processed using the SSE with Elongator mixing element. The objective of this work is to compare the resulting mixedness produced in several material systems using the novel micro-batch mixer and SSE, both fit with the Elongator mixing element.