

# Thermoforming Enhancement With Cyclic Olefin Copolymers

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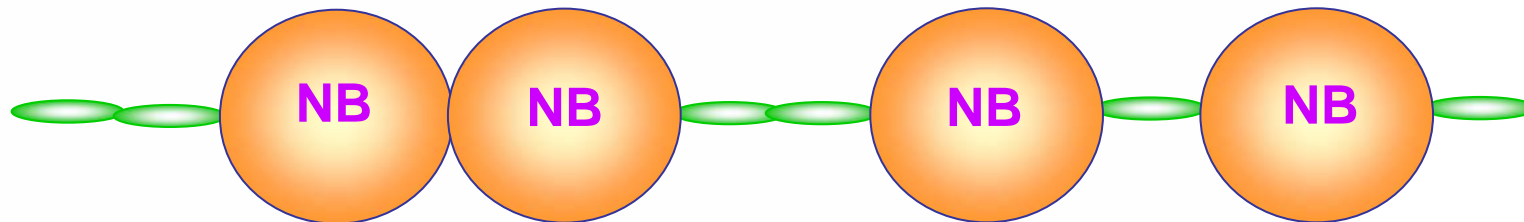
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# What Are Cyclic Olefin Copolymers (COC)?



The cyclic olefin copolymer (COC) molecule is a linear chain of small CH<sub>2</sub>-CH<sub>2</sub> links randomly interspersed with large bridged ring elements

It cannot fold up to make a regular structure, i.e., a crystallite



COC has no crystalline melting point, but only a glass transition temperature,  $T_g$ , at which the polymer goes from “glassy” to “rubbery” behavior

# TOPAS® COC – Value Proposition

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- Amorphous Olefin
  - Dimensional Stability
  - High Transparency
  - Water & Alcohol Barrier
  - Compatibility
  - Heat Resistance
- Broad thermoforming window
  - Little shrinkage & snapback; less overall variation in gauge distribution
  - Clear product; facilitate inspection
  - Satisfies new, unmet needs
  - Enhances polyolefin formability, enabling downgauging & use of low cost materials
  - Impart temperature resistance to polyolefins

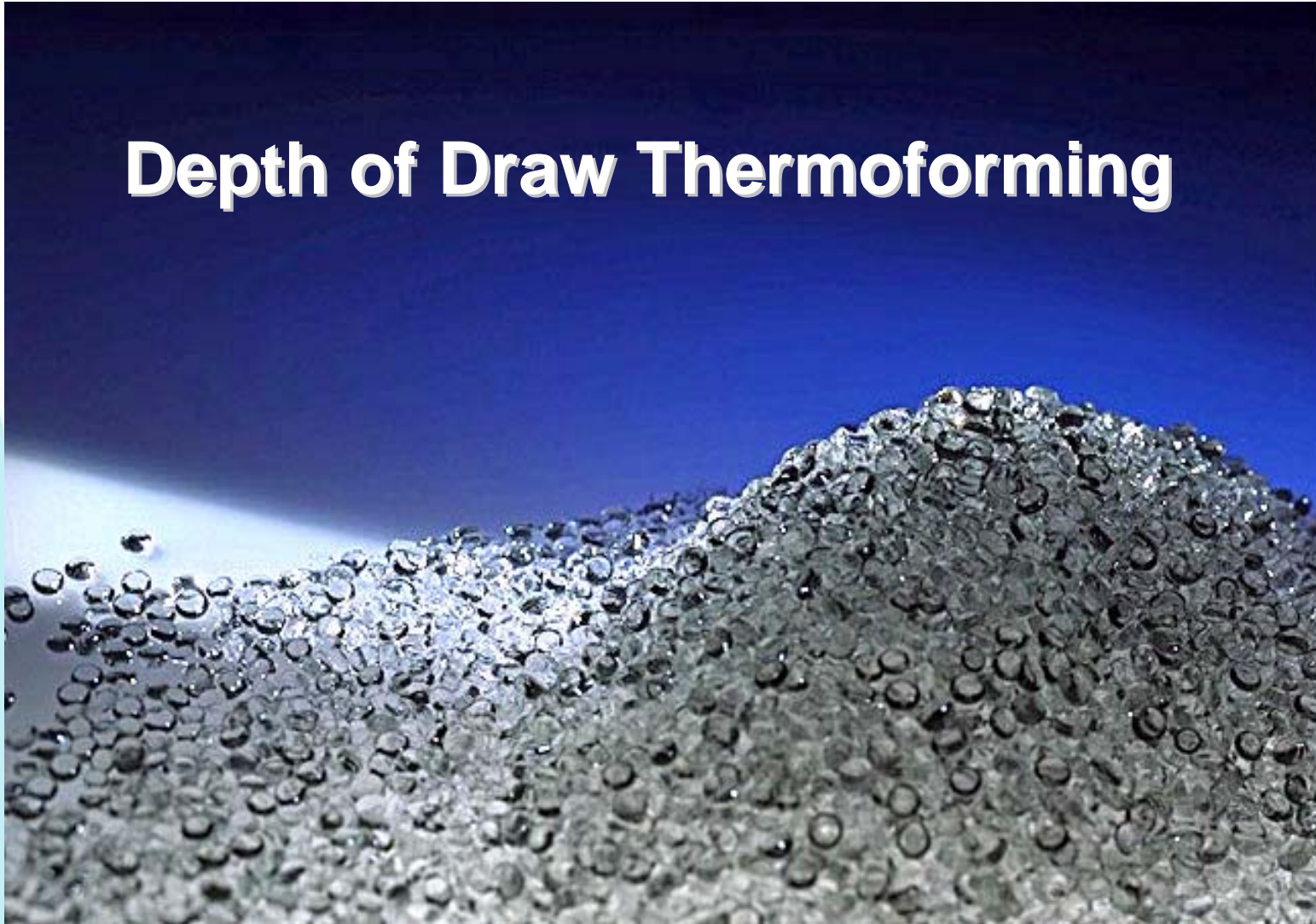
# TOPICS

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- **Depth of Draw Thermoforming**
- **Monolayer vs. Discrete Layer Forming Films**

# Depth of Draw Thermoforming



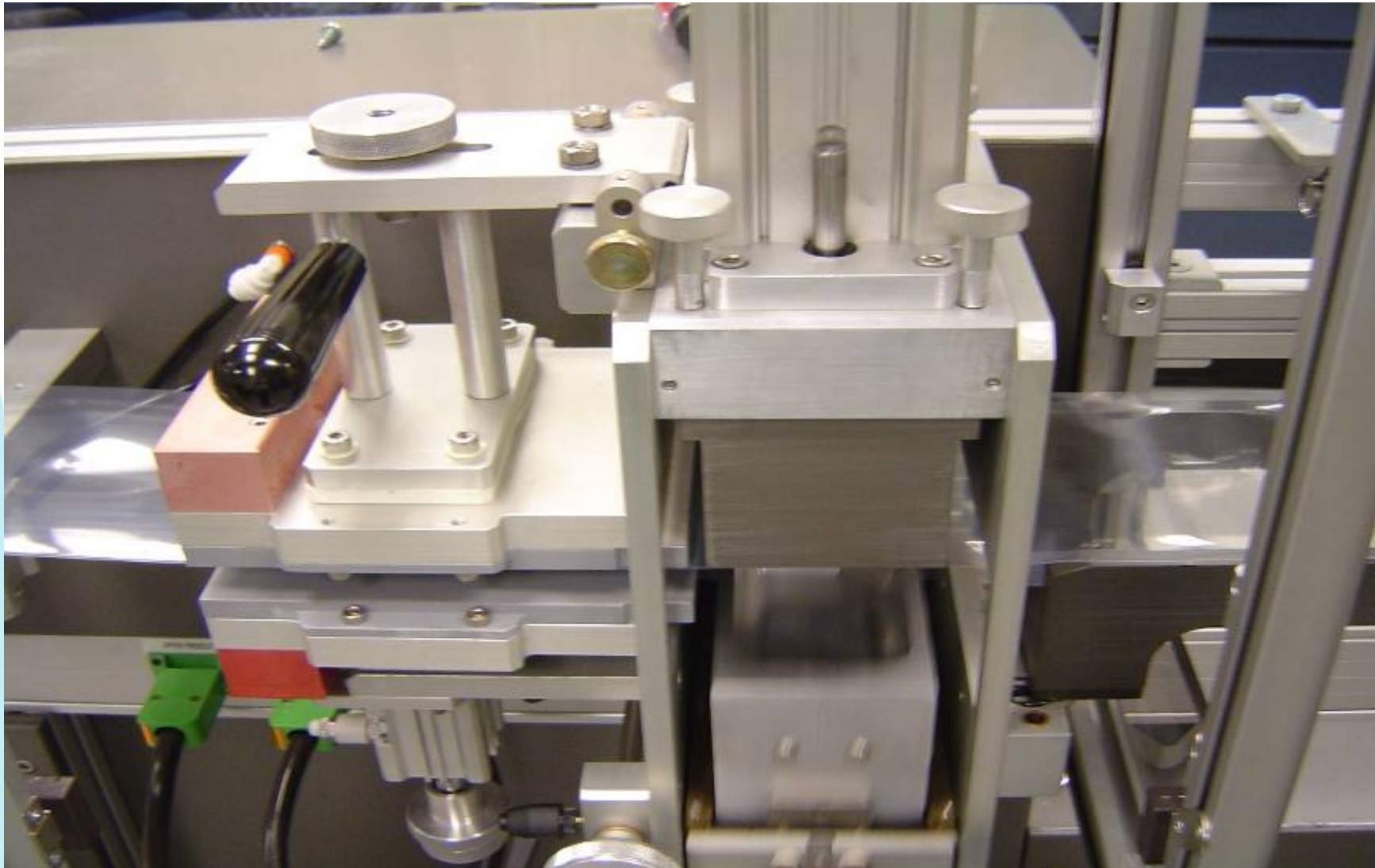
# Outline

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- **Forming Methodology**
- **Film Structures**
- **Thermoforming Properties:**
  - ▶ **Volume Retention**
  - ▶ **Gauge Distribution**
  - ▶ **Bottom Thickness**
  - ▶ **Corner Thickness**
  - ▶ **“Slow” Puncture Resistance**
  - ▶ **“Slow” Puncture Energy**
- **Benefits & Conclusions**

# Macron Thermoforming Machine



# Variable Depth Forming Tool



# Material Stretching Parameters



## ■ Depth of Draw

- ▶ Distance Or Height Between The Top And Bottom Of The Forming Tool

## ■ Areal Draw Ratio

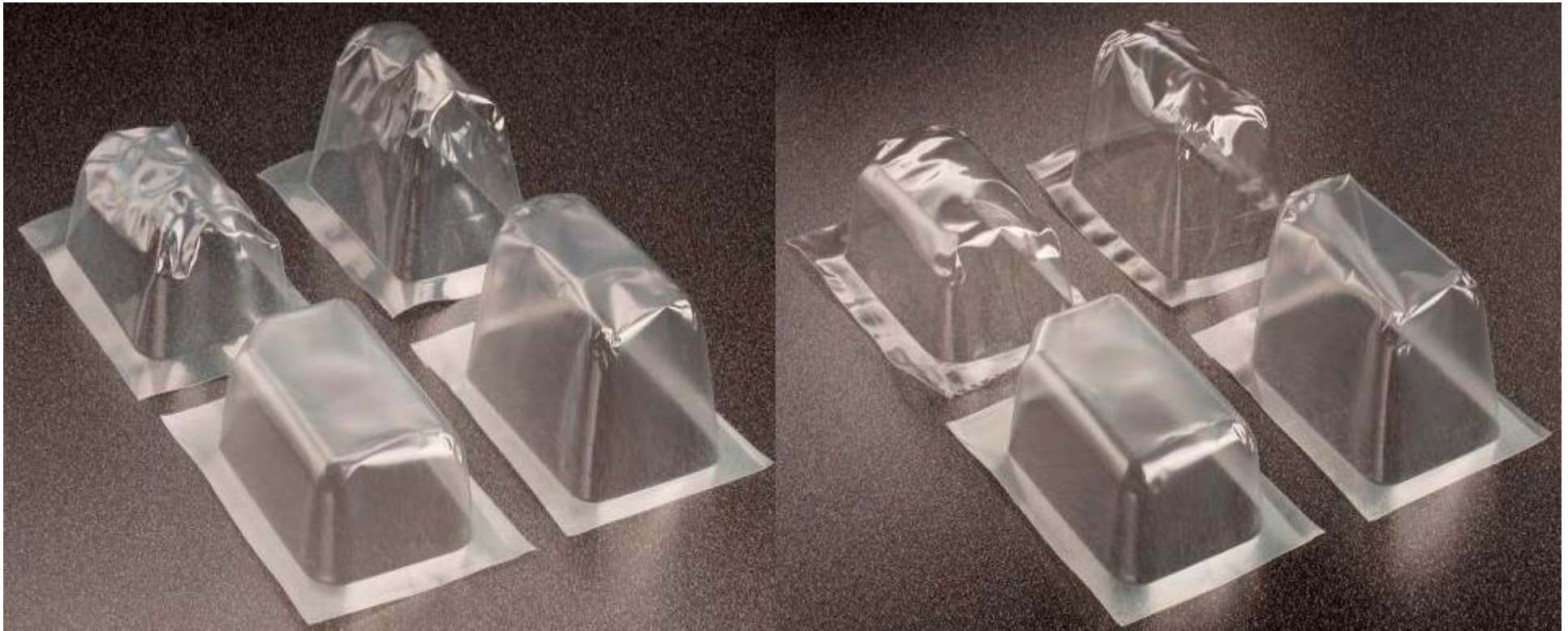
- ▶ The Ratio Of The Surface Area Of The Formed Part To The Available Surface Area Of The Unformed Film Or Sheet
- ▶ Available Surface Area Is Usually Defined By The Open Perimeter Of The Forming Tool

# Film Structures (6-mil)



- **“o-LLDPE” (0.920 g/cc; 1.0 dg/min)**
- **“o-LLDPE + 30% 8007F-04” (Monolayer Blend)**
- **“E / I / E (25 / 50 / 25)” (EVA / Ionomer / EVA)**
- **“E / I / E (7.5 / 85 / 7.5)” (EVA / Ionomer / EVA)**
- **“8007-F400” (COC; tg=80°C; 1.02 g/cc; 1.8 dg/min)**
- **“9506X5” (COC; tg=68°C; 1.02 dg/cc; 0.9 dg/min)**

# Depth of Draw Forming Examples



**o-LLDPE vs. o-LLDPE+30% COC E/I/E (25/50/25) vs. o-LLDPE+30% COC  
1.0-inch vs. 1.50-inch Depth of Draw**

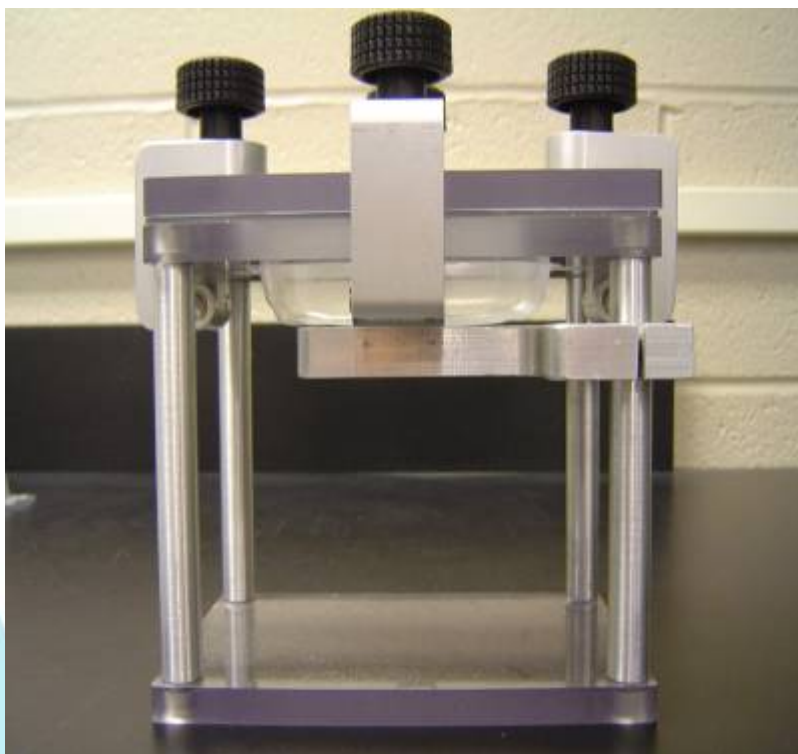
# Formed Cavity Testing

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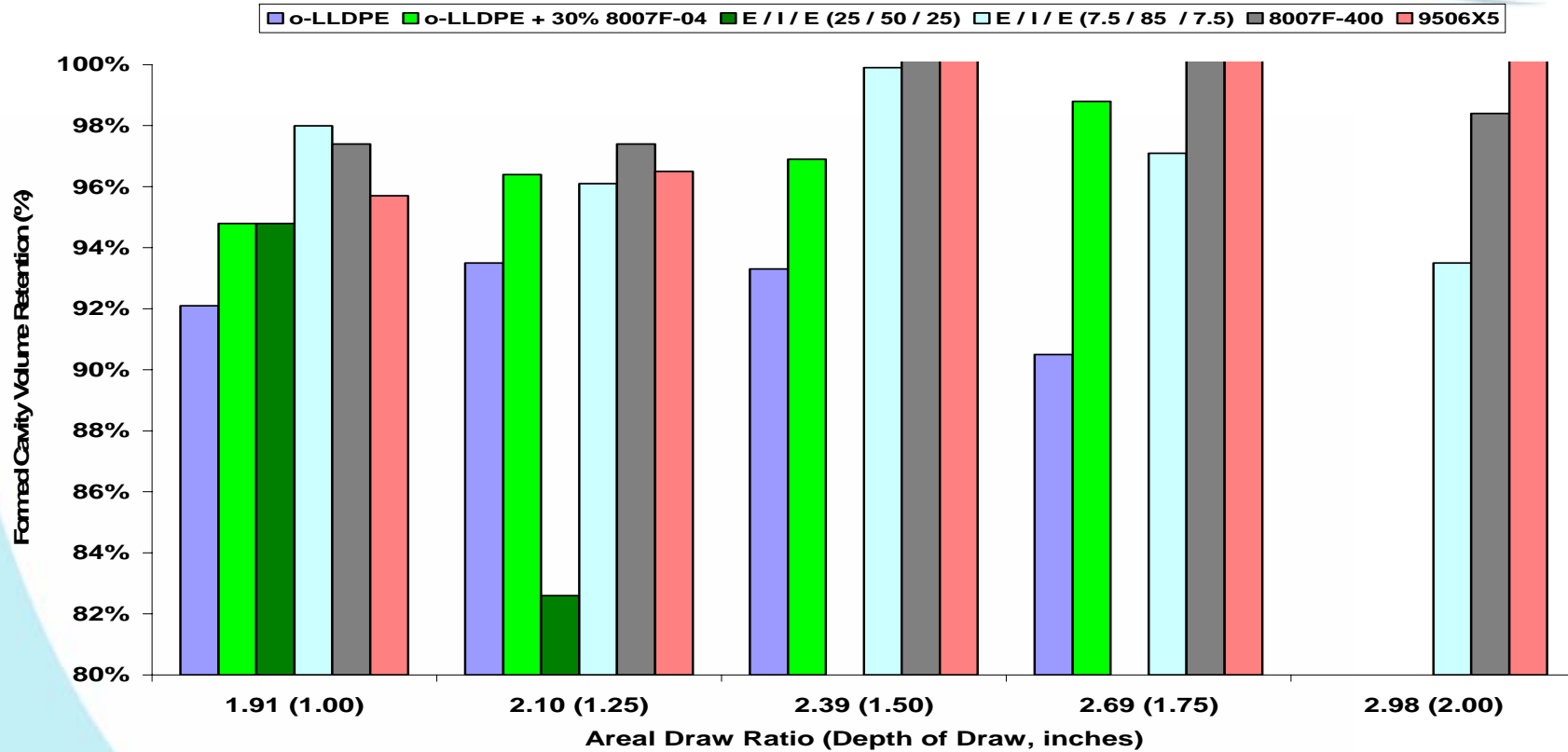
- **Volume Retention, TOPAS® Method**
- **Gauge Distribution via Coefficient of Variation, ASTM D374**
- **Bottom Thickness, ASTM D374**
- **Corner Thickness, ASTM D374**
- **Bottom “Slow” Puncture Resistance, ASTM F1306**
- **Bottom “Slow” Puncture Energy, ASTM F1306**

## Cavity Support Tool: Volume Retention



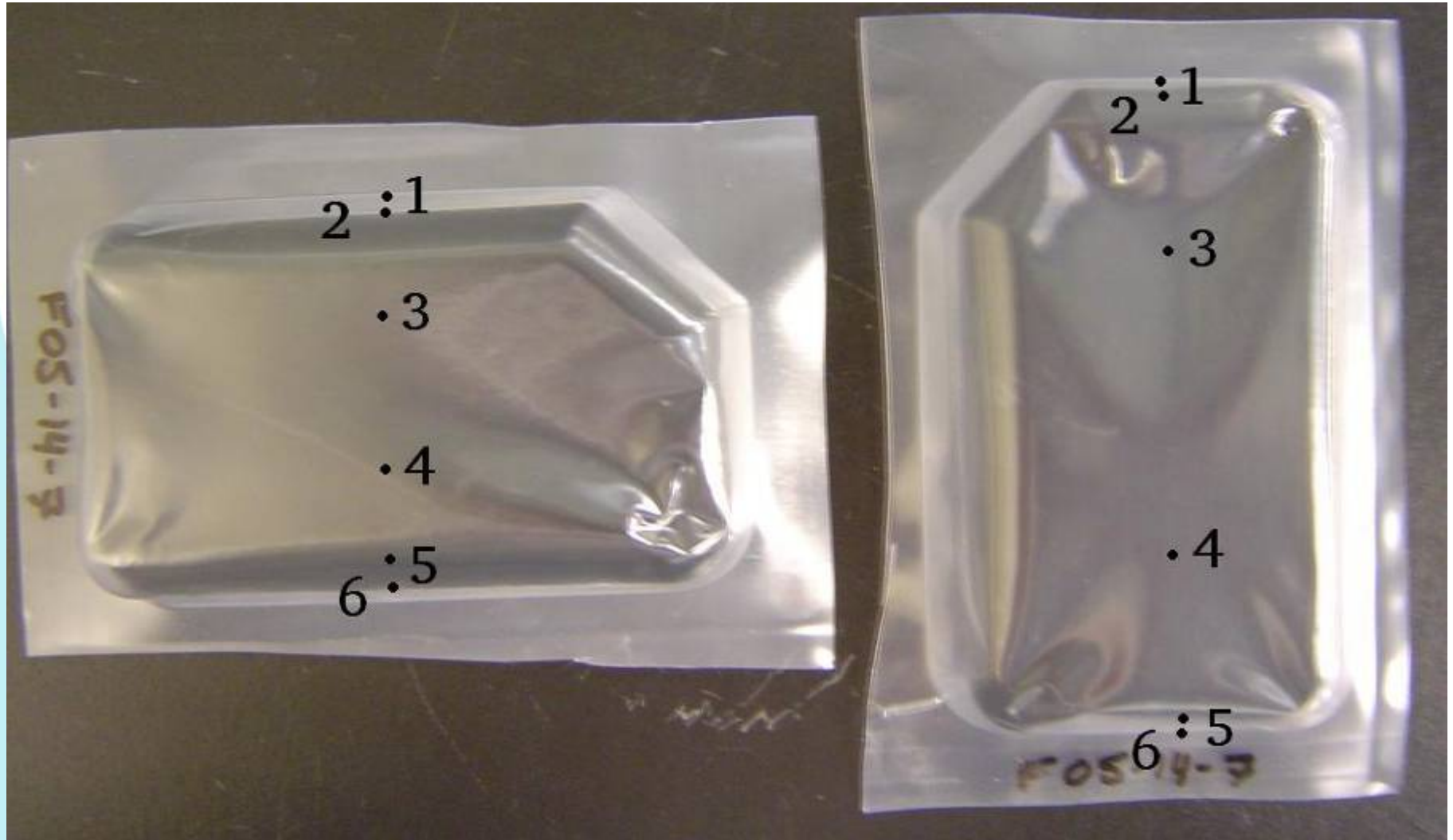
**Adjustable Support Can Accommodate Multiple Cavity Depths  
Fill the Secured Cavity with Water and Measure Its Volume**

# Formed Cavity: Volume Retention

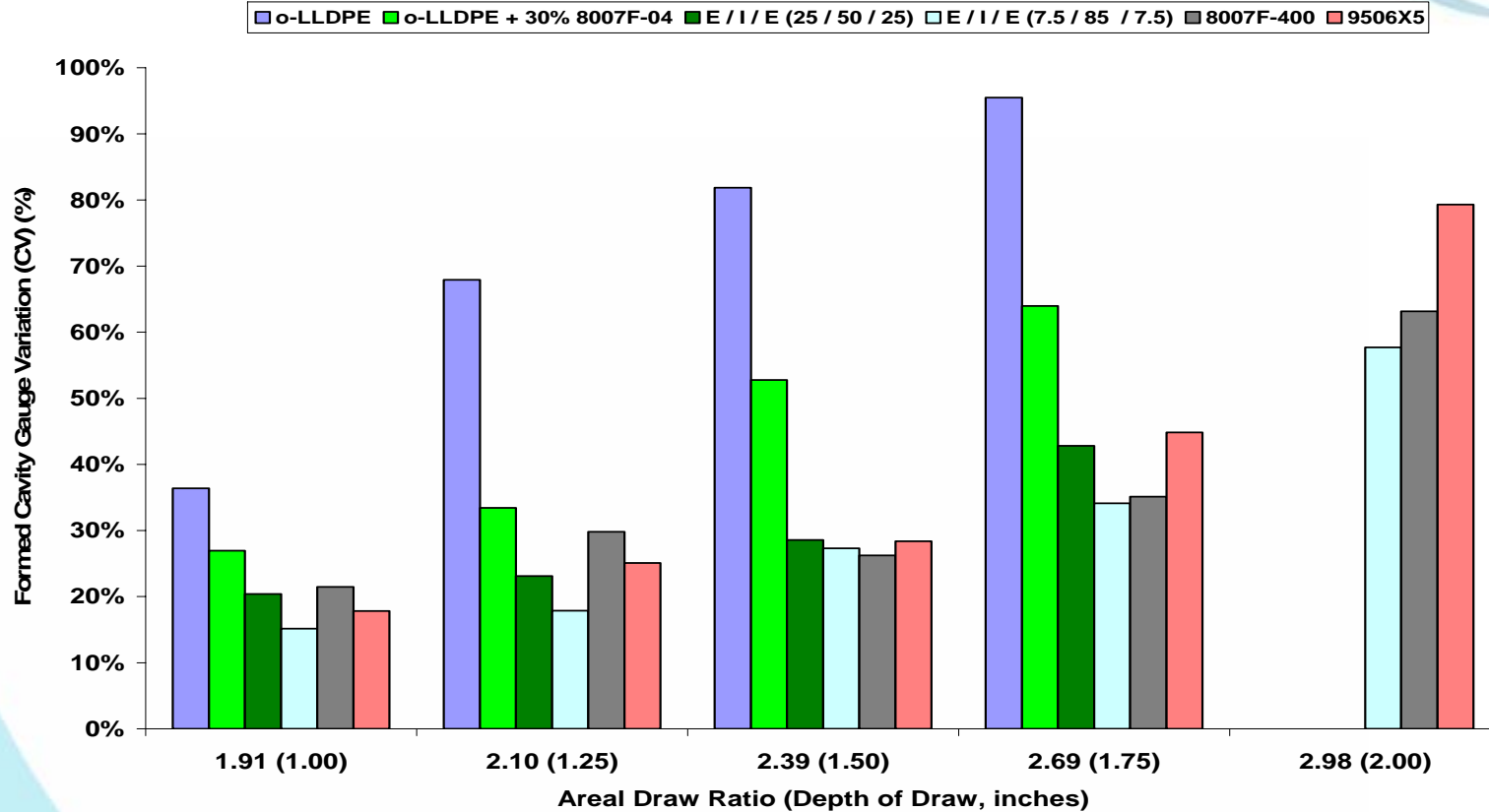


**COC Reduces Snapback Or Shrinkage Of LLDPE Films**  
**Softer Films Distorted Excessively; No Measurement**  
**COC Films Have Little Or No Snapback**

# Gauge Locations in MD and TD

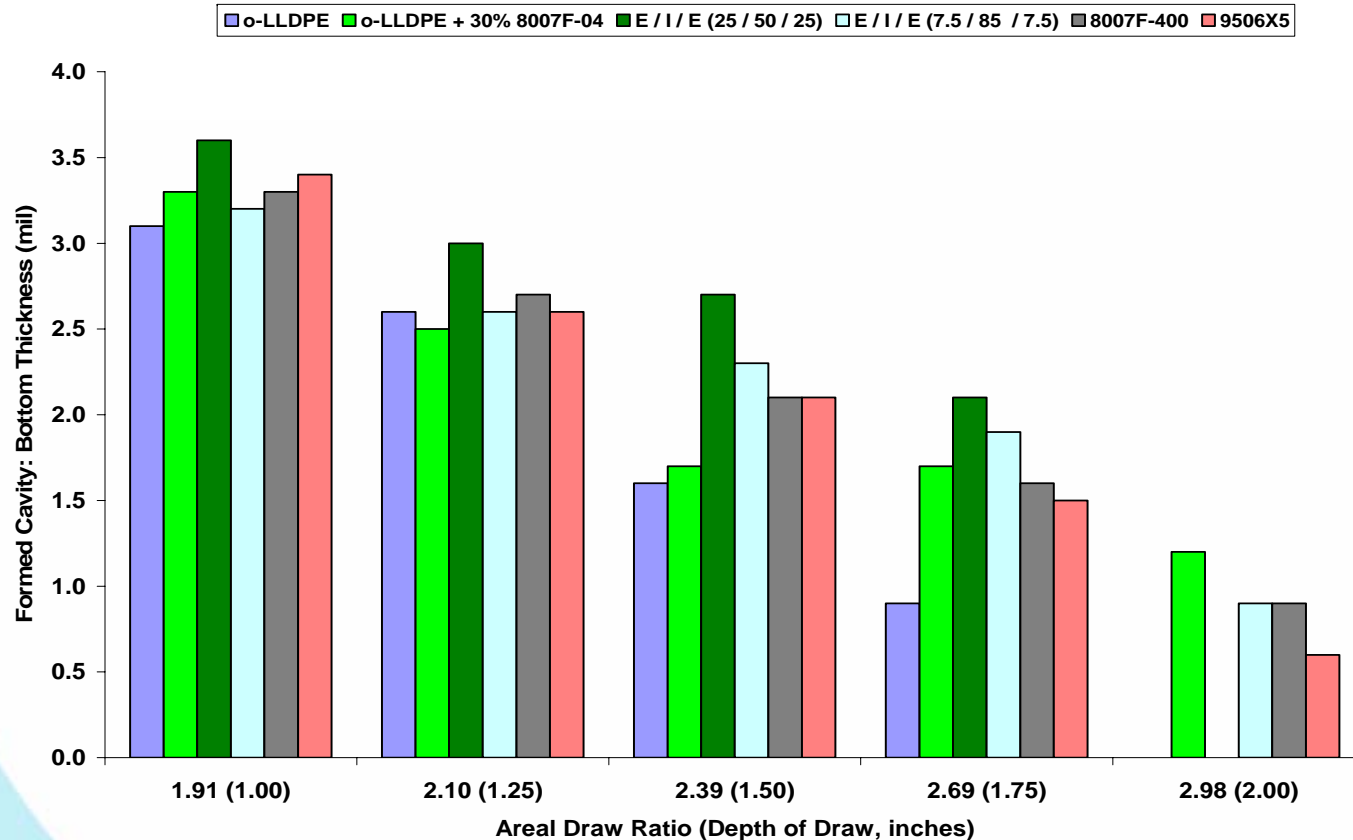


# Formed Cavity: Gauge Variation (CV)



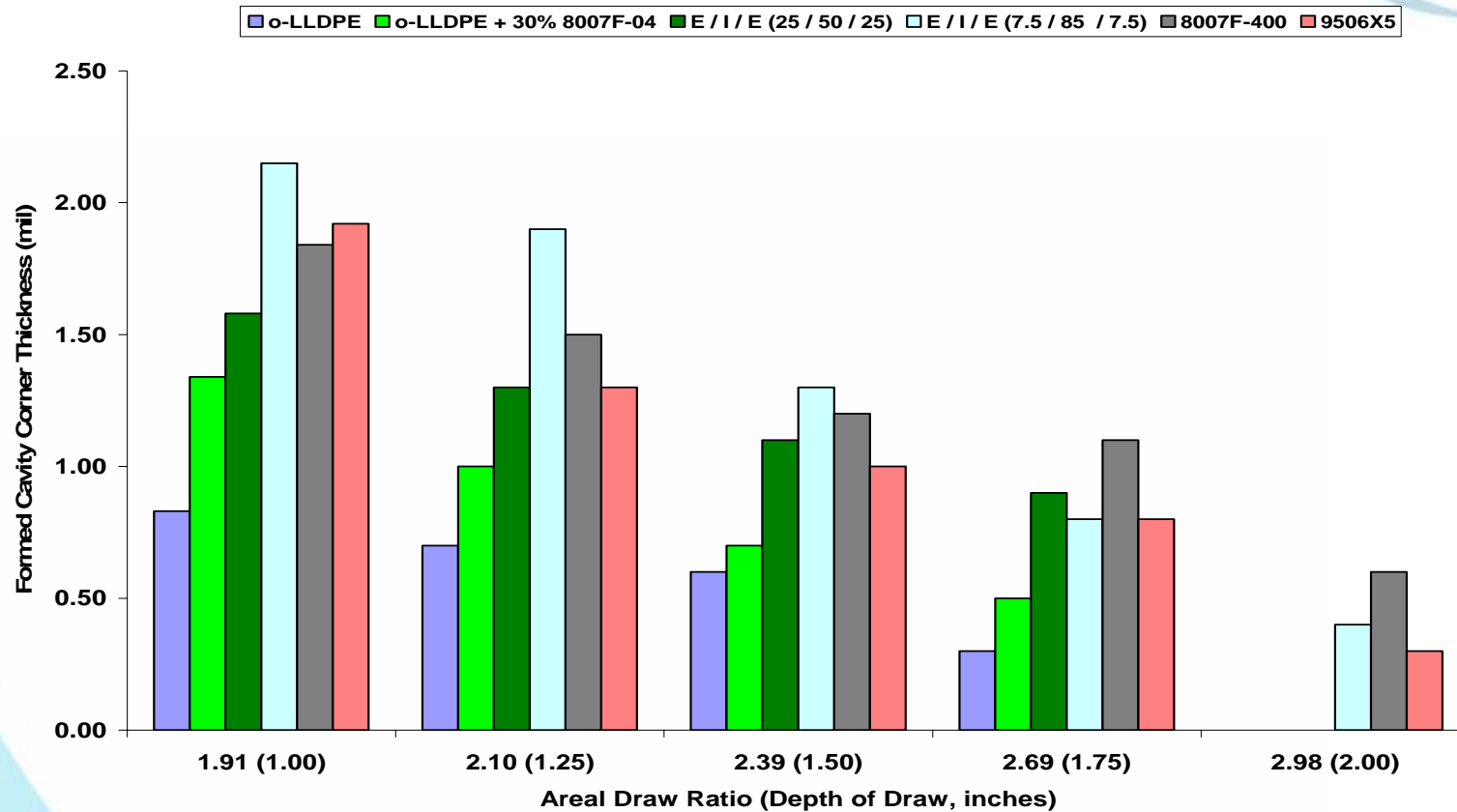
**Ionomeric Films Have Low Gauge Variation**  
**COCs In LLDPE Significantly Reduces Gauge Variation**  
**COCs & Ionomeric Films Have Similar Performance**

# Formed Cavity: Bottom Thickness



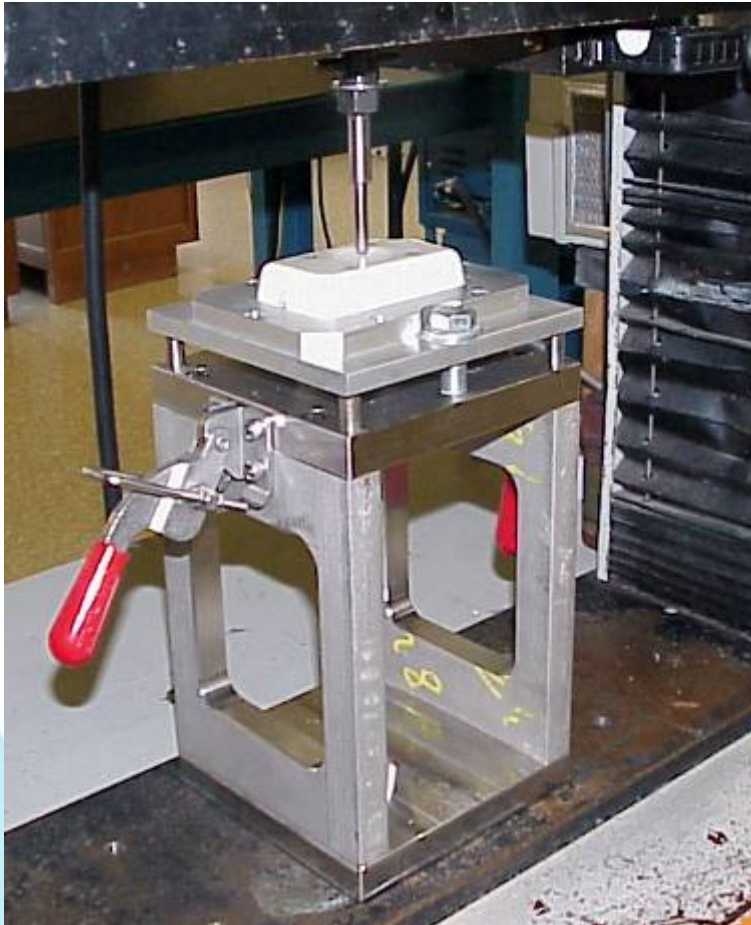
**Equivalent to Average Gauge of Formed Cavity**  
**COCs In LLDPE Increase Bottom Thickness At High Draw Ratios**  
**Ionomeric Films Are Thickest Across Most Draw Ratios**

# Formed Cavity: Corner Thickness



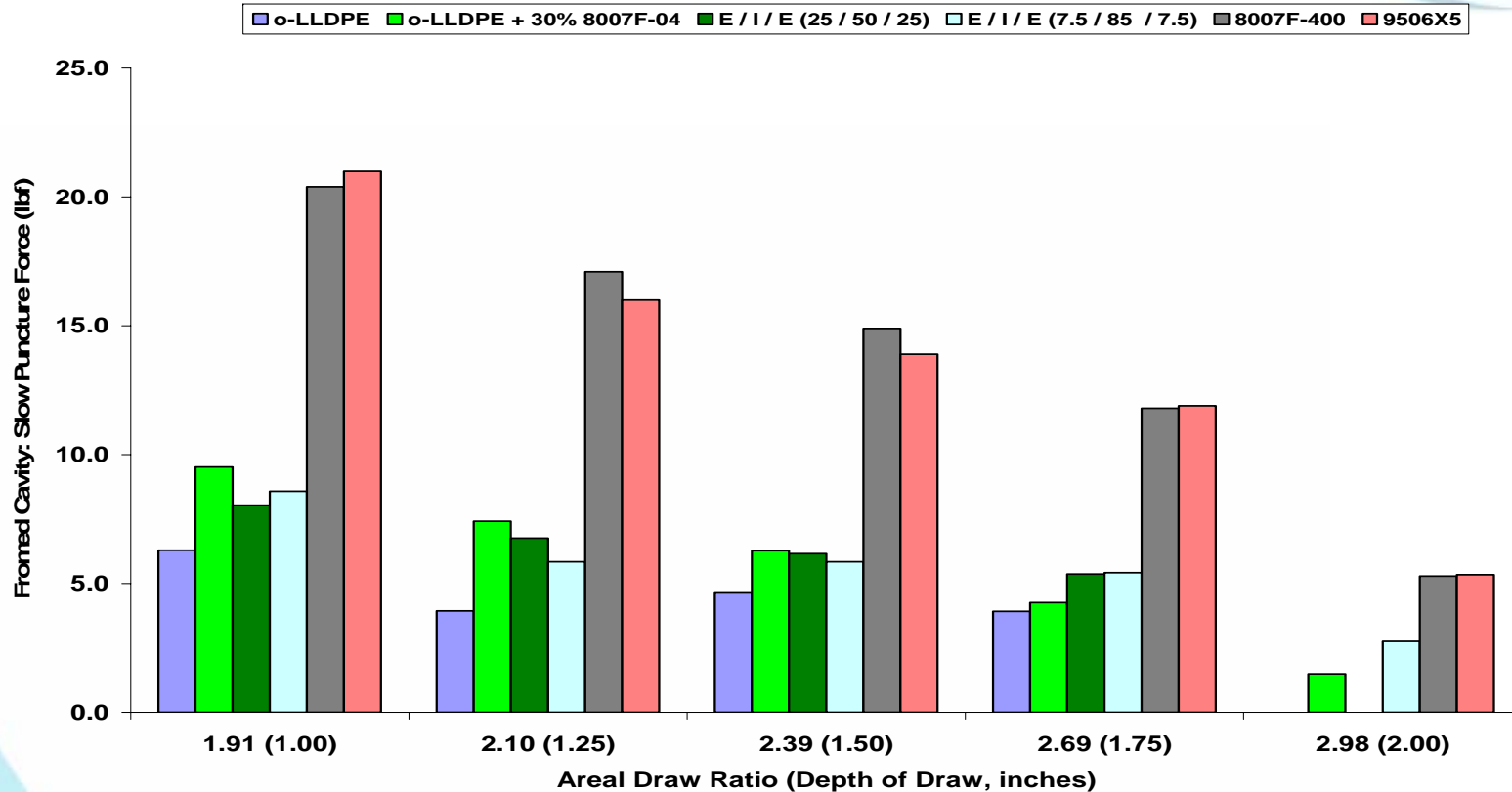
**Ionomeric Films Have Excellent Corner Thickness**  
**COCs In LLDPE Increase Corner Thickness At Most Ratios**  
**COC Is Superior To Ionomer At High Draw Ratios**

# Cavity Puncture Tool: Bottom & Corner



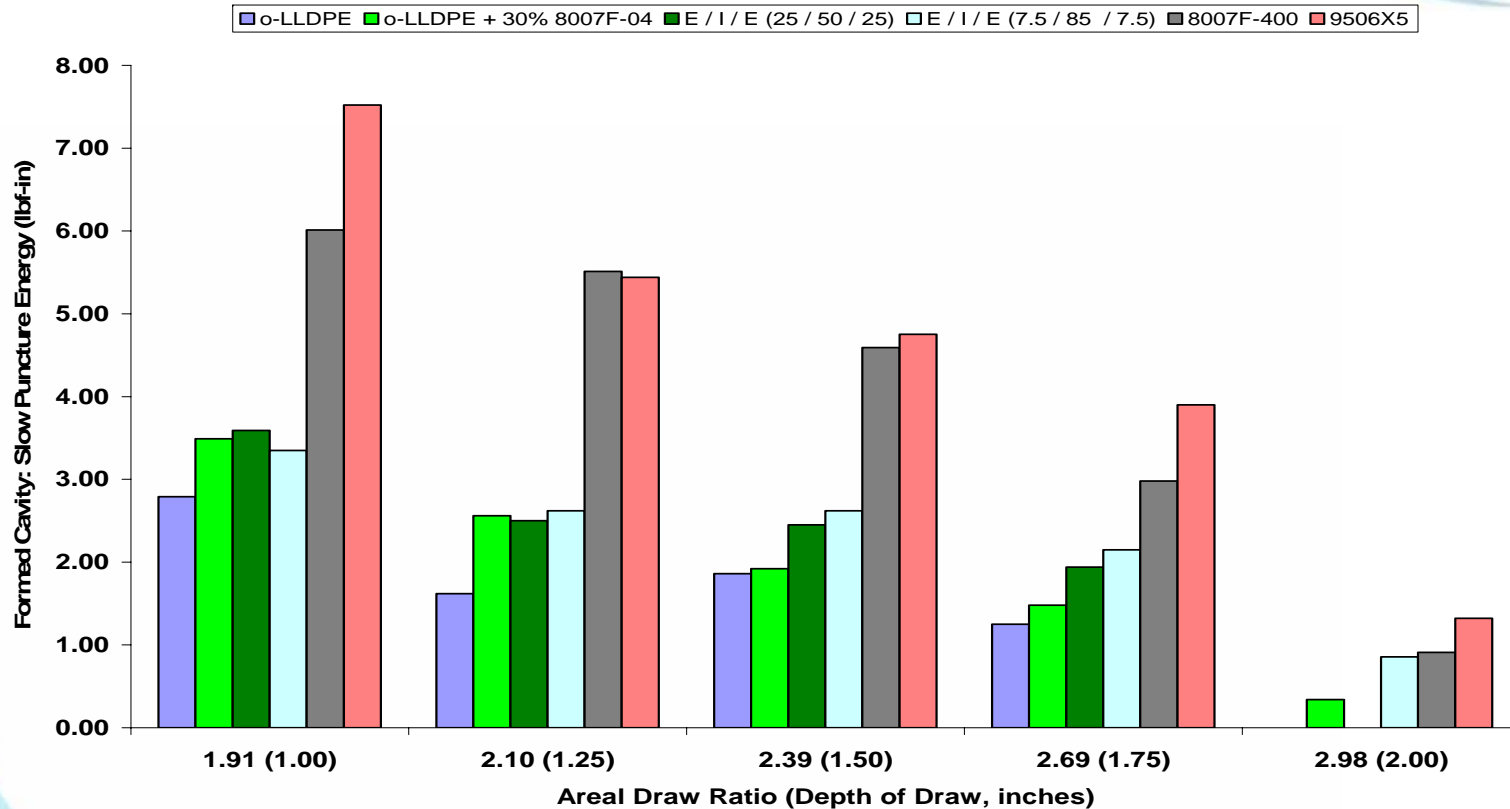
**Flexible Tool Configuration Enables Accurate Measurement of Puncture Resistance of Formed Cavities**

# Formed Cavity: Puncture Force



**COCs Offer Superior Puncture Resistance vs. Ionomer  
COCs Enhance Puncture Resistance of LLDPE Across  
Range of Areal Draw Ratios**

# Formed Cavity: Puncture Energy



**COCs Offer Superior Toughness vs. Ionomer**  
**COC Enhances Toughness of Thermoformed LLDPE**  
**COC Enhances Draw Depth Capacity of Forming Films**

# COC Benefits For Forming Films

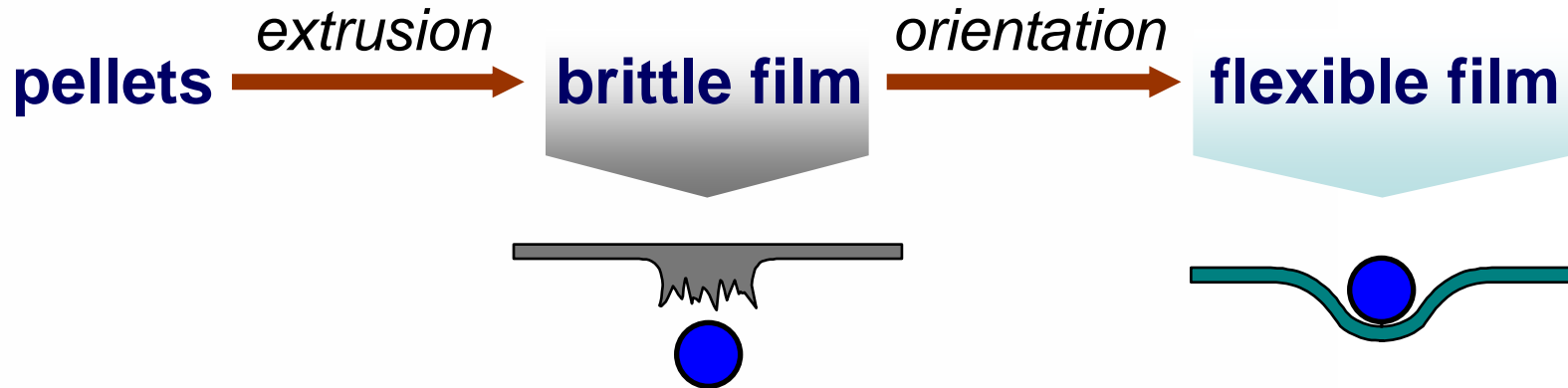
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- **Improve Thermoformability & Enhance Package Integrity with Less Gauge Variation & Good Dimensional Stability**
- **Enable Downgauging to Reduce Material Cost**
- **Improve Most Physical Properties, Including Stiffness, Strength, Impact Resistance & Optics**
- **Apparently, COC Benefits From Orientation During Forming More Than Other Polyolefins**

**Any questions?**

# Oriented COC Films



<i><b>Mechanical Properties</b></i>	<i><b>unoriented</b></i>	<i><b>oriented</b></i>	<i><b>» Factor</b></i>
Modulus of elast. (N/mm <sup>2</sup> )	2100-2200	2800-3800	×1.5
Tensile strength (N/mm <sup>2</sup> )	50-60	100-180	×2.5
Elongation at break (%)	3-5	50-100	×20

# Monolayer vs. Discrete Layer Forming Films

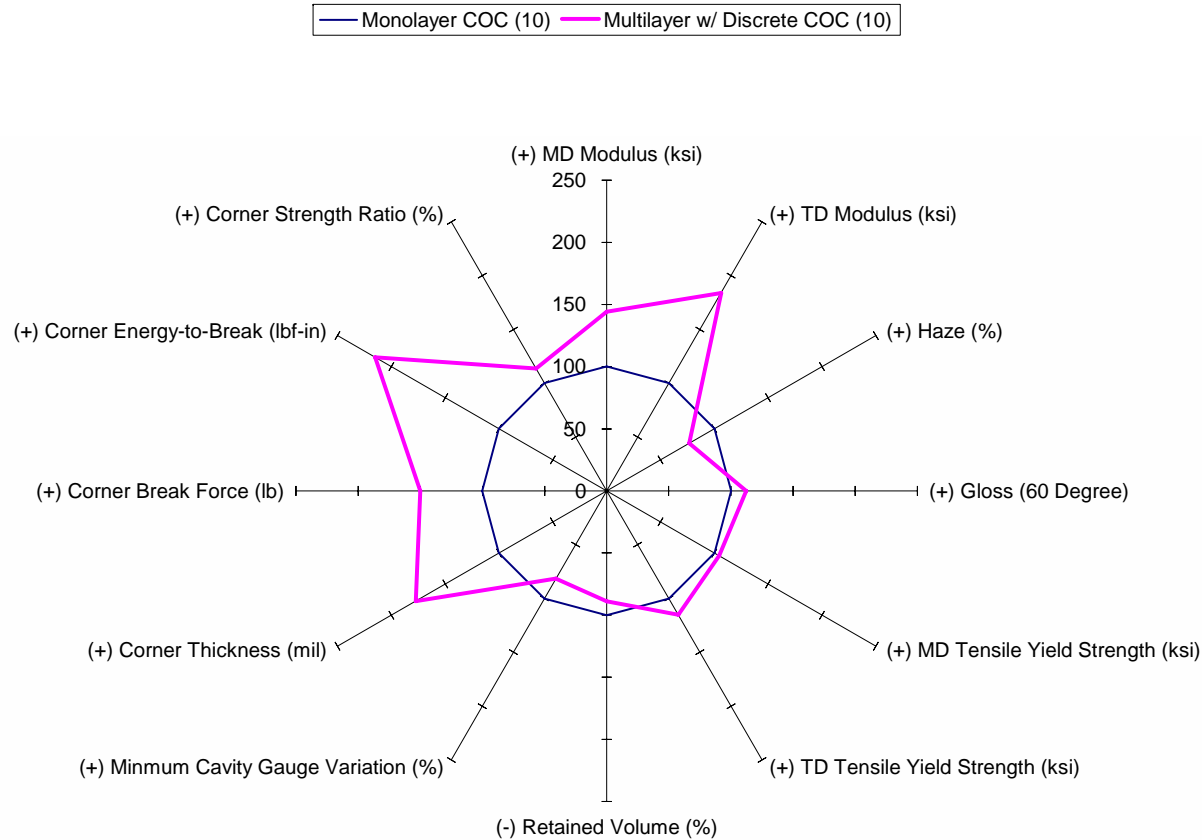


# Comparative Forming Film Structures



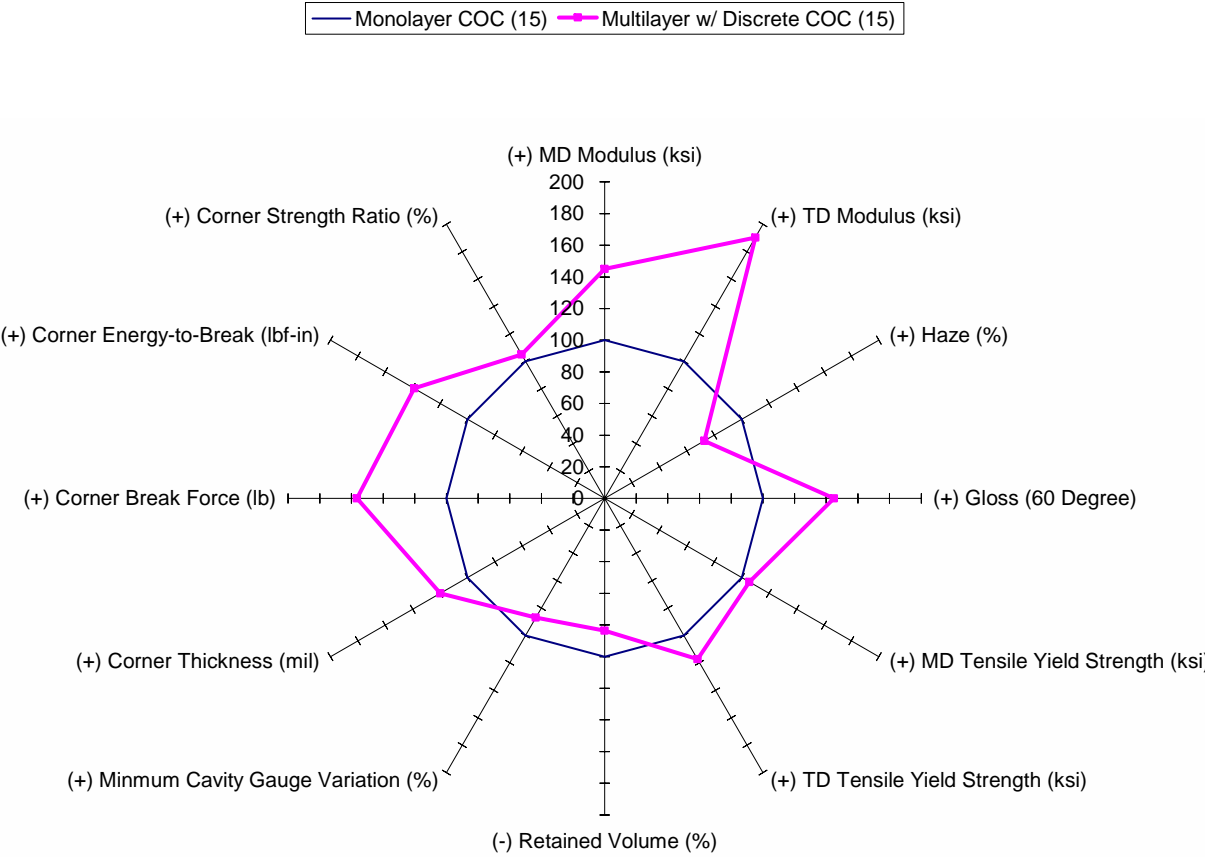
COC	Monolayer	Multilayer
10	90% o-LLDPE (0.920 g/cc, 1.0 dg/min) 10% TOPAS 8007	A: 44.5% (2.7 mil) o-LLDPE B:11% (0.6 mil) 100% TOPAS 8007 A: 44.5% (2.7 mil) o-LLDPE
15	85% o-LLDPE (0.920 g/cc, 1.0 dg/min) 15% TOPAS 8007	A: 42.5% (2.55 mil) o-LLDPE B:15% (0.9 mil) 100% TOPAS 8007 A: 42.5% (2.55 mil) o-LLDPE
20	80% o-LLDPE (0.920 g/cc, 1.0 dg/min) 20% TOPAS 8007	A: 40% (2.40 mil) o-LLDPE B:20% (1.2 mil) 100% TOPAS 8007 A: 40% (2.40 mil) o-LLDPE

# 6-mil Monolayer Blend vs. Multilayer Discrete



**10% COC Discrete Layer Construction Offers  
Improvement to Most Properties  
Best Enhancement: Formed Tray Corner Puncture**

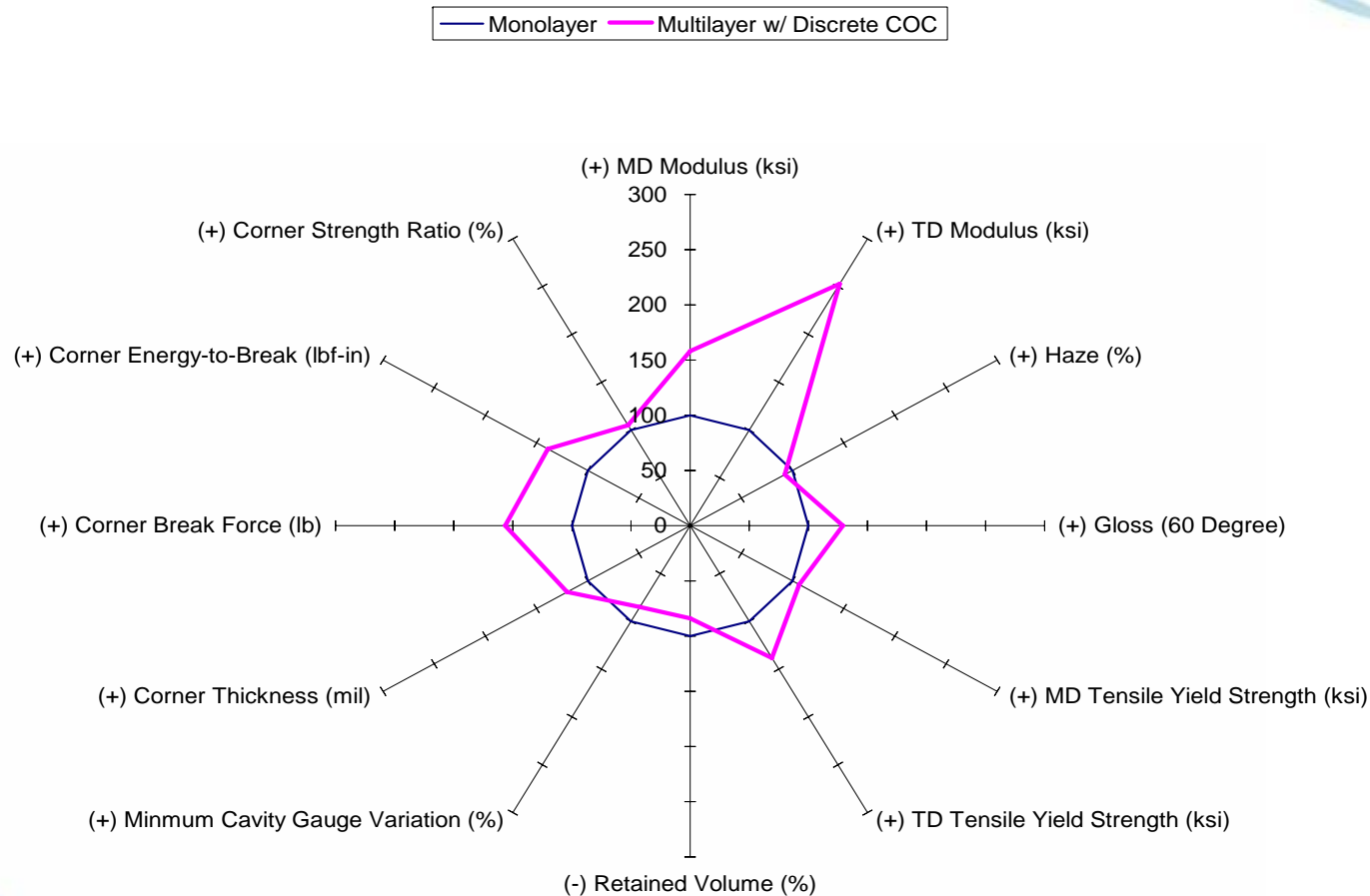
# 6-mil Monolayer Blend vs. Multilayer Discrete



**15% COC Discrete Layer Construction Offers Improvement to Most Properties**  
**Best Enhancements: Modulus & Formed Tray Corner Puncture**



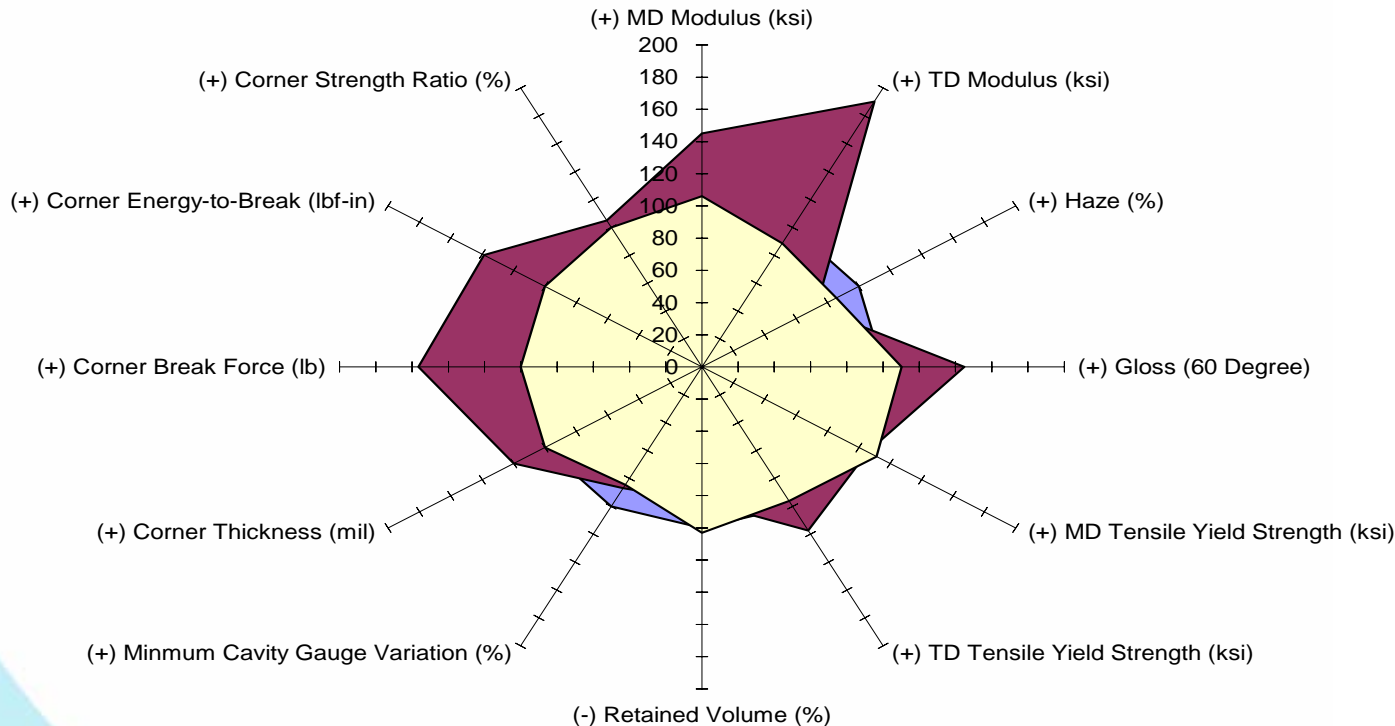
# 6-mil Monolayer Blend vs. Multilayer Discrete



**20% COC Discrete Layer Construction Offers Improvement to Most Properties**  
**Best Enhancements: Modulus & Formed Tray Corner Puncture**

# 20% COC Monolayer vs. 15% COC Multilayer

■ Monolayer COC (15) 
 ■ Multilayer w/ Discrete COC (15) 
 ■ Monolayer COC (20)



**15% COC Discrete Layer Construction Offers Improvement to Many Properties vs. 20% Monolayer Blend**  
**Best Enhancements: Modulus & Formed Tray Corner Puncture**

# Benefits For Films With Discrete COC Layers

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- **Flat Film Enhancements Include Stiffness, Strength and Optical Properties**
- **Formed Tray Enhancements Include Puncture Resistance, Corner Thickness & Reduced Gauge Variation, But Not Retained Volume**
- **Films With Discrete Layers of COC Can Reduce Material Cost Without Sacrificing Performance**
- **Films With Discrete Layers of COC Are Expected To Have Better Barrier Properties**

**Any questions?**

# Acknowledgments

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**TOPAS® Cyclic Olefin Copolymer (COC)**  
*Your Clear Advantage in Thermoforming.*

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