Testing Molded Fiber

BOB VERSLUYS

SENIOR TECHNICAL MANAGER

MOTUS LLC

Oct 7, 2026

Agenda


Formation
Conditioning Chamber
23°C
50%RH
Caliper / Density / GSM
2.35mm
Material Strength
Geometry Strength
Surface Roughness
Cobb
Porosity
WVTR
OTR
Oil Penetration
Blue Dye
Temp Tape

WHO WE ARE

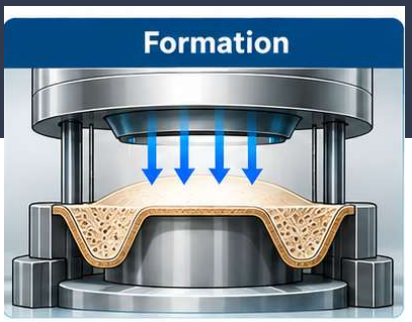
- Machine builder for the molded fiber industry located in Greenville, SC USA
  - Fiber molding equipment and tooling
  - Fiber coating equipment
  - Custom molded fiber solutions

motus
Form. Coat. Connect.

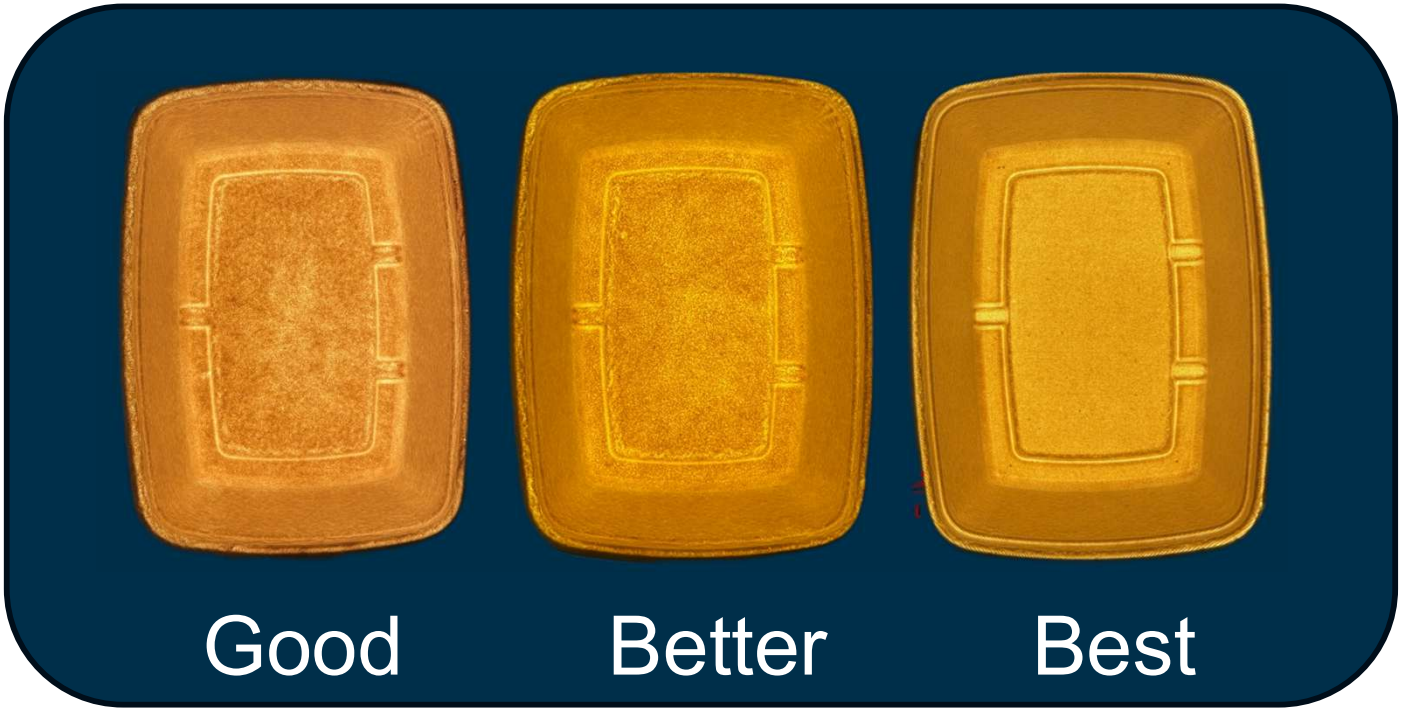
- Pilot facility
  - Pulp prep/refining
  - Two Molding lines (Pilot and Production Scale)
  - Pilot Coating line
  - Testing Laboratory

Our mission is be experts on all aspects of molded fiber so we can bring the most needed solutions to the market

Formation Light



- High-intensity backlighting reveals formation uniformity and defects
- Fast, visual comparison of fiber distribution across the part

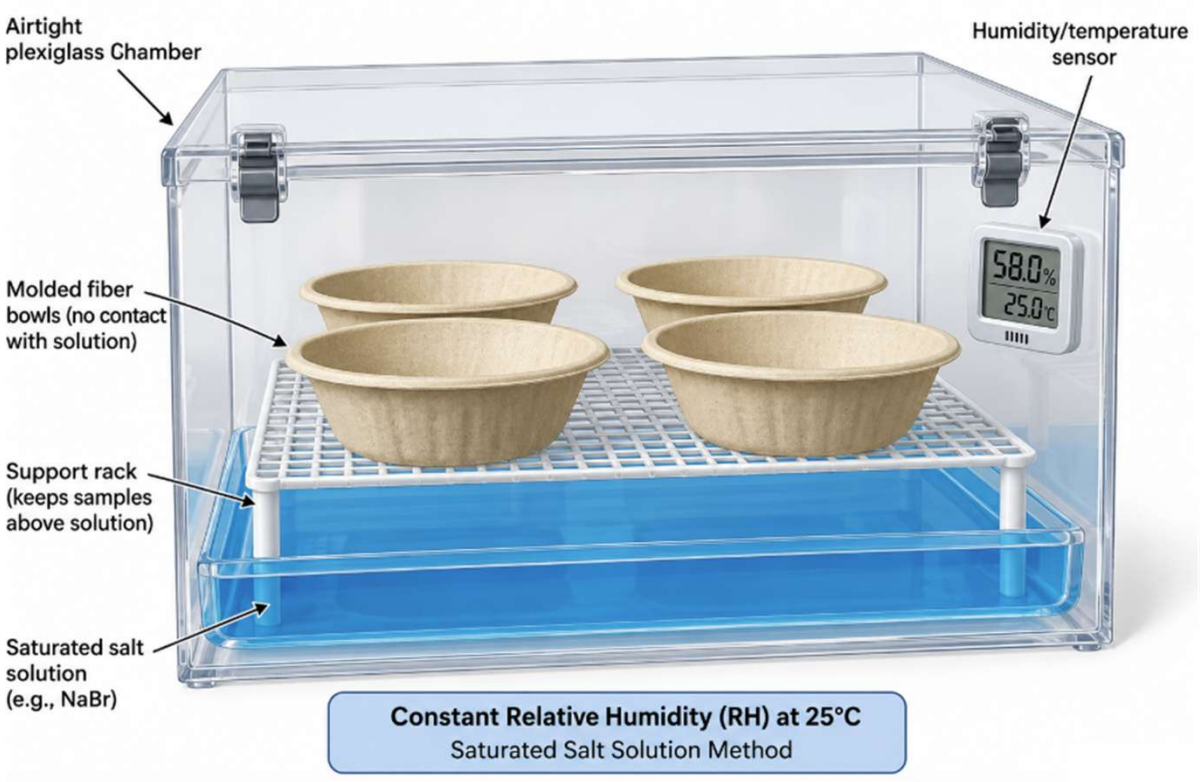


Conditioning Chamber

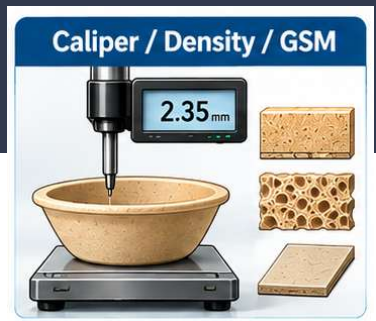


- TAPPI T402 recommends conditioning samples at 23°C / 50% RH to moisture equilibrium before testing
- Molded fiber properties are strongly moisture-dependent
- Small chambers provide a practical alternative to a CTCH room
- Saturated salt solutions provide controlled RH when temperature is stable

Saturated Salt (25°C)	Relative Humidity (% RH)
LiCl	11
CH_3COOK (Potassium acetate)	23
$MgCl_2$	33
K_2CO_3	43
NaBr	58
NaCl	75
KCl	84
KNO_3	93
K_2SO_4	97



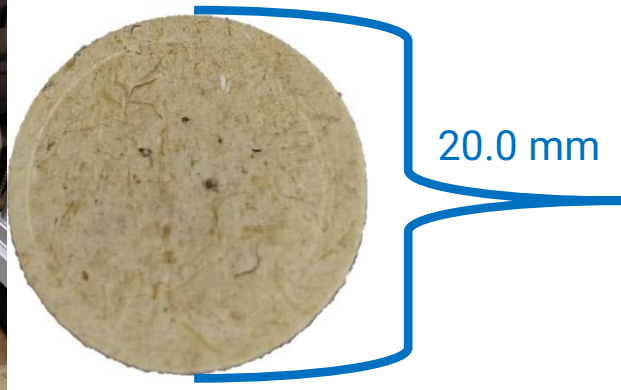
CALIPER/DENSITY/GSM



- Punch a 20 mm disc
- Measure mass and caliper to calculate local GSM and apparent density
- Small specimens map variation across bottoms, walls and other features
- Useful for diagnosing forming and pressing behavior







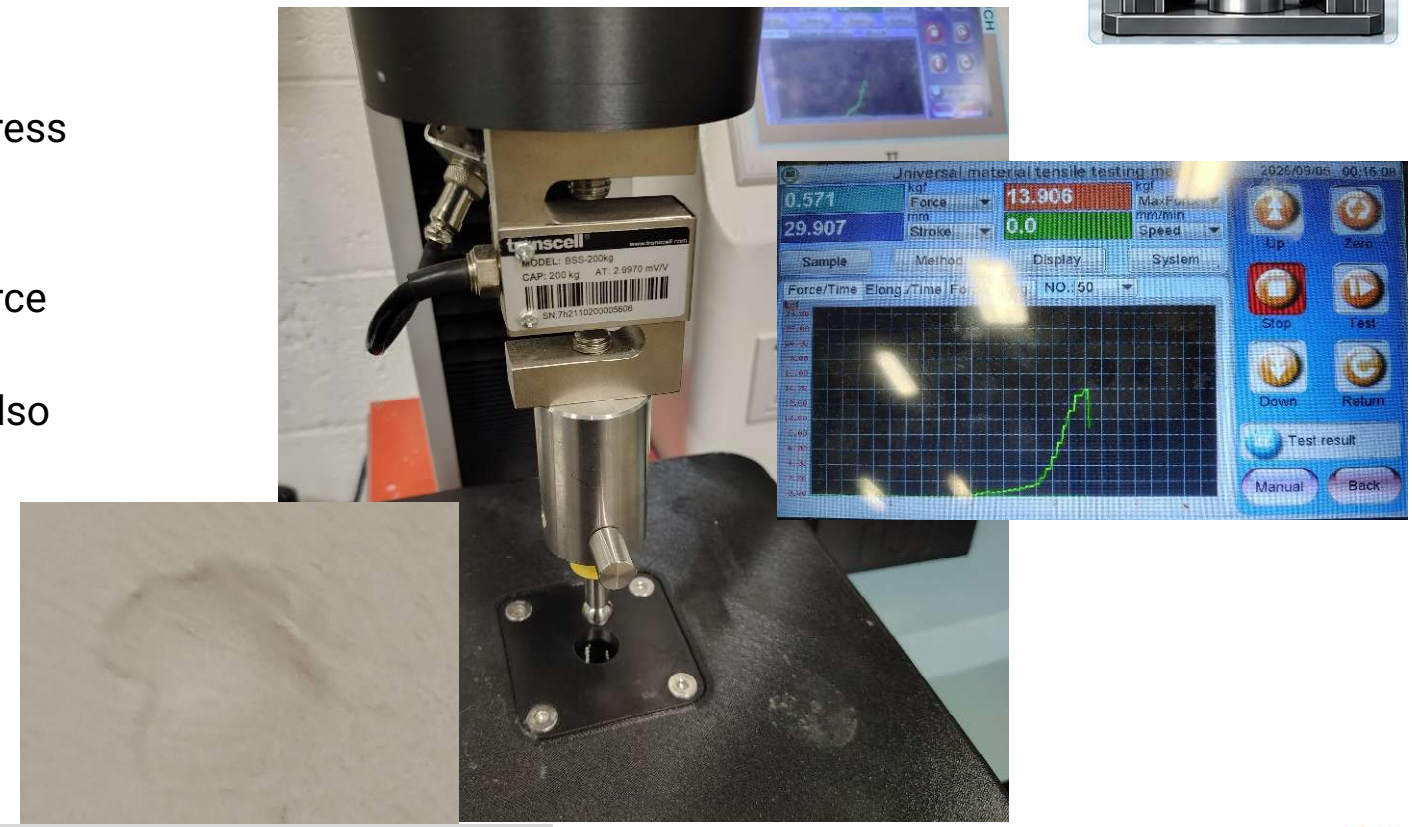
For 20mm circle:

- Density = mass (g) /((2/2)^2*3.14*caliper (um)/10000)
- GSM = mass (g)/(3.14*(20/1000/2)^2)

Material Strength – Puncture



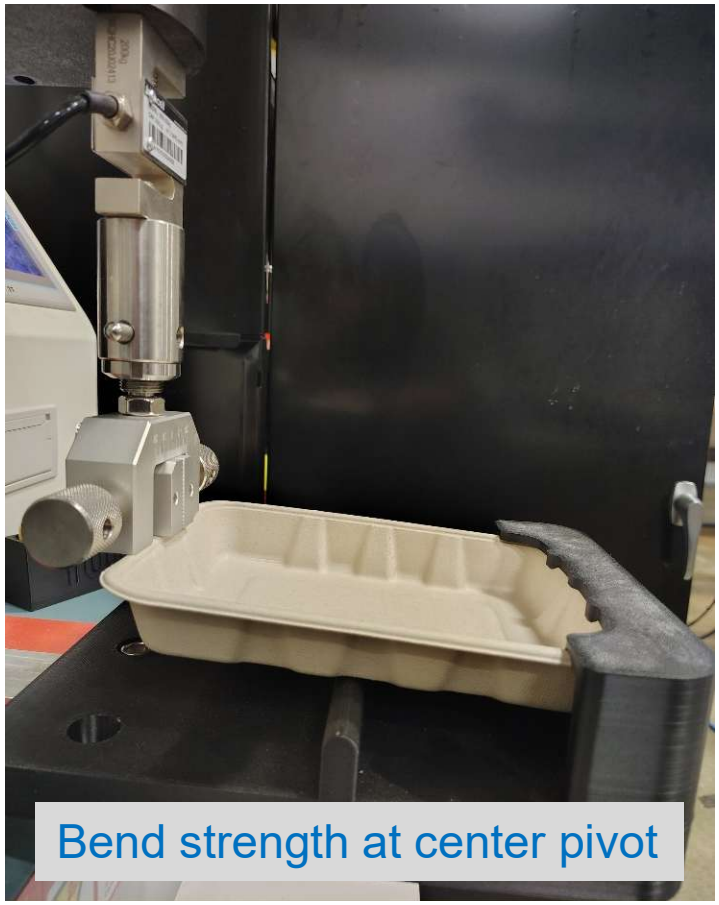
- 0.50 in ball / 0.75 in orifice isolates molded-fiber matrix strength
- Compares pulp, additives and press conditions
- Primary response: maximum force
- Force–displacement data can also provide TEA and other metrics

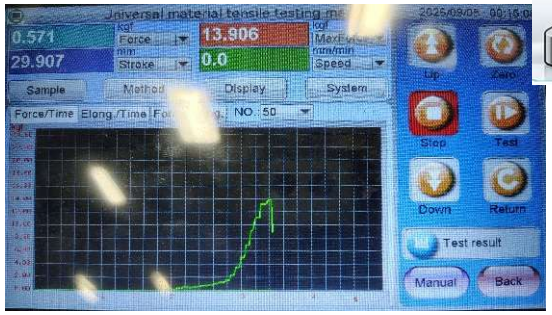


Puncture mark on sample

Material Strength – Geometry Strength

- Full-part fixtures measure structural performance, not just material strength
- Captures the combined effects of fiber strength + part geometry
- Primary response: maximum force; TEA can add insight
- 3D-printed fixtures enable targeted bending and load cases

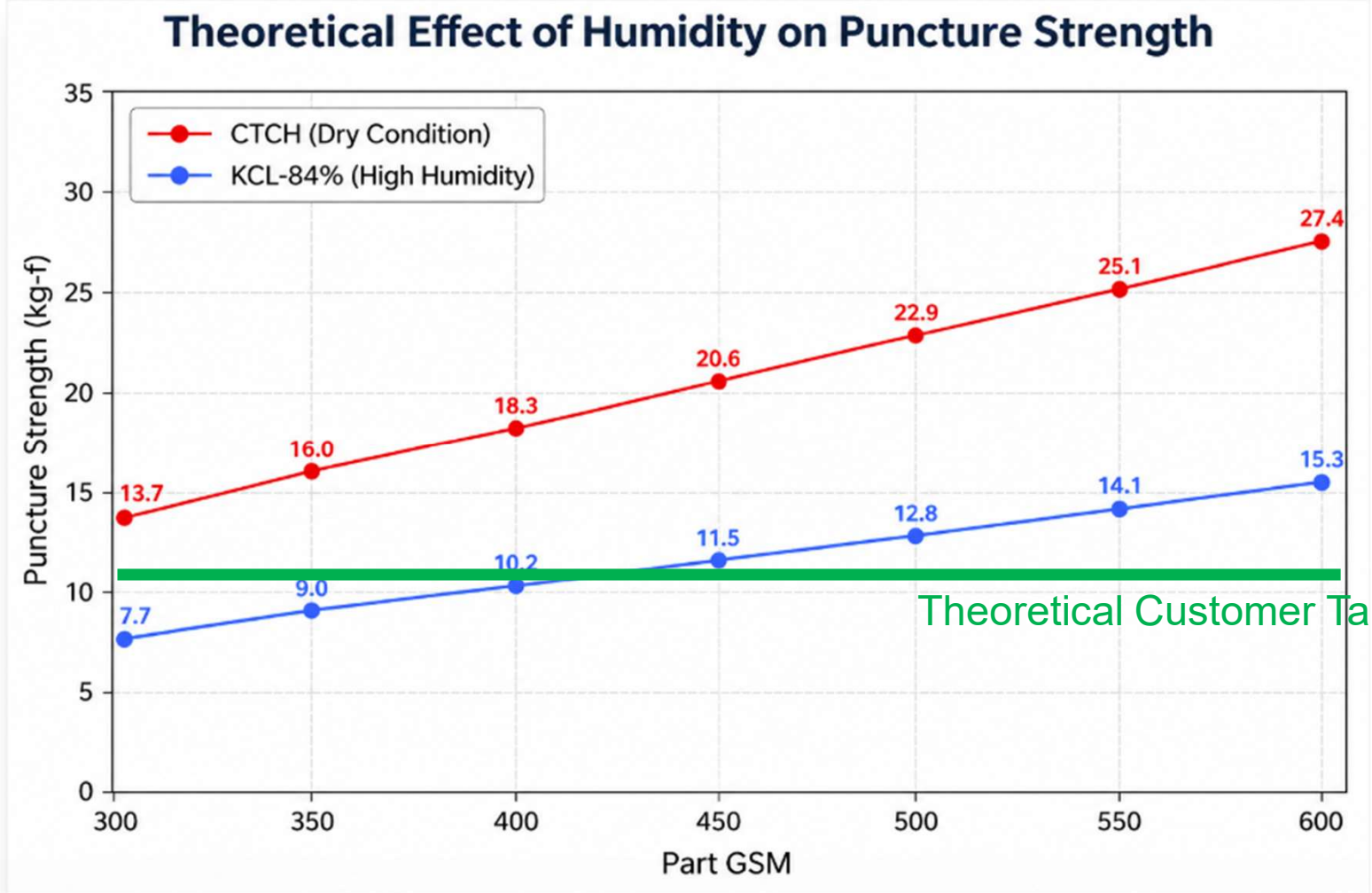




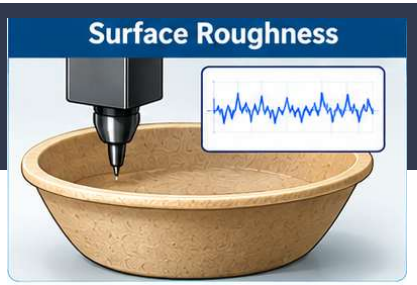




Study: Puncture Strength Vs. GSM at Two Humidity Conditions



Surface Roughness



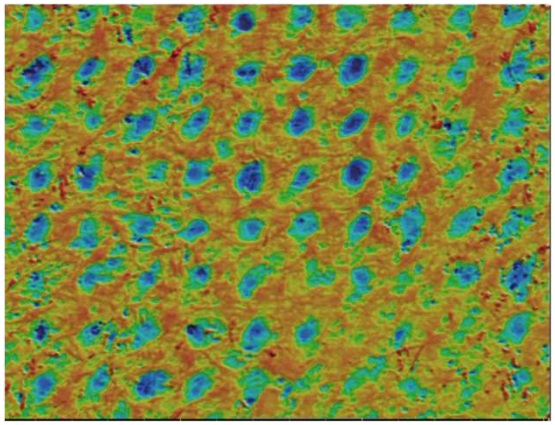
- Traditional paper roughness methods struggle with molded fiber geometry and porosity

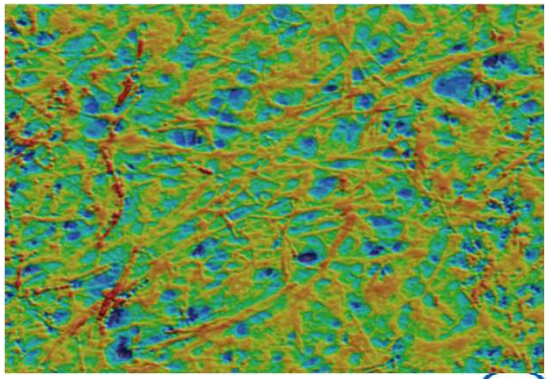
- Optical profilometry measures complex surfaces without contact

- Keyence VR-6000 provides 3D surface maps and ISO 25178 parameters

- Sa, Sdr and Vvc are useful indicators of OGR performance and coatability



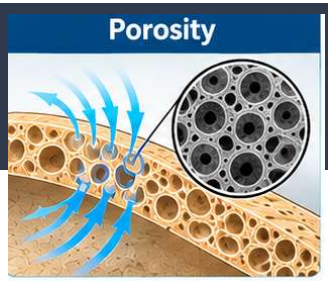




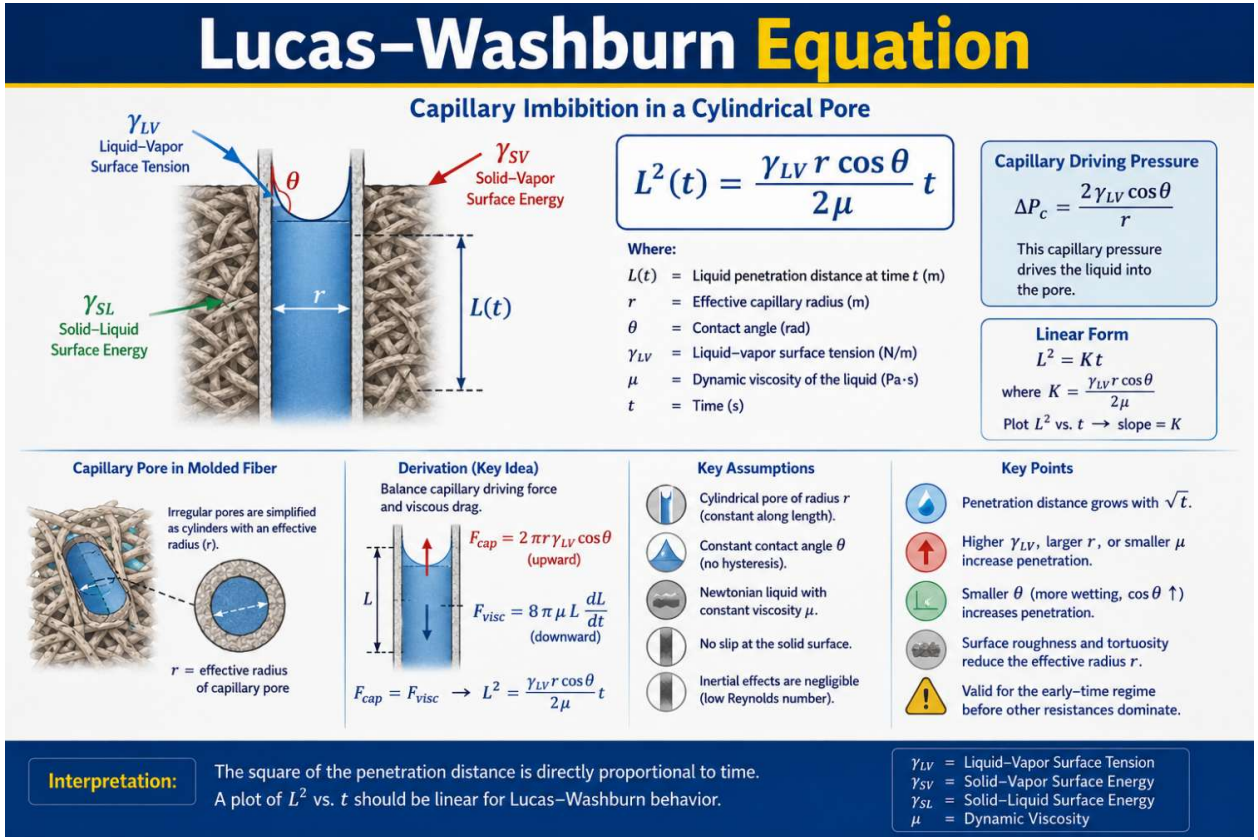
ISO 25178 Surface Parameters – Quick Reference (Molded Fiber)

Parameter	Name	What It Measures	Units	High Value Means	Relevance to Coating / Wicking
Sa	Arithmetical Mean Height	Average roughness (3D Ra)	µm	Rougher surface	Baseline roughness; normalization metric
Sz	Maximum Height	Peak-to-valley extreme	µm	Large defects / voids	Flags outliers; defect screening
Str	Texture Aspect Ratio	Surface isotropy (0–1)	-	→1 isotropic, →0 directional	Indicates anisotropic wicking behavior
Spc	Peak Curvature	Sharpness of peaks	1/mm	Sharper peaks	Higher pinhole risk; coating starvation
Sdr	Developed Interfacial Area Ratio	Extra surface area vs flat	%	More surface complexity	Higher coating demand
Ssk	Skewness	Peak vs valley bias	-	+ peak-heavy, – valley-heavy	Key coating performance indicator
Sku	Kurtosis	Sharpness of distribution	-	>3 spiky, <3 plateau	Localized defect sensitivity
Svk	Reduced Valley Depth	Depth of core valleys	µm	Deeper valleys	Capillary storage near surface
Vvv	Dale Void Volume	Deep valley void volume	mL/m²	More deep voids	Fluid reservoir; drives wicking
Vvc	Core Void Volume	Mid-level void volume	mL/m²	More bulk porosity	Coating uptake indicator

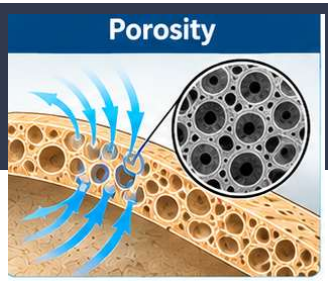
POROSITY



- Conventional paper porosity methods (TAPPI T460) are poorly suited to molded fiber geometry and high airflow
- Air permeability reflects the interconnected pore network created by fiber morphology, refining and consolidation
- Useful for understanding OGR performance and coatability
- Porosity and Vvc can serve as practical proxies for effective capillary radius



Porosity Tester Custom Made for Molded Fiber





1. Punch a 20mm disc from area of interest

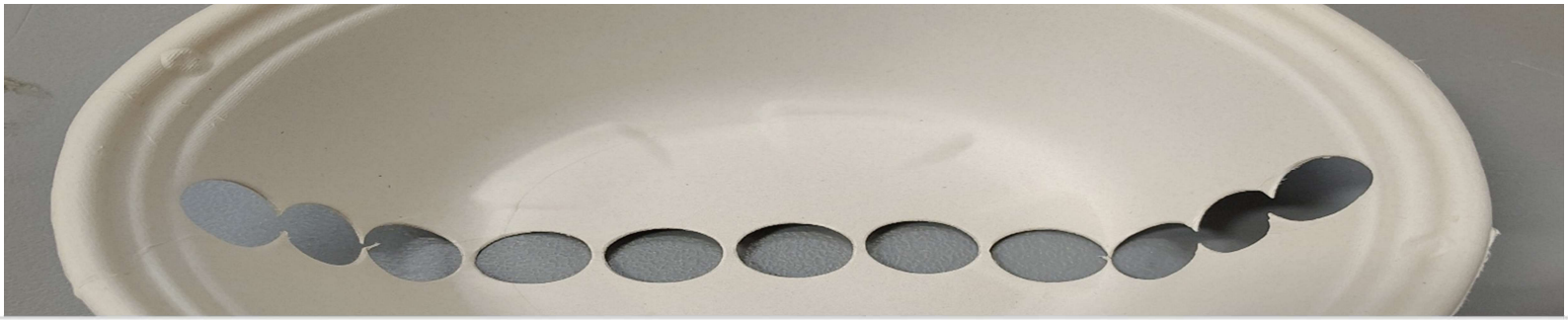


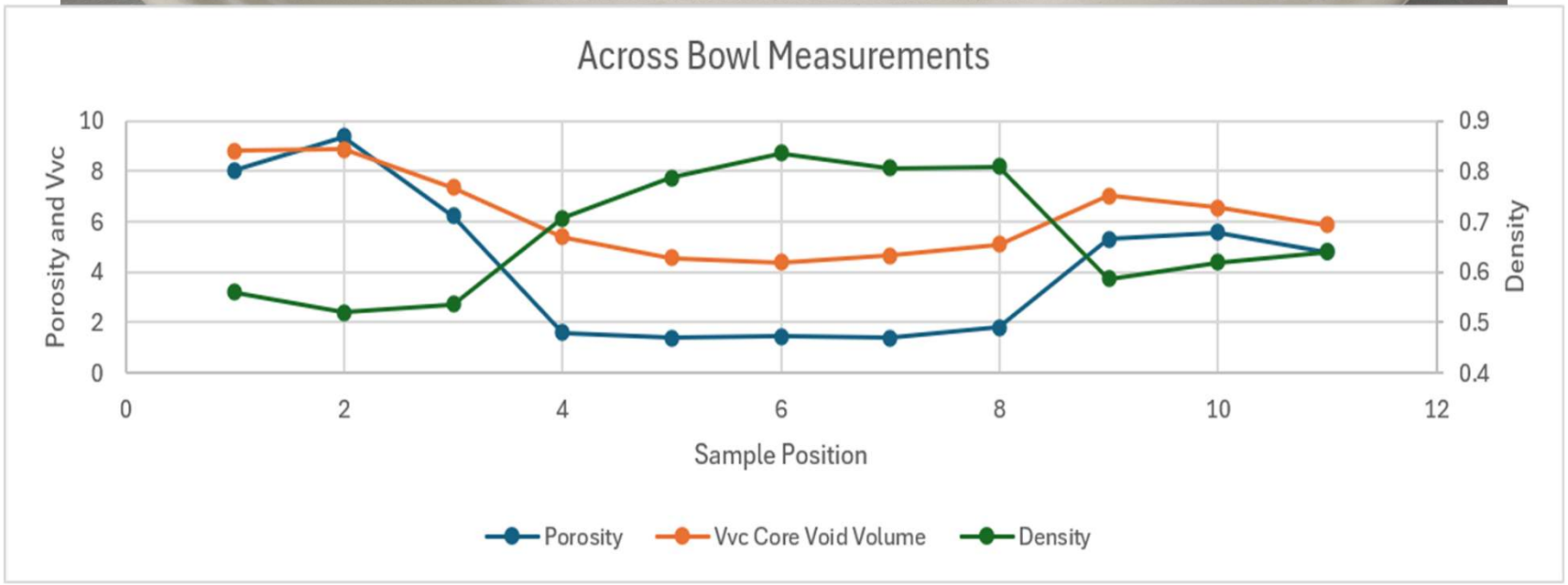
2. Clamp in testing device and read the flow (lpm) at 10 psi.



3. Edges are crimped shut to ensure an excellent seal and no edge leaks

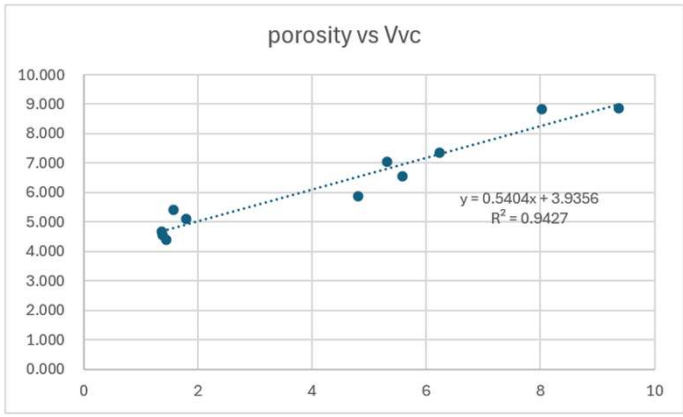
Study: Porosity, Core Void Volume (Vvc) and Density across part



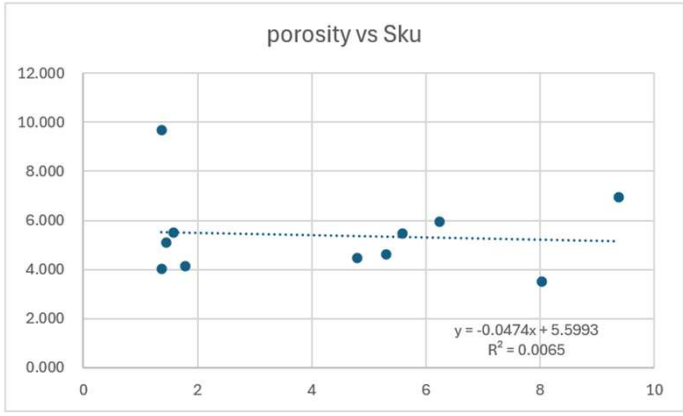


Study: Porosity, Core Void Volume (Vvc) and Density across part

Optical Profiler Value	R-squared Correlation to Porosity
Vvc	0.9427
Sdr	0.9133
Sa	0.9088
Spc	0.8996
Sz	0.5093
Vvv	0.4623
Svk	0.3101
Ssk	0.2374
Str	0.0728
Sku	0.0065



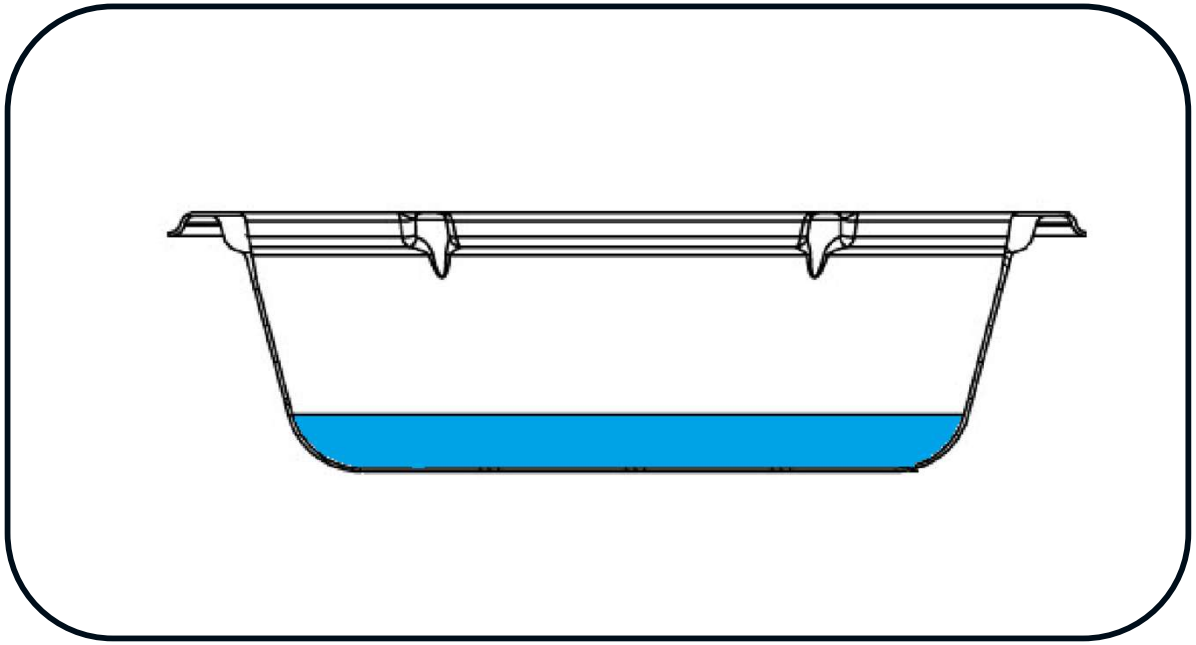
Bulk density alone does not describe the transport structure of molded fiber. Surface topology, particularly Vvc, closely tracked measured air permeability.



2-Minute Water Cobb



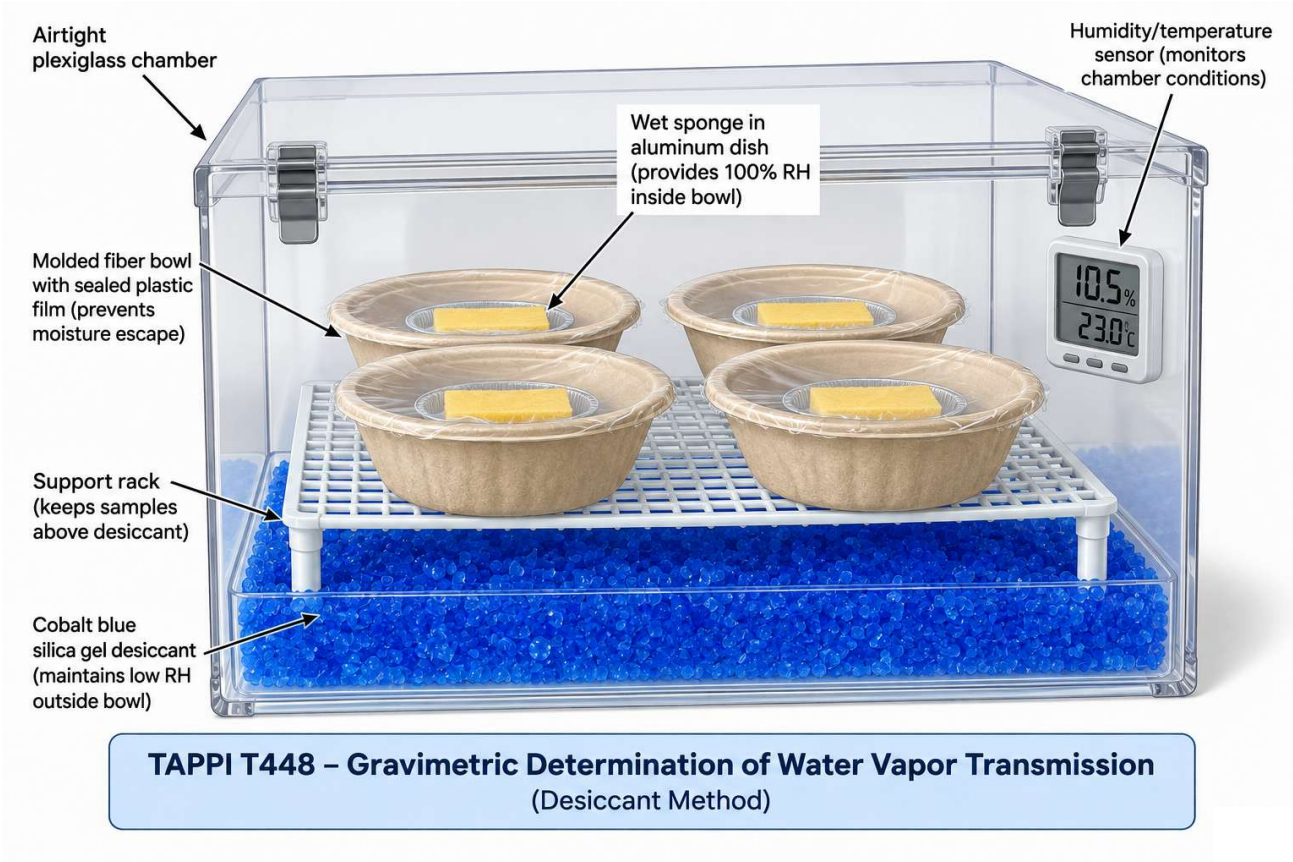
- Adapted from TAPPI T441 for testing the formed article
- Use CAD to determine the wetted surface area
- Add 100 cc water for 2 minutes
- Blot consistently to remove surface water
- Cobb = mass gain / wetted area (g/m^2)



WVTR



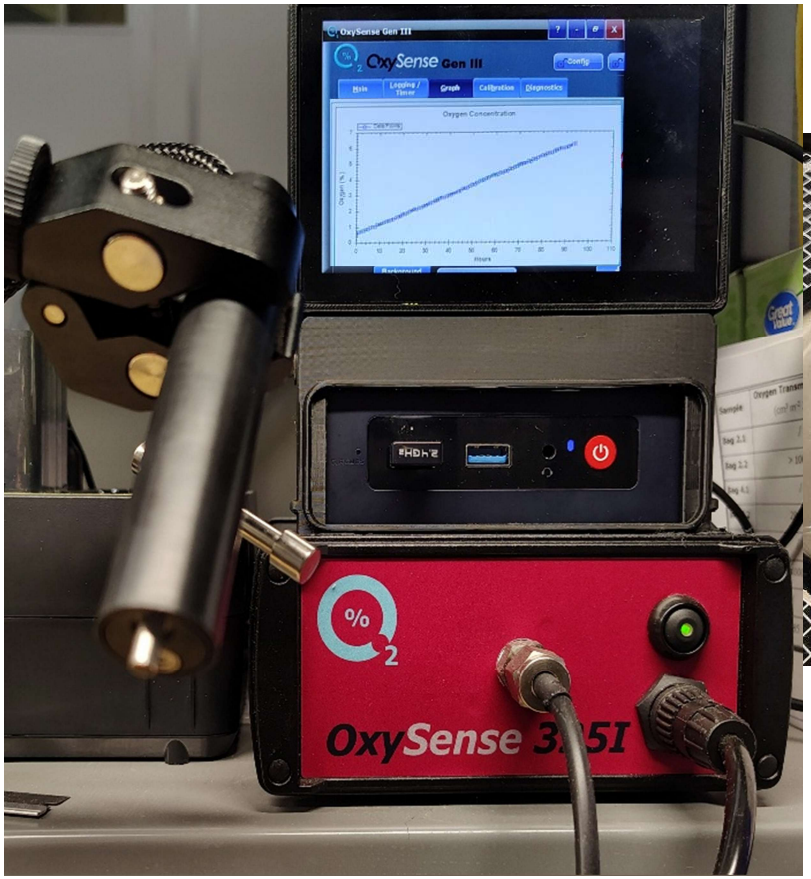
- Gravimetric WVTR adapted from TAPPI T448
- Test the whole coated article to capture geometry and coating-thickness variation
- Well suited to the relatively high WVTR range of many molded-fiber structures
- Simple whole-part screening without requiring an instrumental permeation cell



OTR



- Oxygen-sensitive applications should be evaluated in full part geometry
- Whole-part testing captures coating nonuniformity, pinholes and sealing effects
- OxySense provides a practical alternative for these structures
- Seal the part to a fixture, nitrogen-flush the headspace and track O_2 ingress over time





Oil Penetration and Pinholes



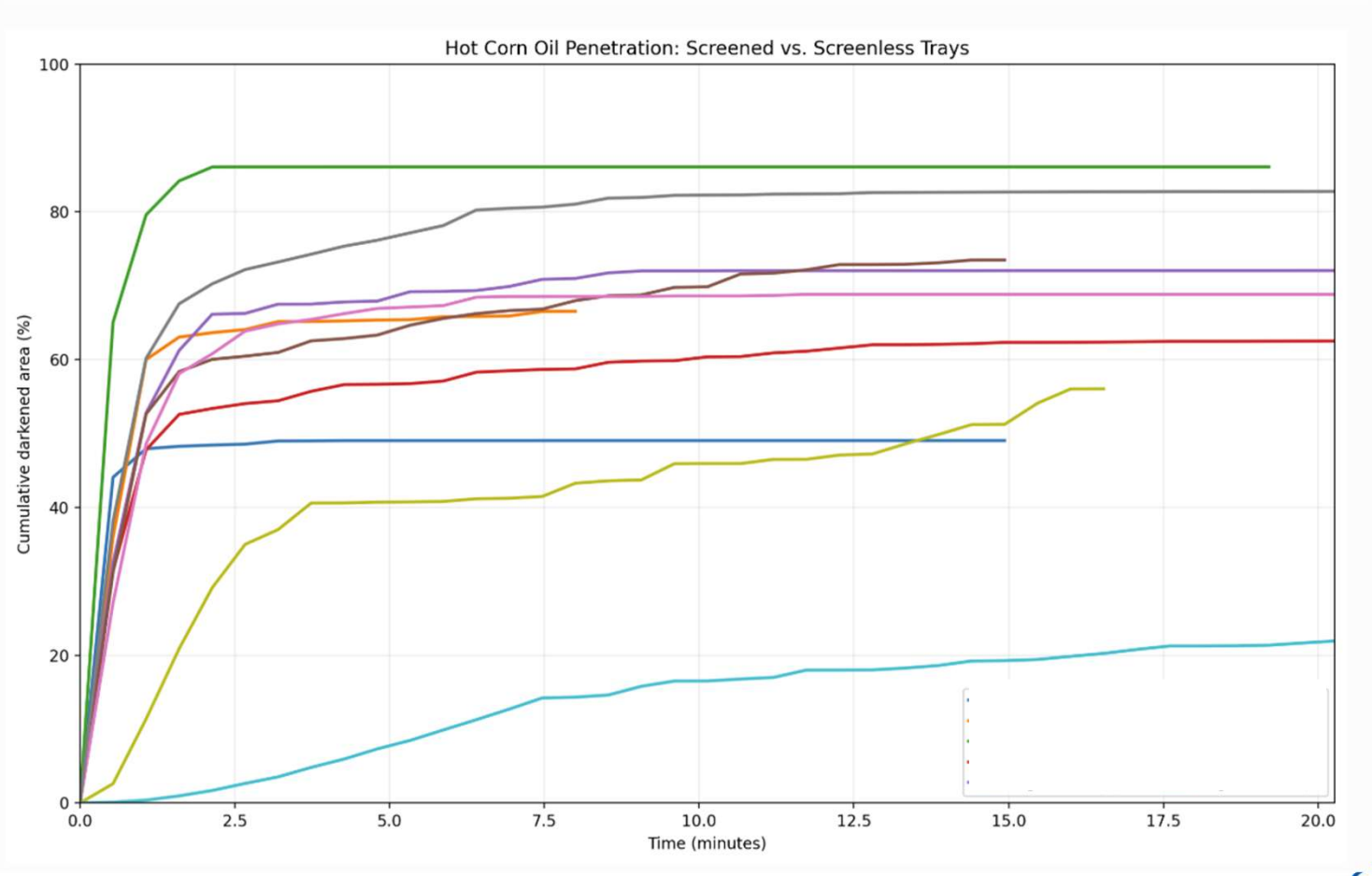
- Oil penetration is critical in food-service applications but is often judged visually
- Vision analysis converts failure into continuous, quantitative data
- Track cumulative darkened area versus time
- The same approach can detect and quantify coating pinholes



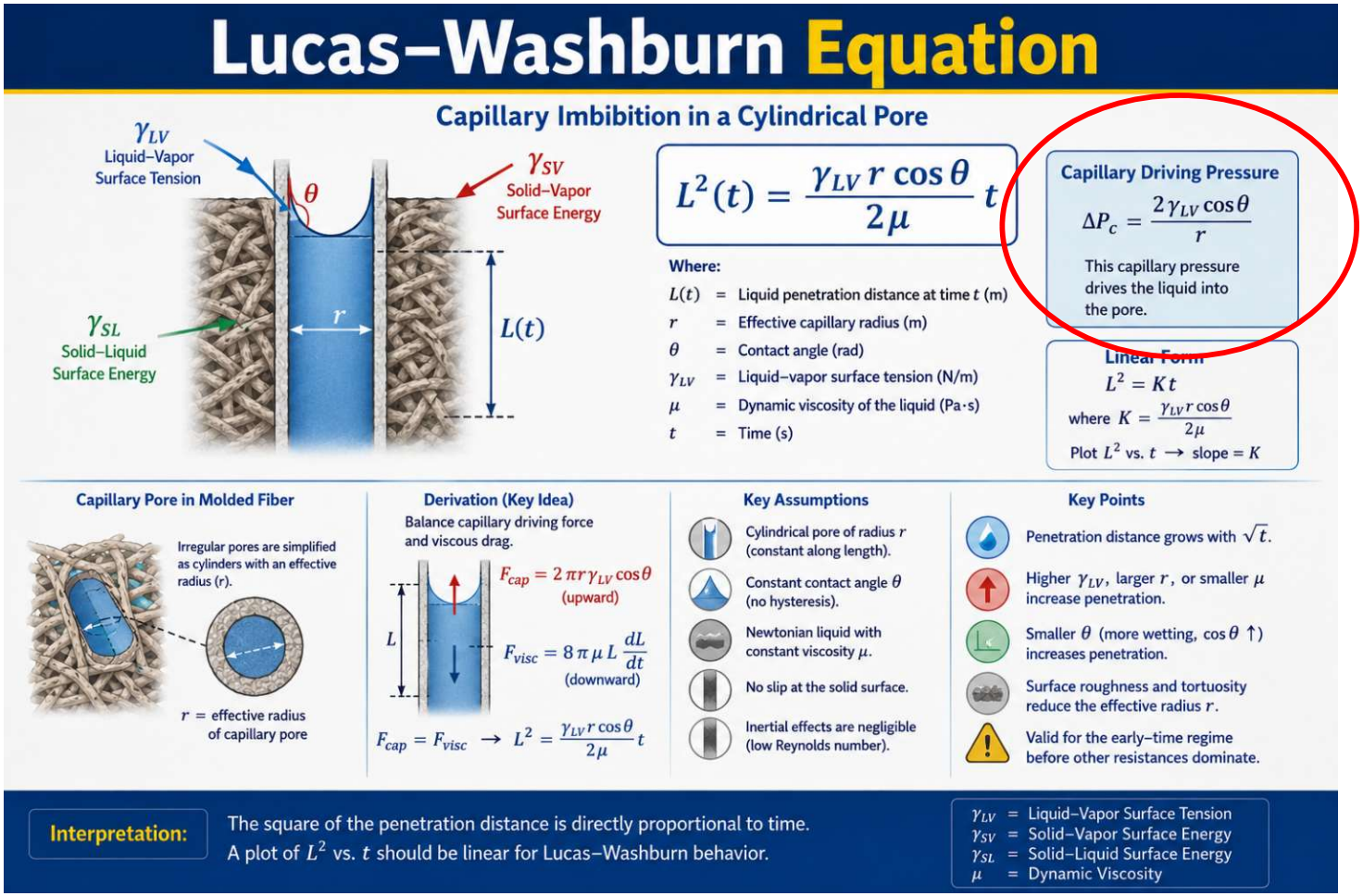


Oil Penetration and Pinholes

- Accommodates a wide range of part sizes
- Hot or cold oil
- User-defined failure threshold
- Output: cumulative darkened area (%) versus time
- Reveals penetration kinetics hidden by simple pass/fail testing



LUCAS-WASHBURN PASSIVE WICKING EQUATION

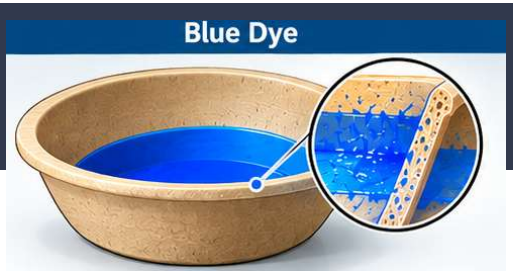


Capillary driving pressure helps explain liquid transport through pinholes and pores.

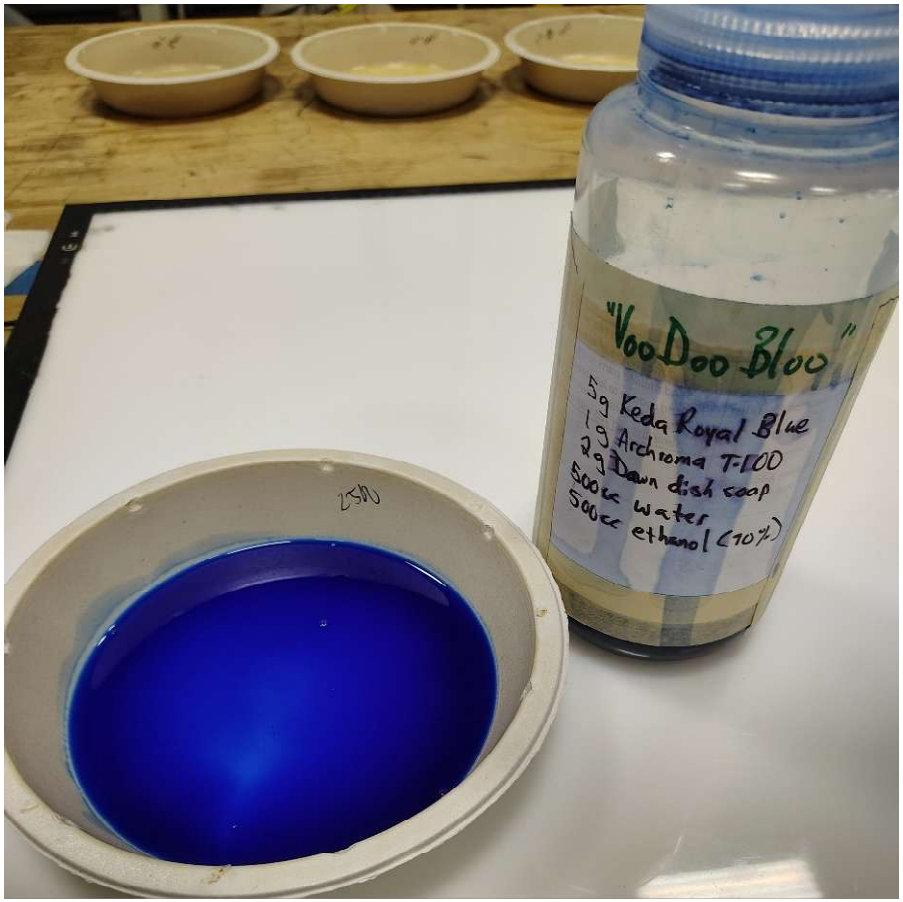
Key variables:

- Liquid viscosity
- Surface tension
- Coating wettability / contact angle
- Effective pore or pinhole radius
- Time

Blue Dye



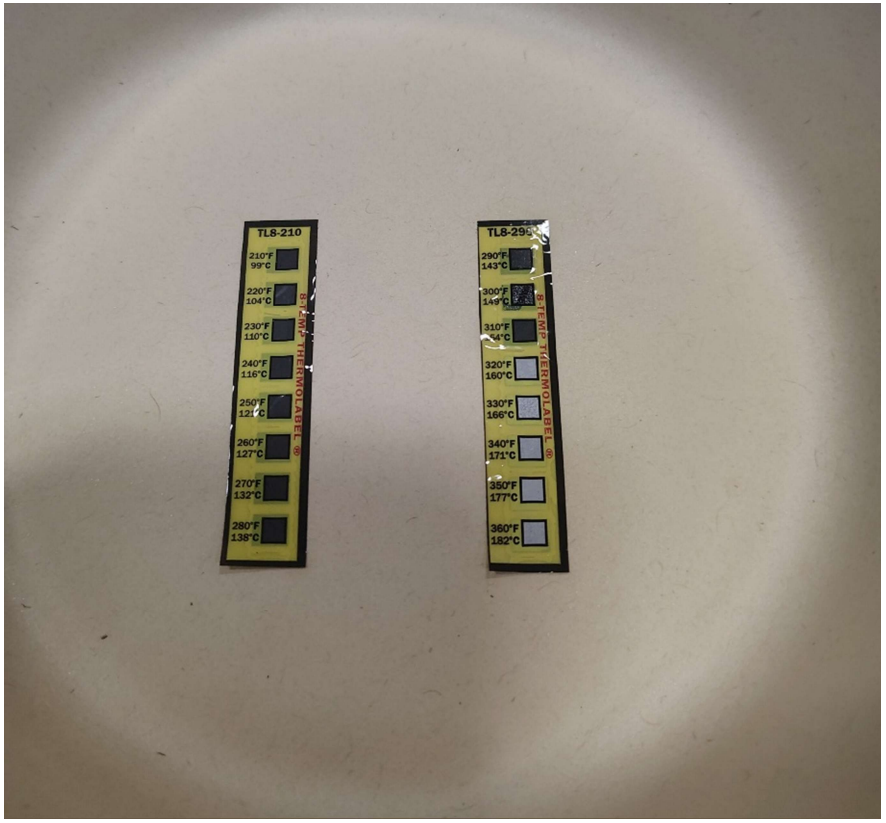
- Simple diagnostic tool for locating barrier defects
- Avoids oil contamination when samples will be imaged by SEM
- Dye chemistry can be tuned to approximate an oil's capillary driving pressure
- More aggressive formulations can reveal very small defects for high-barrier applications



Temperature Tape



- Direct surface-temperature measurement after an oven can be unreliable
- Heat-activated labels record the maximum surface temperature experienced by the part during drying, including the effect of evaporative cooling
- Apply labels before coating / oven exposure



amazon
PaperThermometer

Paper Thermometer

Visit the Paper Thermometer storefront

Testing Protocols

Meat Trays	Formation, Density, Caliper, GSM, Puncture, Bending (at CTCH and High Humidity), Cobb
Food Service/QSR	Formation, Density, Caliper, GSM, Puncture, Cobb, Oil Penetration
Coated Ready Meals	Formation, Density, Caliper, GSM, Porosity, Roughness, Cobb, Pinhole, WVTR, Temp tape
Coated Yogurt Cups	Formation, Density, Caliper, GSM, Porosity, Roughness, Cobb, Pinhole, WVTR, OTR, Blue Dye, Temp tape

Substrate Optimization for Coating

- Molded Fiber parts need to be optimized for coating
- Compared to flat paper, Molded Fiber is a sponge
- Contrary to conventional coating wisdom, Molded Fiber parts should have very low surface energy to keep coatings on the surface

Property	Suggested Range	Test Method
Low porosity	<3 lpm	Motus Porosity Tester
Med/High density	>0.6 g/cc	From 20mm punch
Low surface roughness	<8 um Sa	Keyence VR Series Confocal
Moderate 2-minute Cobb	30-80 GSM	Test in part, not with ring
Propylene Glycol Abs	>120 sec	Absorption rate with drop of PG

- To achieve this properties, parts will require
  - Good refining to <400 cfs, moderate fines concentration
  - Chemical package with sizing, retention and drainage aids
  - Tools designed for even pressure across formed part

Thank You

Questions?



Bob Versluys
Senior Technical Manager
Motus LLC
500 Hartness Drive
Suite A
Greenville, SC 29615

bversluys@motusus.com