TAPPI INTERNATIONAL FLEXIBLE PACKAGING & EXTRUSION DIVISION

Circular Economy for Flexible Packaging

March 17, 2021
10:00 a.m. – 1:00 p.m. E.S.T.
Virtual Conference
REGISTER TODAY

Rethinking the Paper Cup

Andrew Christie & Andrea Auchter

SAM NORTH AMERICA, LLC

ingeo™

HAPPY ST.PATRICKS DAY

Introductions

Andrea Auchter

- NatureWorks LLC Application Development Engineer
- General Mills Associate Principal Packaging Engineer
- Certified Packaging Professional by IoPP
- Certified SOLIDWORKS Associate in Mechanical Design

Andrew Christie

- SAM North America Managing Director
- Optex Process Solutions, Inc. Founder
- Black Clawson Extrusion Business Unit Manager
- SPE Flexible Packaging & TAPPI IFPED

Agenda

- Evolution of Paper Cups and Circular Economy Considerations
- Extrusion Coating Process for Package Manufacturing
- Experimental Procedure for Current Study
- Results
- Conclusions

Designing the Paper Cup: Drinking Cup History

1910 Campaign Against Common Cup

On railroad trips no other lips have touched the cup that Phoebe sips.

1957 development of PE coating eliminating staining of the cup

2006 development of the compostable coated cup

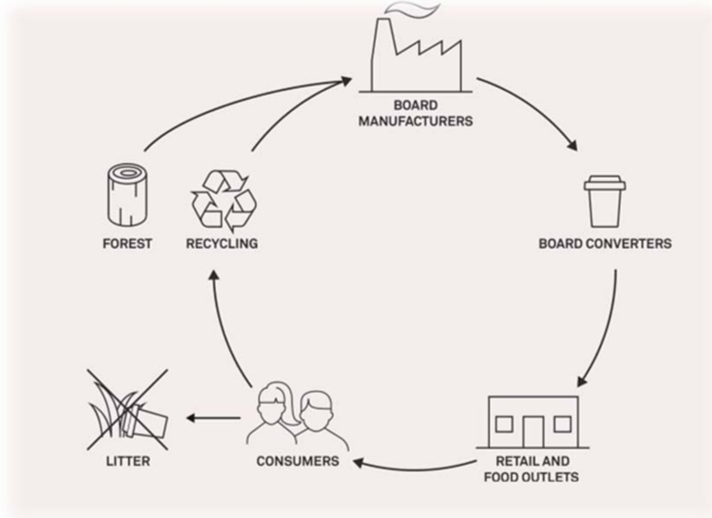
1. Voss-Hubbard, Anke, *Dixie Cup Company History*, Lafayette College Libraries. August 1995. https://sites.lafayette.edu/dixieexhibit/1960s/

End of Life Options: Recycling of Paper Cups (Circular Economy wants to get the fiber)

• Materials, including cups, which are placed in recycle bins are sorted at Material Recovery Facilities (MRFs) based on bale specifications.

• The Foodservice Packaging Institute (FPI) endeavors to have paper cups included in the bale specifications at recycling centers.

• The American Forest & Paper Association is working toward having a post consumer stream collected and accepted by MRFs to recover the fiber.

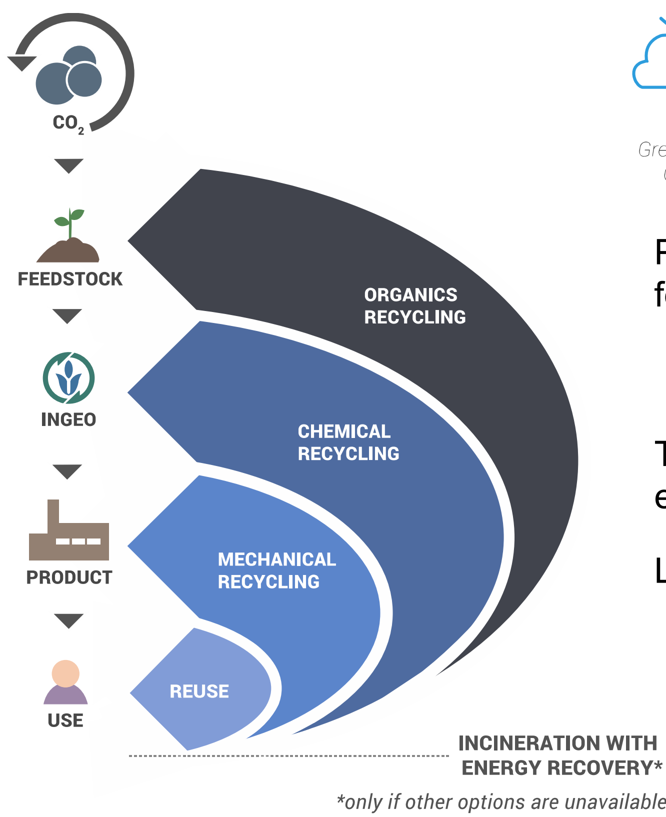


2. 5/28/2018 Closing the loop – the lifecycle of a paper cup
https://www.kemira.com/insights/closing-the-loop-the-lifecycle-of-a-paper-cup/

End of Life Options: Industrial Composting

- **Compost** is made by decomposing organic materials into simpler organic compounds in a process called composting.
- **Disintegration** the process of losing cohesion to degrade into small particulates.
- **Biodegradation** is the consumption of organic matter by microorganisms, such as bacteria and fungi.
- **Industrial composting** is a manufacturing process with time, temperature, and moisture controls; whereas backyard composting has much more variation. Both reduce carbon emissions of managing food waste and improve soil quality.
- See ASTM D6868 for time and temperature requirements.

Can One Design for Multiple End-of-life Scenarios? Transition to Circular Economy



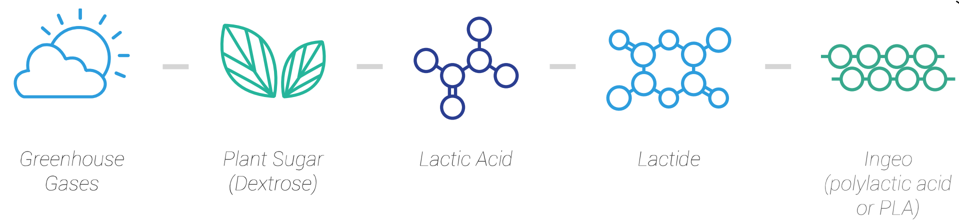
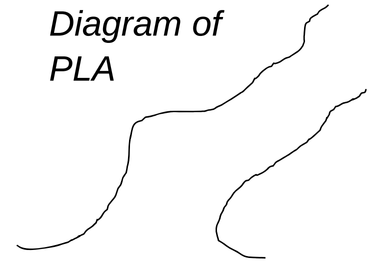


Diagram of PLA



PLA is biobased since the raw material lactic acid is fermented from sugars.

- Once PLA is fully degraded many composting microorganisms recognize lactic acid as a food source

This PLA grade balances melt strength and viscosity to extrusion coat more efficiently.

LDPE molecular architecture gives melt strength.

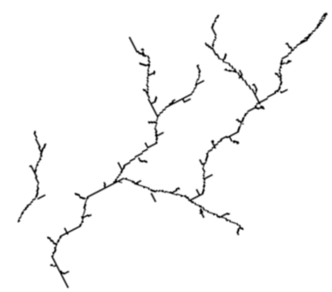
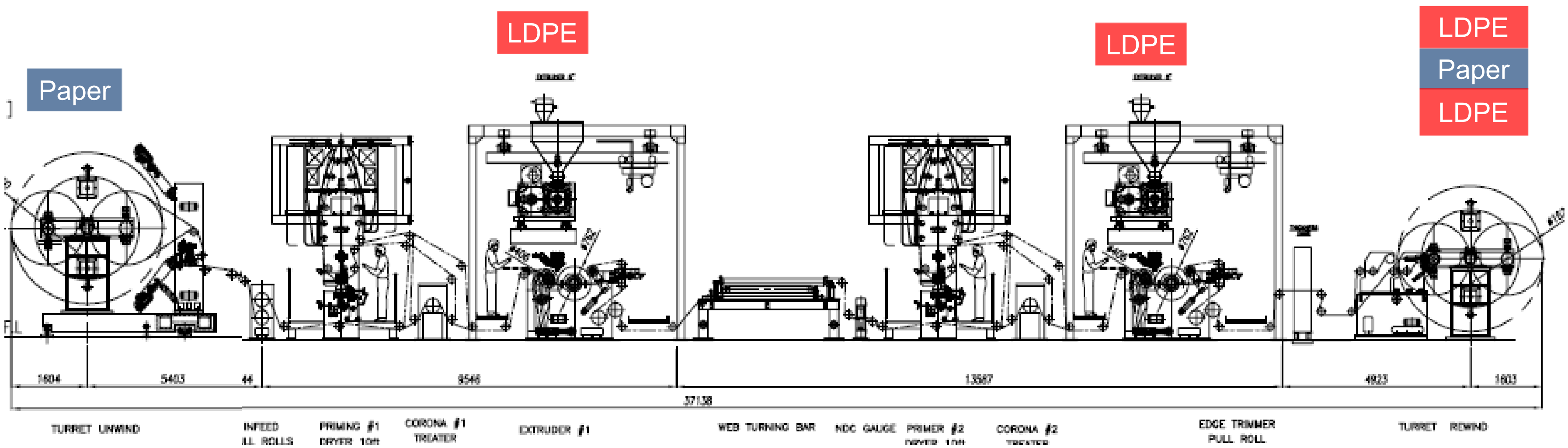


Diagram of LDPE

Extrusion Coating Process – Tandem Arrangement for 2 Side Paper Coating



Basic steps:

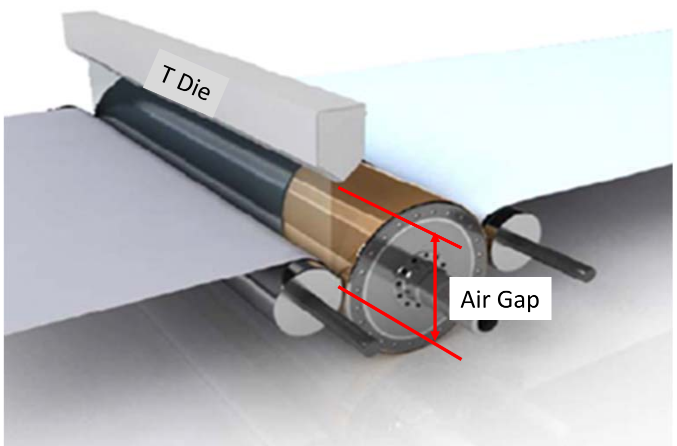
1) Unwinding a roll of substrate to be coated (paper, film, foil, or fabric)
2) Surface preparation to promote bond of the polymer:
   a. Corona pre-treat.
   b. Plasma (flame or corona with gas) pre-treat.
   c. Chemical prime (liquid coating).
   d. Ozone flood (reacts with substrate and polymer melt).
3) Melt the polymer(s) and extrude via slot die onto the moving substrate.
4) Resolidify the polymer while in intimate contact with the substrate.
5) Rewind the newly coated substrate.

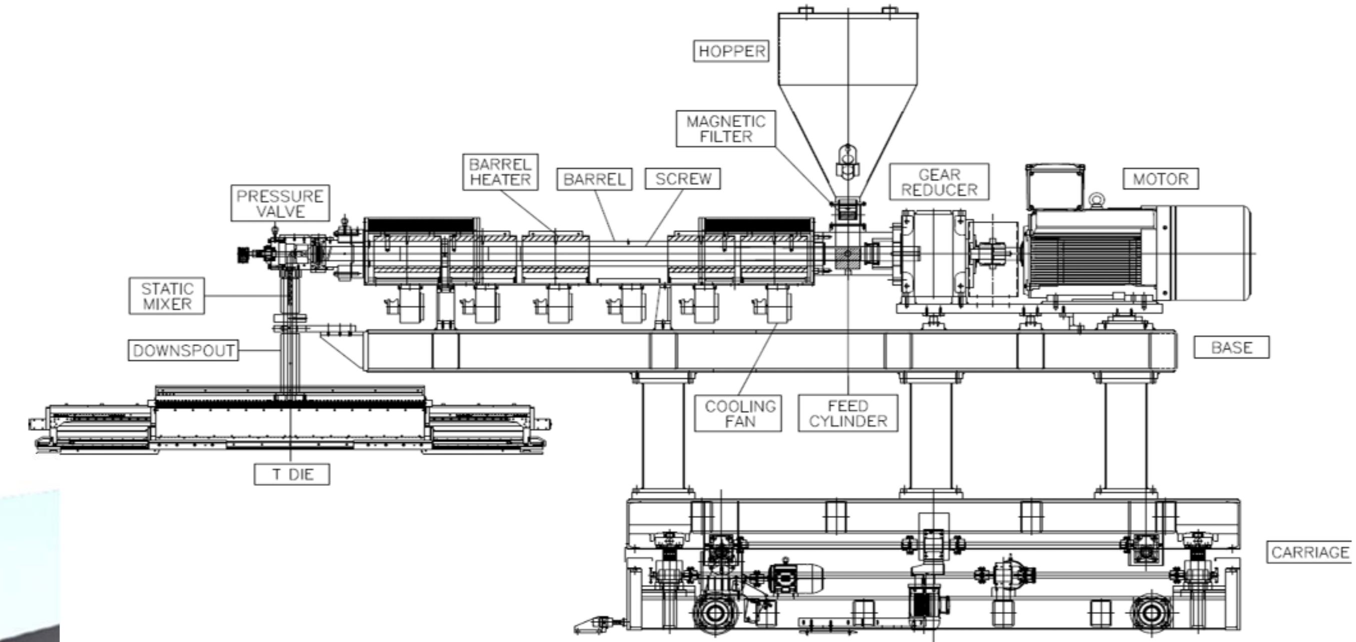
By introducing a second substrate at the point of extrusion the molten polymer becomes the adhesive to bind the two substrates into a laminate.

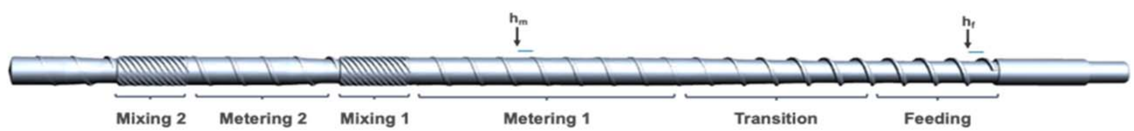
Extrusion Coating Process – Extruder, Die, Coating Nip

Typical LDPE extruder requires:

1. High-shear extrusion coating feed screw – develop high temperature for LDPE oxidation.
2. Back-pressure valve - closed to increase LDPE temperature.
3. Low-pressure T-slot die with internal deckles – low viscosity polymer distribution with edge bead control.
4. Die lip to chill roll – adjustable air gap for optimized time for oxidation of LDPE.

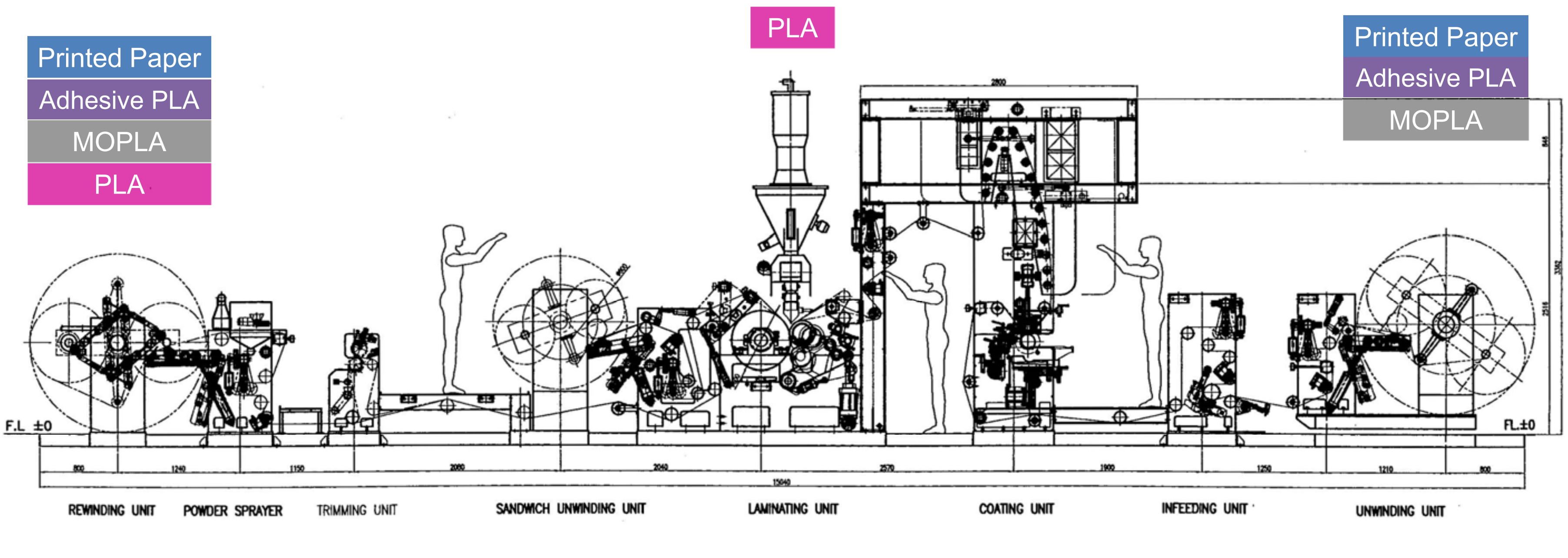






Typical High Shear Extrusion Coating Screw

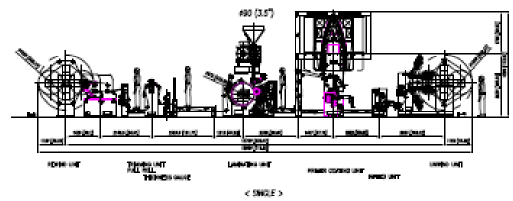
Monolayer Extrusion Laminating with Primer Coater



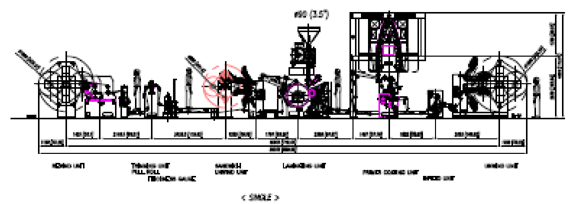
Lidding Film

Flexible Packaging Hierarchy

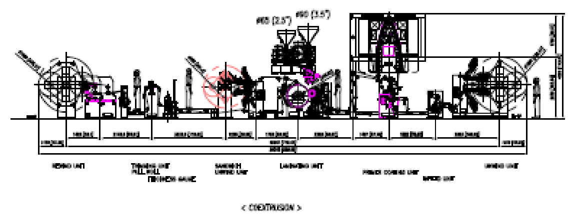
Single Coating, Mono Extrusion, With Primer



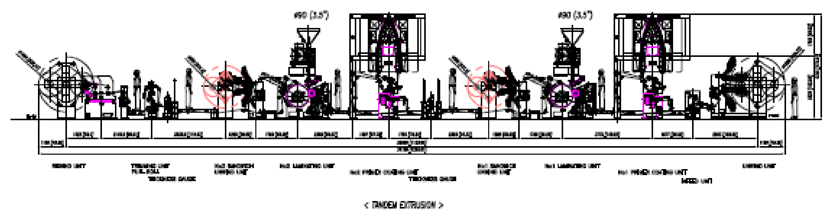
Single Coating or Laminating, Mono Extrusion, With Primer



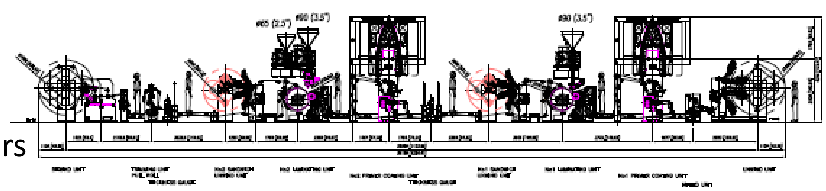
Single Coating or Laminating, Co-Extrusion, With Primer



Tandem Coating or Laminating, Mono Extrusion, With Tandem Primers



Tandem Coating or Laminating, Mono & Co-Extrusion, With Tandem Primers



The PLA Challenge – On Systems Designed For LDPE

- Output of PLA limited due to high melt temperature caused by high shear from the screw.
  (Note: maximum processing temperature of PLA is 55-75°C lower than LDPE)
- Valve pressure causes heat generation in PLA
- PLA curtain stability limited due to:
  - Melt strength of linear polymer (more neck-in)
  - High melt temperatures (bulk vs indicated)
  - Thinning capabilities at edges (distribution in T-die due to effective viscosity)
  - High draw down ratios (impacts stability)
    - $DD_{ratio} = \frac{V_{chill\,roll}}{V_{die\,lip\,exit}} \approx \frac{h_{\,die\,lip\,gap}}{h_{\,coating\,thickness}}$
  - High draw down rates (%/min)
    - $DD_{rate} = 100 * \left(\frac{V_{chill\,roll} + V_{die\,lip\,exit}}{2 * Air\ Gap}\right) * (DD_{ratio} + 1)$

Experimental Procedures

Conduct rate checks at a range of screw speeds / screw designs

- Determine specific output & linearity
- Determine screw speed / screw design impact on melt temperature
  - Maximum temperature
  - Temperature uniformity (position dependent variation)
  - Temperature stability (time dependent variation)
- Determine screw speed / screw design output limitation (abuse of polymer – temp / fumes)

Evaluate run-ability at output limitation of screw

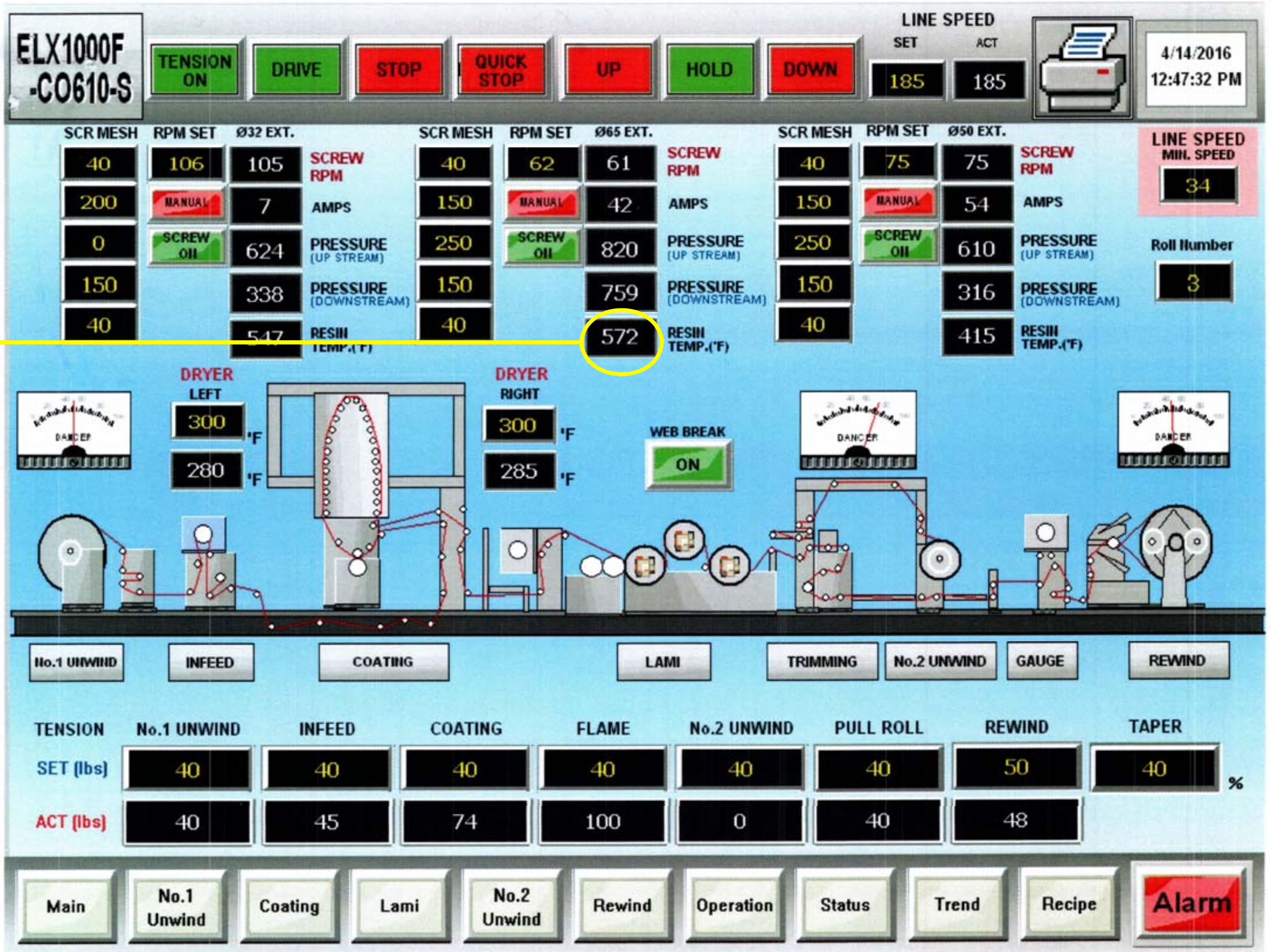
- Die gap
- Air gap
- Edge Encapsulation
- Line speed / coat weight

Evaluate process and product performance

- Adhesion
- Gels / unmelts
- Voids / holes
- Edge weave
- Melt curtain stability

Typical HMI Operations View

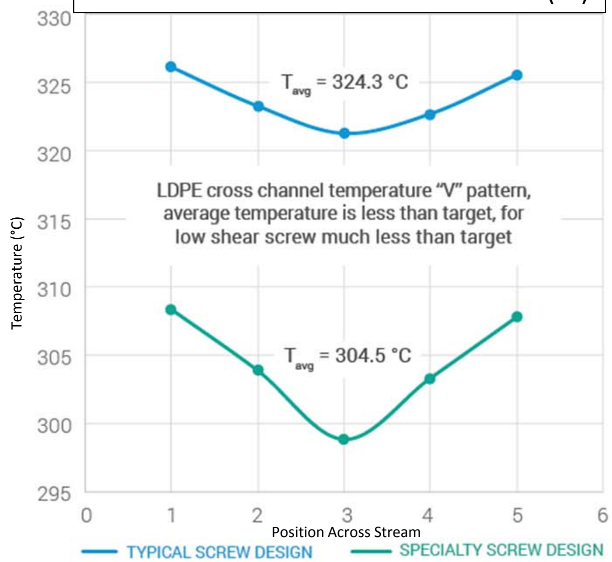
Single point
melt temperature
can be misleading

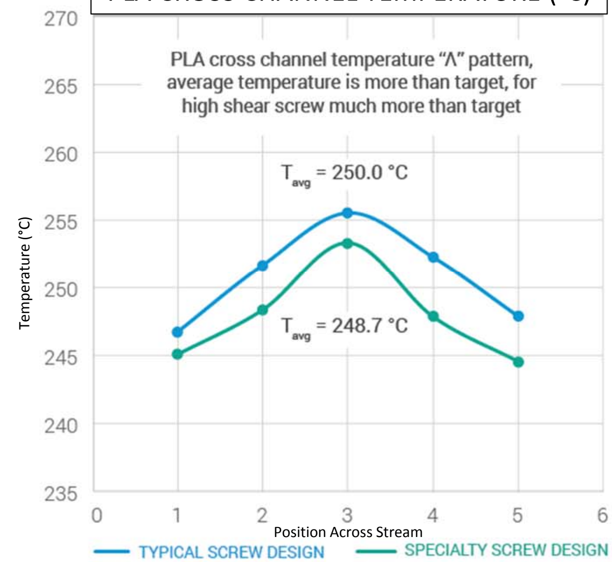


Screw Design / Polymer Structure – Effect Output Limitation

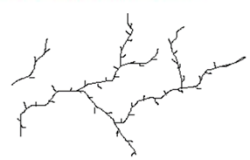
- \ mfy%nx%ltti%ktw%f%q|%{nxhtxny~% ymjwr fq%xyfgqj%utqr jw%QIUJ.%nx% sty%ltti%ktw%f%mnlm%{nxhtxny~% ymjwr fq%xjsxnyn{j%utqr jw%UQF.

- R jfxzwnsl%yjr ujwfyzwj%tsq%fy% hmfssjq%jilj%itjx%sty%fhhzwfyjq% wjkqjhy%r ni2hmfssjq%r jq% yjr ujwfyzwjx3%\ nym%UQF%ts%fs% QIUJ%xhwj|1%ymj%wzj%r jq% yjr ujwfyzwj%nx%pjq%mtyyjw%ymfs% jilj%r jfxzwjr jsyx%nsinhfyj3

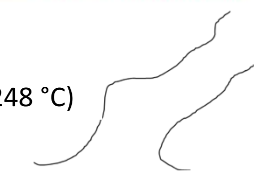




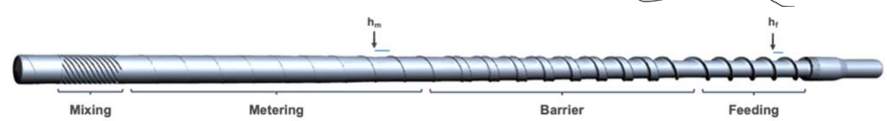
LDPE Target Average (324 °C)



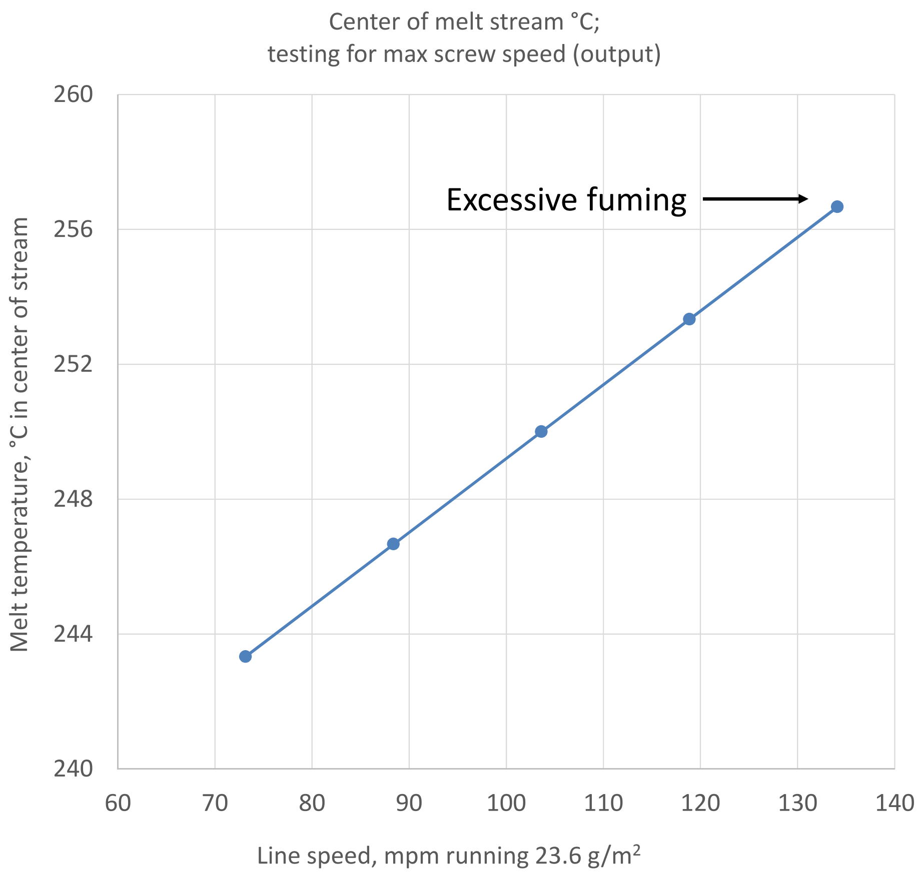
PLA Target Average (248 °C)

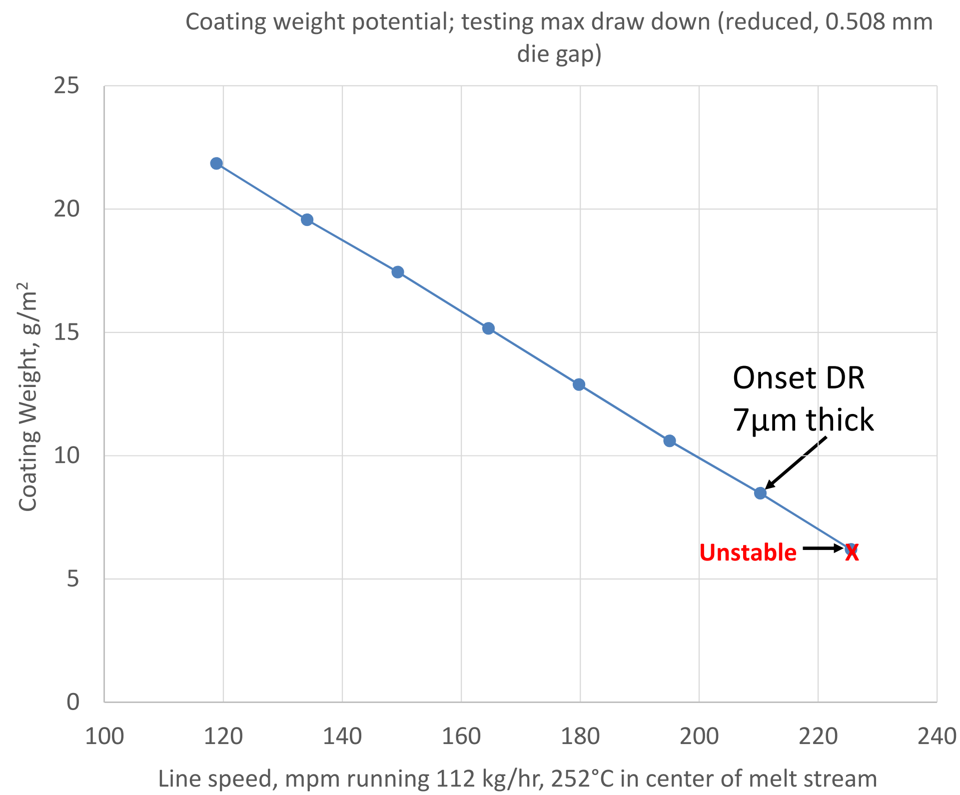


Low Shear Design for PLA



Optimized Processing Further Demonstrates Stable Melt Curtain and Low Coat Weight Potentials





PLA Optimization Can Increase Output and Line Speed by 150-200%

Screw Design	Output at 75 rpm: LDPE Kg/hr (Temp. °C)	Output at 75 rpm: PLA Kg/hr (Temp. °C)	Output at 75 rpm: PLA Increase over standard screw design	Line Speed: PLA Increase over standard screw design	Line Speed: PLA Increase by reducing die lip gap	Line Speed: PLA Increase by edge encapsulation
Single Flight Double Mix Standard Extrusion Coating Design	50 (324)	78 (252)			130%	
Barrier Flight Single Mix Moderate Shear Compromise Extrusion Coating Design	66 (314)	107 (253)	137%	131%		
Barrier Flight Single Mix Low Shear Specialty Extrusion Coating Design	64 (304)	119 (249)	153%	143%	186%	202%

Process recommendations

- Low shear high output screw design
- Minimize Die Lip Gap
- Keep melt temperature <250°C or <482°F
- Include edge encapsulation extruder

Extrusion Coating PLA Conclusions

- Capital investment is needed to gain output and reduce coating weights.
  - Alignment of screw design to new materials like PLA increases output rate and line speeds.
  - Investment facilitates market growth potential in coated cups and formats beyond cups.
- Resulting manufacturing ease and efficiency due to
  - Stable web for faster line speeds, lower coating weights, less scrap .
  - Extended process range for light coating weight with broader and more stable web and great adhesion. – with additional new equipment recommendations on the horizon.

TAPPI INTERNATIONAL FLEXIBLE PACKAGING & EXTRUSION DIVISION

Circular Economy for Flexible Packaging

March 17, 2021
10:00 a.m. – 1:00 p.m. E.S.T.
Virtual Conference
REGISTER TODAY

Thank You

For further information there is a white paper that has been accepted to the Tappi Journal, currently a version is available at:

Christie, Andrew; Prue, Michael; Auchter, Andrea; Whiteman Nicole (1/12/2021) Rethinking the Paper Cup
https://www.tappiflexible.org/media/1095/2020-11-16-rethinking-the-paper-cup_tappiifped.pdf

SAM NORTH AMERICA, LLC

ingeo™

Andrew Christie
awc@sam-na.com

Andrea Auchter
Andrea_Auchter@natureworksllc.com

HAPPY ST.PATRICKS DAY