7-9-11 Layers
Which are the Most Suitable Applications

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Agenda

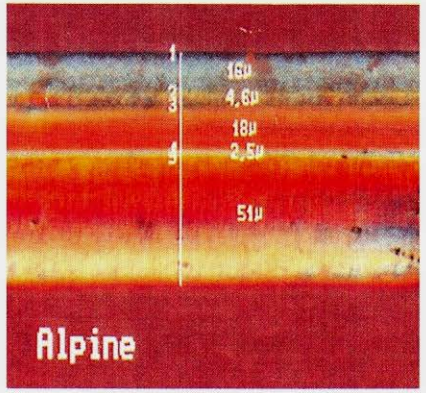
- Introduction
- Background/technology revisited
- Benefits of coextrusion
- Advantages of multilayer lines with example structures
- The next generation
- Alternative technologies

Introduction (Equipment)

- Mono-layer blown film extrusion is very well established
- Film manufacturing evolved from mono-layer to coextrusion for many reasons
  - Equipment developments
  - Resin developments
  - Process development
  - Education
  - Market needs
  - Economic forces
- Coextrusion development began about 60 years ago

UMASS-Lowell Plastics Engineering Department Mono-Layer Blown Film Lab
Photo by Tom Bezigian

Alpine 5-Layer Plate Die



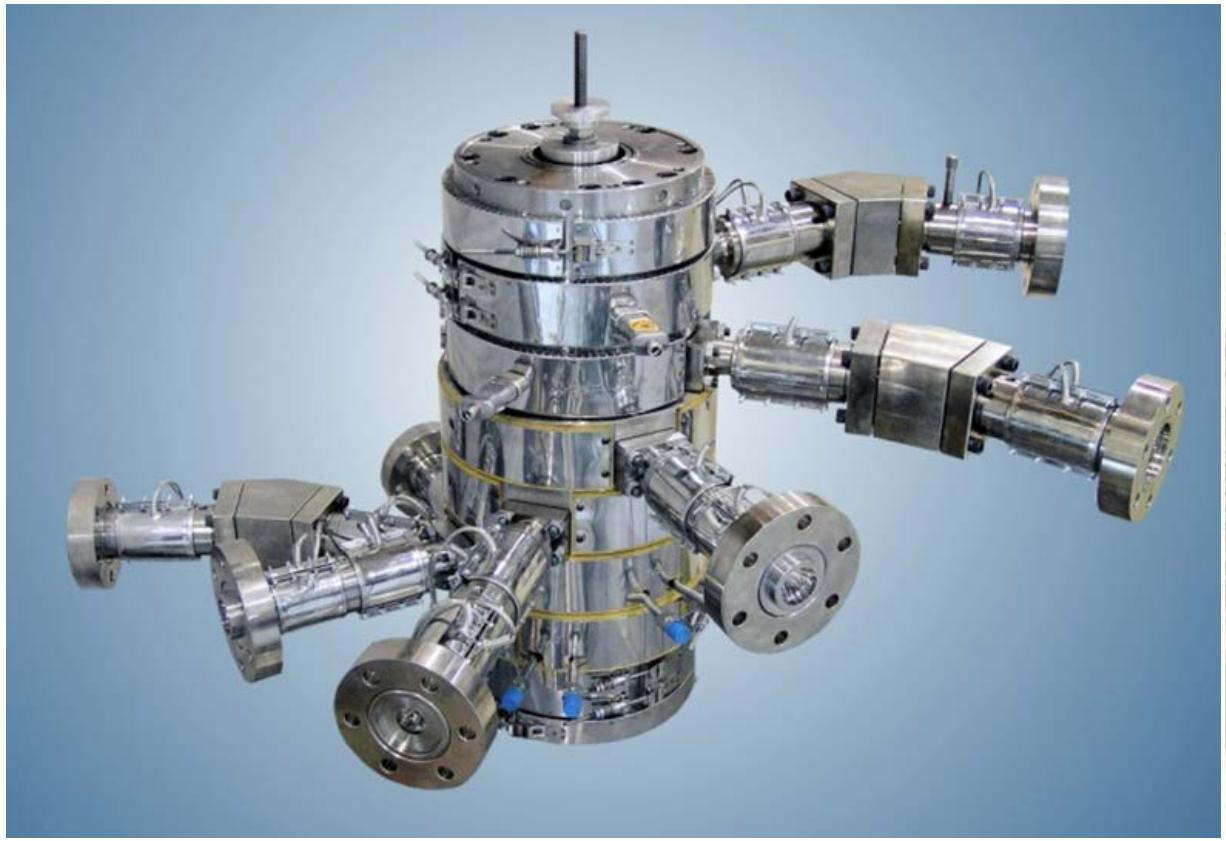
Layer gauge of a 5-layer film.

Process data / Practical results

ALPINE extruder	HS 50 / 25 L/D
	HS 50 / 25 L/D
	HS 50 / 25 L/D
	HS 50 / 25 L/D
	HS 75 / 25 L/D
Plate die	FBF 35-50.P
Die	350 x 1,5
Output	approx. 165 kg/h
Film gauge	approx. 90 µm
Layflat width	approx. 700 mm

(Adapted from the UMASS-Lowell Plastics Engineering Department Process Engineering curriculum – UML)

Stacked Conical Mandrel Coextrusion Blown Film Die

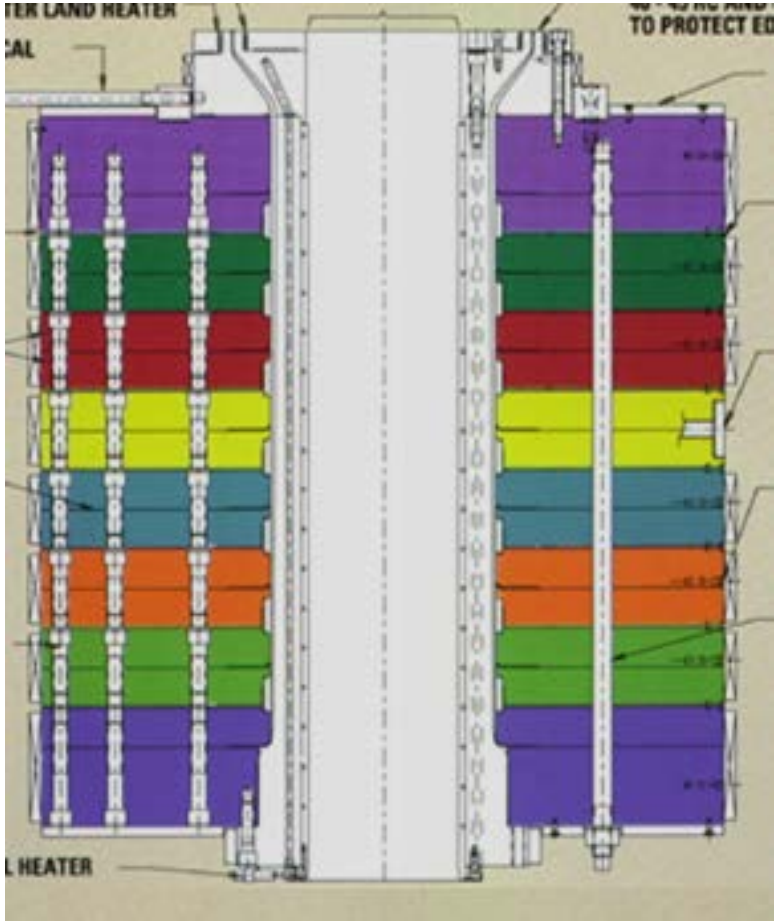


7-Layer Taper Pack Macro Engineering Coextrusion Die for Heat Shrinkable Biax Film, Courtesy Macro Engineering

9-Layer Concentric (Nested) Spiral Die (UML)

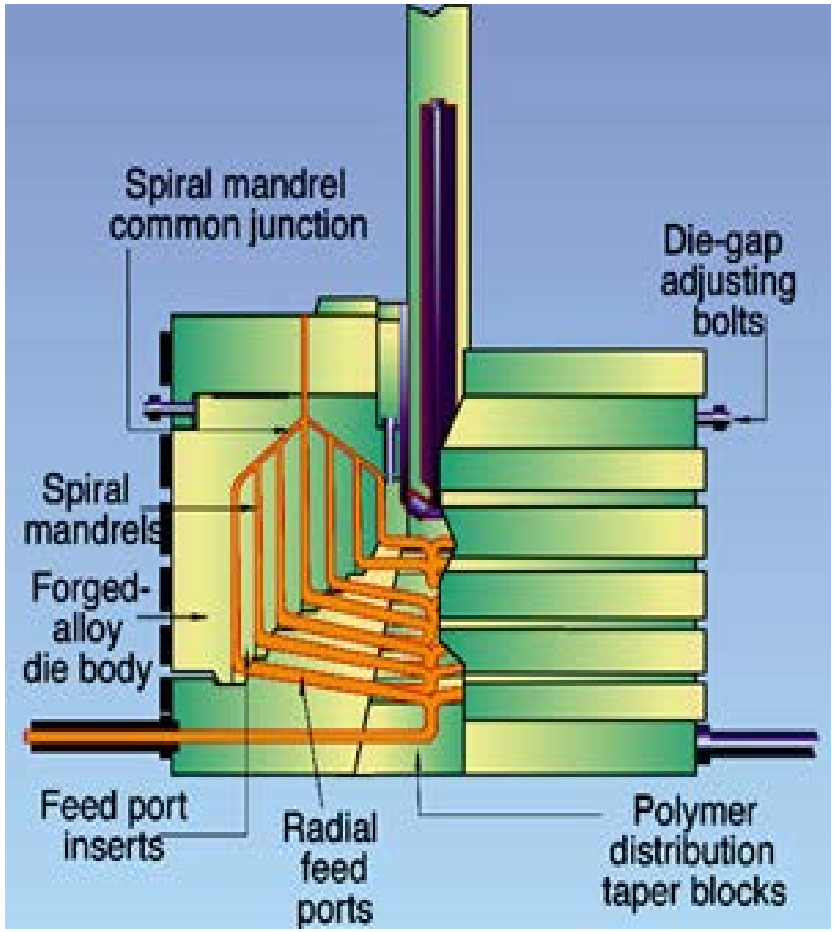
Courtesy Battenfeld Gloucester

Blown Film Die Variation



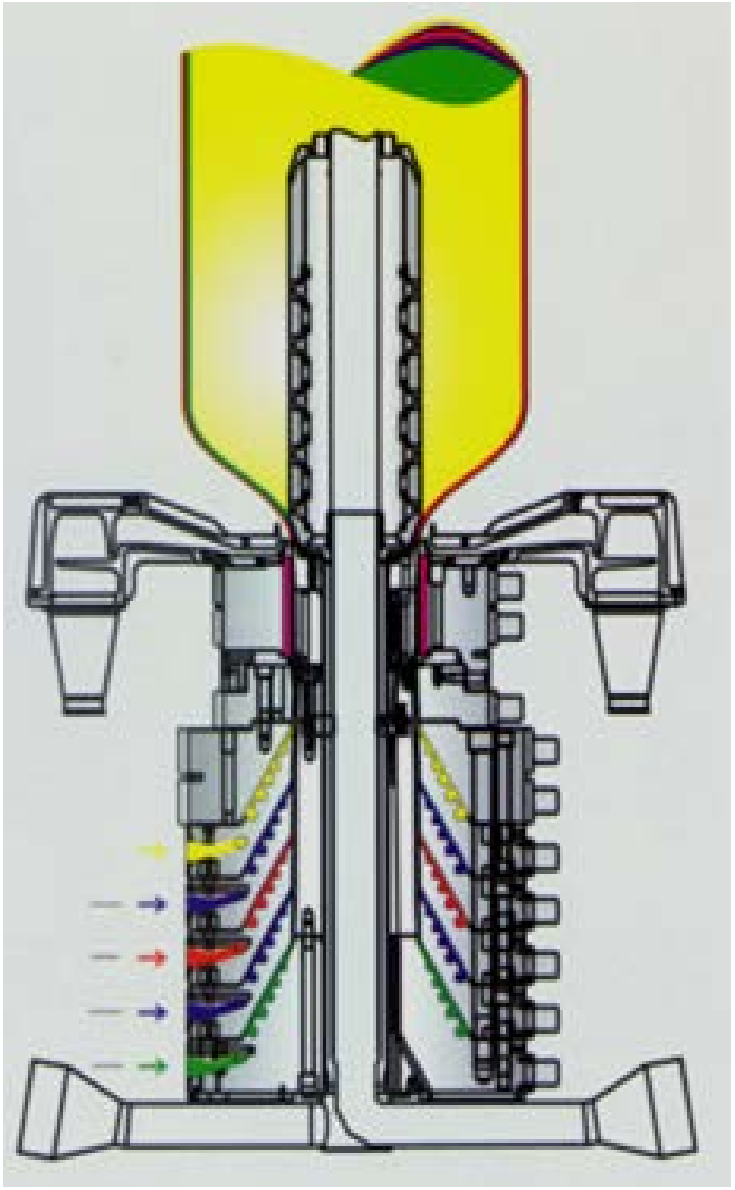
Courtesy Brampton Engineering

Plate, or Pancake Die



Courtesy Battenfeld Gloucester

Concentric Spiral Mandrel



Courtesy W+H

Stacked Conical Spiral Mandrel

All images courtesy Gloucester Engineering

Benefits of Coextrusion

- So, how did we go from one to three and five layer films to 7, 9, and 11-layer films?
- What is driving the market to films with more and more layers? It seems all the major manufacturers are offering 7, 9, and 11 layers machines.
- The big question is why?
- Is there a real benefit to be gained from the additional capital expenditure, or is it marketing hype?

Benefits of Packaging & Coextrusion

Packaging

- Product protection
- Puncture and abuse resistance
- Vapor barrier
- Moisture barrier
- Grease barrier
- Chemical barrier
- Light barrier
- Printability
- Heat seal strength
- Heat seal initiation temperature
- Hot tack
- Machinability

Coextrusion

- Combining incompatible polymers in one step (lamination not needed)
- Optimization of film structures for specific applications
- Improved barrier properties
- Reduced layer thickness of expensive resins
- Controlled respiration (O_2 & CO_2 transmission)
- Improved physical properties
  - Improved Gelbo flex resistance (reduced flexural failures)
  - Thinner, stronger films
  - Improved gloss
- Additional attributes, such as anti-fog, anti-block, COF, two-sided color
- Expanded markets, i.e., competes with rigid packaging
- Reduced cost
- Use of new polymers

Benefits of Coextrusion – Barrier Properties

POLYMER	OTR @ 20°C, 65%RH (cm^3 20µ / m^2 day atm)	GAS BARRIER
27 Mol% Ethylene EVOH	0.2	Excellent (High)
44 Mol% Ethylene EVOH	1.5	
PVDC	2.6	
PA	38	Fair (Medium)
PET	54	
HDPE	2300	Poor (Low)
PP	3000	
PC	5000	
PS	8000	
LDPE	10000	
EVA	18000	

50,000 x

Benefits of Coextrusion – Toughness

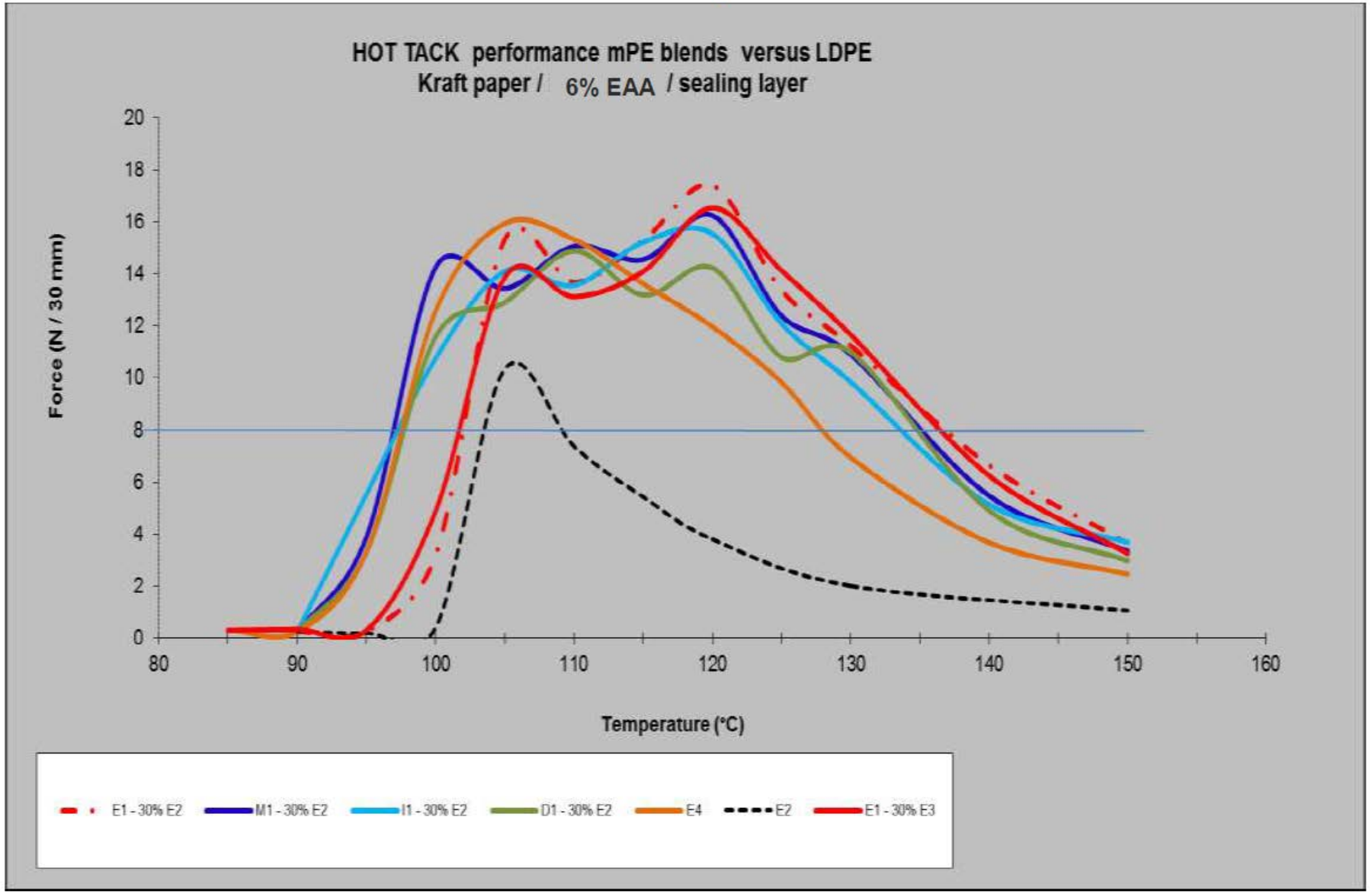
- Using LDPE instead of EVOH as an example would require a 1 meter thick (50000 x 20µ) of LDPE to achieve the same O_2 barrier as EVOH
- Thinner layers are obviously less stiff than thicker layers, so improved Gelbo flex resistance is anticipated with thinner layers of stiff materials
- For example, polyamides can be substituted for polyester in a coex structure, allowing for a strong, tough structure with good permeability properties in a one-step blown film process
- For example, frozen food packaging

Benefits of Coextrusion – Heat Seal

- Heat seal strength, heat seal initiation temperatures, and hot tack strength can be adjusted based on the performance required in the end product

From: Kramer, Van den Bossche, "New Solutions in Flexible Packaging", TAPPI PLACE, May 2014

Hot Tack Performance – Competitive Assessment

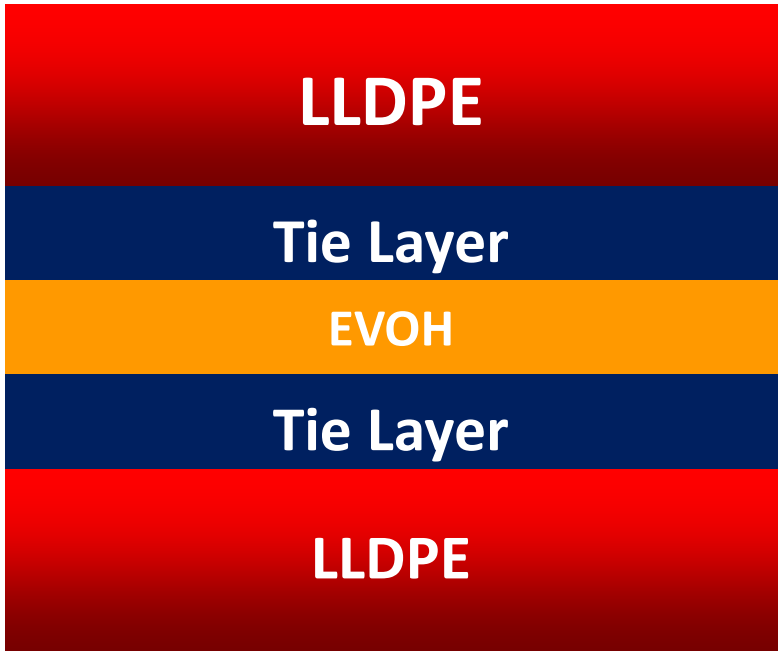


1-, and 3-Layer Films

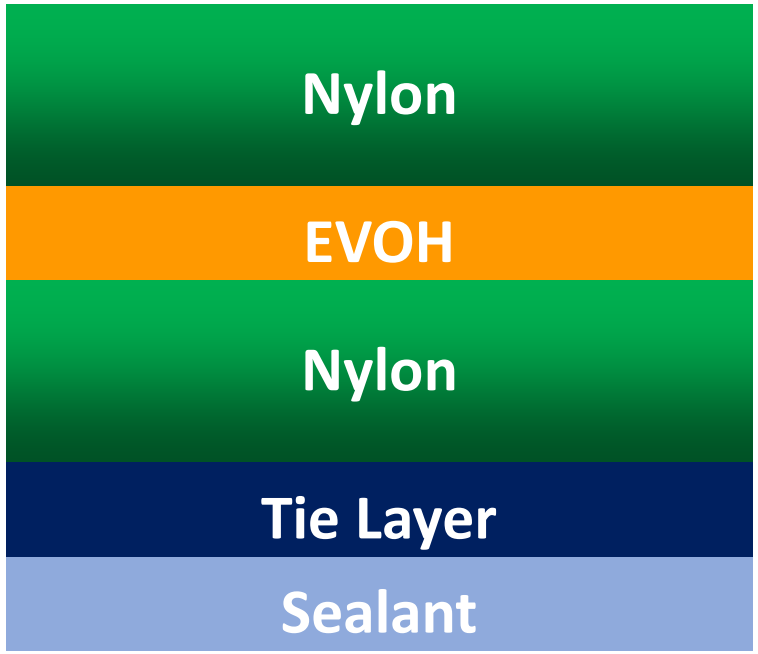
- These are the backbone of the blown film industry, and certainly will not disappear any time soon
- Monolayer lines are perfectly suited for commodity, non-barrier films
- Existing lines require no capital outlay
- 1- and 3-layer films feed into the adhesive laminating market
- The limitations of 1- and 3-layer films are barrier, stiffness and heat seal properties

5-Layer Films

- Offer more options and flexibility than 3-layer films
  - Most typically as a barrier film with an EVOH core layer or a PA/EHOH/PA outer skin



Cereal liner, lidding & tube stock, meat packaging, medical devices (fin or lap seal)



Frozen food packaging (fin seal)

5-Layer Film Line

- 5-layer films eliminate the need for the secondary step of adhesive lamination (of simple structures)
- The modulii of laminated oriented PA, PP or PET films are similar ro unoriented polyamide coex blown films [6]
- 5 extruders in (more or less) a semi-circle
- Big improvement over 3-layer films, but limited in performance compared to 7, 9, 11-layers

Photo courtesy Hosakawa Alpine

7-Layer Films – Cost reduction

- 7-layer structures can utilize a lower-cost LLDPE in the second layer and an expensive, high-performance metallocene LLDPE as the skin layer, which has superior hot tack and heat seal properties.
- [mLL / LL / Tie / EVOH / Tie / LL / mLL] optimizes performance and cost, and is used for milk packaging [4]
- Basically a cost reduction analog to the 5-layer structure previously shown.

7-Layer Films – Improved Barrier/Strength Properties

- If improved barrier properties and toughness are required in the finished product, the following structure is applicable and can be made with a 7-layer die

  [LL / Tie / Nylon / EVOH / Nylon / Tie / mLL]

- This structure is used as a lidding film with excellent barrier properties and gloss.
- Flexibility is controlled with thickness
- The metallocene PE layer can be anymPE, such as POP, etc.

7-Layer Films – Thermoform Fill Seal Trays

- Substituting the mLLDPE with EVA is used in a thermoformable cheese tray
- The point made here is that more layers offers the package designer more options
- Thought to be about 100 7-layer lines in use today

9-Layer Films – Semi-Rigid Barrier Structure

- 9-layer rigid, high barrier structure using cost/ performance optimized PE resins
- The thickness of the nylon layers control modulus
- Similar to the 7-layer structure except that the skin layers can be split into two to optimize cost and performance for a particular application
- Frozen foods, stand -up pouches, thermoform-fill-seal
- Approximately 50 9-layer lines are reported to be in use today

11-Layer Films

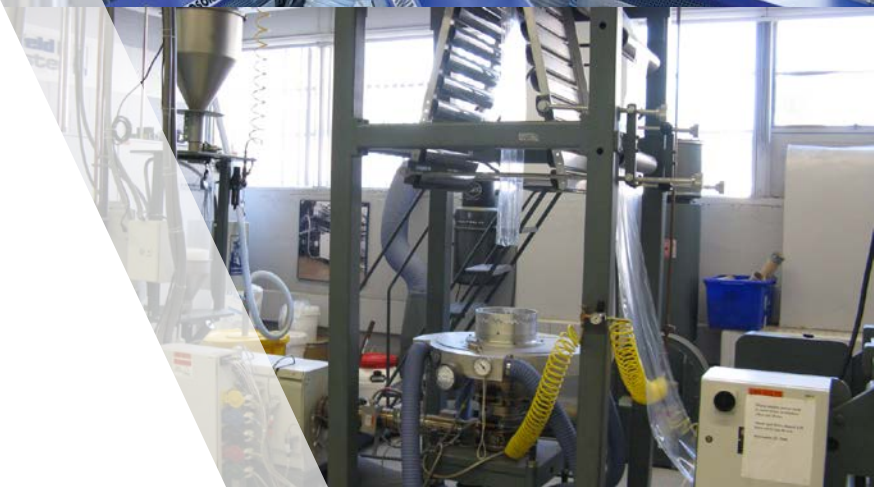
- 11-layer retortable, high-barrier structure using cost/performance optimized PP and copolymer PP resins
- Sous-vide cooking is all the rage today
- Sous-vide is slow cooking (up to 96 hours) at low temperatures (55-60°C) in a hermetically sealed bag
- 11-layers appears to give the converter & R&D specialist the ultimate in flexibility to optimize barrier, rigidity, heat seal properties and cost.

11-Layer Hosakawa Alpine Coex Line (UML)

11-layer vs 5 layer vs monolayer

- Repairs become more challenging than on 11-layer lines vs 1/3/5-layer lines

- At some point there will be diminishing returns at which the cost, complexity, and maintenance of more extruders limits further development



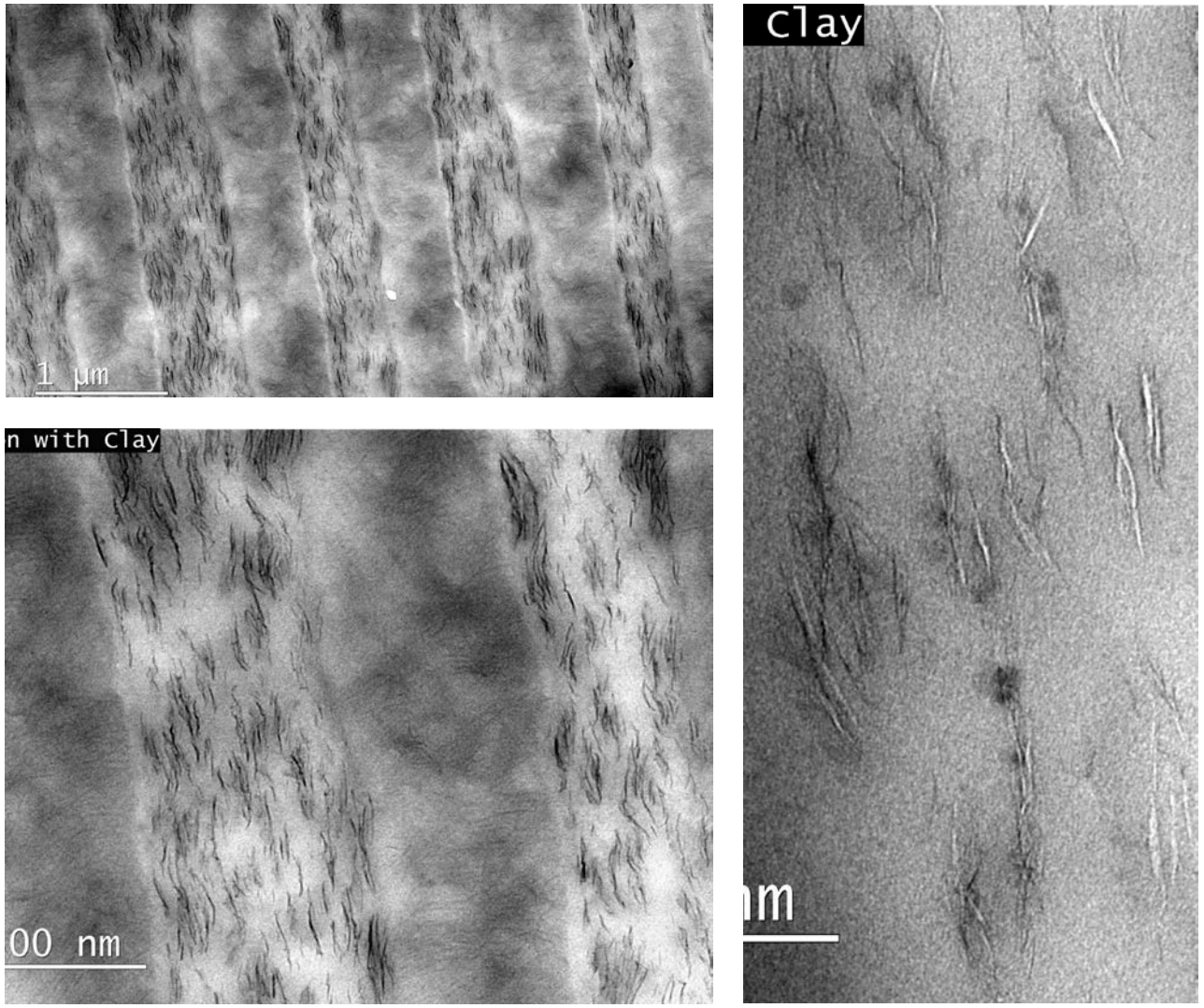
The Next Generation

- While it is not possible to predict the future, at some point simply adding more extruders into bigger and bigger dies becomes unfeasible.
- Layer splitting technology is common now in flat film dies
- BBS Technologies has developed a nano-layer blown film die (US Patent # 8870561)
- True nanolayers in a 77-layer structure

Photo by Tom Bezigian

Photomicrographs of nanoclay-filled mPE at 1µ, 500 nm, and 200 nm

- These are photos of a 77-layer polyolefin/polyamide coextrusion
- The benefits of this die are:
  - Greater strength and modulus due to increased BUR capability (5:1)
  - Improved barrier properties, which effectively halves the amount of polyamide required while retaining stiffness



Photomicrographs courtesy of Alpha Marathon Extrusion, Toronto

Thank you for your attention

Disclaimer: The author has no business affiliation and has received no compensation from any company or product shown in this presentation.

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