RANDCASTLE COMPOUNDING

These pictures and examples offer pictorial insight into our patented single screw compounders—the SFEM Elongator and AFEM Recirculator. They demonstrate unrivaled mixing performance. As this can be a complex subject, feel free to call us any time. *Keith Luker, President*

- Pictures by scale of mixing:
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*Technical paper, “Comparison Of Flow Striations Of Various SSE Mixers To The Recirculator and Elongator Mixers” at website.

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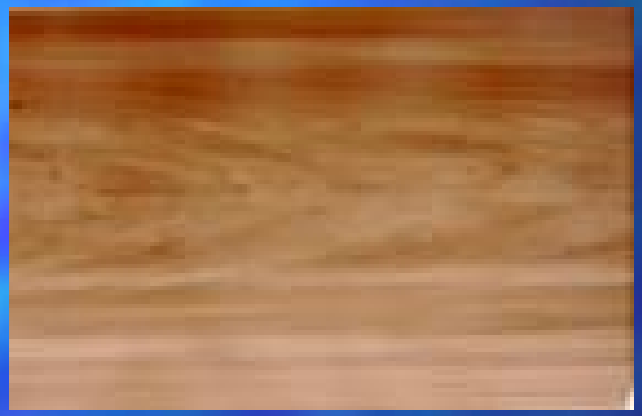
Single Screw Mixer Comparison

10% Elastomer & LDPE

UC Mixer

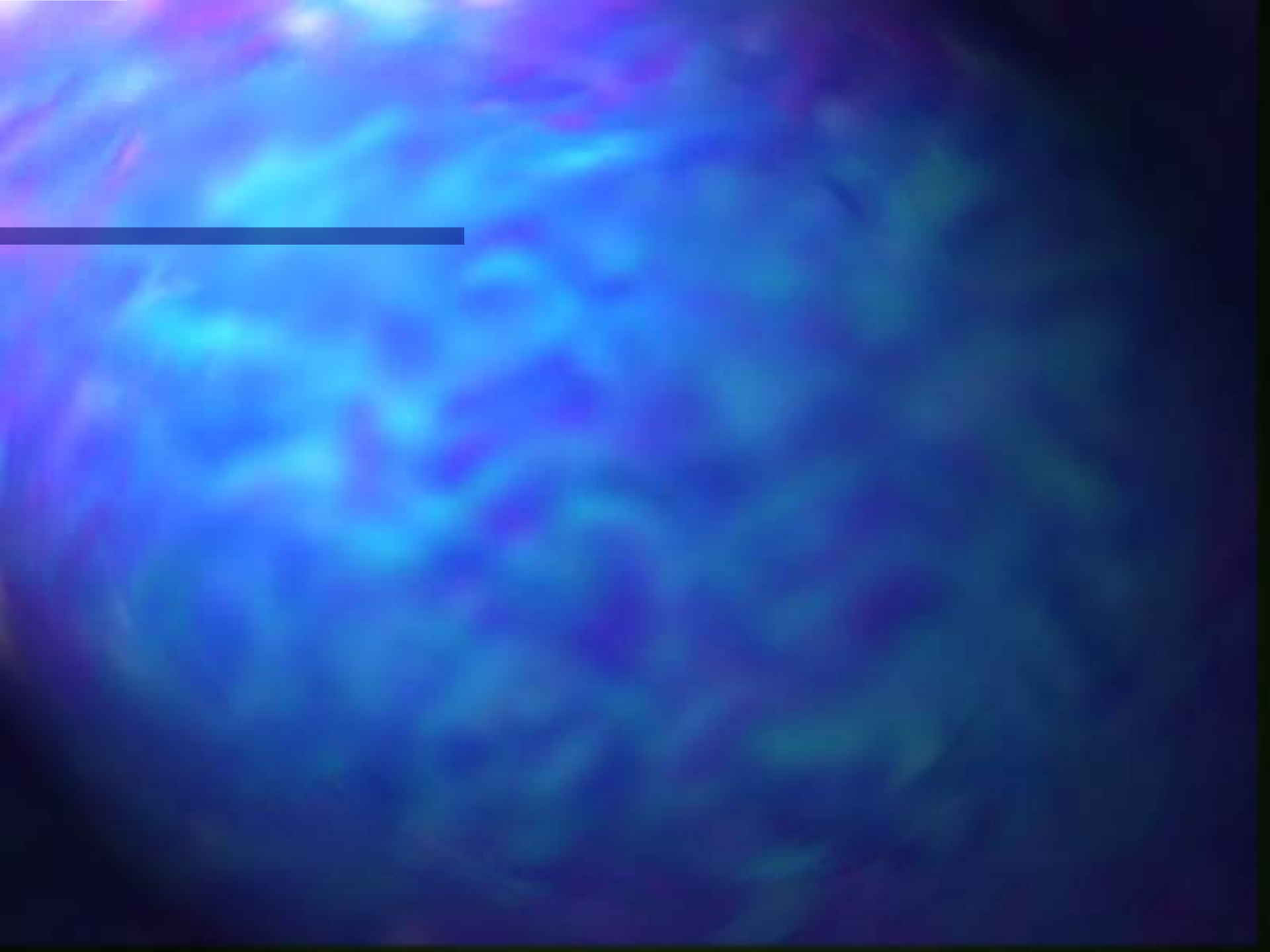
Double Wave

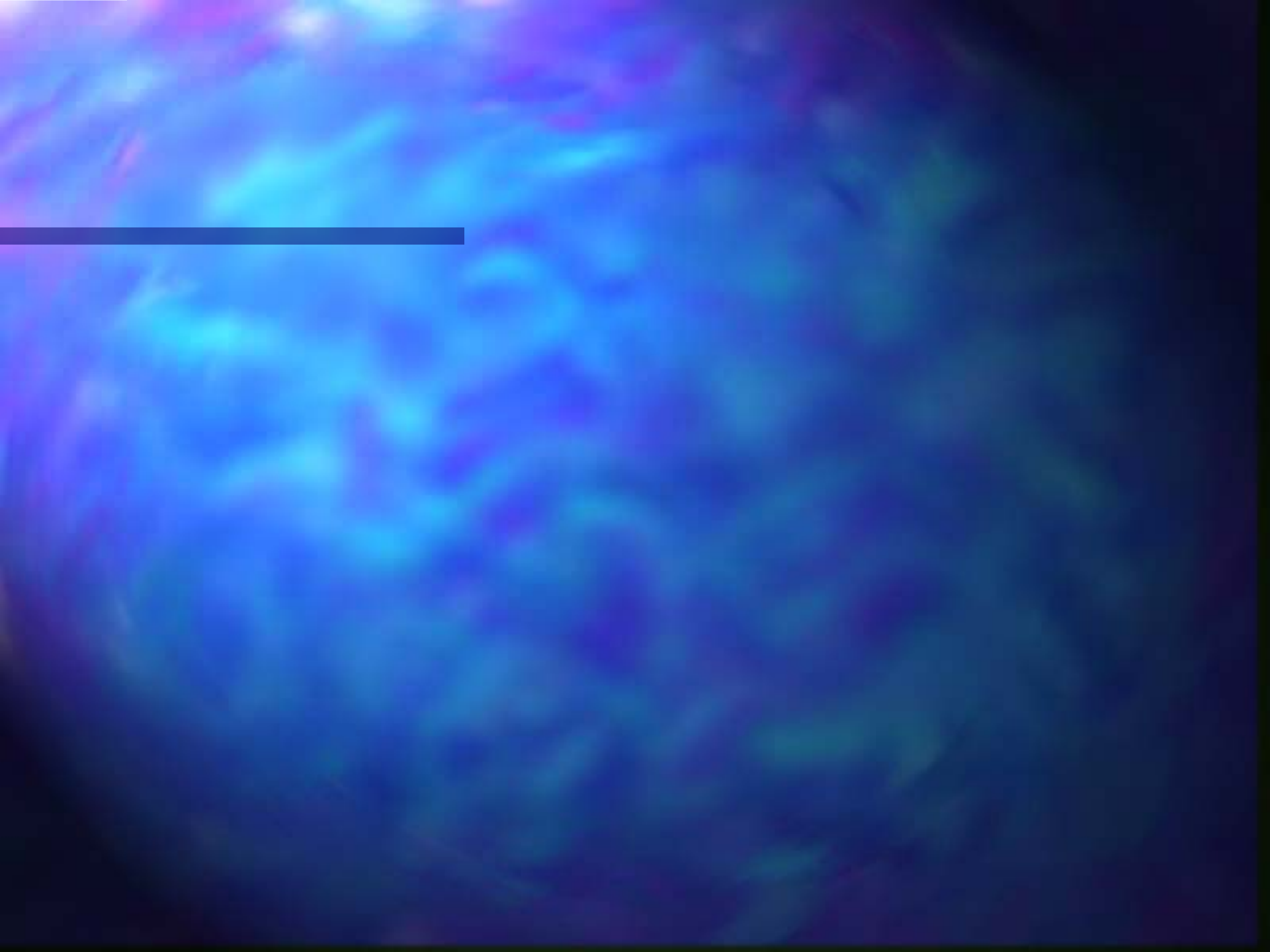


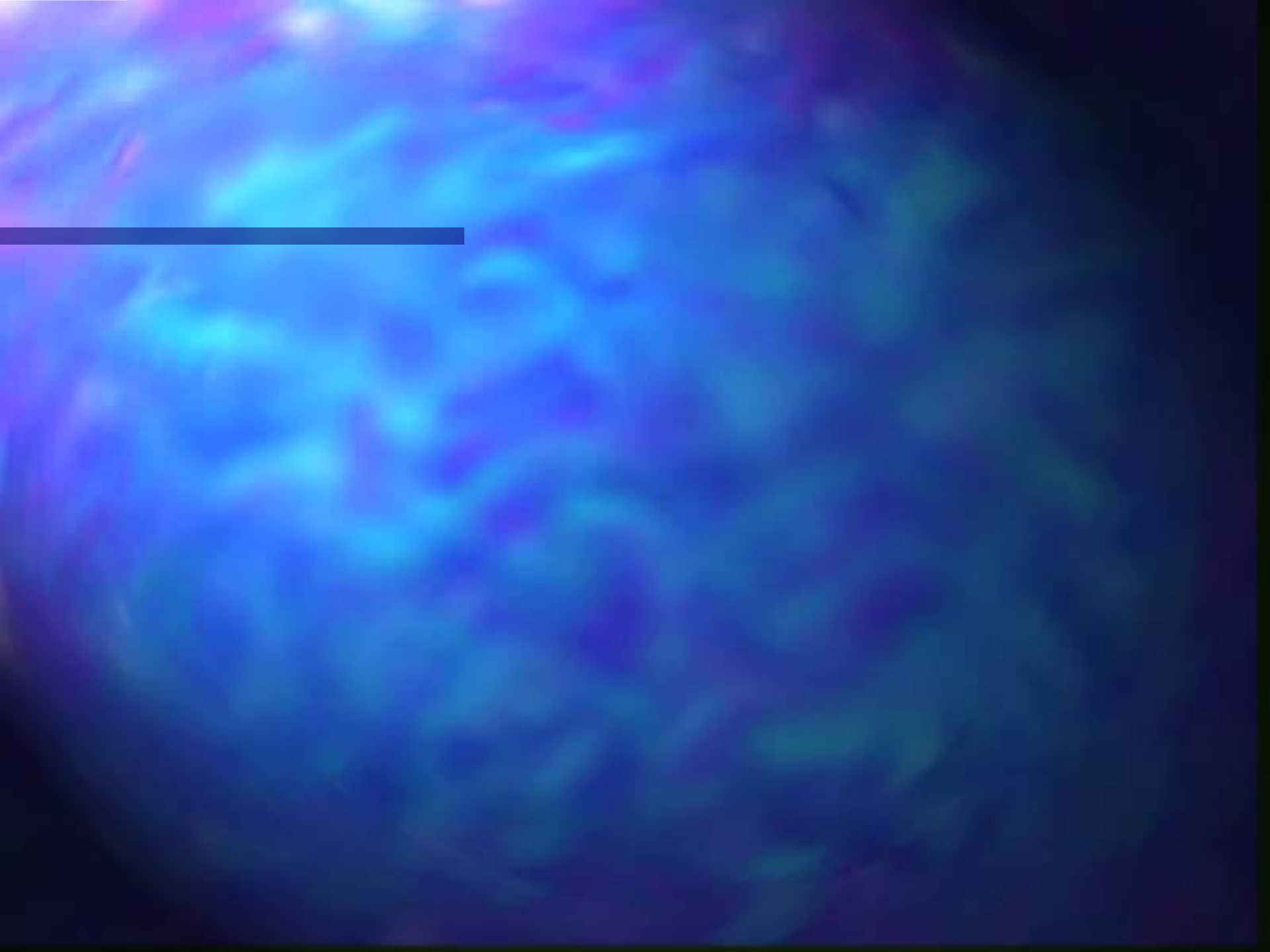
AFEM Recirculator

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

TPO (olefins and elastomer) compounding was long believed too difficult for single screw extruders since it was believed that they could not reach sufficiently high critical shear stress. On the right, the multiple extensional flow fields of the AFEM Recirculator are sufficient.







Batch Mixer Cooling Experiments 4.3 RPM

2.5 Minutes	3.0 Minutes	4.0 Minutes
~11 Revolutions	~13 Revolutions	~17 Revolutions

1% red color concentrate followed by LDPE pellets was fed into the Randcastle SFEM-BM-1000-4 10 gram batch mixer. The mixtures were cooled in place before removal from the rotor. These were laid flat above. It is remarkable how fast the mixing took place. Imagine the improved mixing at 100 rpm.

1% Color Concentrate & LDPE

Film From SFEM Elongator Screw

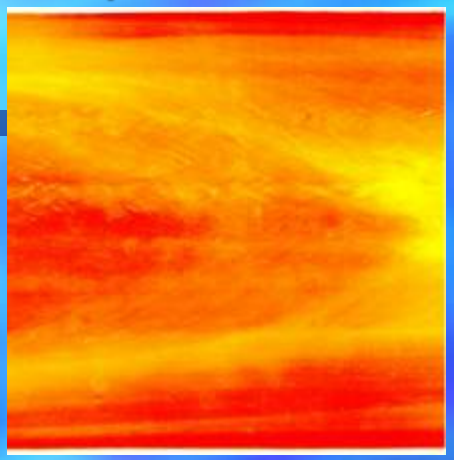
Strand From SFEM Batch Mixer

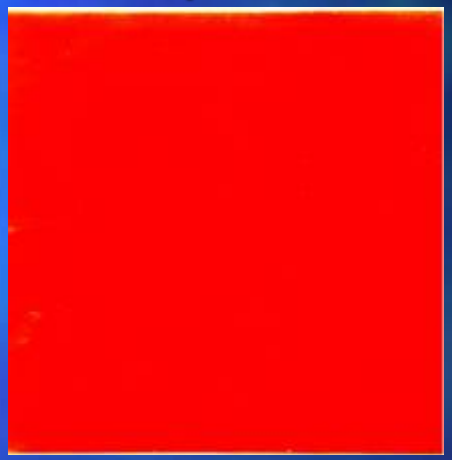
Our Randcastle SFEM batch mixers conveniently extrude a strand. In many cases, there's no need to spend time scraping molten samples off the rotor. Here, a film made with an SFEM Elongator screw and the SFEM batch mixer, perhaps not surprisingly, look the same.

Coloring Vinyl Film

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

UC Mixer





AFEM Recirculator

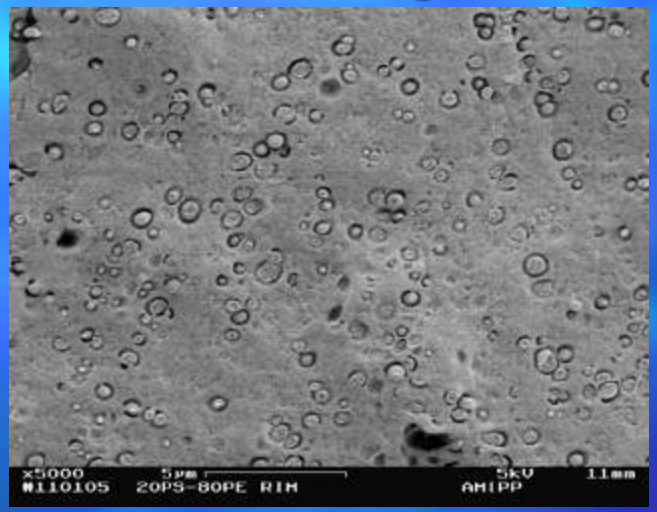
On the left, a conventional mixing section screw (aka Union Carbide mixer or Maddock mixer) compared to the AFEM-Recirculator.

Mixing yellow and red at 0.5% is extremely difficult for small extruders. For example, the 5/8 inch screw that made these films has about 300 pellets in the entire screw. That's less than 2 pellet of each color in the entire extruder! These pictures give you a good idea about distributive mixing. The classic screw on the left just pushes the poor input out the die. The AFEM Recirculator stretches the film many ways and many times so that you get a better product.

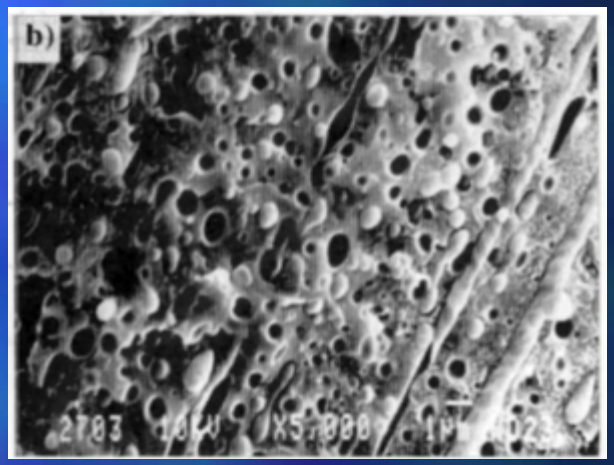
Single Screw vs. Twin Screw

Continuous Domains: 20PS/80PE

Recirculator Single Screw



Twin Screw



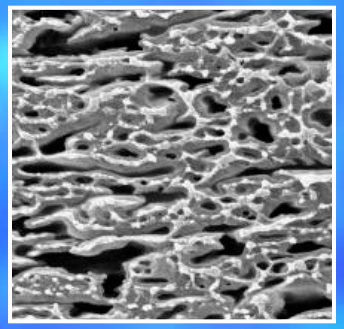
The Randcastle AFEM Recirculator shows the same size domains as the twin screw in this immiscible polymer blends without compatibilizer at 5,000 times magnification.

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

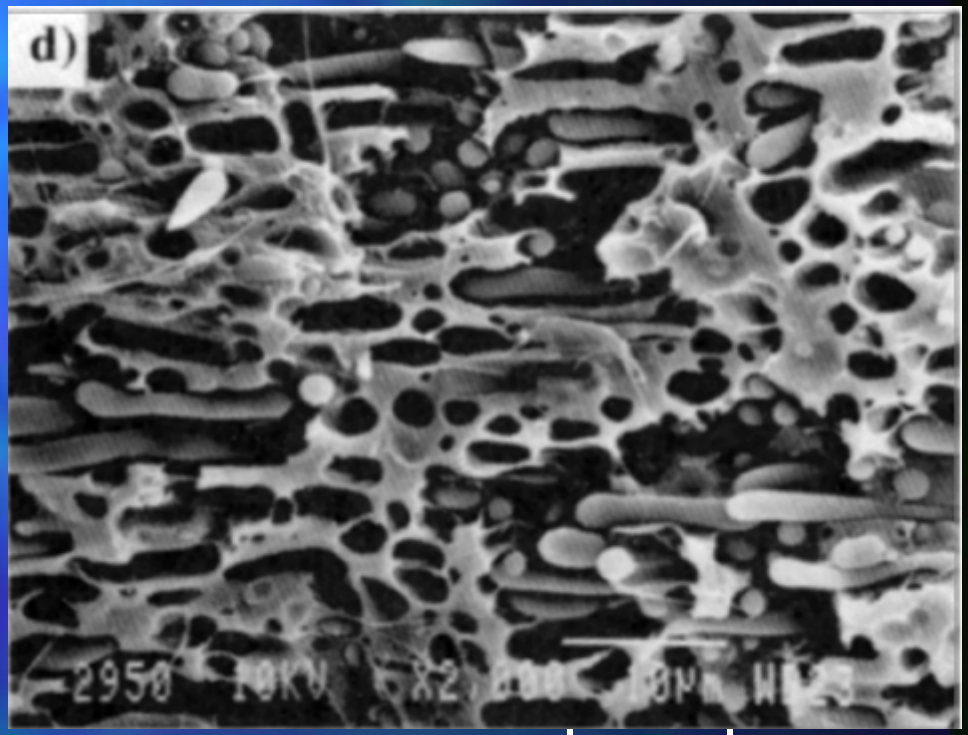
Co-Continuous Domains: 30PS/70PE

10 microns



Picture courtesy Rutgers.

Our AFEM-Recirculator single screw extruder shows a much better mixture than the twin.

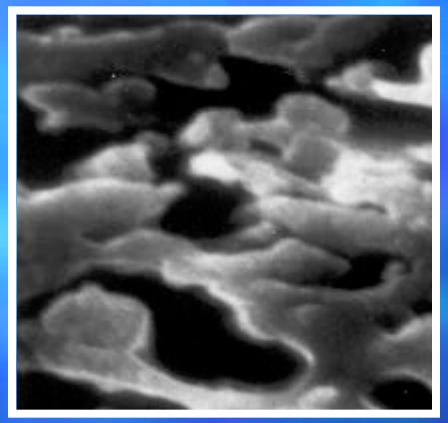


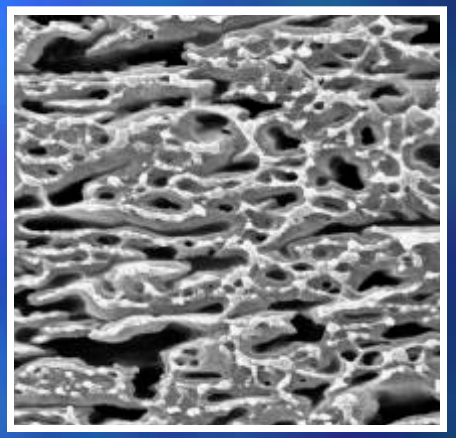
10 microns

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

Conventional Mixing Screw

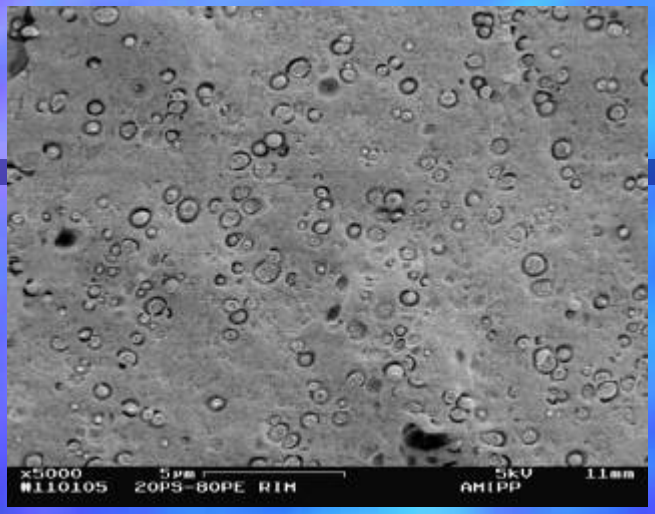




AFEM Recirculator

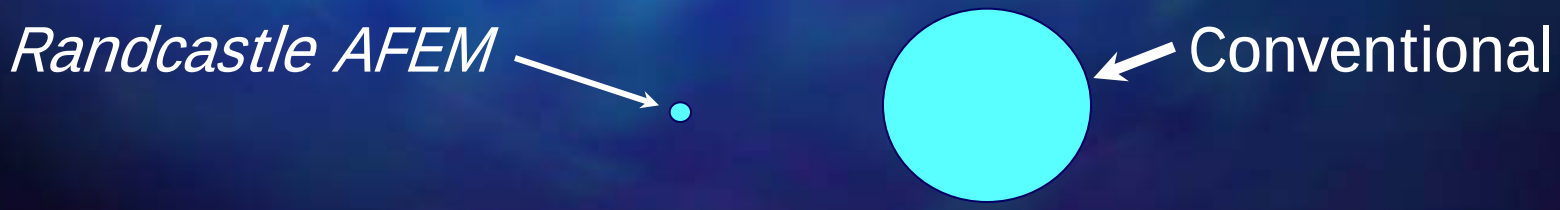
These 20 micron square pictures show that the AFEM Recirculator give a much finer structure than the conventional mixing screw. The pictures are courtesy of Rutgers.

Mixing 1,000 Times Better



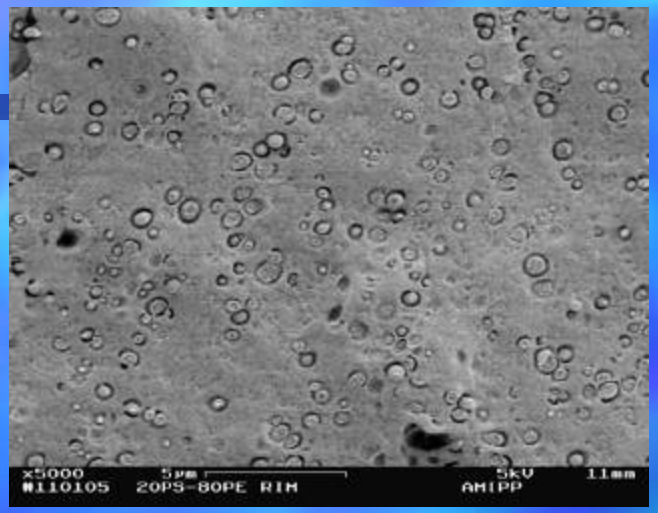
This picture shows minor phase domains of 1 micron from our AFEM mixing screw.

Conventional single screws are known to make domains of about 10 microns.* Our screws make 1 micron. How much better is that? Micro-photographs show two dimensional domains that are really three dimensional spheroids. Every time you halve the diameter, you reduce the volume 8 times. So, if have a 10 micron sphere, you need eight 5 micron spheres to contain the same amount of material. Likewise, you need eight 2.5 micron spheres to have the same volume as a 5 micron sphere. So, you need 8 x 8 x 8 x 2 = 1,024 spheres of 1 micron to equal the volume of a 10 micron sphere. *Our AFEM and SFEM screws are 1,000 times better.*

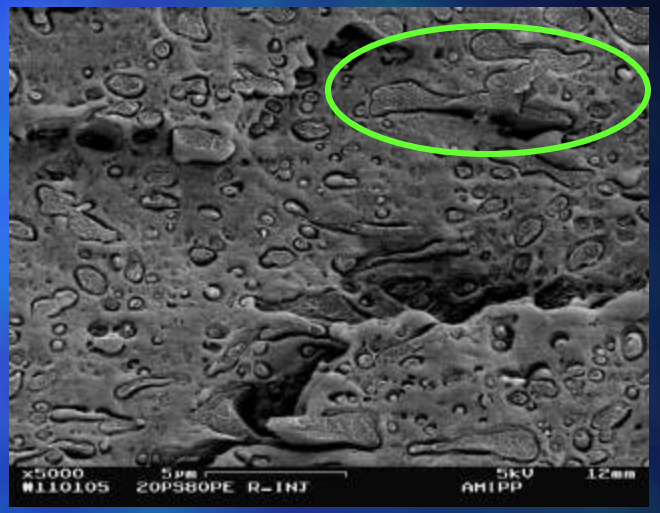


**See Summary Results of A Novel Single Screw Compounder, Antec -07 www.randcastle.com under technical papers.*

20PS/80PE De-mixing During Molding



AFEM Recirculator

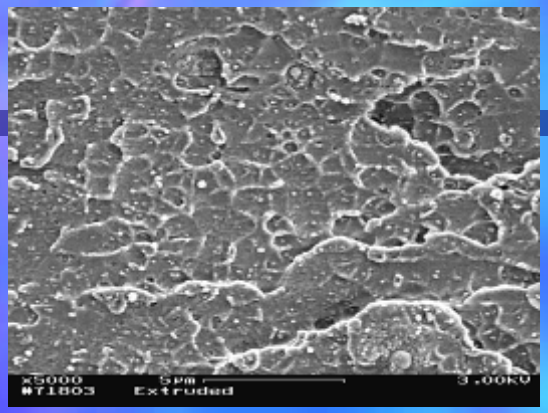


Conventional Injection Screw

The AFEM Recirculator compounded the mixture on the left. This was then injection molded with a conventional screw. Coalescence takes place without the AFEM Recirculator and the domains increase as seen in the green oval. When the AFEM-Recirculator is installed in a molder, coalescence does not occur. The pictures are courtesy of Rutgers.

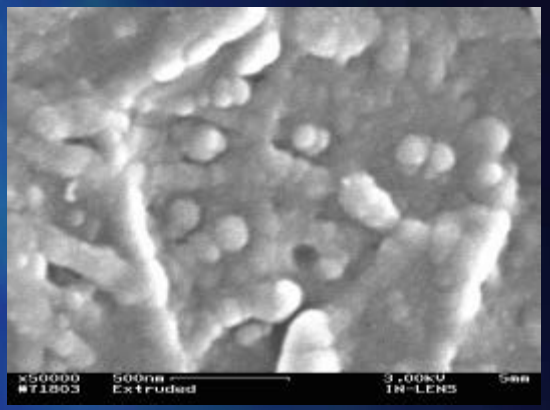
Ceramic Nano-Composites

PMMA Pellets & 5% Nano Ceramic 30 to 60 nm



5,000 X

10,000X



50,000X

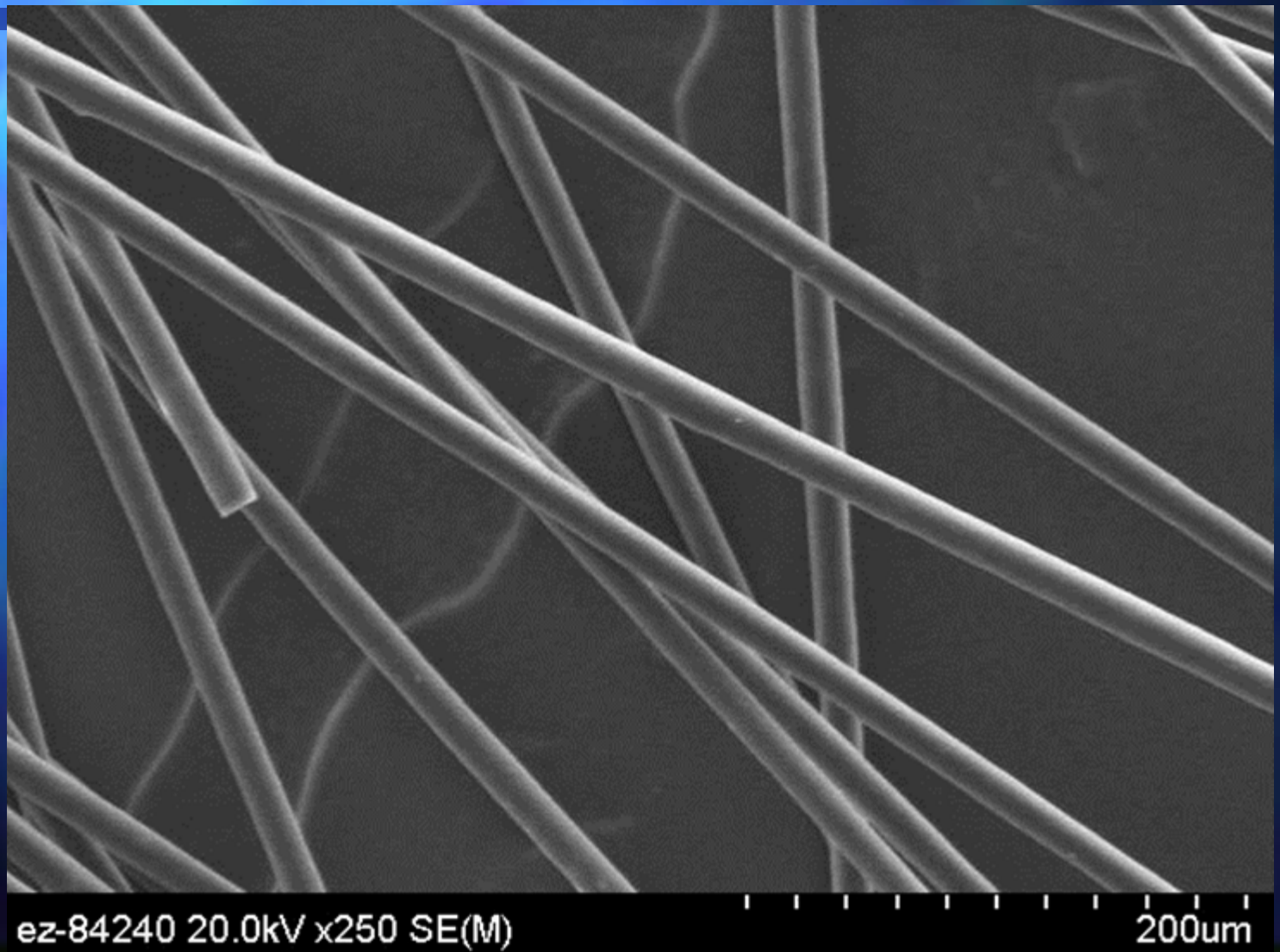
Nano compounding is very difficult because the particulate is so small compared to a pellet. If a 45 nm ceramic were a baseball, then a pellet would be 3.2 miles high! *That's a tough input mixture!*

These pictures are from a starve fed 5/8 inch Microtruder with three Recirculators rotating at 350 rpm. Even at 50,000X, we still see uniform distribution.

Pictures courtesy Rutgers.

1% Carbon Nano-Tubes In Lignin

Compounded on 50/1 Microtruder With
1 SFEM Elongator and 3 AFEM Recirculators



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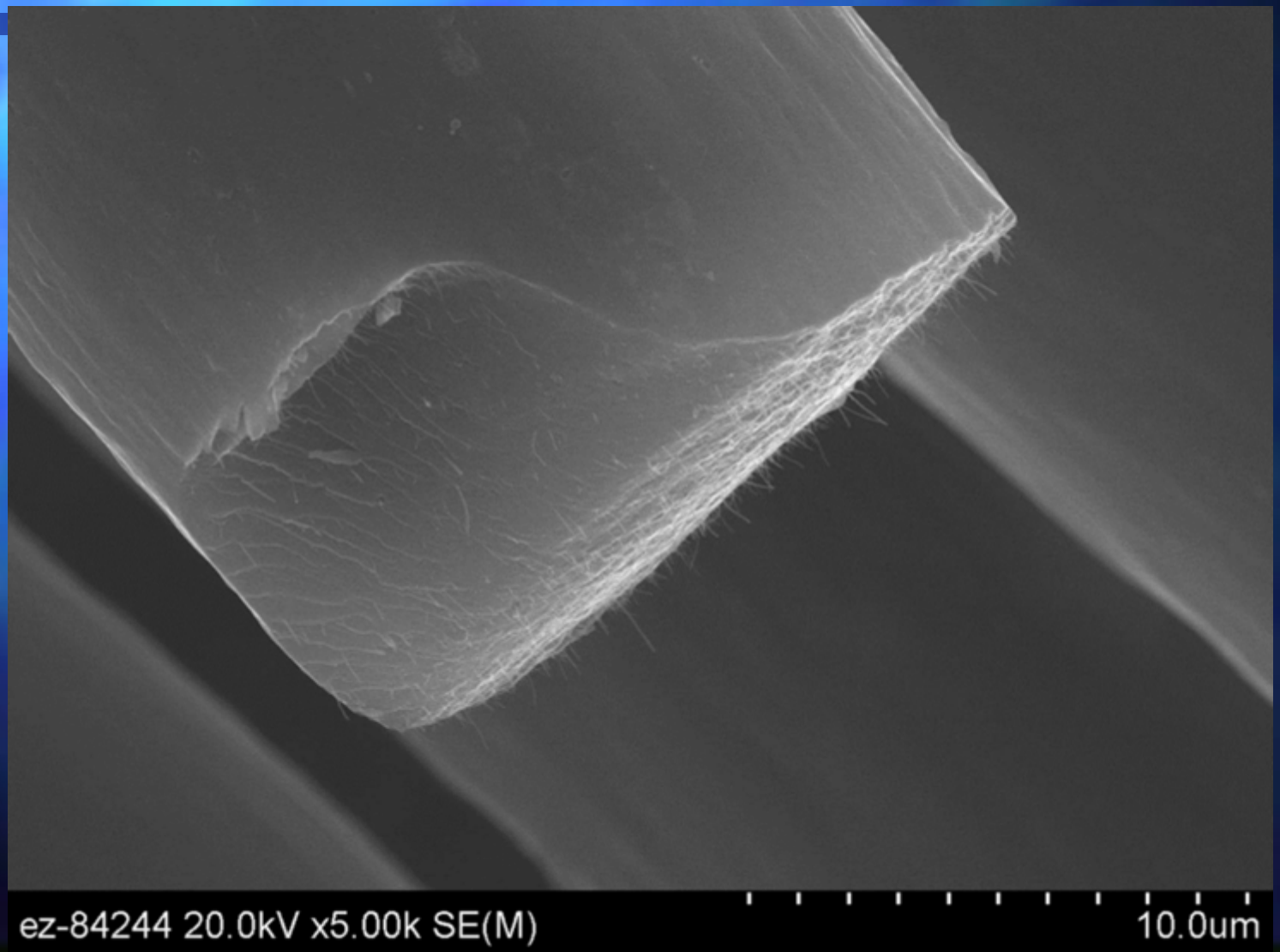

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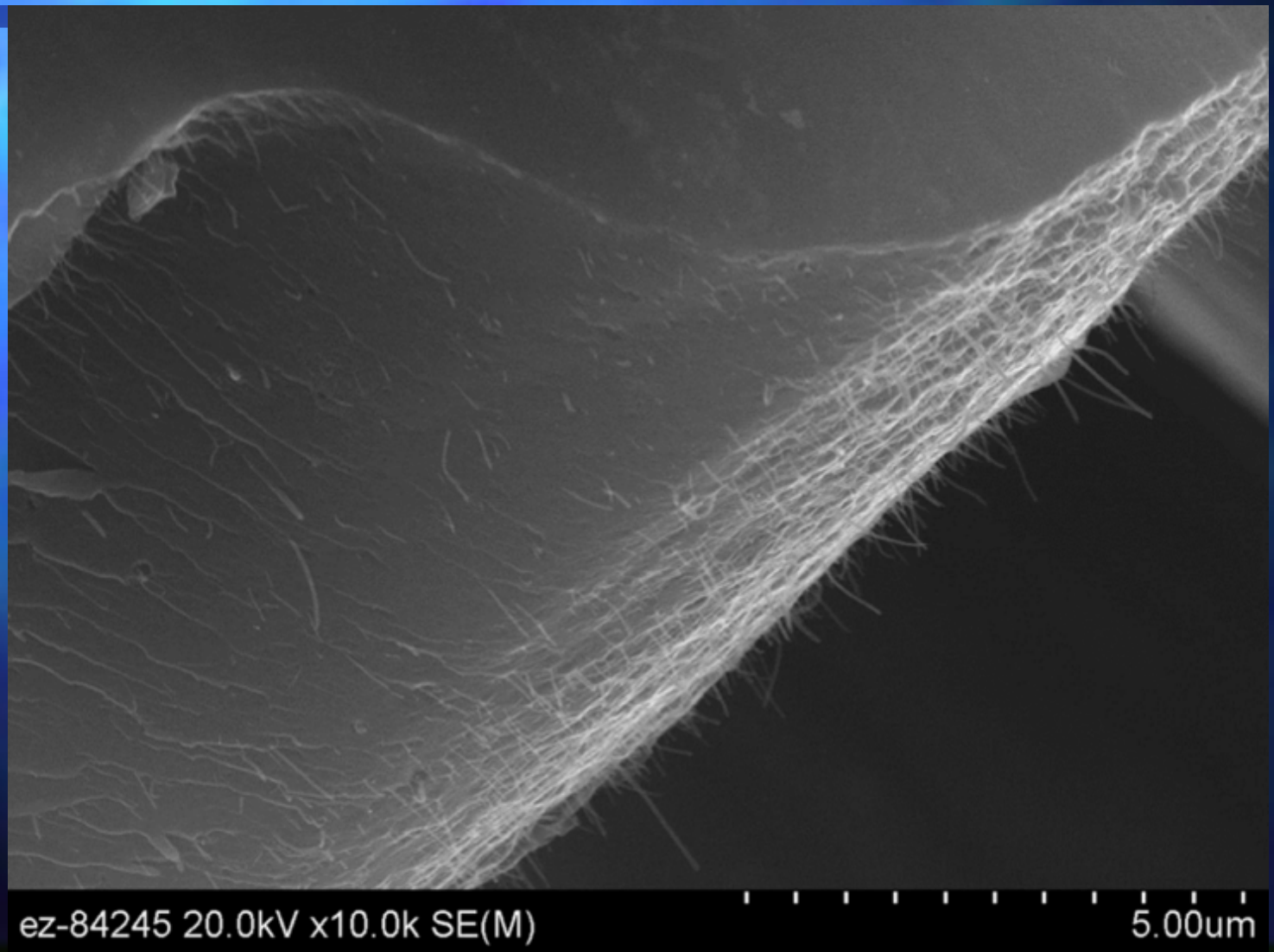

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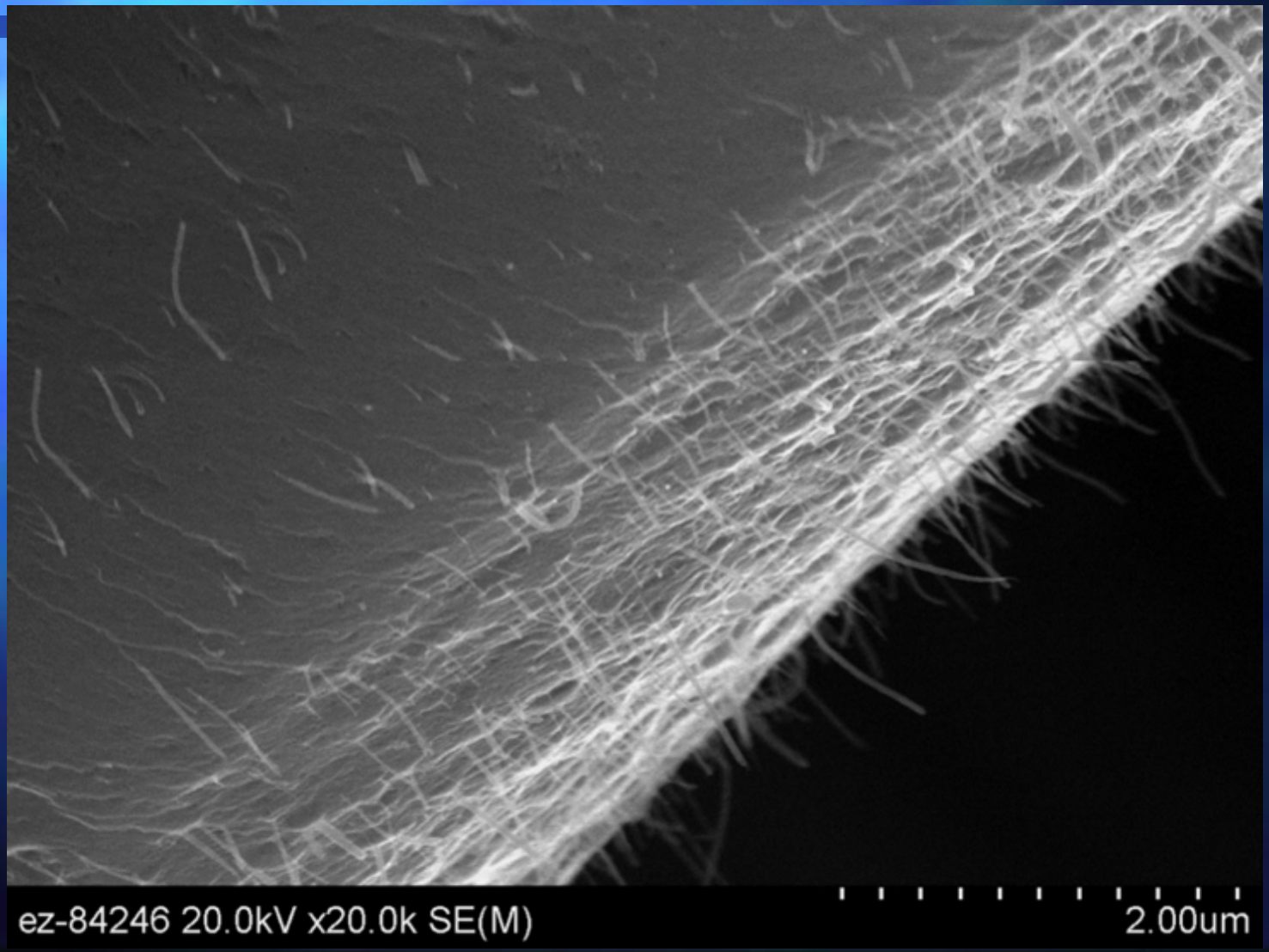
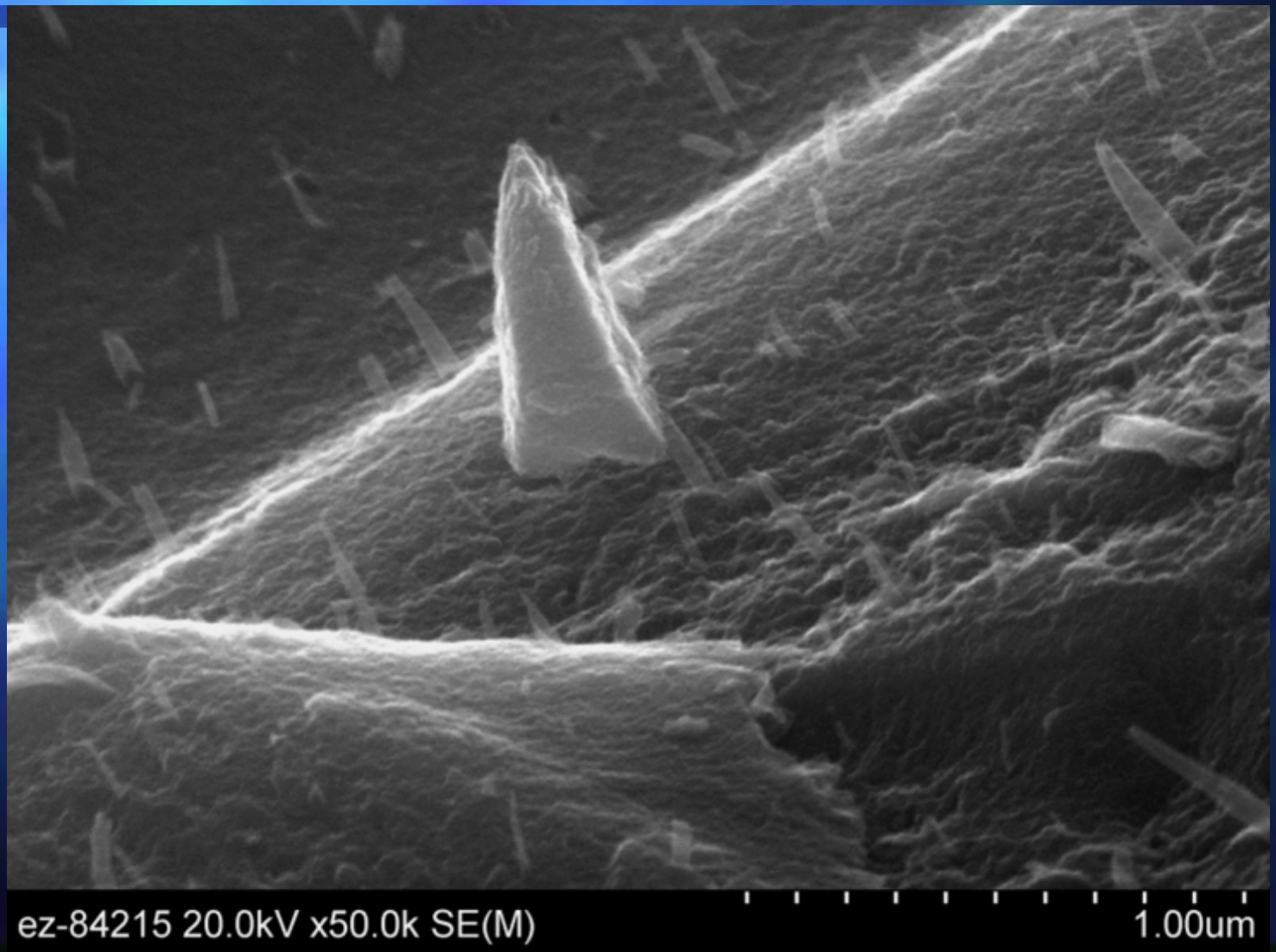


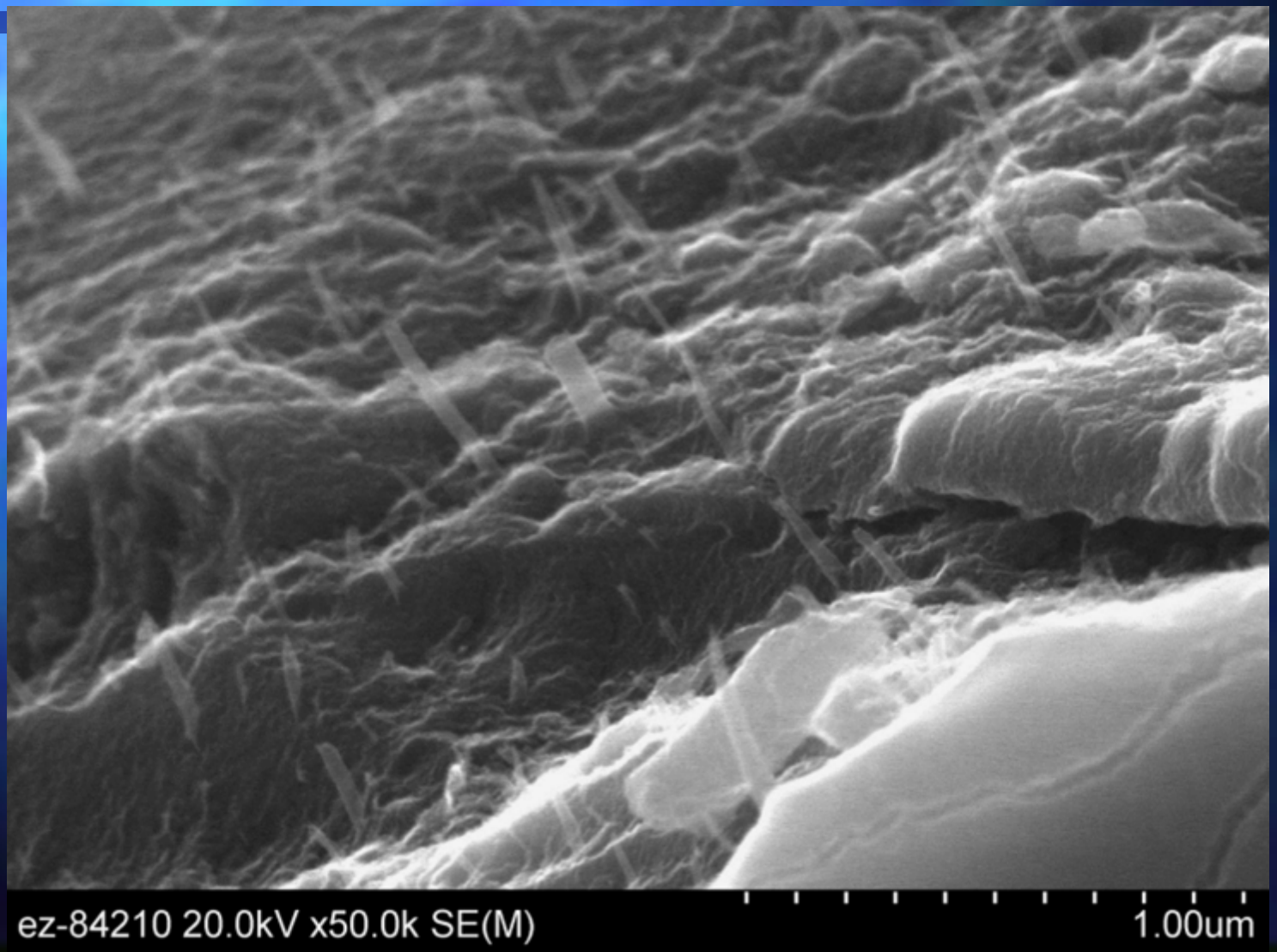
1% Carbon Nano-Tubes In Lignin

Compounded on 50/1 Microtruder With
1 SFEM Elongator and 3 AFEM Recirculators



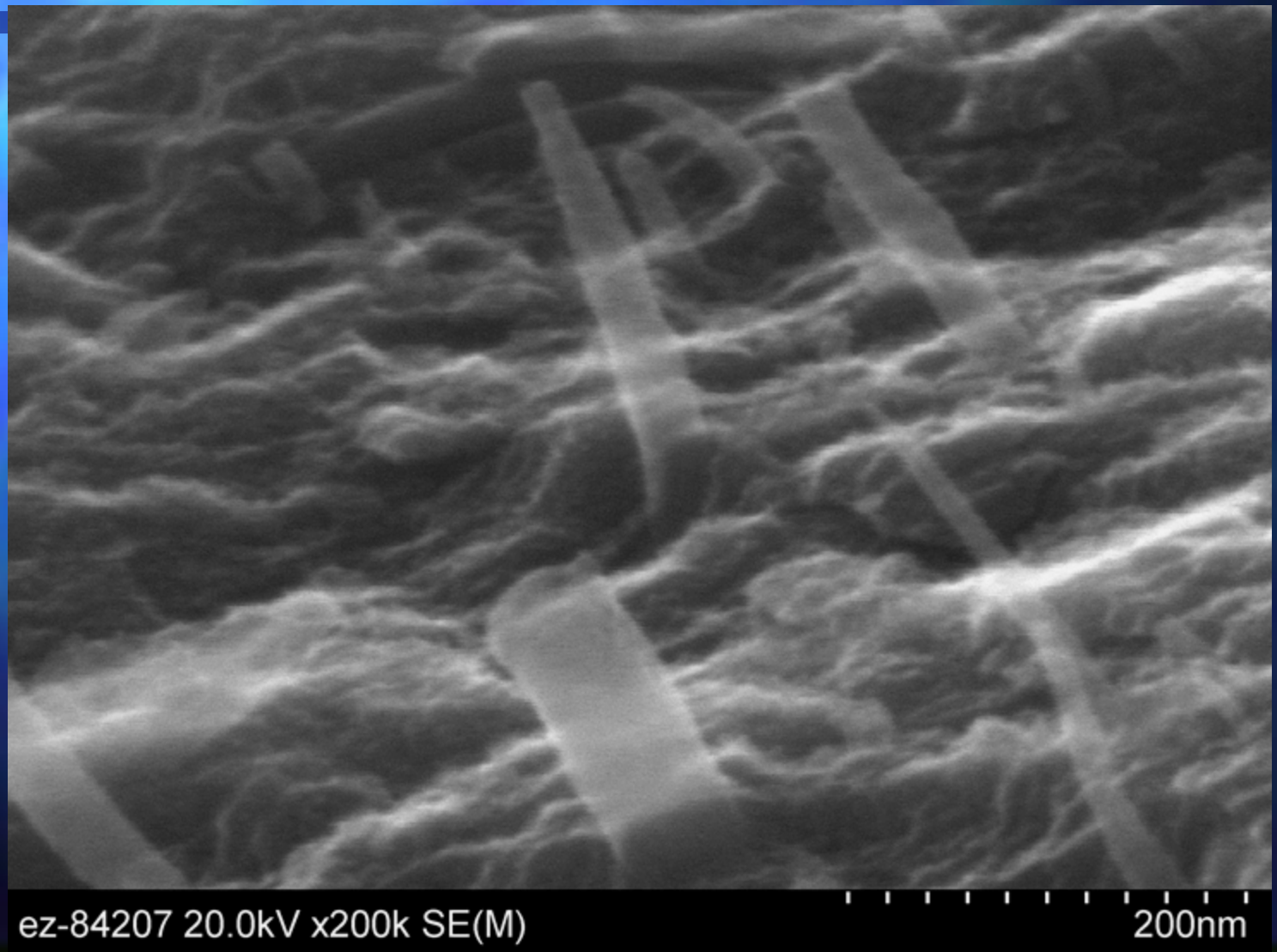
1% Carbon Nano-Tubes In Lignin

Compounded on 50/1 Microtruder With
1 SFEM Elongator and 3 AFEM Recirculators

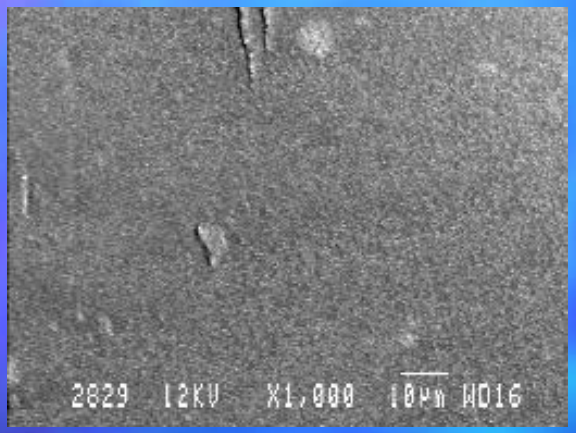


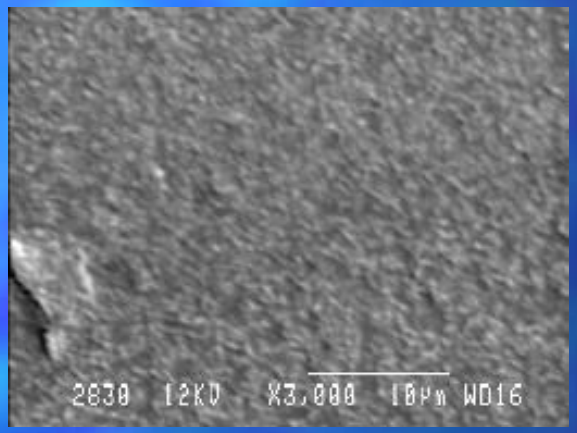
1% Carbon Nano-Tubes In Lignin

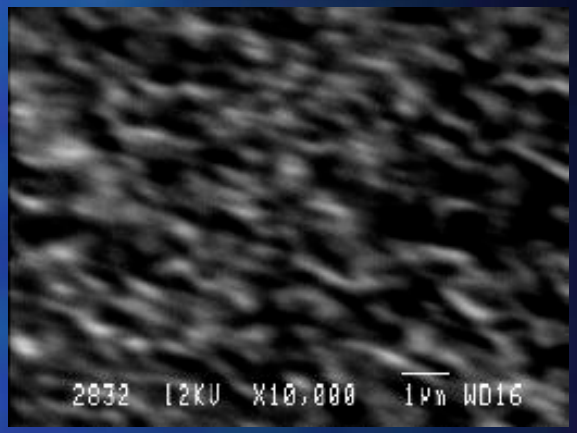
Compounded on 50/1 Microtruder With
1 SFEM Elongator and 3 AFEM Recirculators



5% Carbon Nano-Tubes In PMMA



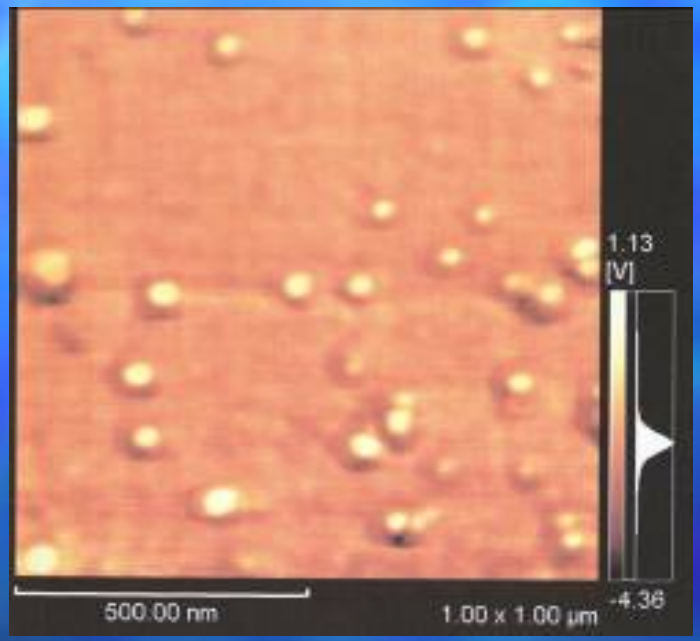


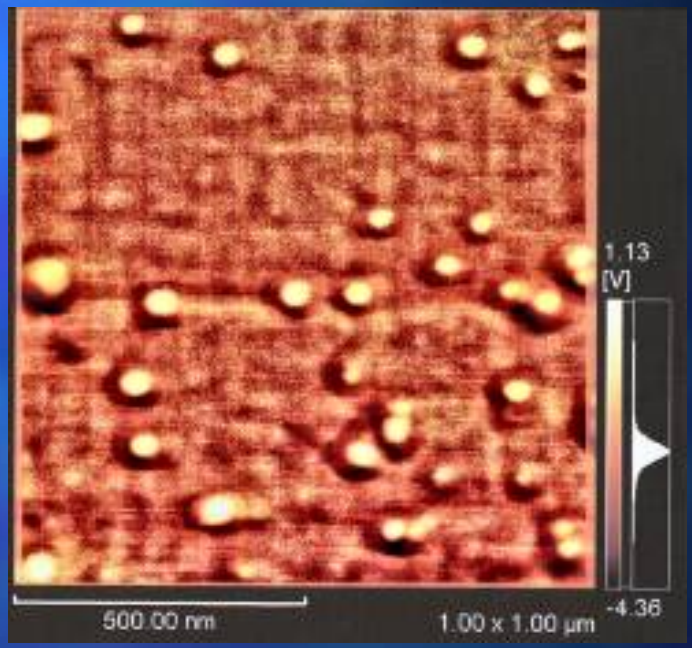


This sample of 600 grams was processed in Randcastle's 50/1, low output, 4 Recirculator screw, 350 rpm, 5/8 inch Microtruder. We returned 300 grams to the customer in pelletized form.

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





Here we see the end of CNT's in polycarbonate (PC). The polycarbonate was in pellet form. The picture on the right is software enhanced. This was compounded on the RCP-0625 5/8 inch Microtruder using 3 AFEM Recirculators.

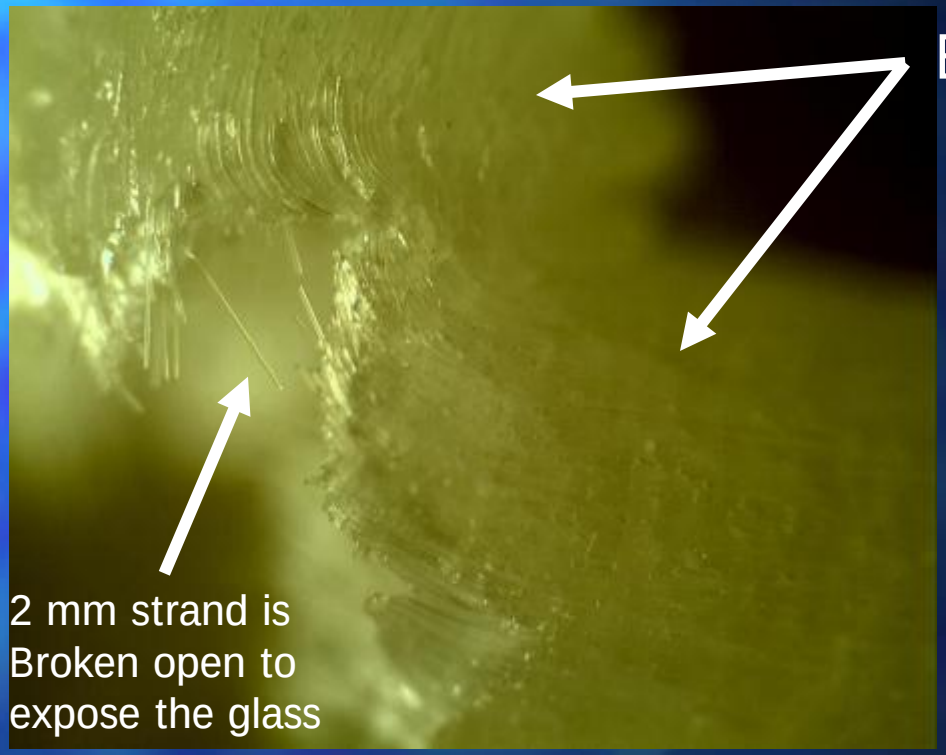
5% Carbon Nano-Tubes In Acetal
Conductive to Dissipative Range

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

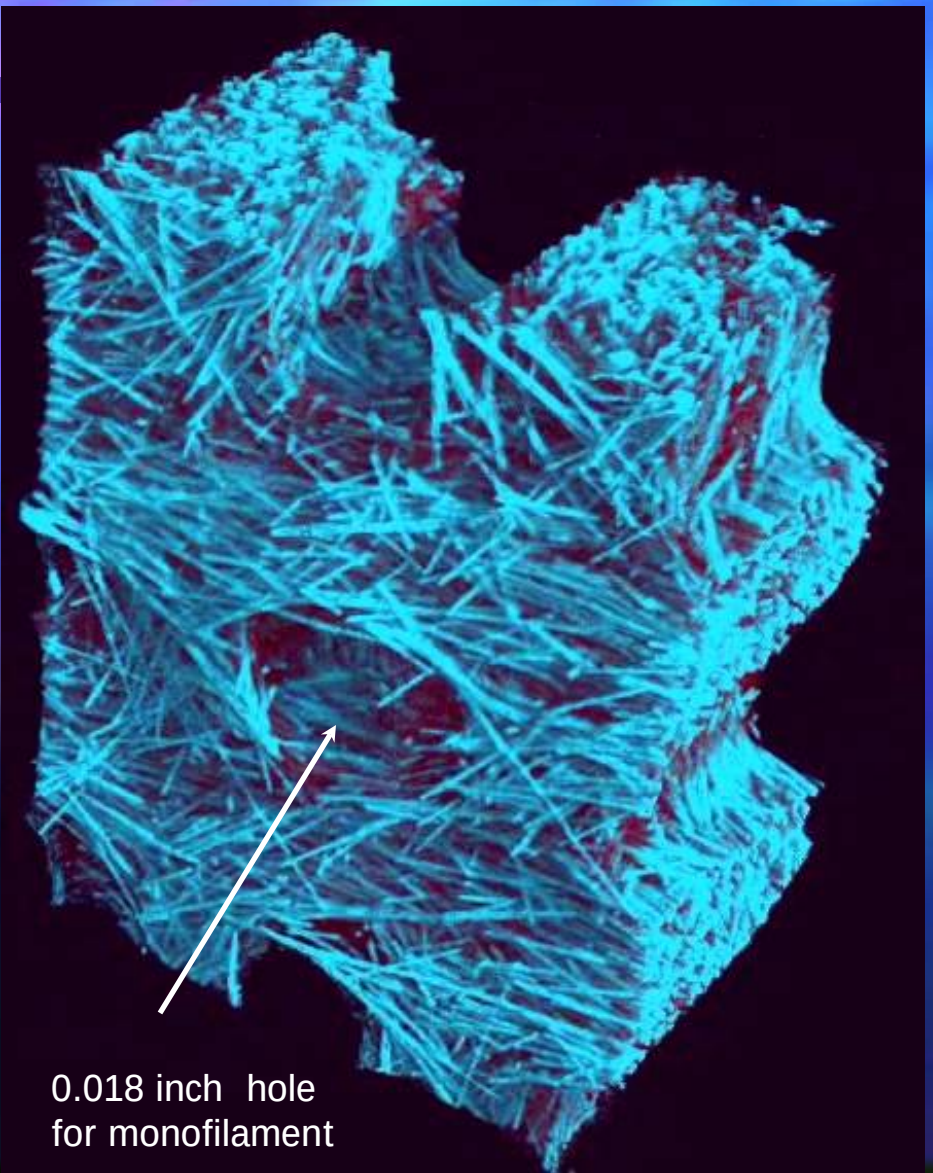
3/16 glass



This was compounded on our 1 inch Taskmaster, 36/1 L/D, with 3 Recirculators and two vents.

Direct Extrusion

X-Ray Topography 12% Glass/Elastomer



Several ingredients, including 12% glass and elastomer were compounded with nylon while coating a plastic monofilament. Making a product while compounding is sometimes called “direct extrusion.” Twin screw manufacturers use expensive gear pumps to build stable pressure. The AFEM Recirculator and SFEM Elongators have surge suppression so that, as in this case, the high pressure is stable and production tolerances were held. The monofilament was 0.018 inches and the strand 0.060 + - 0.002 inches. The strands were placed side by side and then compression molded to make the part shown.

In this picture taken from an X-ray topography video, most of the red plastic and the monofilament have been removed to expose the glass. The glass is remarkably distributed. Randcastle’s 1 inch 36/1 Taskmaster was starve fed, used 3 Recirculators, 2 atmospheric vents and our coating line in the Randcastle lab. 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.

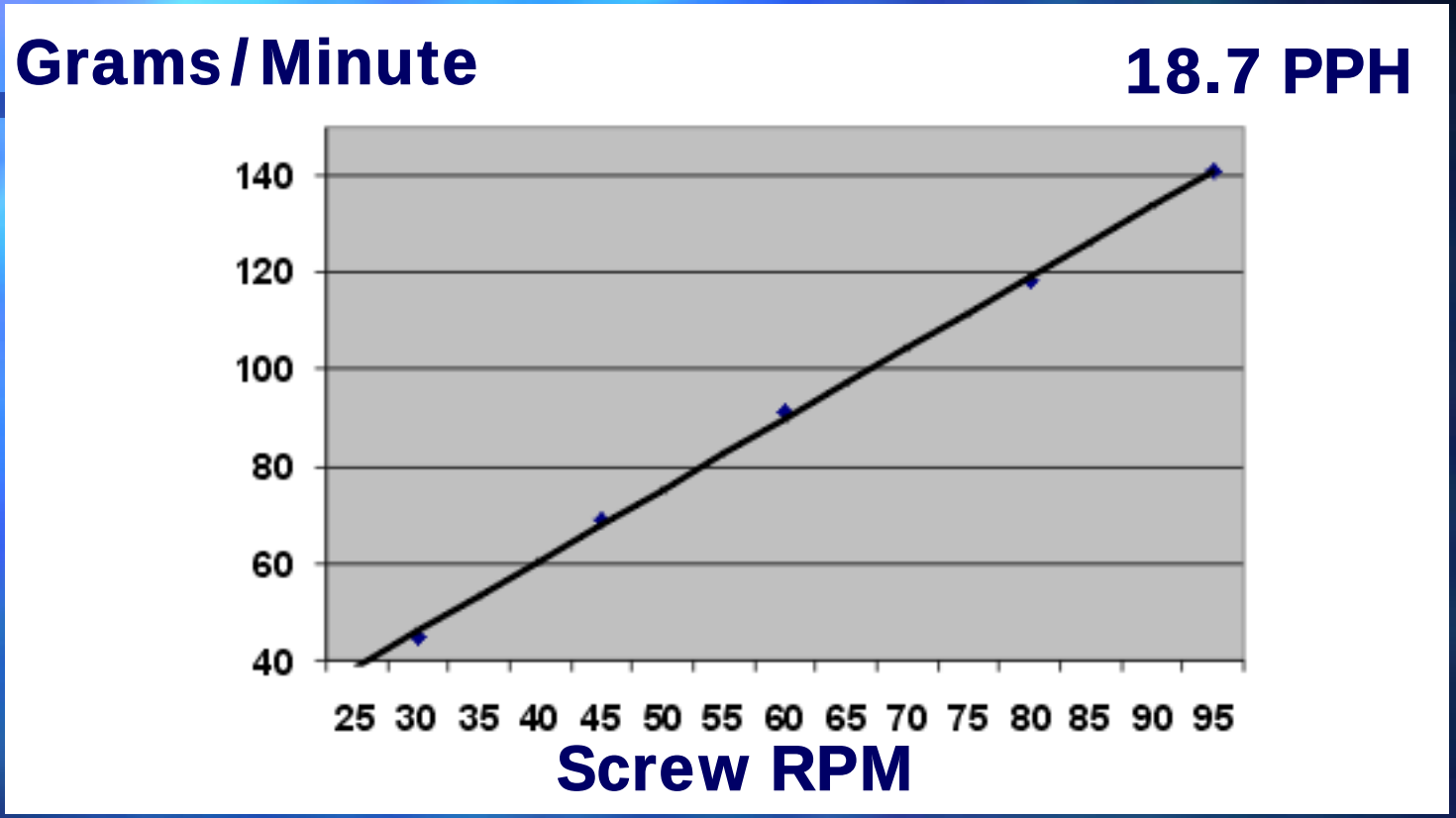
Our SFEM Elongator eliminates the second extruder and vents off the water in a single operation!

Direct Extrusion: RPVC Powder & Wood Flour For Tensile Bar Stock

It has been long believed that single screws cannot process rigid polyvinylchloride (RPVC) in powder form; that RPVC can't be processed at screw speeds above 30 rpm; and that singles can't mix. We won Best Paper of VinylTec 2007 for showing otherwise. Low cost vinyl powder is readily extruded with our SFEM Elongator technology. At the National Plastics Show (NPE) of 2009, we demonstrated processing at 180 rpm. There are multiple technical papers on vinyl processing at www.randcastle.com

Output RPVC Pellets

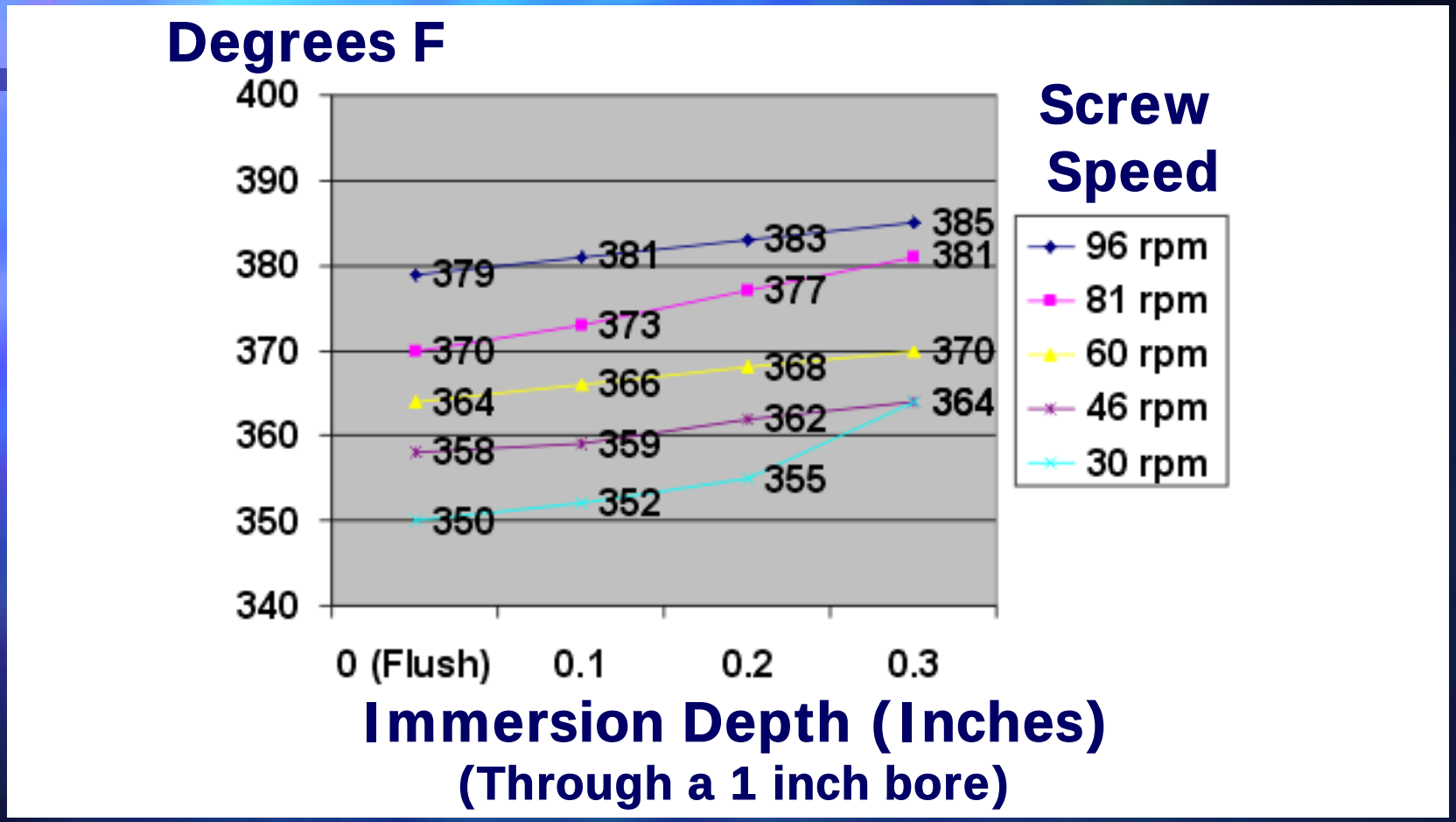
1 Inch 36/1 Extruder



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 SFEM Elongator technology.

Melt Temperature RPVC Pellets

1 Inch 36/1 Extruder



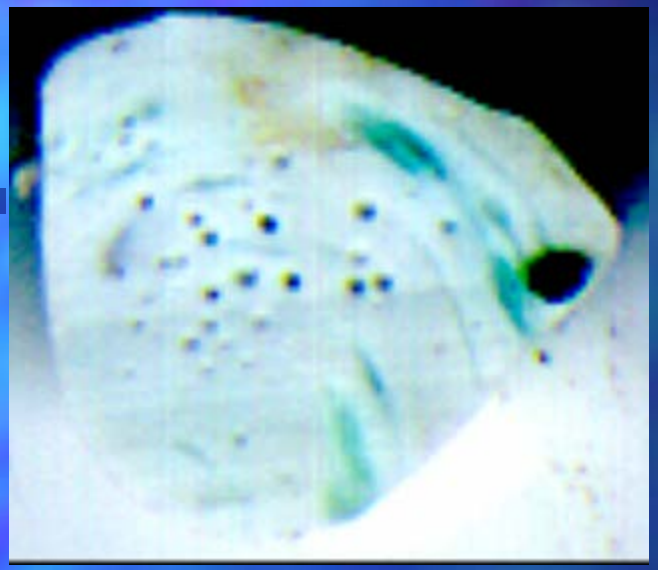
This chart of stock temperatures refers to the previous output page. The typical recommended maximum stock temperature is 391F (200C).

Direct Compounding
RPVC Pellets & 15% Calcium Carbonate

This profile was compounded using a 3 mixer SFEM Elongator at 90 rpm for very high output. To insure that no degradation took place, the clear RPVC was also processed at the same 90 rpm and no signs of burning—such as yellowing, browning or black spots, were visible. We would like to thank Meg Henke, Colorite Plastics, for the clear RPVC.

PVC 95/72 Durometer PVC

Barrier Screw
With Mixer



Barrier Screw
With Mixer

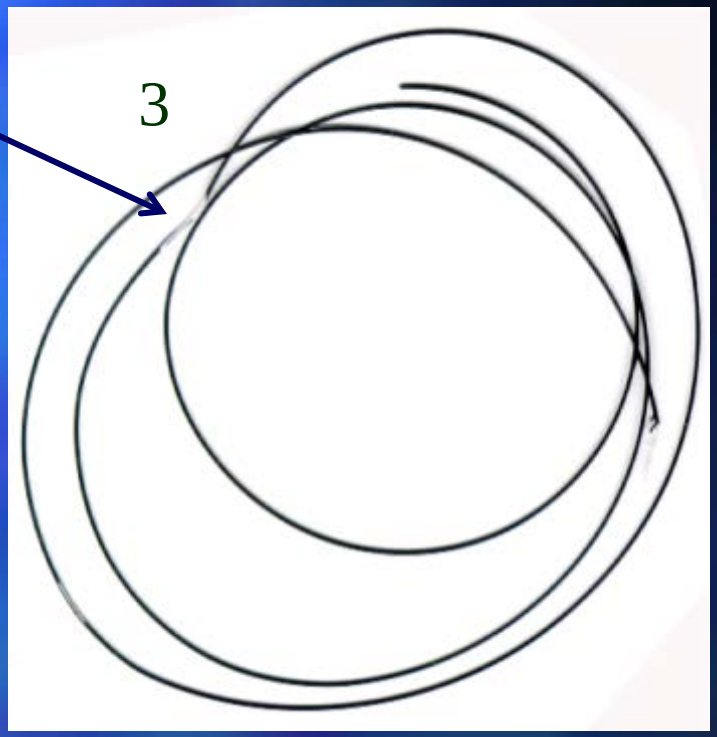
AFEM
Recirculator

On the left, an underwater cut pellets from a 6 inch diameter barrier screw with a mixer. The center picture is a partial cross section of a pellet. A mixture of the two materials were fed into the extruder in the hope of reclaiming the mixture for resale. As you can see, the more fluid 72 durometer material surrounded the stiffer 95 durometer material.

On the right, the same feedstock is successfully mixed and pelletized in a strand pelletizing line. Surprising different viscosities are processed in our screws.

Direct Extrusion Of Nylon & Filler

The monofilament can be seen where wer removed the black coating

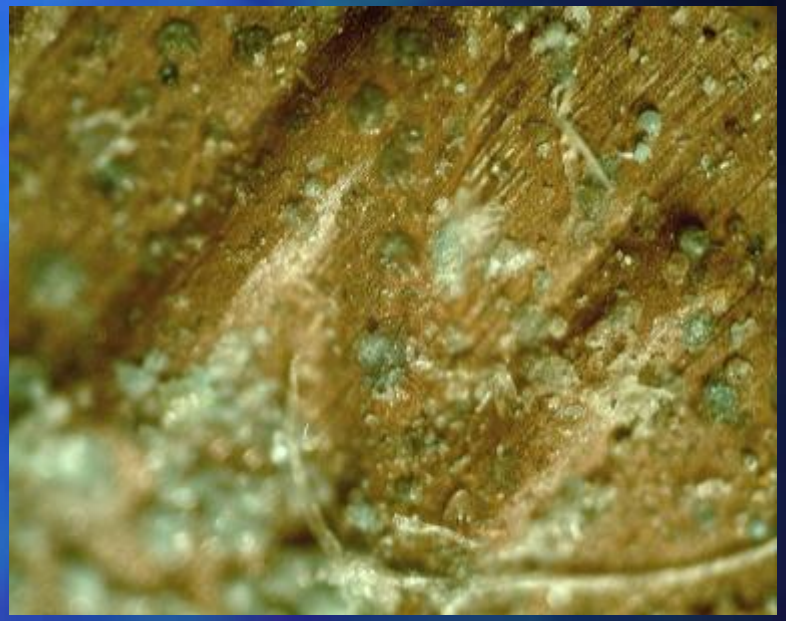


A twin compounded material which was pelletized. The twin strand was shiny, smooth, readily drawn even into a fiber. These pellets were extruded in a conventional single screw with two spiral UC mixers (aka Egan Mixers), strand 1. It shows gross agglomeration of the filler—which the twin had mixed very well. The conventional single screw, even with two Egan Mixers, demixed the filler because it was not chemically bonded to the nylon during compression.

Strand 2 is from the AFEM Recirculator from the same pellets . Quite smooth. This proved to the customer that his single screw with even the two Egan was the culprit.

Strand 3 is the “direct extrusion” of the final product—a 0.001 inch coating over a 0.028 inch monofilament using 3 AFEM Recirculator screw. No gear pump was necessary to maintain the tolerance or build pressure.

35% Calcium Carbonate Powder Compounded With 30 MI PP Pellets



It is well known that conventional single screws cannot compound large amounts of inexpensive fillers such as calcium carbonate and talc. The filler shows gross agglomeration—instantly visible by eye so without magnification. It is also well known that a separate compounding step costs more than the savings from the filler.

The left picture is the surface microscopy of a strand we compounded in our lab at 100 times magnification. You do not see any agglomerations. The strand surface feels as smooth as a virgin polypropylene strand. For comparison, on the right, the “N” in the surface of a penny at the same magnification. This was processed on our 1 inch Taskmaster with three SFEM Elongator screws on a high output vented screw on a 1 inch Taskmaster at 18.4 pph without vent flow.

Cellulose: Extreme Viscosity Processing

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

General Purpose Screw

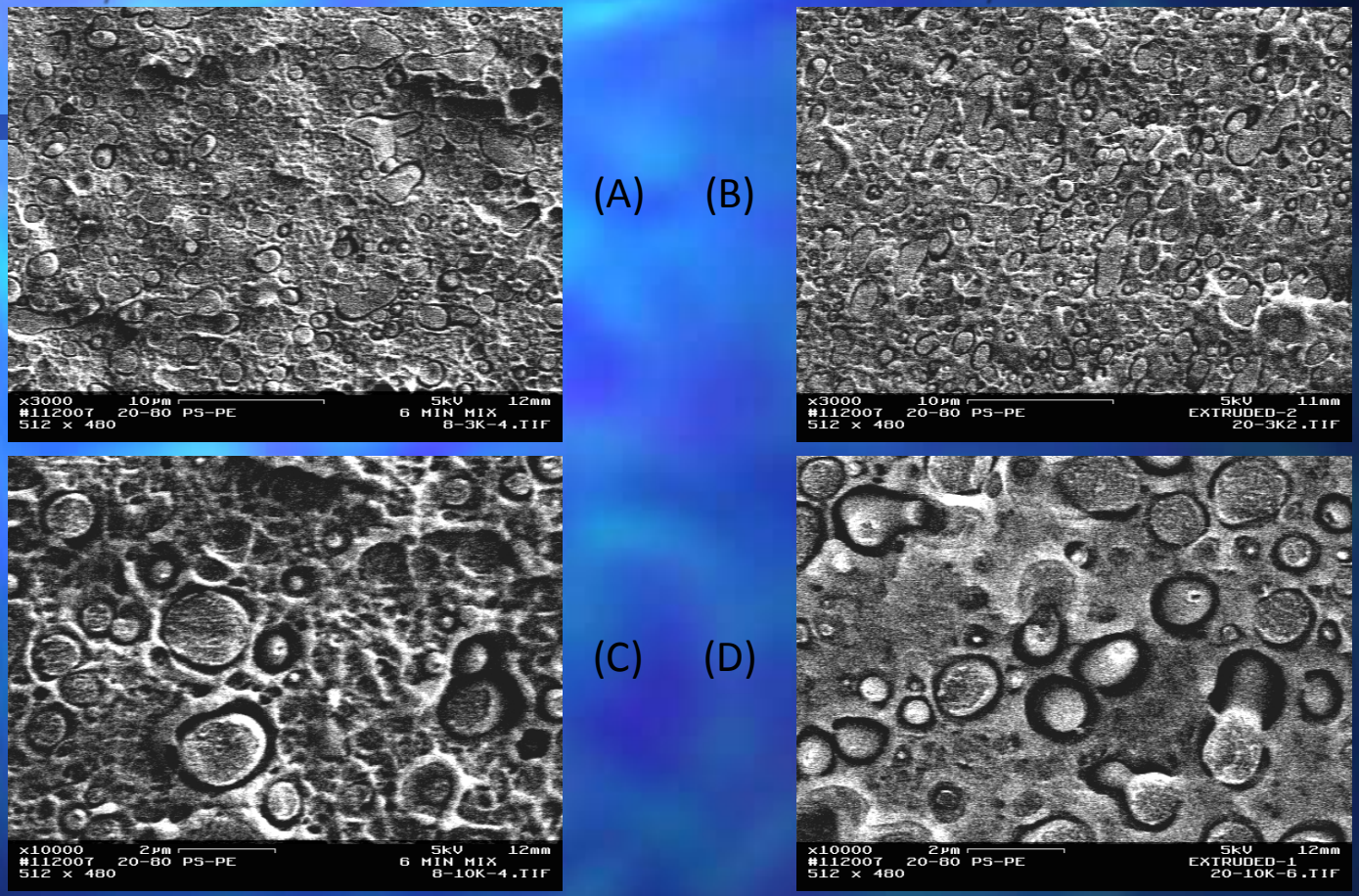
SFEM Elongator

On the left, the plasticizer oil forms bubbles with the conventional mixing screw as the oil coalesces. The SFEM Elongator keeps the oil so well mixed that we can't see it. This was processed on a 24/1 L/D Microtruder with only two SFEM Elongators.

Scaling From SFEM Batch Mixer To SFEM Extruder

4 L/D SFEM Batch Mixer

24/1 Extruder

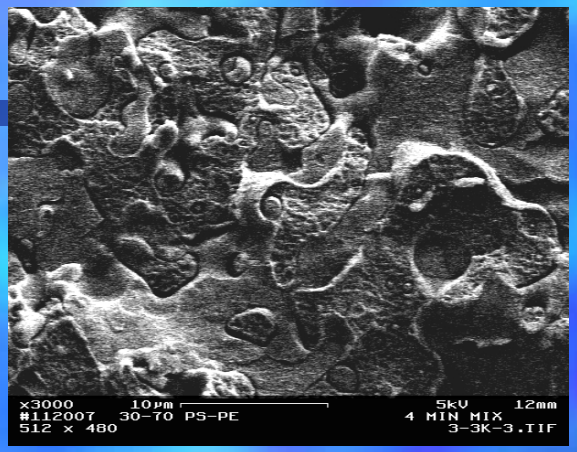


A mixture of 20% PS and 80% HDPE pellets were mixed in the SFEM batch mixer and a 5/8 inch Microtruder with two SFEM Elongators. They show very similar domains in the continuous domain region. See “A Novel Batch Mixer That Scales To A Single Screw Compounder” at www.randcastle.com under technical papers.

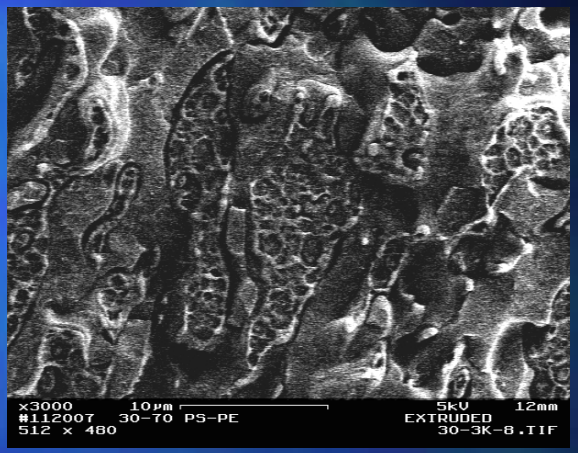
Scaling From SFEM Batch Mixer To SFEM Extruder

4 L/D SFEM Batch Mixer

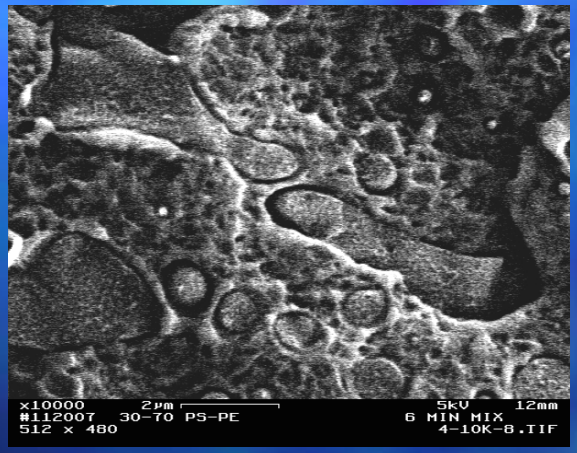
24/1 Extruder



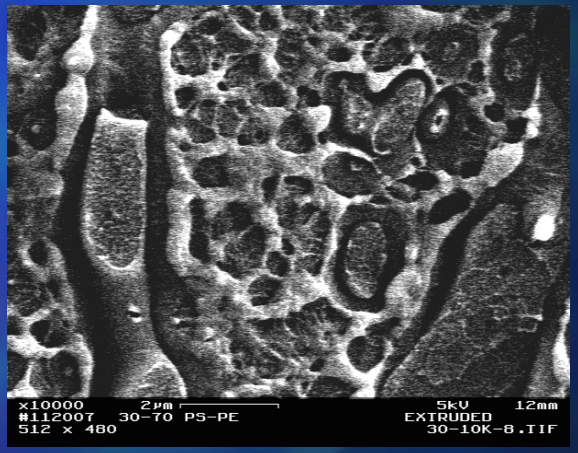
(E)



(F)



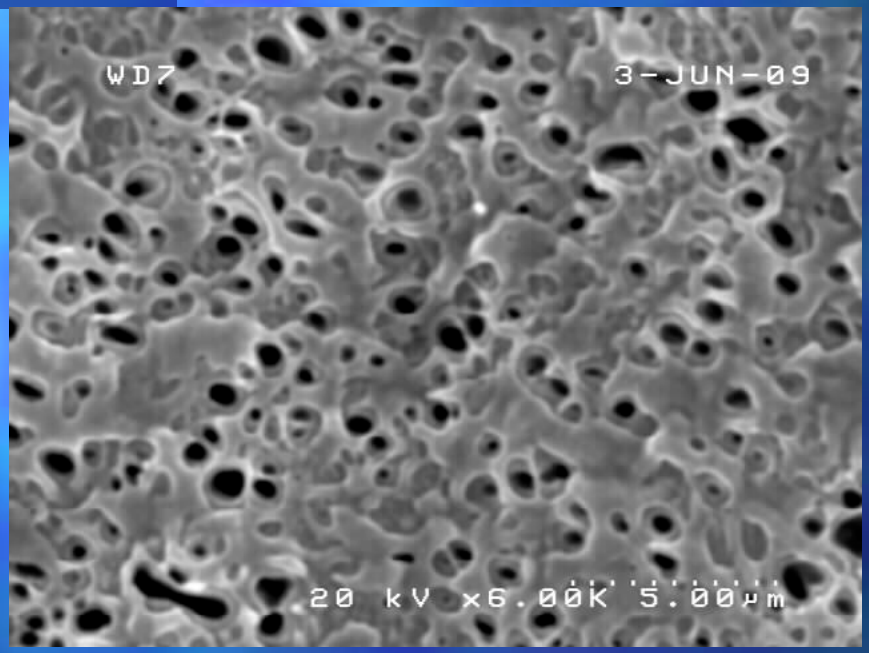
(G)



(H)

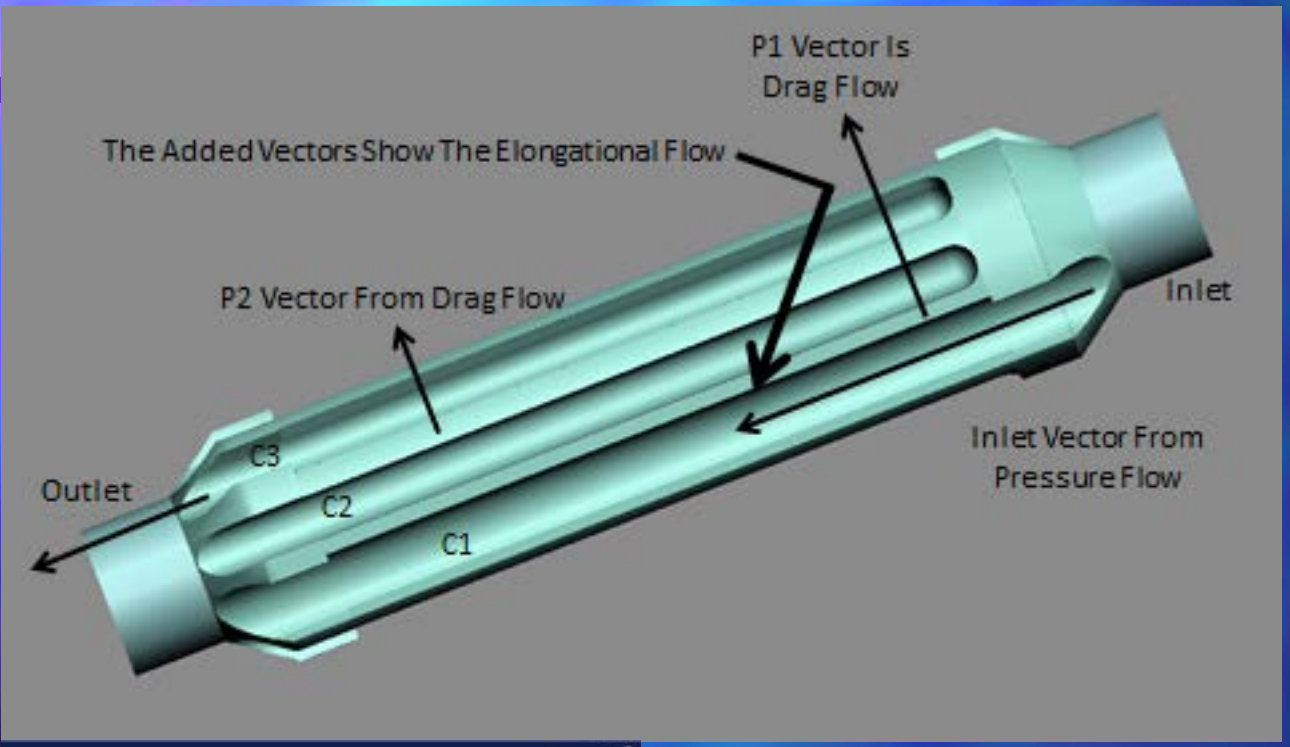
A mixture of 30% PS and 70% HDPE pellets were mixed in the SFEM batch mixer and a 5/8 inch Microtruder with two SFEM Elongators. They show very similar domains in the co-continuous domain region. See “A Novel Batch Mixer That Scales To A Single Screw Compounder” at www.randcastle.com under technical papers.

Injection Molded 10-90 PS-HDPE



Injection molding no longer needs a separate compounding step. PS/HDPE in, and see the mixing at the 5 micron scale. Each of the minor phase domains looks like about 1 micron average or more than 1,000 times better than your conventional molding screw. This material was compounded on a two mixer AFEM Recirculator

Randcastle's AFEM Recirculator



Initial Mixing: C1 Channel

Pressure flow at the inlet pushes material along (as shown by the inlet vector arrow) while the P1 surface pulls (shown by the P1 drag flow vector arrow. The material in the C1 channel is stretched (shown by the added vector angle).

For Additional Description: www.randcastle.com

Technical Papers:

- For Extrusion: Summary Results of A Novel Single Screw Compounder
- For Injection Molding: Development of Novel One-Step Hybrid Processing

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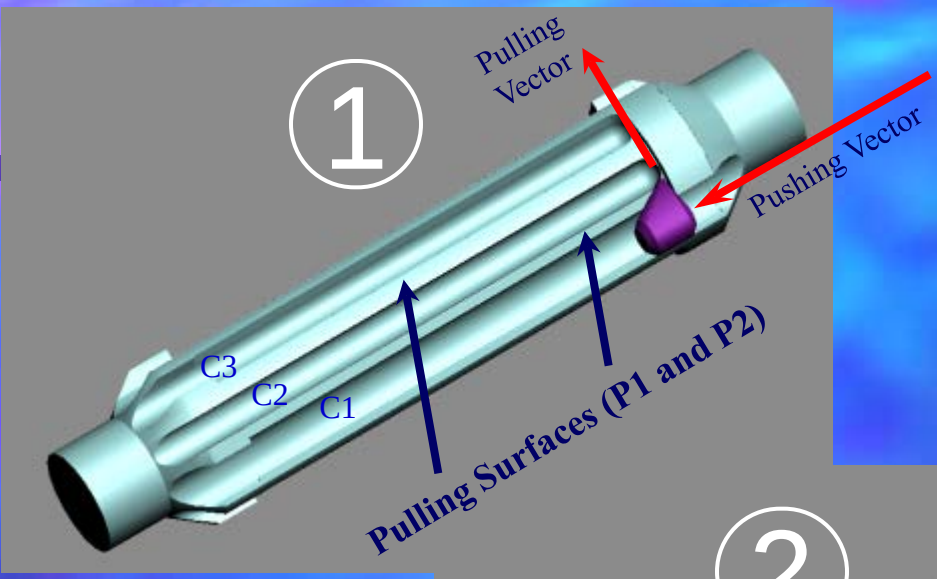
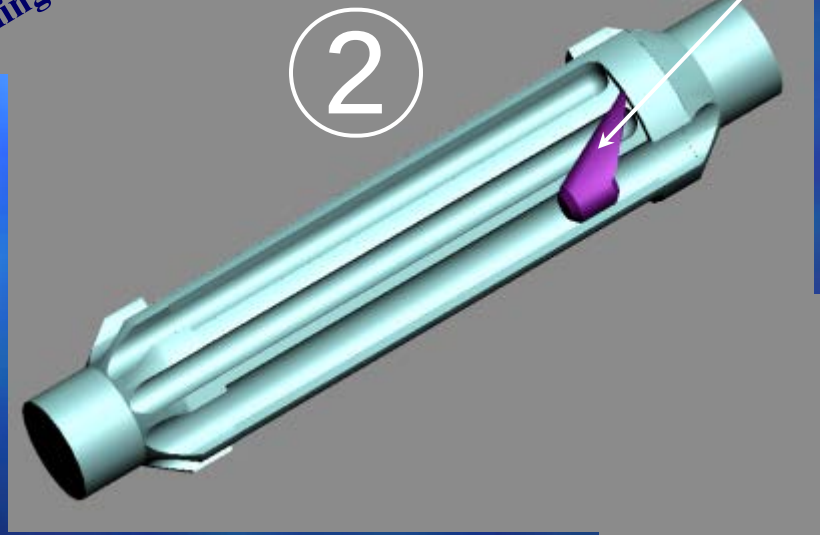
Randcastle's AFEM Recirculator

Surface Expands Exponentially

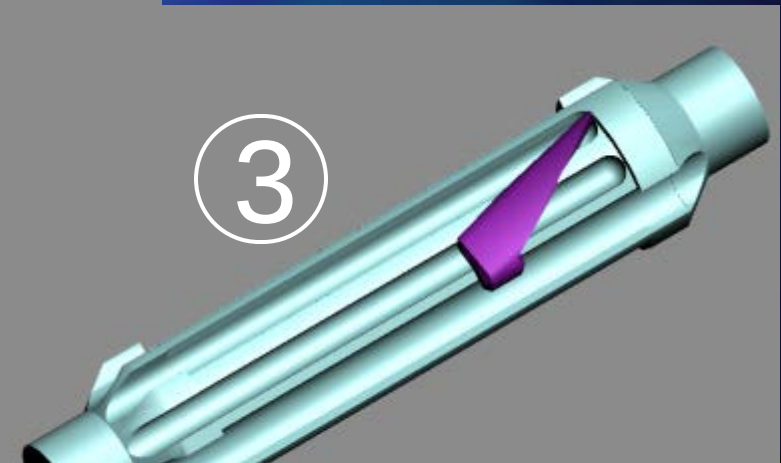


1) A purple agglomeration (clear material in front and behind) is pushed down the C1 channel by pressure flow. The pulling surface "grabs" the material (the same as a nip roll can grab your finger) and starts to stretch it.

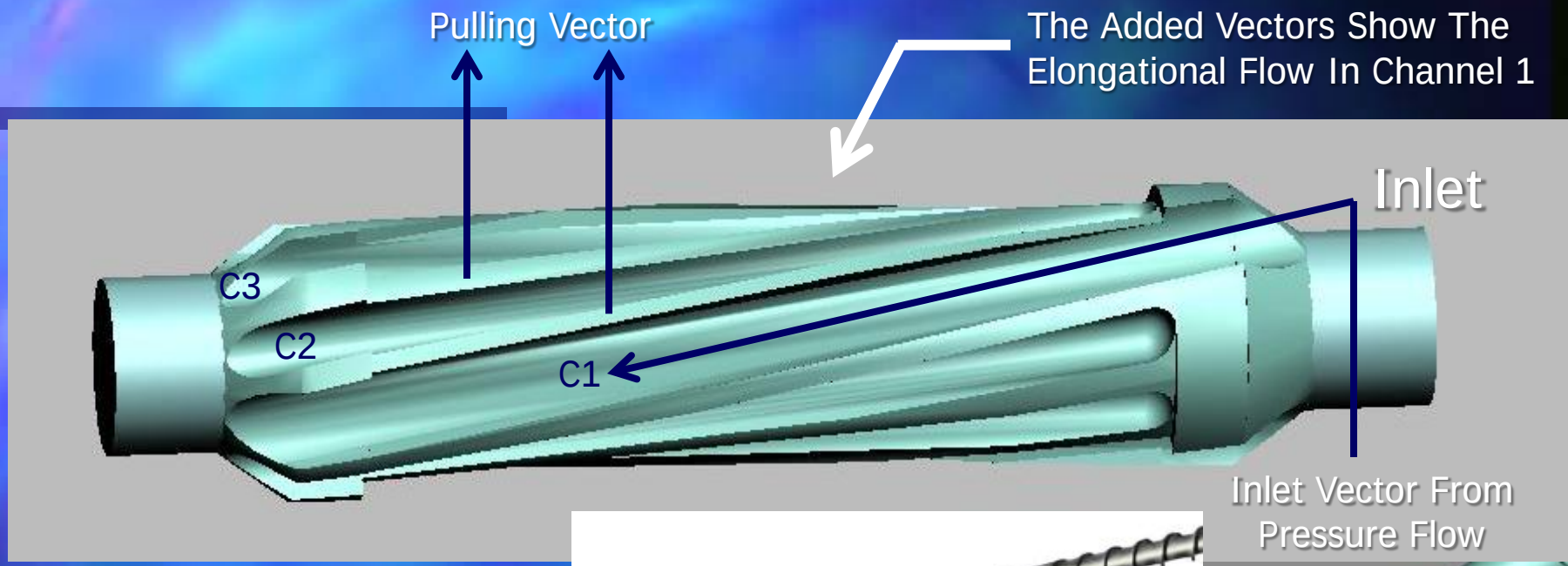


2) The pulling surface and drag flow start to convert the cylinder into a film.

3) The cylinder is converted into a film. The area of the film is exponentially higher than the cylinder so the the mixing is exponentially better.

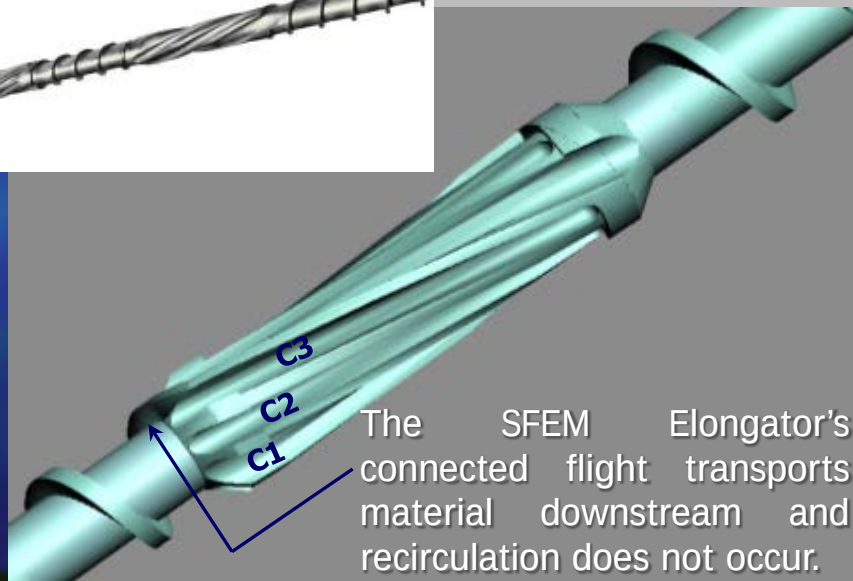


Randcastle's SFEM Elongator



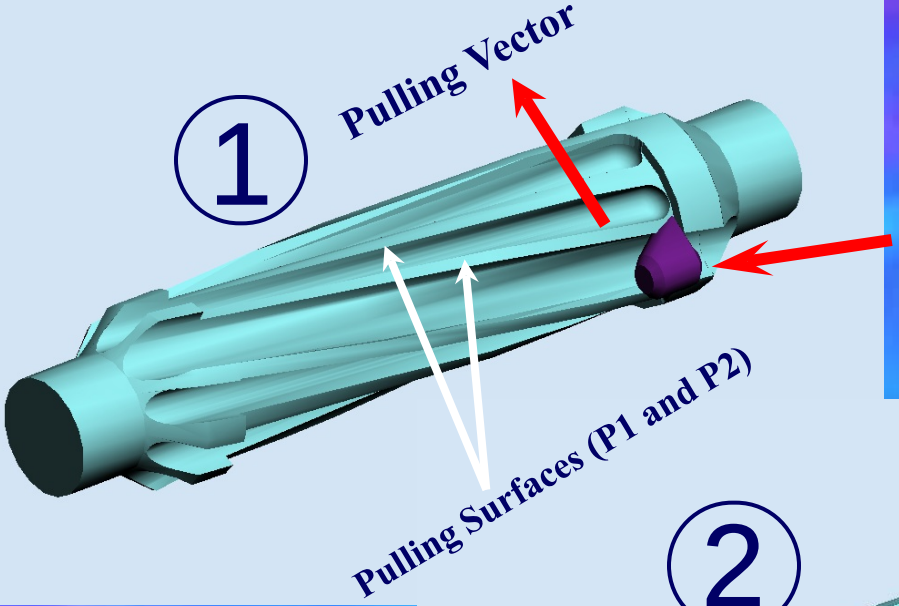
Initial Mixing: C1 Channel

Pressure flow at the inlet pushes material along (as shown by the C1 inlet vector arrow) while the P1 surface pulls (shown by the P1 drag flow vector arrow). The material in the C1 channel is stretched (shown by the added vector angle).

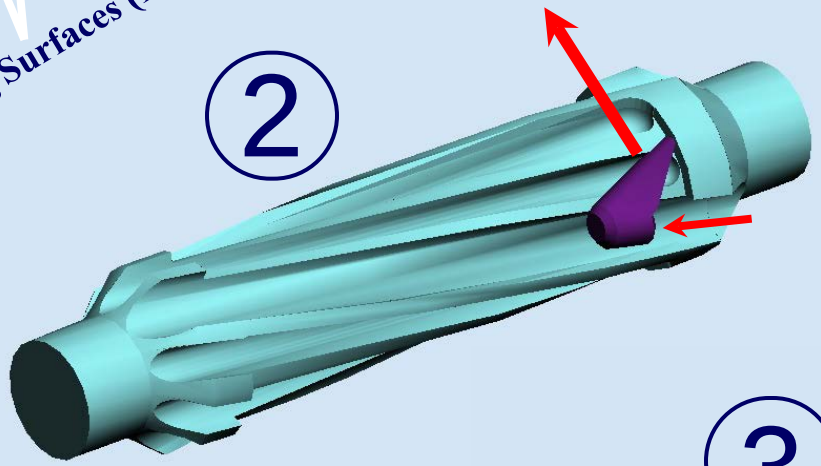


The SFEM Elongator's connected flight transports material downstream and recirculation does not occur.

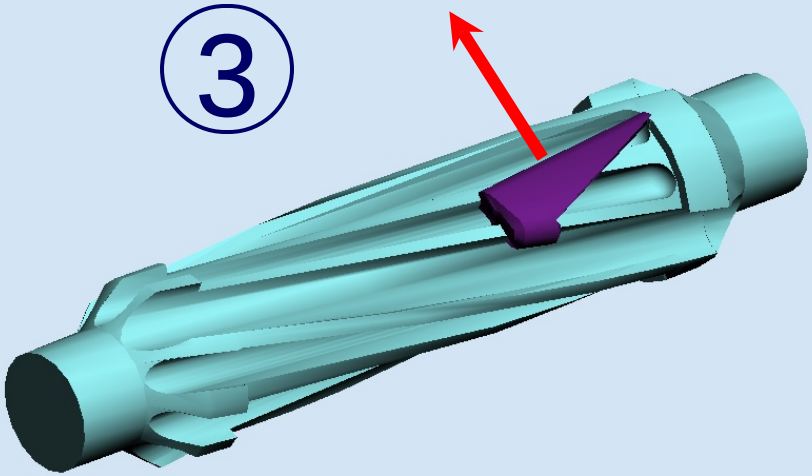
Surface Expands Exponentially



1) A cylindrical concentration of unmixed material (purple) enters the first channel pushed along by pressure flow by upstream flights. It is immediately grabbed by the pulling surface—just as pull rolls would grab your finger.—that begins to stretch it.



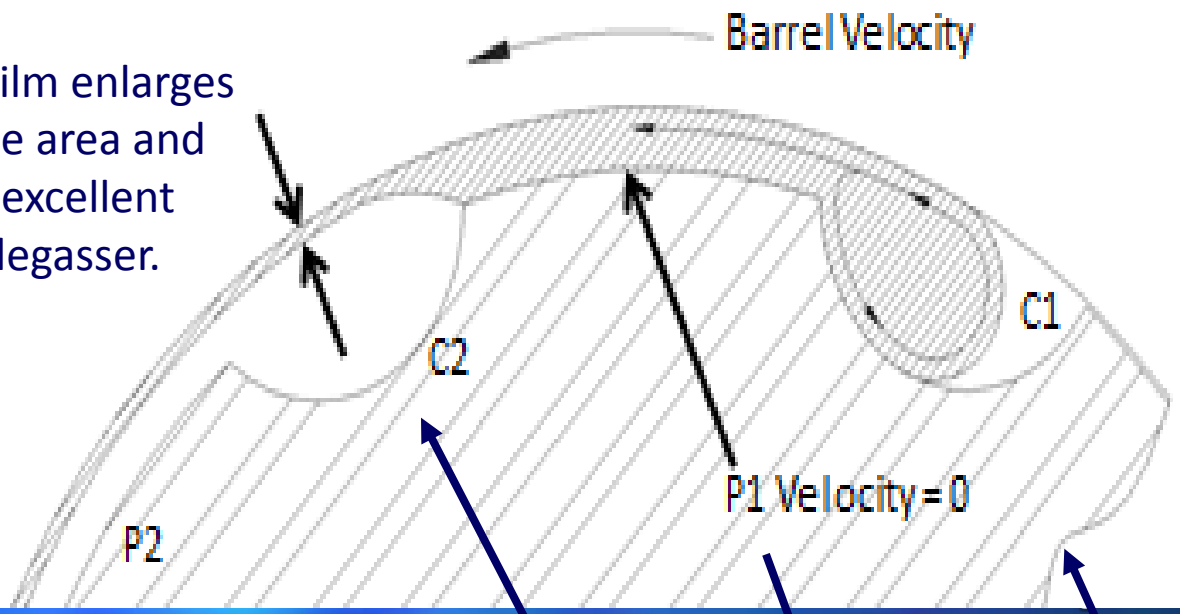
2) Pressure flow pushes the material along the inlet channel while the pulling surface and drag flow begin to convert the cylinder into a film.



3) The concentration nears total conversion to film. The actual film is much longer than depicted because the drag velocity is much higher than that inlet channel velocity. Since the area of the film is exponentially higher than the volume of the cylinder, the mixing is exponentially better.

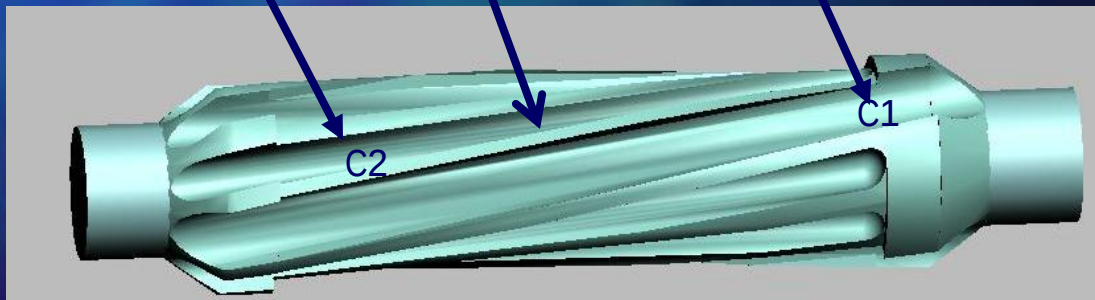
Randcastle's SFEM Elongator

This thin film enlarges the surface area and makes an excellent thin film degasser.



Thin Film Creation

The material movers at the barrel velocity because it is stuck to the barrel. The material velocity at the surface of P1 is 0 because it is a resistive surface. At channel 2 (C2) the resistance drops. Because the material is stuck to the barrel, it stretches into a thin film.



Randcastle's SFEM Elongator
Additional Information

For Additional Description Go To Home Page Of Randcastle: www.randcastle.com

Then The Technical Papers Tab For:

- Facile TPO Dispersion Using Extensional Mixing
- Comparison of SFEM Elongator Single Screw Compounder to Bowl Mixer and Twin Screw
- A Novel Batch Mixer That Scales To A Single Screw Compounder
- Investigation Into A High Output Polypropylene Screw And Its Mixing Mechanism
- Novel Single Screw Compounder For Thermally Sensitive Materials
- Comparison Of Flow Striations Of Various SSE Mixers To The Recirculator and Elongator Mixers
- The Development Of A New Elongational Mixing Screw For Foam And Its Advantages

VINYL PAPERS

- Novel Single Screw For RPVC Dry Blend
- Novel Single Screw for RPVC Powder That Compounds
- RPVC Flow Streams Identify Elongational Flow
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