CHEMICALLY RESISTANT POLYMERS FOR NEXT GENERATION HEALTHCARE AND CONSUMER PRODUCTS

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AVIENT™

INTRODUCTION

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Specialty Engineered Materials

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DISCUSSION TOPICS

- Disinfection and cleaning
- Where does it matter?
- Disinfectants & material challenges
- What is Environmental Stress Cracking (ESC)?
- What causes ESC & why?
- Chemical resistance testing methodology & results
- Chemically resistant solutions

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DISINFECTION & CLEANING

We clean or disinfect surfaces everyday to remove germs from surfaces and prevent the spread of diseases and viruses

In the healthcare industry, infection prevention is critical

Enhanced disinfection & cleaning can lead to material failure

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WHERE DOES IT MATTER?

HIGH-TOUCH DURABLE SURFACES

DISINFECTANTS & MATERIAL CHALLENGES

DISINFECTANT FEATURES

	Healthcare					Consumer / Industrial		
Disinfectant	**CaviCide™**	**Super Sani-Cloth®**	**SporGon™**	**Vesphene® IIse**	**Virex® Tb**	**Clorox® Disinfecting Wipes**	**Lysol® All-Purpose Cleaner**	**Formula 409® Heavy Duty Degreaser**
Active Ingredient(s)	**quaternary ammonium** (0.3%)	**quaternary ammonium** (0.2-2%)	hydrogen peroxide (7.35%) peracetic acid (0.23%)	2-phenylphenol (5-10%) 4-tert-pentylphenol (5-10%)	**quaternary ammonium** (0.2-2%)	**quaternary ammonium**	**quaternary ammonium** (<0.1%)	N/A
Other Relevant Ingredients (e.g. solvent / surfactants)	isopropanol (17.2%) 2-butoxyethanol (1-5%)	isopropanol (30-60%)		potassium hydroxide (1-5%) sodium hydroxide (1-5%)	diethylene glycol butyl ether (5-10%)	hexoxyethanol isopropanol C12-C14 ethoxylated alcohols	1-phenoxy--2-propanol ethanolamine lauramine oxide (0.1-1%) dipropylene glycol	ethanolamine lauramine oxide myristamine oxide
EPA Reg. No.	46781-6	9480-4	No (FDA 510K)	1043-87	70627-2	5813-79	67619-10	777-66
pH	11 – 12.5	6.2 – 8.5	1.8 – 2.2	10.4 – 12.3	12.2	6 – 9	10.5 – 11.3	11 – 11.8
Comparable Products	- Sani-Cloth® Plus - Sani-Cloth® HB - Opti-Cide3® (pH neutral)	- Opti-Cide3® (contains 2-butoxyethanol)	- Clorox Healthcare™ - Hydrogen Peroxide - SteriCide™ RTU	- LpH® se - Birex® SE (acidic) - Sporcidin®	- Sani-Cloth® AF3			- Formula 409® Cleaner Degreaser Disinfectant (contains QAC)

CaviCide™ is a trademark of Metrex Research, LLC; Sani-Cloth® is a trademark of Professional Disposables International, Inc.; SporGon™ is a trademark of Decon Labs, Inc.; Vesphene® is a trademark of Steris Corporation; and Virex® is a trademark of Diversey, Inc.

Lysol® is a trademark of Reckitt Benckiser LLC.
Formula 409® is a trademark of The Clorox Company.
Clorox® is a trademark of The Clorox Company.

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DISINFECTANTS & MATERIAL CHALLENGES

AMORPHOUS

- **Poor ESC resistance**
- **Low shrink**
- **Good impact**
- **Transparent**
- **PC, PC/ABS, PC/PET, CoPE**

SEMI-CRYSTALLINE

- **Better ESC resistance**
- **High shrink**
- **Lower impact**
- **Opaque**
- **PC/PBT, PBT, PK, POM, PA**

Common Material Options & Considerations

- Amorphous
- Semi-Crystalline

Other Considerations

- ISO/USP biocompatibility
- Flame retardancy (halogen/non-halogen)
- Part design
- Cost

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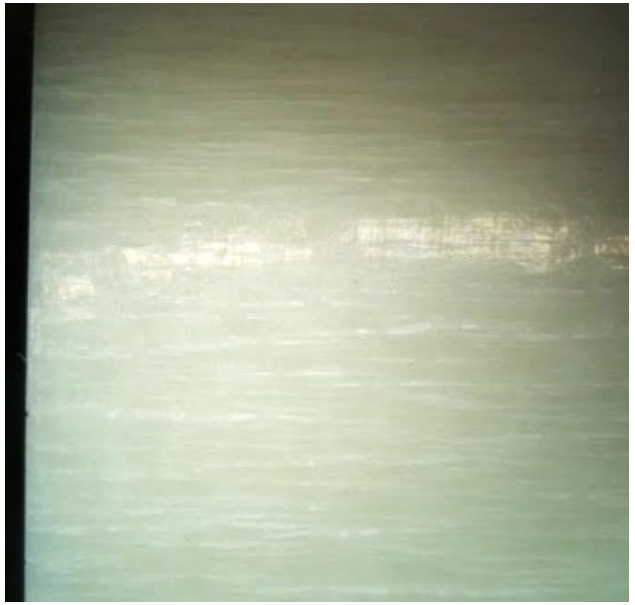
DISINFECTANTS & MATERIAL CHALLENGES

ENHANCED DISINFECTING OR CLEANING PROTOCOLS CAUSE MATERIALS TO FAIL



CRAZING

CRACKING/FULL BREAK

BRITTLE FAILURE

Other failures include non-temperature related deformations, discoloring or fading

MATERIAL NEED: IMPROVED CHEMICAL RESISTANCE

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WHAT IS ENVIRONMENTAL STRESS CRACKING (ESC)?

Pre-mature embrittlement and crack propagation leading to material failure, caused by the synergistic action of **stress** and **chemical exposure**

- Believed to be responsible for nearly 1/3 of plastic failures!
- Applied stress (if any) is below level normally required to cause mechanical damage
- Environmental stress cracking can be thought of as accelerated creep

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WHAT CAUSES ESC AND WHY?

1. Factors
2. Mechanism of Stress Cracking
3. Features that Influence Resistance

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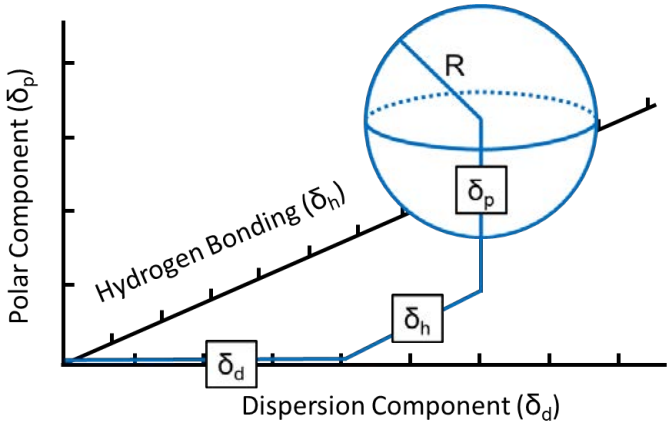
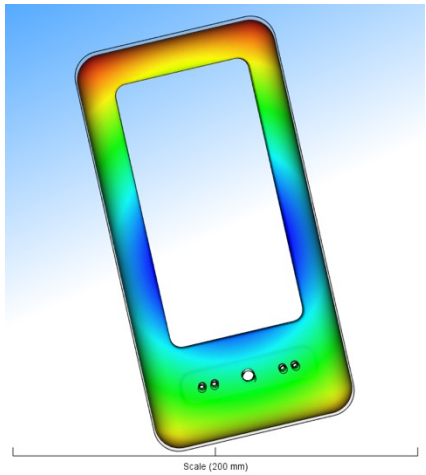
WHAT CAUSES ESC AND WHY?

Factors

- Frequency of cleaning
- Cleaning agent (polymer solubility)
- Residual or applied stresses
  - Processing & part design





$$D_{(S\text{-}P)} = [4(\delta_d s - \delta_d p)^2 + (\delta_p s - \delta_p p)^2 + (\delta_h s - \delta_h p)^2]^{½}$$

Kjellander, C. K.; *et al*. *Polymer Degradation and Stability* **2008**, *93* (8), 1486–1495.

Molecule	δ_d	δ_p	δ_h	R	$D_{(S\text{-}P)}$
Polycarbonate	18.7	7.5	9.3	6.0	N/A
2-propanol	15.8	6.1	16.4	N/A	9.3
Diethylene glycol butyl ether	16.0	7.0	10.6	N/A	5.6

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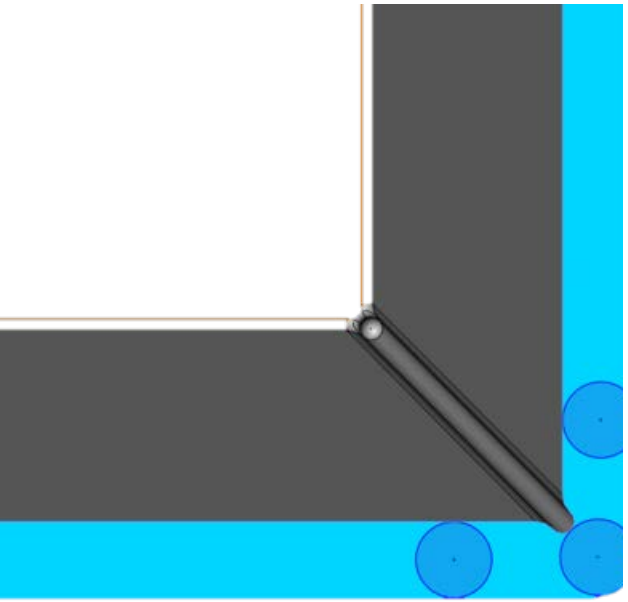
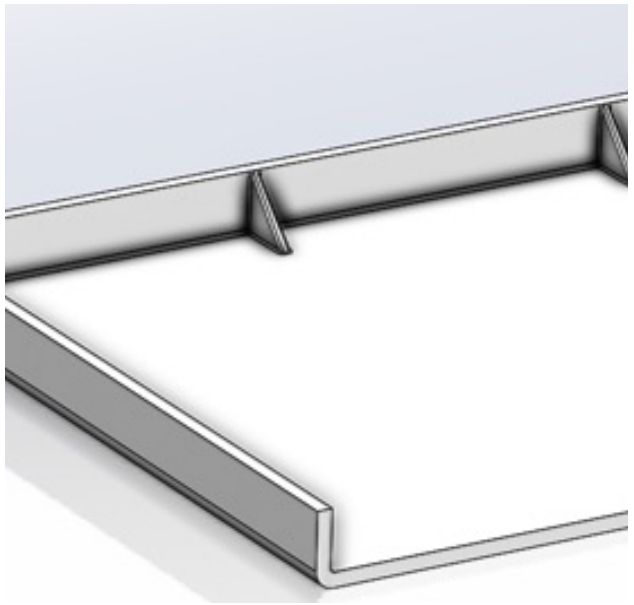
WHAT CAUSES ESC AND WHY?

PART DESIGN TO REDUCE RESIDUAL STRESS

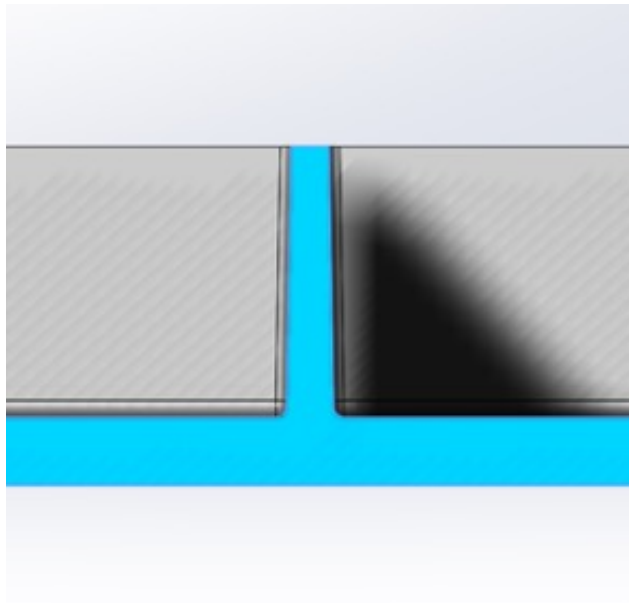
CORING FEATURES



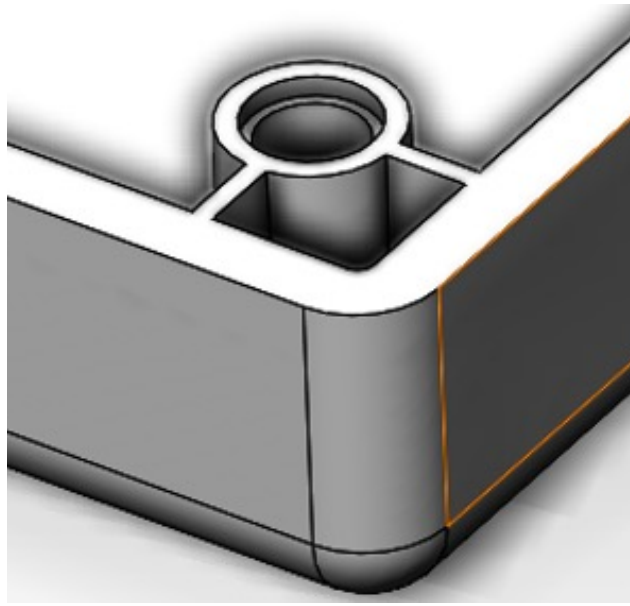
GUSSETS



RIBS



BOSSES



General Guidelines:

- Generous radii & coring features to maintain constant wall thickness
- Contoured to eliminate fluid pooling; gussets, ribs, and bosses to reduce warp
- Minimal holes (preferably round or oval and parallel to flow path)

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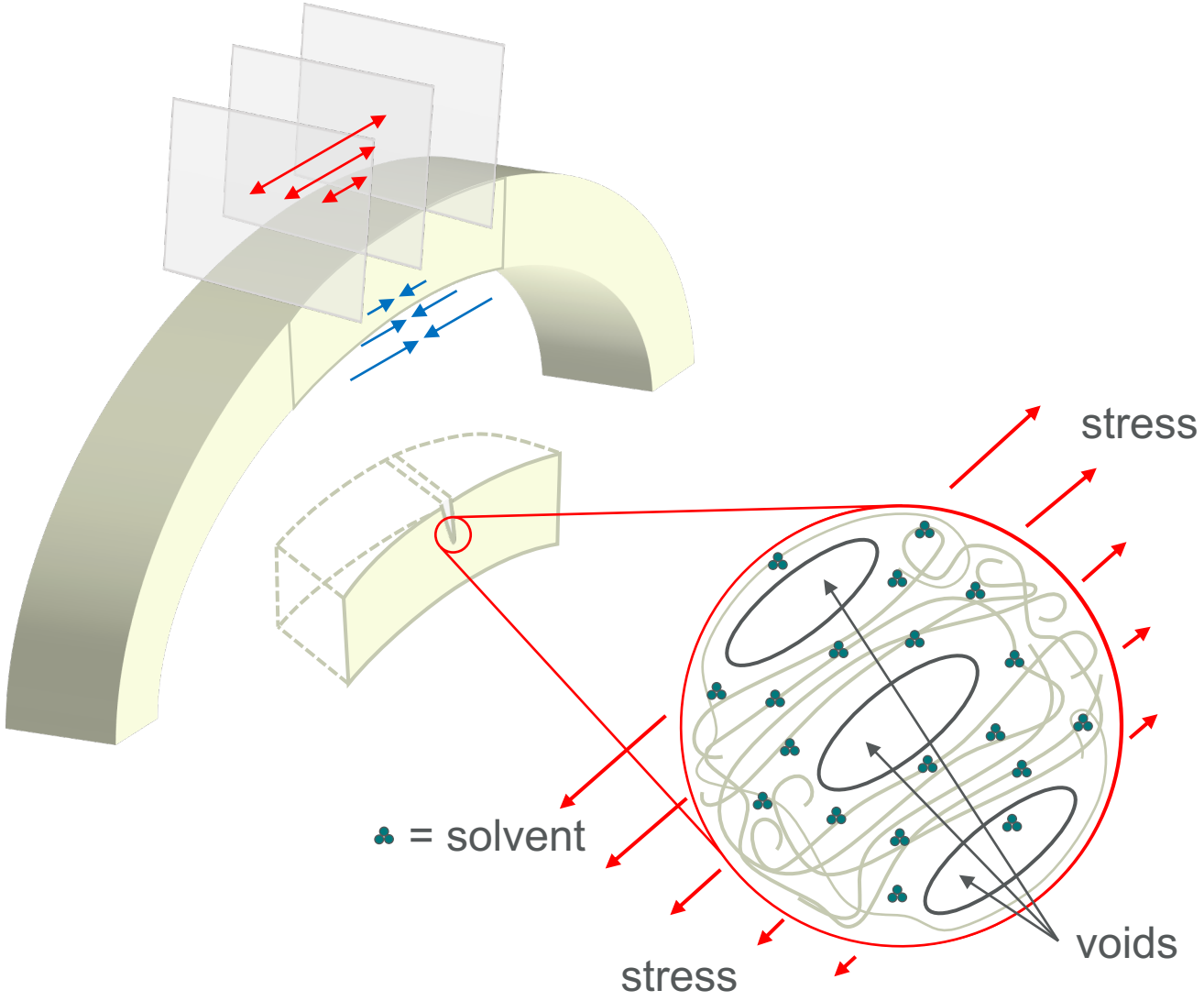
WHAT CAUSES ESC AND WHY?



Mechanism of Stress Cracking

- Chain alignment in response to stress
- Micro-void formation (crazing) → propagation → brittle fracture
- Surface wetting (solubility)
  - Reduces critical strain
  - Stress-enhanced fluid absorption

Robeson, L. M. *Polymer Engineering & Science* **2012**, *53* (3), 453–467.

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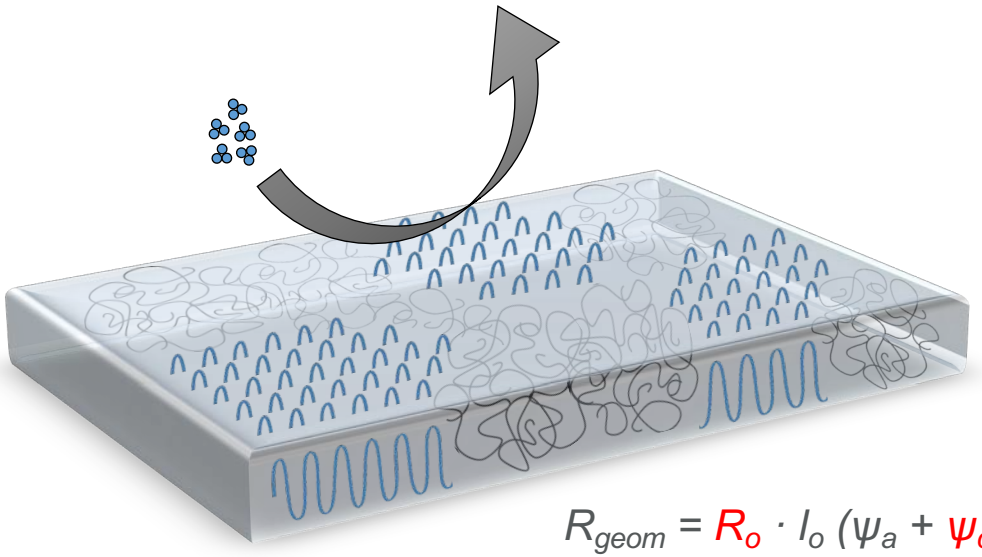
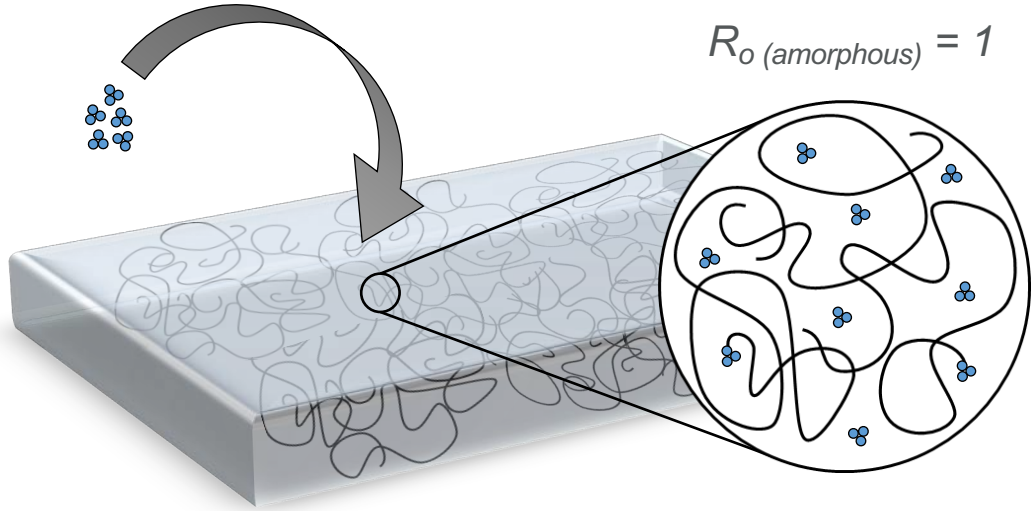
WHAT CAUSES ESC AND WHY?



$$R_{geom} = R_o \cdot I_o \, (\psi_a + \psi_c \cdot \Phi_a)^{1-n} \cdot \Phi_a^{1+n}$$

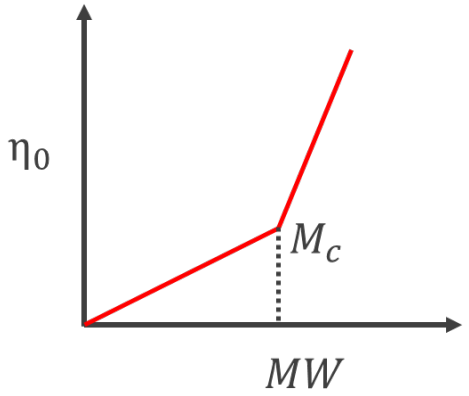
$$R_{o\,(crystalline)} = A_c^2 / 4\pi N \cdot \psi_a^2$$

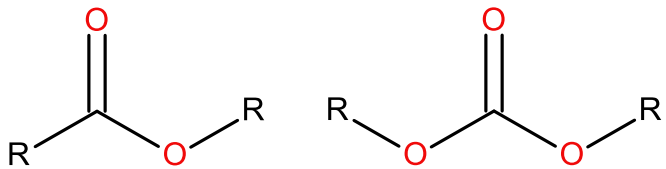
$$R_{o\,(amorphous)} = 1$$



Features that Influence Resistance

- Barrier / mass transport (crystallinity)
- MW for amorphous
- Polymer blends & chemistries
  - Solubility parameter





Bitter, J. G. A. *Desalination* **1984**, *51* (1), 19–35.

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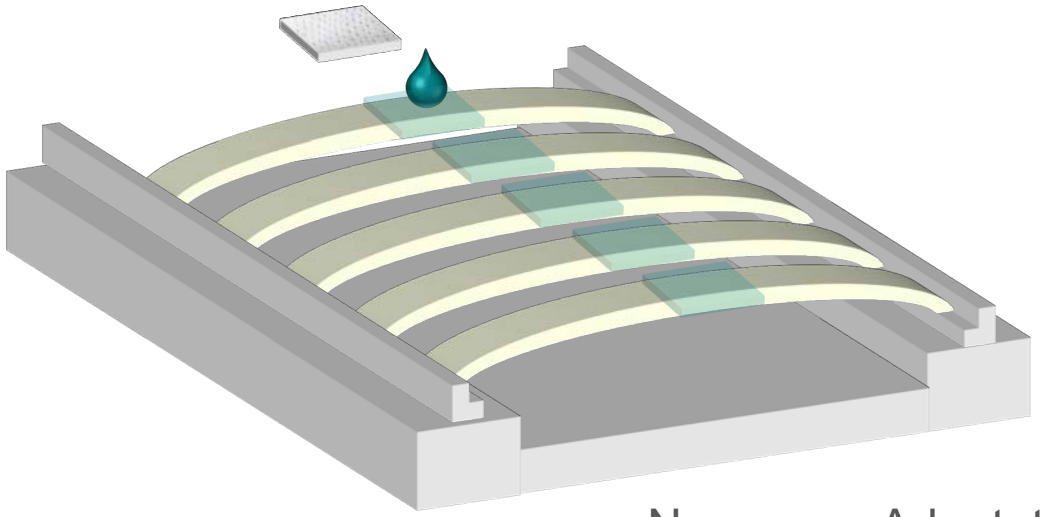
CHEMICAL RESISTANCE TESTING

COMPARING METHODOLOGIES

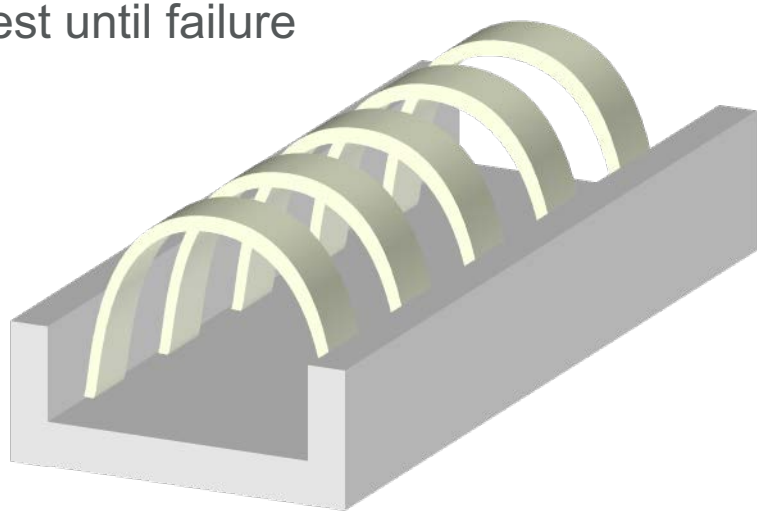
ASTM D543B (ISO 22088-3)

- Fixed strain (1-2%) to simulate molded-in stresses
- Disinfectant applied for 72 hrs



ASTM 1693 (Ethylene plastics)

- Very high strain
- Submerged in chemical/solution
- Test until failure



Numerous Adaptations:

- Repeat wipe testing (e.g. wipe 10×, not saturated)
- Wet-to-dry cycles (24 hr × 3 applications)
- Performing testing on impact bars

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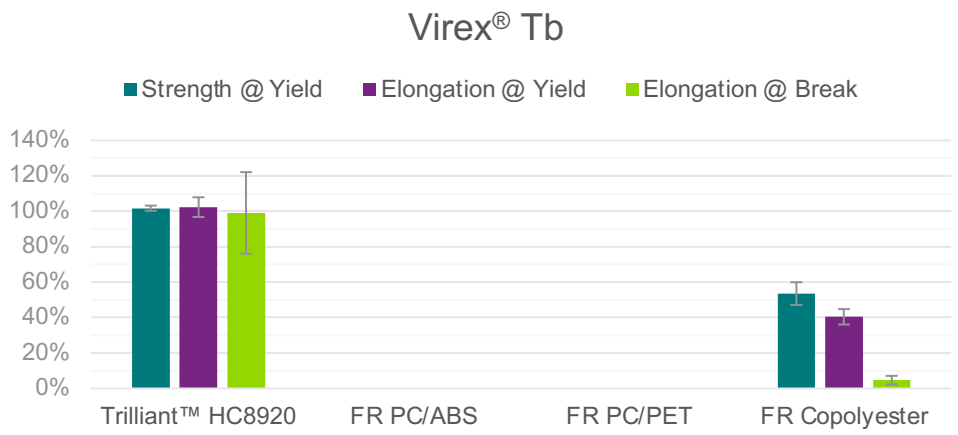
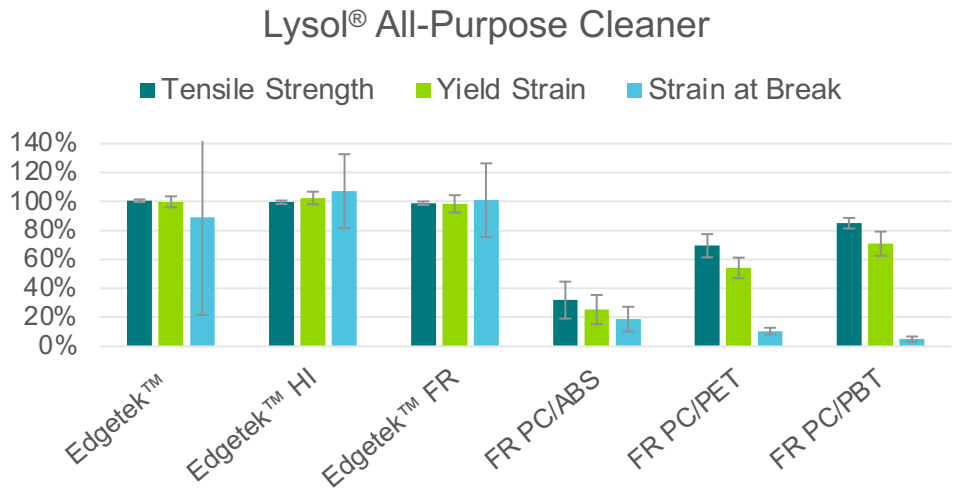
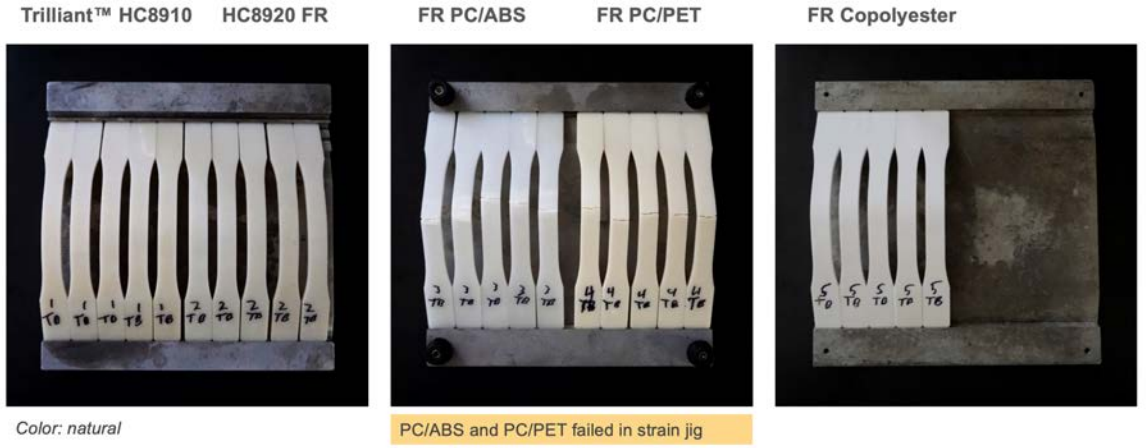
TEST RESULTS

TENSILE RETENTION DATA

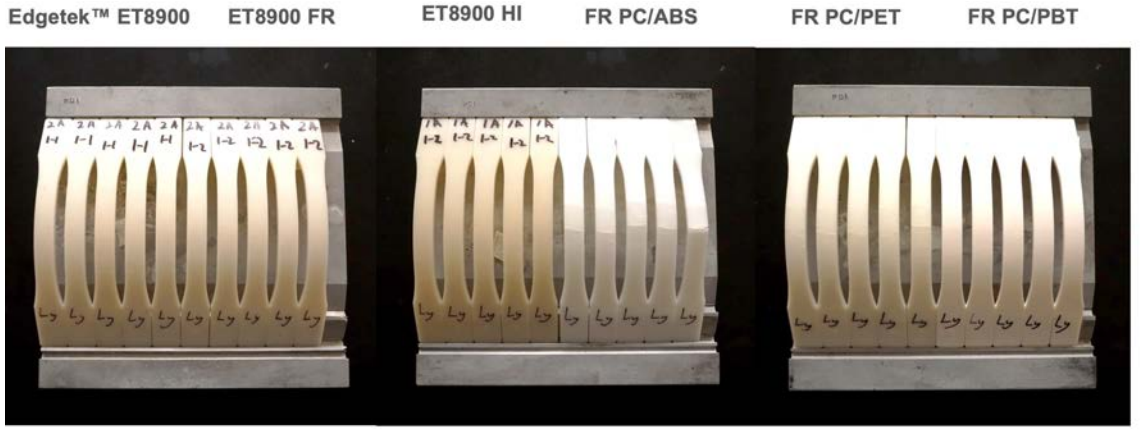






Color: natural

PC/ABS and PC/PET failed in strain jig



Color: natural

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HEALTHCARE MATERIALS

ESCR SUMMARY

CRITERIA FOR RESISTANCE RATING

- \+ strength and elongation at yield retention between 90-110%
- \+ strength and elongation at yield retention between 75-125%
- \+ no statistically significant reduction in elongation at break ($p < 0.05$)
- \+ visual observation score of 4 or better (minor/no crazing, no cracks)
- \+ samples survived disinfectant exposure in strain jig

DISINFECTANT	EPA REGISTRATION	RELEVANT INGREDIENTS	RESISTANCE RATING				
			TRILLIANT™ HC8910	TRILLIANT™ HC8920 FR	FR PC/ABS	FR PC/PET	FR COPOLYESTER
CaviCide™	46781-6	Quaternary ammonium; Isopropyl alcohol	+++++	+++++	+++	++++	+++++
Super Sani-Cloth®	9480-4	Quaternary ammonium; Isopropyl alcohol	+++++	+++++	+++++	+++++	+++++
SporGon™	No (FDA 510K)	Peracetic acid; Hydrogen peroxide	+++++	+++++	++++	++++	++++
Vesphene® IIse	1043-87	Phenolic	+++++	+++++	-	++	++++
Virex® Tb	70627-2	Quaternary ammonium; Diethylene glycol butyl ether	+++++	+++++	-	-	++

HEALTHCARE MATERIALS

PHYSICAL & MECHANICAL PROPERTIES

Property	Trilliant™ HC8920 FR	FR PC/ABS	FR PC/PET	FR PC/PBT	FR COPE
Density (g/cm3)	1.20	1.19	1.28	1.34	1.29
Mold Shrinkage (%) *	0.8 to 1.0	0.4 to 0.6	0.6 to 0.8	0.9 to 1.0	0.5 to 0.7
Yield Strength (MPa)	45	60	58	56	42
Elongation: Yield, Break (%)	12, 50	4.0, >50	4.5, 100	4.3, 109	6, 70
Tensile Modulus (MPa)	1920	2700	2350	2300	1820
Flexural Strength (MPa)	78	90	86	85	68
Flexural Modulus (MPa)	2410	2700	2300	2300	1590
HDT: 0.45, 1.8 (MPa)	110, 80	90, 80	123, 100	115, 85	100, 70
UL-94 Rating @ 3.0 mm	**5VA**	**V-0**	**V-0**	**5VA**	**V-0**
UL-94 Rating @ 1.5 mm	V-0	V-0	V-0	V-0	V-0
UL-94 Rating @ 0.75 mm	V-1	V-2	None	None	V-2

*Approximations based on internal testing method on plaques. Expect results to vary based on application geometries.

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CONSUMER/INDUSTRIAL MATERIALS

ESCR SUMMARY

CRITERIA FOR RESISTANCE RATING

- \+ strength and elongation at yield retention between 90-110%
- \+ strength and elongation at yield retention between 75-125%
- \+ no statistically significant reduction in elongation at break ($p < 0.05$)
- \+ visual observation score of 4 or better (minor/no crazing, no cracks)
- \+ samples survived disinfectant exposure in strain jig

DISINFECTANT/CLEANER	EPA REG. NO.	RELEVANT INGREDIENTS	RESISTANCE RATING					
			EDGETEK™ ET8900 CR	EDGETEK™ ET8900 HI CR	EDGETEK™ ET8920 FR CR	FR PC/ABS	FR PC/PET	FR PC/PBT
Clorox® Disinfecting Wipes	5813-79	Quaternary ammonium, isopropanol	+++++	+++++	+++++	++	+++	++++
Formula 409® Heavy Duty Degreaser	N/A	Lauramine oxide, ethanolamine	+++++	+++++	+++++	+	++	+++
Lysol® All-Purpose Cleaner	777-66	Quaternary ammonium, dipropylene glycol	+++++	+++++	+++++	+	+	++

CONSUMER/INDUSTRIAL MATERIALS

PHYSICAL & MECHANICAL PROPERTIES

Property	Edgetek™ ET8900 HI CR	Edgetek™ ET8920 FR CR	FR PC/ABS	FR PC/PET	FR PC/PBT
Density (g/cm3)	1.16	1.20	1.18	1.28	1.2
Mold Shrinkage (%) *	1.0 to 1.4	0.8 to 1.0	0.5 to 0.7	0.8 to 1.1	0.9 to 1.3
Yield Strength (MPa)	48	45	60	58	56
Elongation: Yield, Break (%)	N/A, 220	12, 50	4.0, 25	4.5, 58	4.5, 109
Tensile Modulus (MPa)	1206	1920	2700	2350	2300
Flexural Strength (MPa)	59	78	100	86	85
Flexural Modulus (MPa)	1530	2410	2600	2300	2300
Notched Izod, 23 °C (ft-lb/in)	16.0	1.5	11.5	12.9	10.4
HDT: 0.45, 1.8 (MPa)	100, 70	110, 80	100, 90	123, 100	115, 85
UL-94 Rating @ 3.0 mm	-	5VA	5VA	5VA	5VA
UL-94 Rating @ 1.5 mm	-	V-0	V-0	V-0	V-0 (2 mm)
UL-94 Rating @ 0.75 mm	-	V-1			

*Approximations based on internal testing method on plaques. Expect results to vary based on application geometries.

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CHEMICALLY RESISTANT SOLUTIONS

SUMMARY

- Trilliant™ HC8910 and HC8920 materials and Edgetek™ ET8900 series are disinfectant resistant thermoplastics
  - Trilliant™ formulations include 6 new grades, formulated with medical grade raw materials without BPA ingredients and available in FR and non-FR formulations
  - Edgetek™ formulations include 3 new grades, available in high impact and FR formulations

- Key features
  - Best-in-class chemical resistance
  - Comparable physical and mechanical performance to benchmarks
  - Formulated without BPA ingredients
  - Flame retardant
  - Colorable

THANK YOU

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