Production, High Output Single Screw Venting

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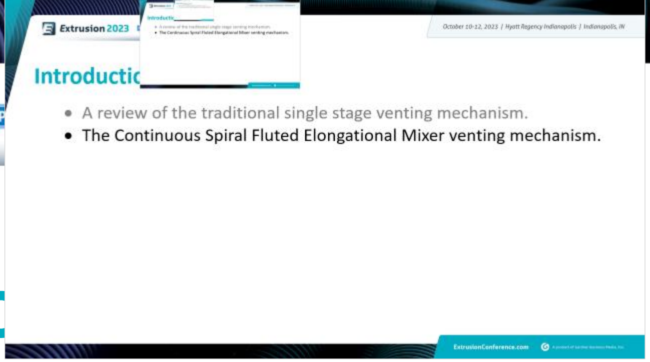
1974 -1987 Killion Extruders as Sales Manager, Production Manager, Lab Manager and VP of Development.

1988 to Present: Founder/President of Randcastle Extrusion Systems—a manufacturer of small extrusion equipment. He taught extrusion for SPE for 20 years. He's given many papers on extrusion. Seven patents on extrusion including compounding, pressure stability, pressure control, coextrusion and has an additional patent pending for compounding.

Introduction:

- A review of the traditional single stage venting mechanism.



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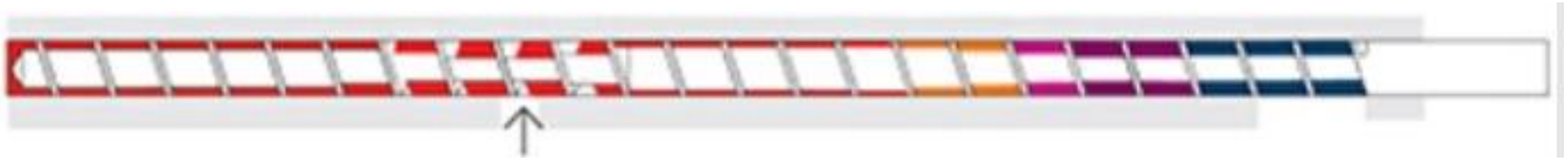
- Results of undried material testing in vented, starved CSFEM screw.
- Conclusions.

Conventional Two Stage Screw For Degassing



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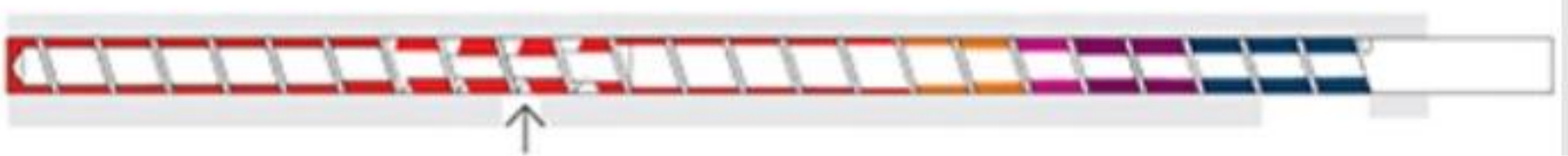

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First Stage Has Trapped Gases: Polymers can have gases trapped within them including water vapor and volatiles. These are trapped within the polymers *at the molecular level.* Unlike air which is simply between the feedstock particles, these gases cannot readily escape out the hopper. If they could, we wouldn't need to use heated, dessicated dry air—*a process taking hours*—to remove water vapor from hygroscopic materials.

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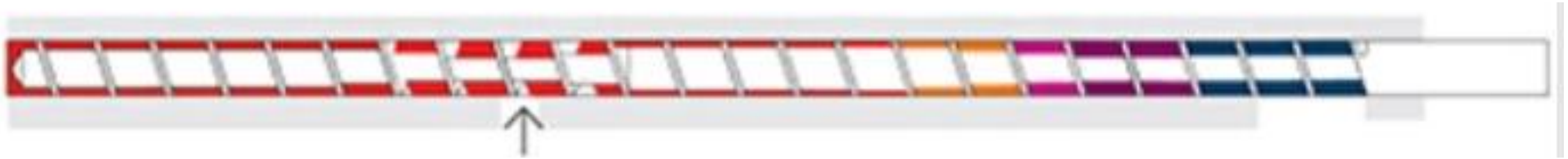

Second Stage Venting Limitations: Venting occurs after decompression in a short, 4 L/D, partially filled section of the screw. At the arrow, a hole in the barrel allows gases to escape to atmosphere or vacuum. The problems is getting a quality gas reduction:

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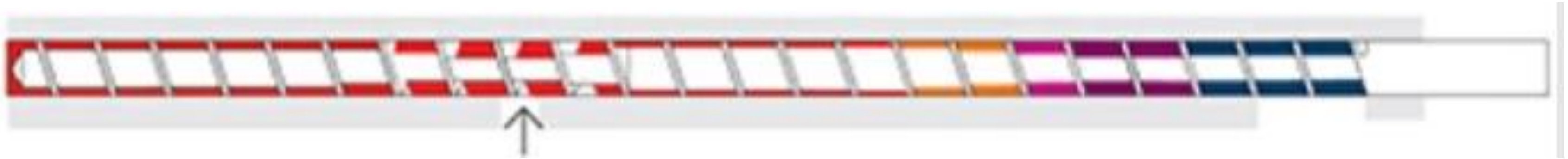

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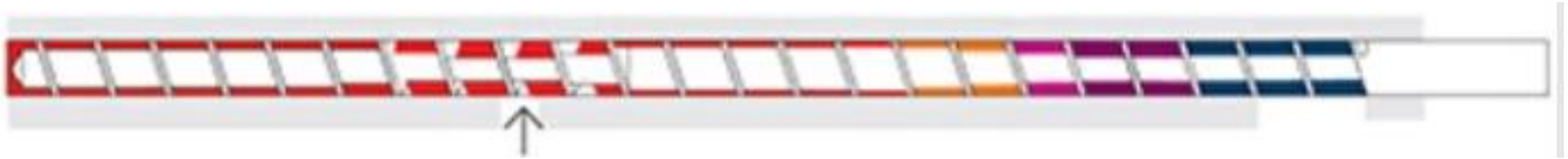

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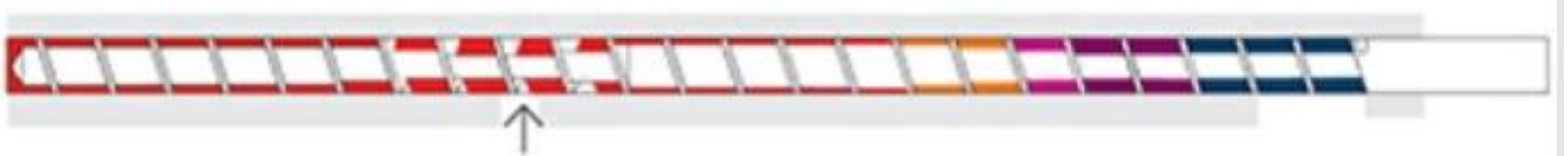

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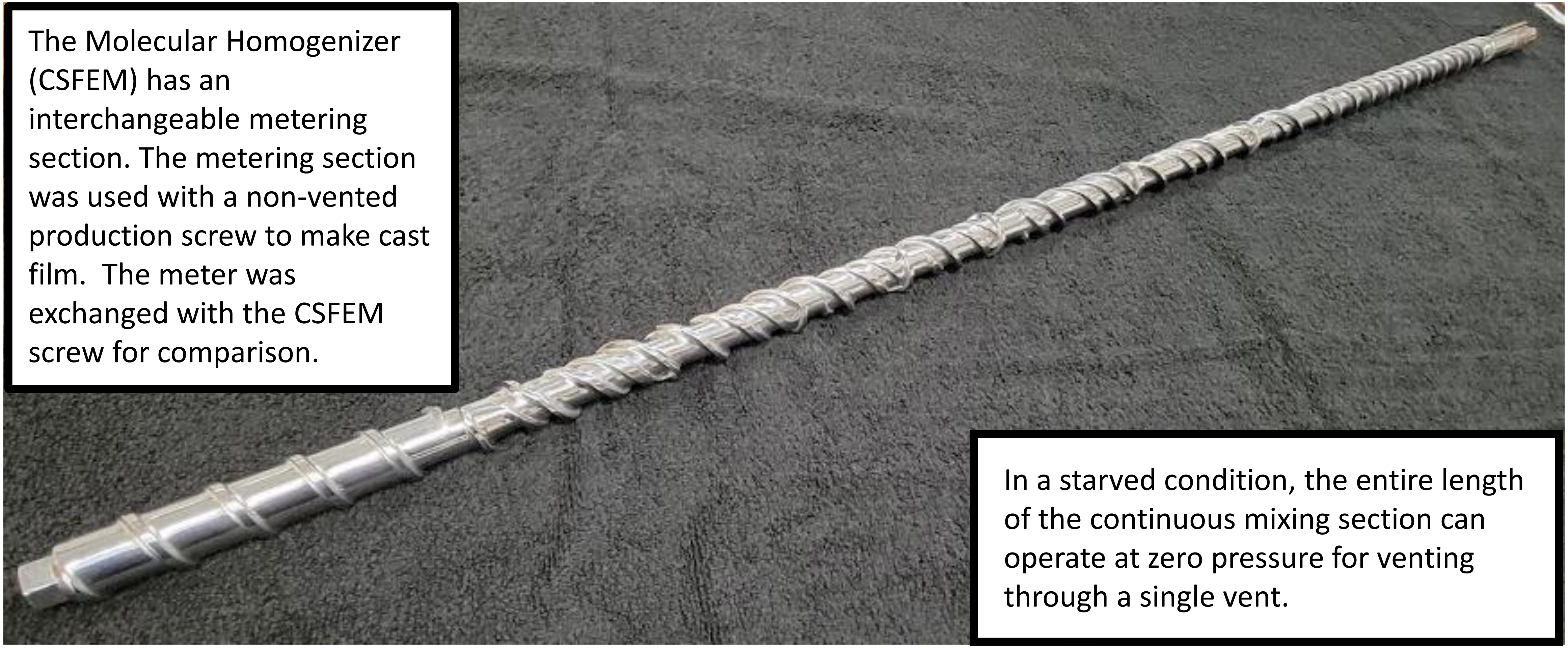
- **Short Residence Time Under Vent:** Four L/D’s limit the degassing length and therefore little time to break the gas bubbles.
- **Output Decrease:** In the range of 20 to 50% less usually with lesser quality than drying.

The Continuous, Spirally Fluted, Elongational Mixer (CSFEM)



The Molecular Homogenizer (CSFEM) has an interchangeable metering section. The metering section was used with a non-vented production screw to make cast film. The meter was exchanged with the CSFEM screw for comparison.

In a starved condition, the entire length of the continuous mixing section can operate at zero pressure for venting through a single vent.

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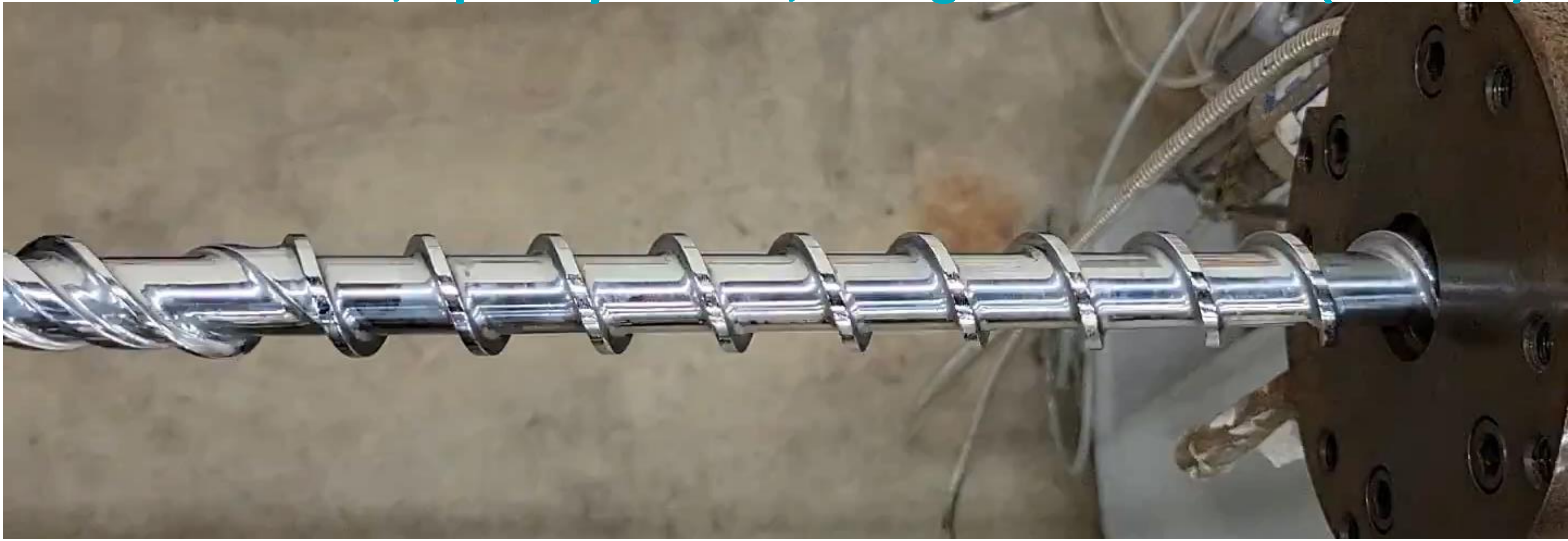
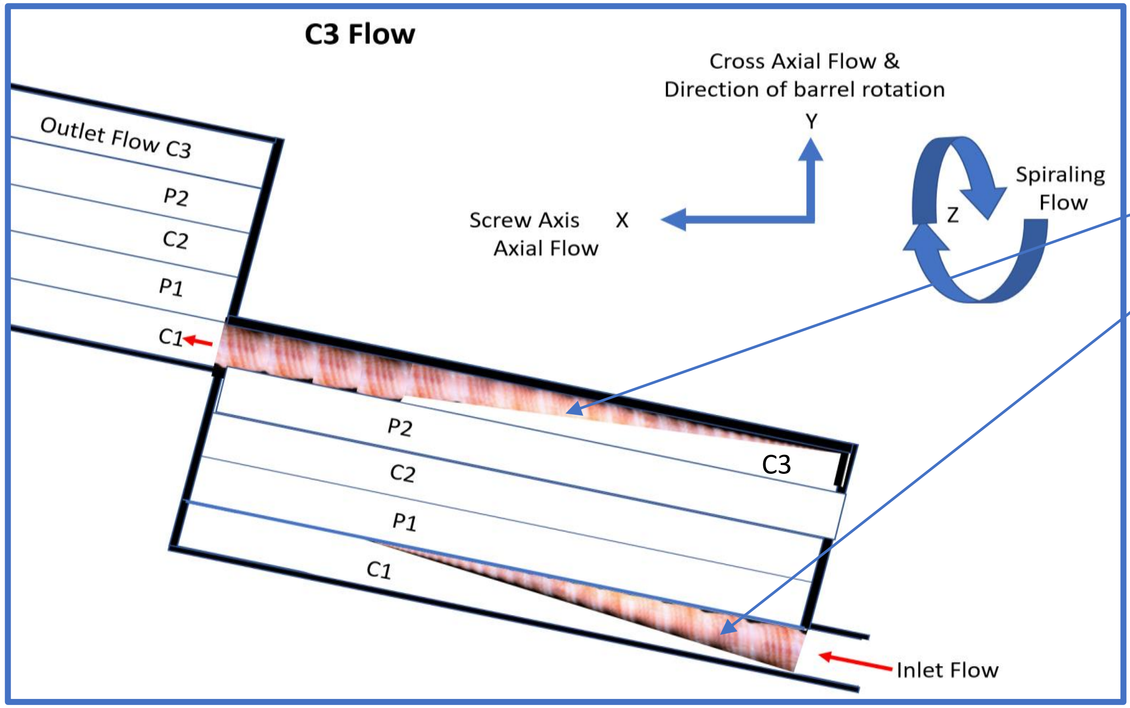
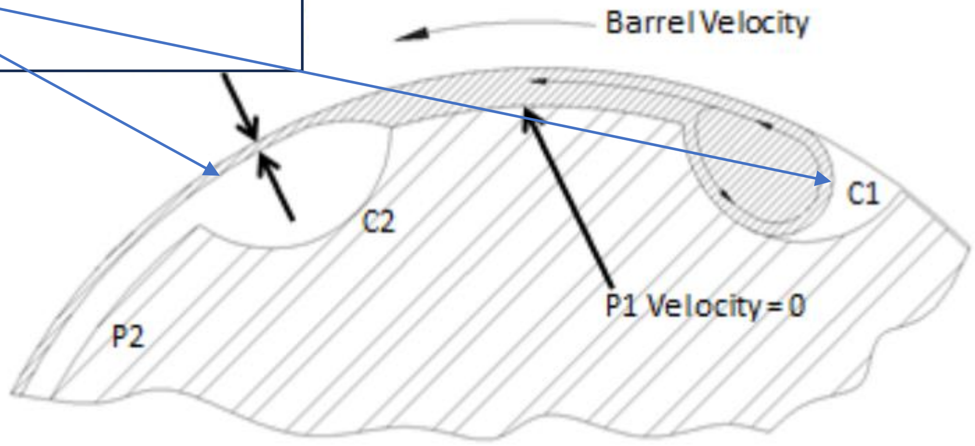


The trade name for this dynamic, multiplicative mixer is the Molecular Homogenizer (MH).

Degassing In CSFEM Over C1, C2, and C3



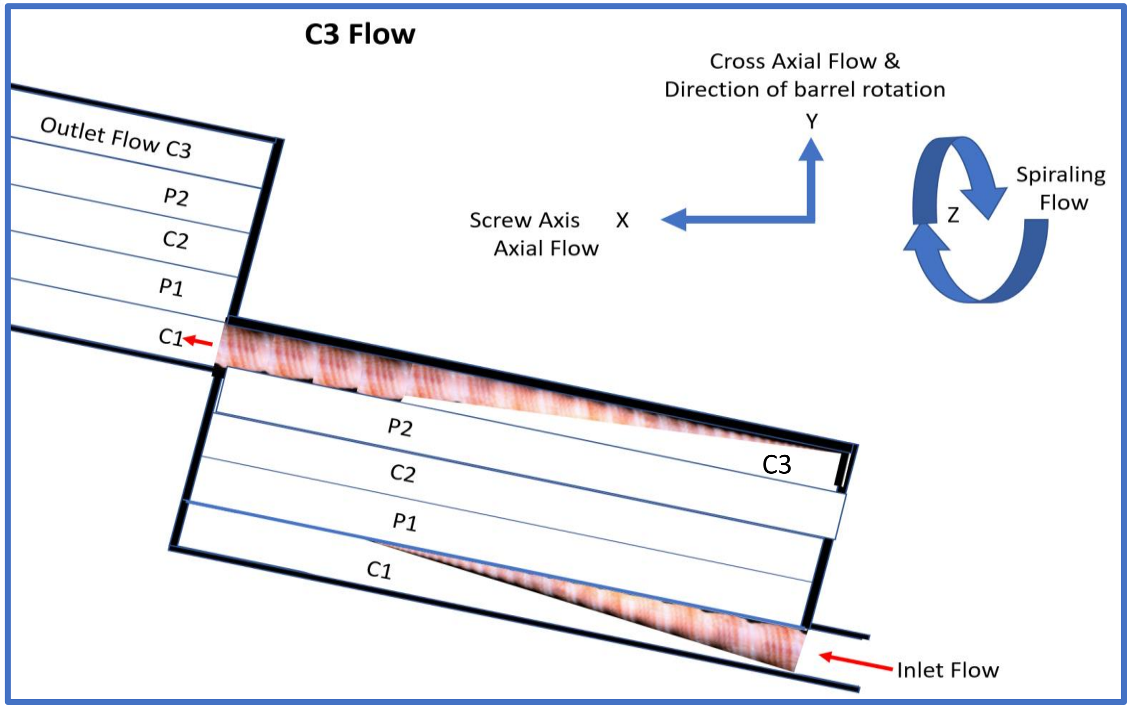
Elongation in C1, C2 and C3 breaks bubbles.



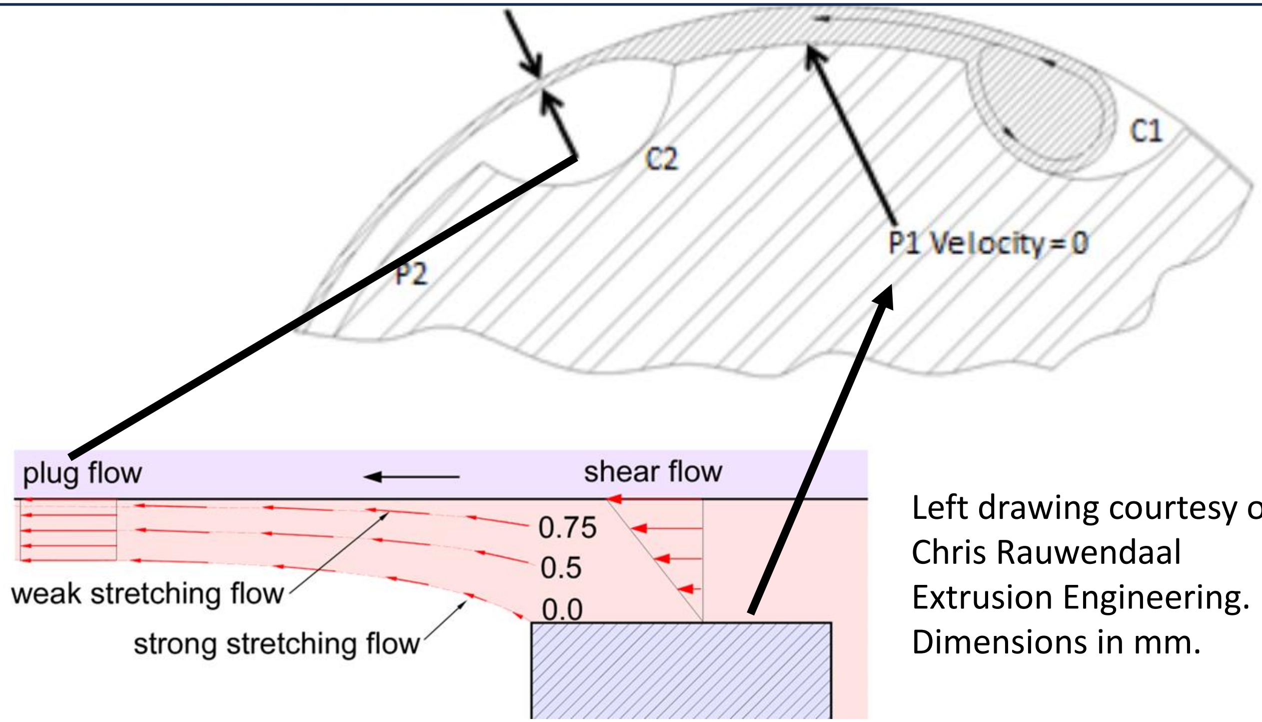
3D mixing is essential so that volatiles are brought to the surface where bubbles can break and gas escape.

- The outside of C1 becomes the inside of C3 after stretching over C2.
- When C3 flow enters the next C1 channel, the outside again becomes the inside.

Degassing In CSFEM Over C1, C2, and C3

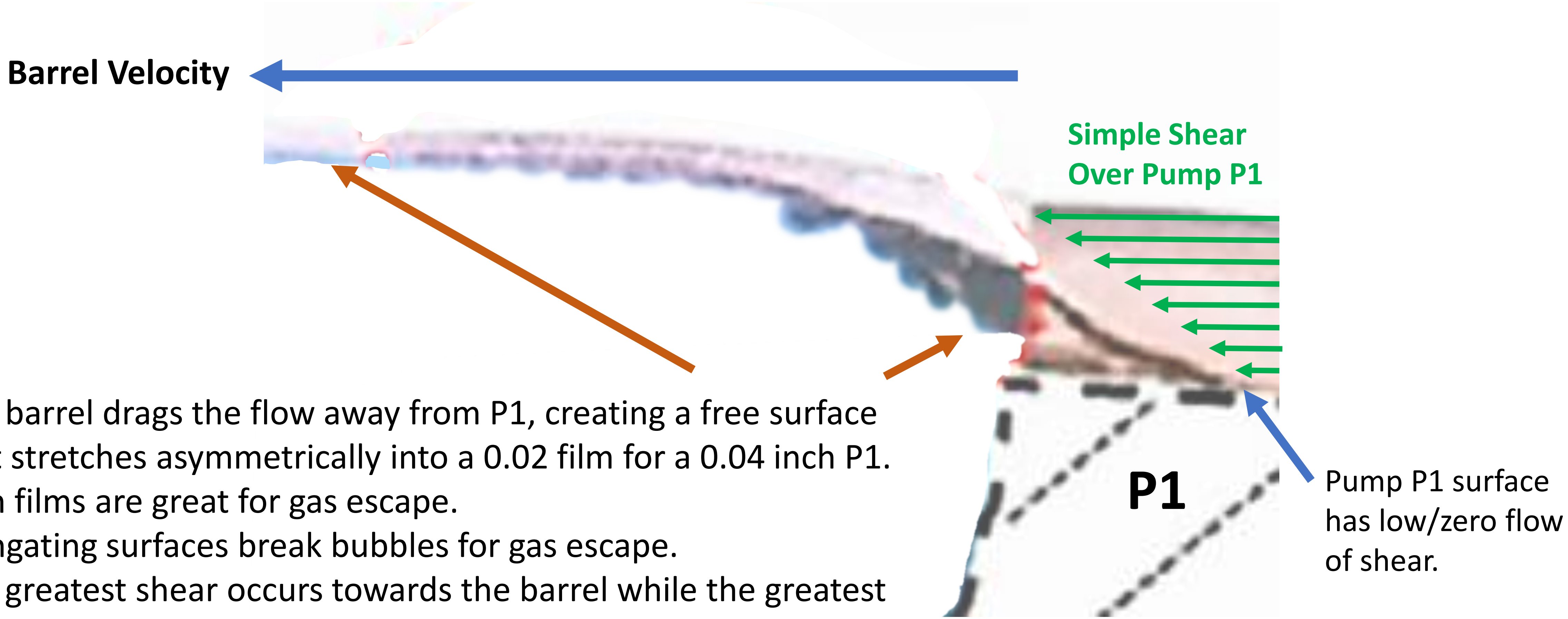


After giving the presentation, Chris Rauwendaal was kind enough to show me some math where the C2 layer is necessarily 0.02 inches for the 0.04 P1 gap.



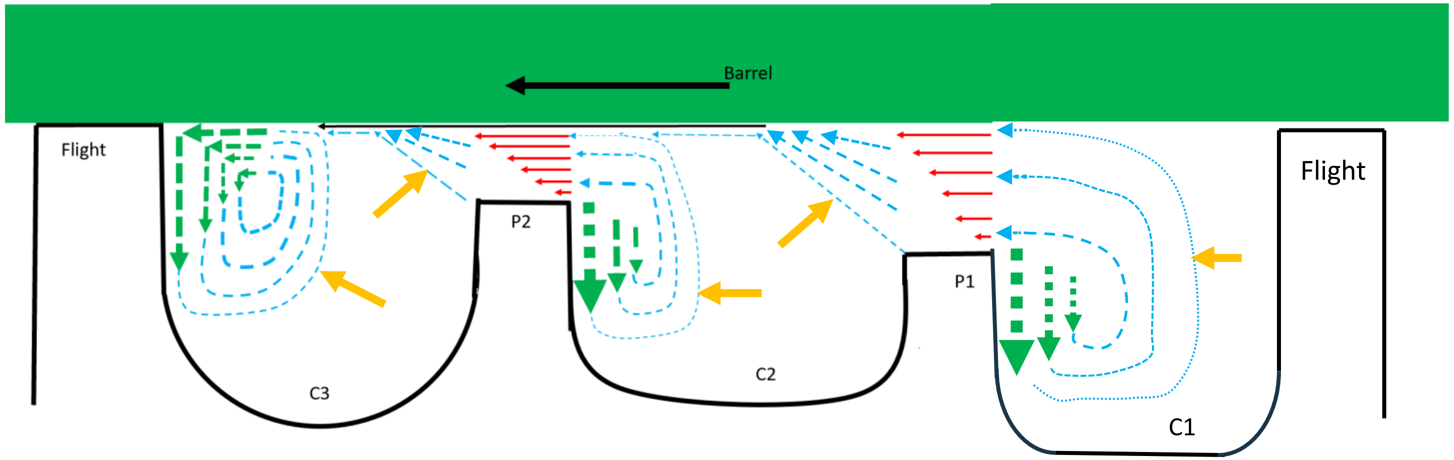
Left drawing courtesy of Chris Rauwendaal Extrusion Engineering. Dimensions in mm.

Degassing In Dynamic Multiplicative Mixer Over C2



- The barrel drags the flow away from P1, creating a free surface that stretches asymmetrically into a 0.02 film for a 0.04 inch P1.
- Thin films are great for gas escape.
- Elongating surfaces break bubbles for gas escape.
- The greatest shear occurs towards the barrel while the greatest stretching occurs away from the barrel in the elongational flow.

Complete Side View With Shallow P2 & Starved Flow



Red Arrows: Simple Shear

Aqua: Elongational Flow

Green: Adhesion/slowed velocity

Orange: The 5 Free Surfaces

P2 Having A Shallower Clearance Than P1:

- **Increases Fill Width Ahead Of P2:** The P2 pump capacity is less than P1 so the fill length increases in C2.
- **5 Free Surfaces Are Created:** These are all elongational and therefore best for breaking bubbles and degassing.
- **Asymmetrical Elongation:** In this view, it become easy to see that the tether ball flow in the channels is also asymmetrical. The flow at the free surfaces is highest and diminishes moving inwards.

Orderly Mixing: *While complicated comparted to the Baker's Transformation, all the material is treated in an orderly manner. It proceeds through* C1's tetherball elongation, P1's simple shear, C2's asymmetric elongation, C2's tetherball elongation, P2's simple shear, C3's asymmetrical elongation and finally the downstream tetherball elongation of C3.

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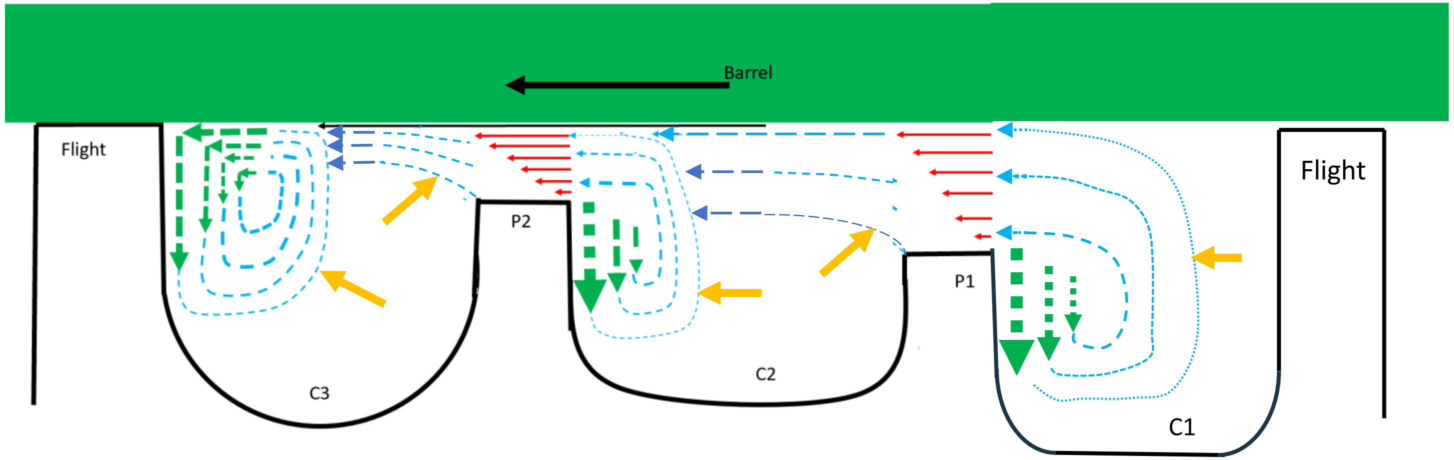

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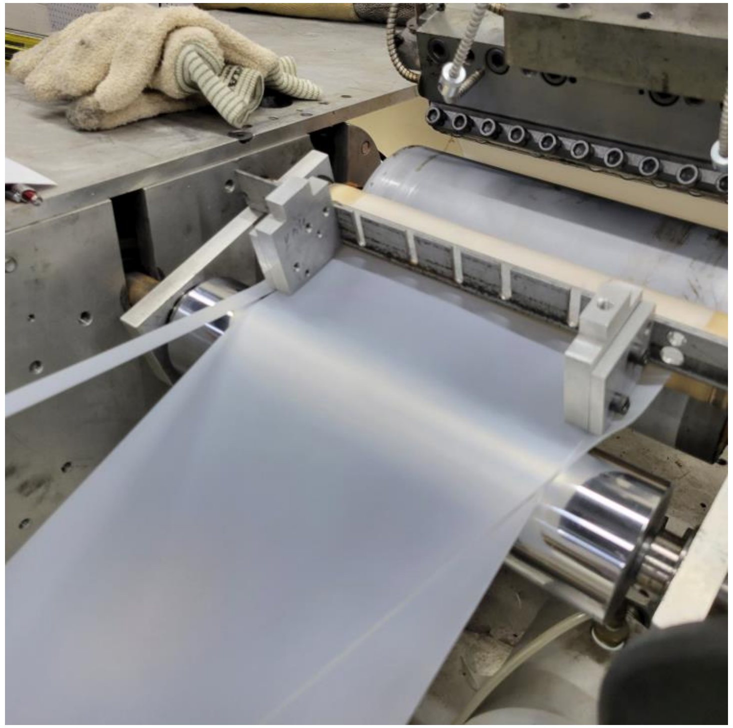
After giving the presentation, Chris Rauwendaal was kind enough to show me some math that allowed for better scaling in this view. Here, the P1 gap is 0.09 inches and thickness leaving P1 becomes 0.045 inches. This allows filling of a P2 gap of 0.040 inches and a 0.02 inch film thickness leaving P2.

The downstream fill length of C2 will be twice the C1 fill length.

Production Run Of Dried Nylon Blend: Cast film 0.0039”



- Material was dried in a dessicant drier for a minimum of 8 hours at 230F.
- Material was flood fed in 3 Elongator screw, 2:1 ACR.
- Dried material was processed for several days under identical process conditions at 90% of drive amp max.

Production Run Of *Undried* Nylon Blend: Cast Film w/Holes

- Undried material was flood fed.
- Undried material was processed under identical process condition.

Set Up Changes:

Screw Changed to Continuous Spirally Fluted Elongational Mixer (CSFEM)

Changed Pulley Ratio For Increased RPM

Changed From Flood Fed To Starve Fed

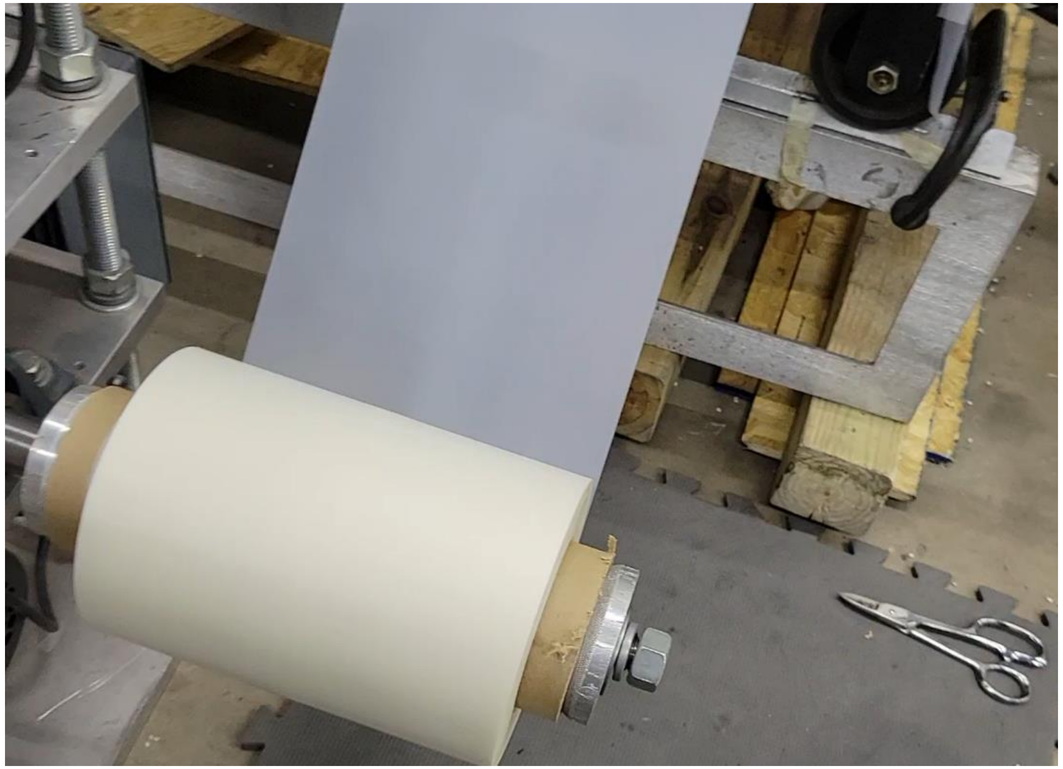
Open Single Atmospheric Vent Over Mixer

Results *Undried* Nylon Blend Production: Cast Film 0.0039”

Conditions

Starved feeding and RPM were increased to 90% of drive amps.

All temperatures zone remained the same.



Results

There were no bubbles.

Output pressure and stability remained the same.

Output and line speed remained the same.

The cast film die did not require adjustment.

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- Because the die did not require adjustment, the implication is that the viscosity is the same.
- In the customer's judgment, the undried material is the same as the dried.
- Processing undried material is not just a cost savings but an energy savings—a sustainable result.

Thanks!

I owe a great deal to many. However, Chris Rauwendaal of Rauwendaal Extrusion Engineering keeps helping me. Sometimes this is before, during and, as in this paper, after the presentation when he’s time to think about what I presented.

I’ve made corrections accordingly.

Thanks Chris!


Any Questions