Effects of Liquid Disinfectants on Aircraft Cabin Interior Materials

Advanced Virtual Engineering and Testing Laboratories

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National Institute for Aviation Research

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Agenda

Effects of Liquid Disinfectants on Aircraft Cabin Interior Materials

- Research Team
- Motivation and Approach
- Project Overview
- Phase-I: Aircraft Seat
- Phase-III: Cabin Interior
- Conclusion
- Future work

Research Team

Effects of Liquid Disinfectants on Aircraft Cabin Interior Materials

- Evaluate the effect of liquid disinfectants on flammability performance and mechanical properties of materials used in aircraft interior
- Project Participants (NIAR AVET)
  - PI: Gerardo Olivares
  - Researchers: Akhil Bhasin, Luis Gomez, Tanat Maichan, Luis Daniel Castillo, Aswini Kona Ravi
  - Student Researchers: Clayton Ehrstein, Carlos Gatti, Javier Martinez, Irene DeGiacomi, Hunter Griffith, Garret McClain, Hoolooman Ramdial, Anoushka Raju
- FAA Technical Monitor: Cindy Ashforth
- Other FAA Personnel: Jeff Gardlin, Ahmet Oztekin
- Industry Partnerships/Other Collaborations: SAE Seat Committee, SAE Cabin Interior Committee, Jamco America, Boeing, Aviation Consulting and Engineering Solutions (ACES), Collins Aerospace, AmSafe, SABIC, Lantal Textiles, Schneller

Motivation and Approach

Effects of Liquid Disinfectants on Aircraft Cabin Interior Materials

- Motivation & Key Issues
  - Covid-19 pandemic outbreak.
  - Increased aircraft disinfection procedures enforced by regulatory bodies.
- Objective & Scope
  - Evaluate and understand the long-term effects of use of disinfectants on aircraft interiors.
  - Scope of the project extends to liquid and ultraviolet-c disinfection on aircraft cabin and seating materials.
- Approach
  - Identify the commonly used disinfectants for aircraft interior cleaning.
  - Subject the materials to accelerated disinfection tests.
  - Evaluate the effects on mechanical properties, flammability, weight and color.

Project Overview

Effects of Liquid Disinfectants on Aircraft Cabin Interior Materials

PHASE-I: Effects of Liquid Disinfectants on Aircraft Seating Materials

- 5 Liquid Disinfectants
- 17 Seating Materials
- Properties:
  - Flammability &
  - Mechanical

PHASE-II: Effects of UV-C Disinfection on Aircraft Seating Materials

- 3 Wavelength Configurations
- 5 Seating Materials
- Properties:
  - Mechanical

PHASE-III: Effects of Liquid and UV-C Disinfection on Aircraft Cabin Materials

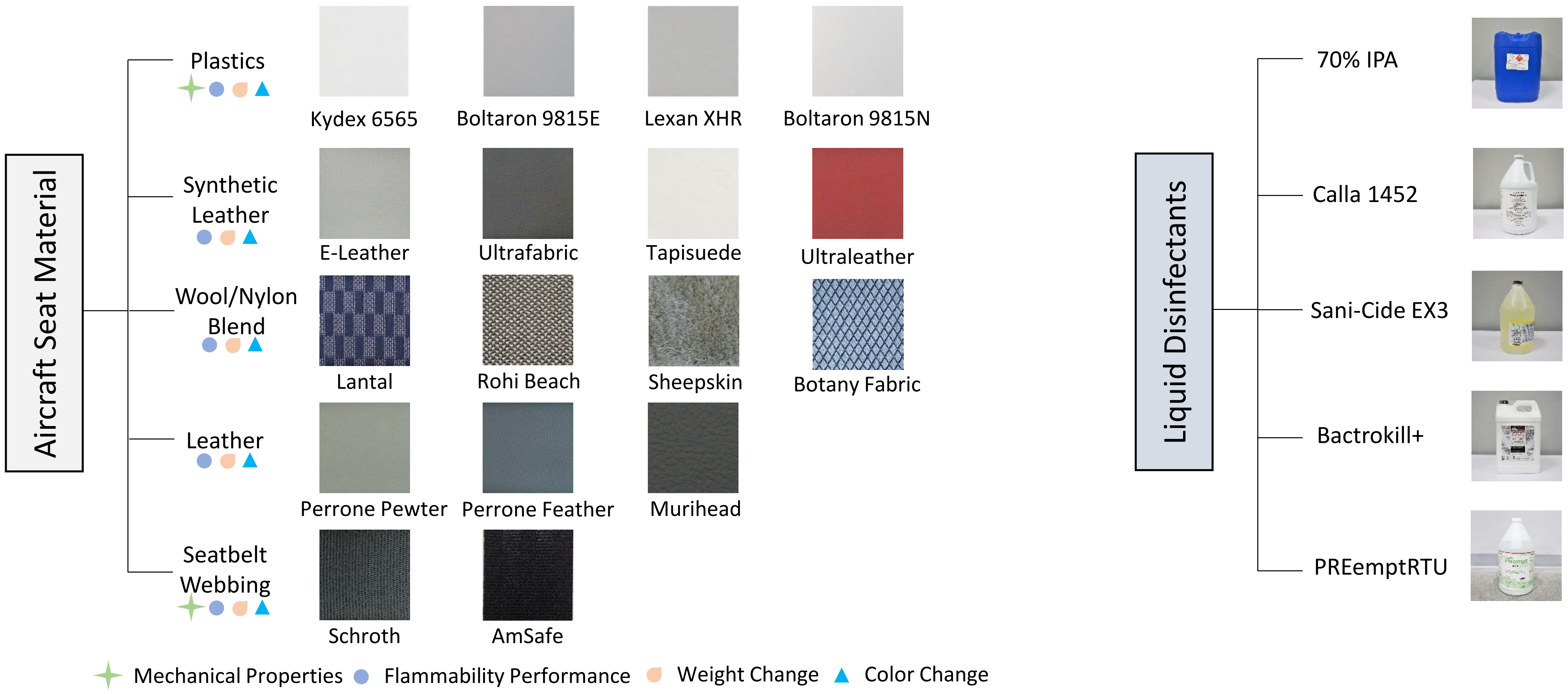
- Cabin Materials: Decorative laminates, floor carpets & honeycomb sandwich panels.

Phase-I: Effect of Liquid Disinfectants on Aircraft Seating

Effects of Liquid Disinfectants on Aircraft Cabin Interior Materials

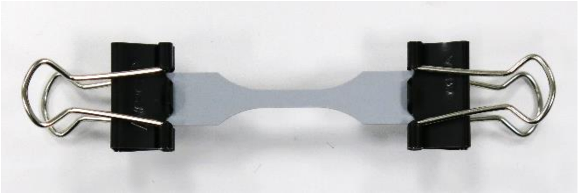
Materials and Disinfectants

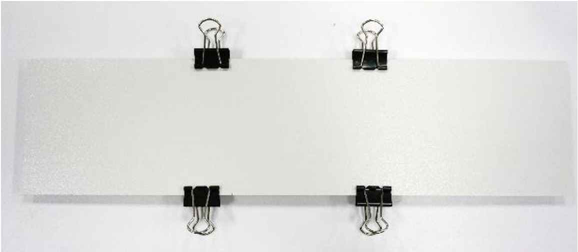
Phase-I: Effect of Liquid Disinfectants on Aircraft Seating



Conditioning Method: Submersion

Phase-I: Effect of Liquid Disinfectants on Aircraft Seating



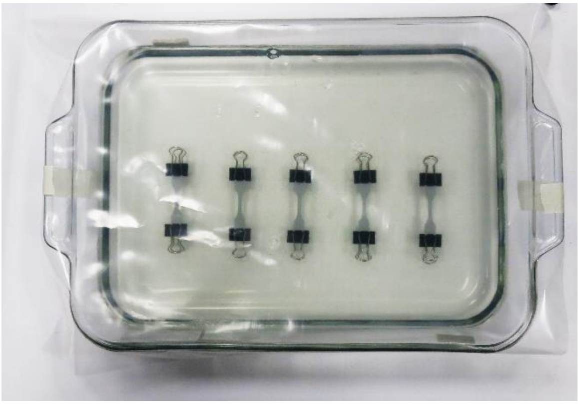


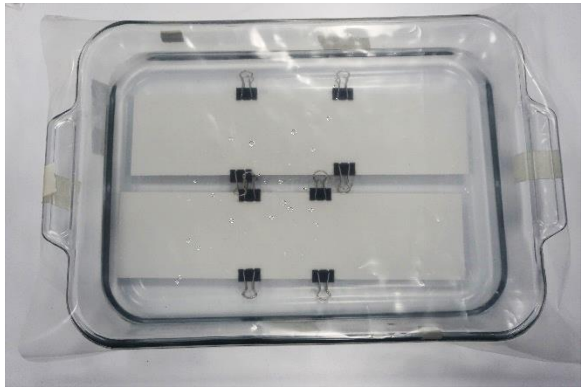
Clamp each specimen with paper clip

Place them in a tray filled with disinfectant

Label the tray with conditioning start time

Cover the tray with vacuum bag





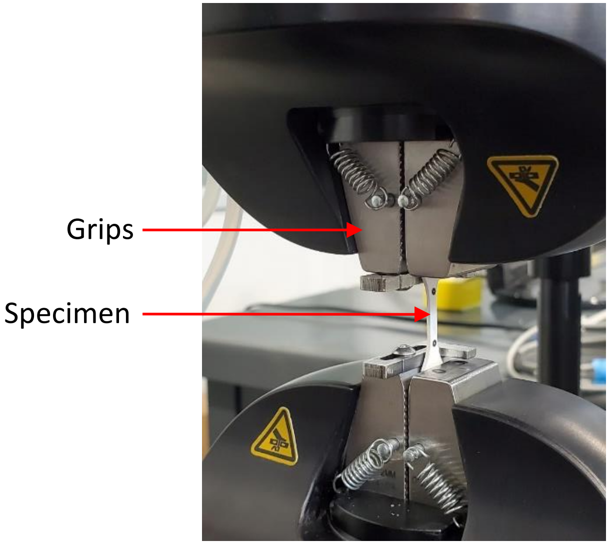
Mechanical Properties

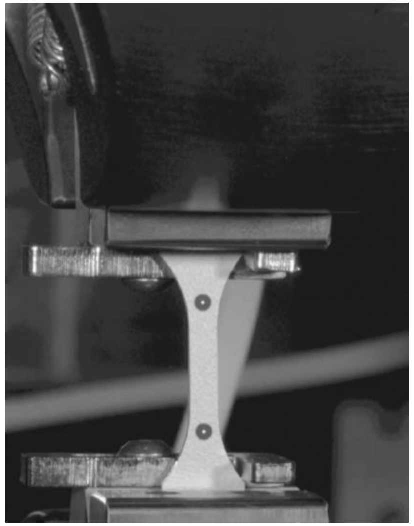
Phase-I: Effect of Liquid Disinfectants on Aircraft Seating

Test Details: Plastics

Mechanical Properties

Test Setup





Kydex 6565

Boltaron 9815E

Lexan XHR

Boltaron 9815N

- Mechanical Test Method: Uniaxial tension experiments
- Test Standard: ASTM D638
- Test Equipment: MTS electrodynamic test frame
- Instrumentation: DIC for elongation measurements

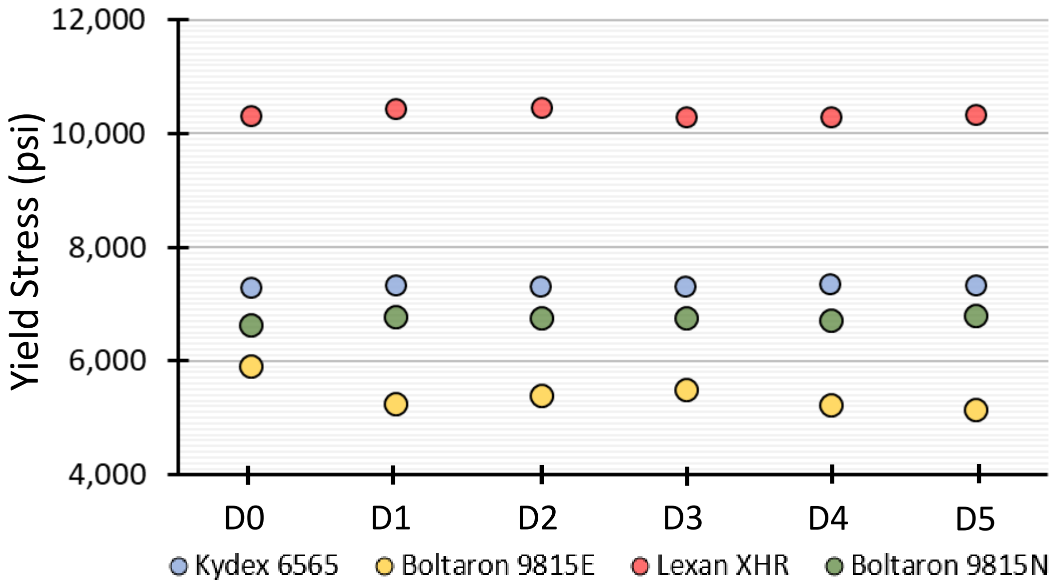
Tensile Test Matrix

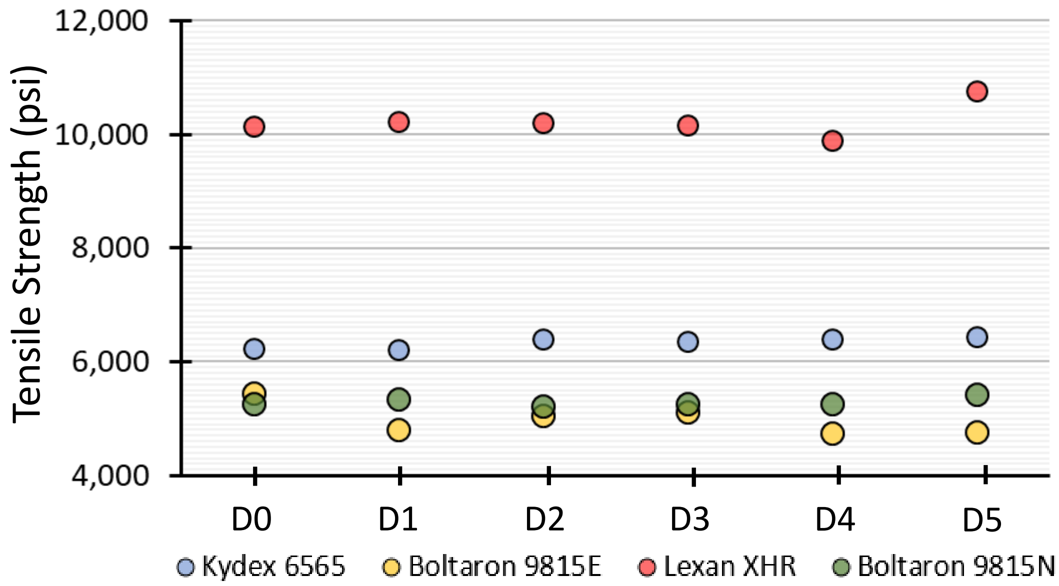
Plastic Type	Liquid Disinfectant Type					
	D0	D1	D2	D3	D4	D5
Kydex 6565	x 5	x 5	x 5	x 5	x 5	x 5
Boltaron 9815E	x 5	x 5	x 5	x 5	x 5	x 5
Lexan XHR	x 5	x 5	x 5	x 5	x 5	x 5
Boltaron 9815N	x 5	x 5	x 5	x 5	x 5	x 5

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Test Results: Plastics

Mechanical Properties





D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Statistical Evaluation: Plastics

Mechanical Properties

- To further investigative if the liquid disinfectants had any detrimental effect on the material properties of selected plastics, statistical analysis following guidelines in CMH-17 was done.
- To have a larger data set, additional uniaxial tension tests were conducted for Kydex 6565 and Boltaron 9815E
- Material properties obtained from unconditioned specimens were treated as qualification batch. Equivalency of the tensile strength and yield stress of all plastics conditioned with liquid disinfectants was conducted.

Additional Specimens Tested						
Plastic Type	Liquid Disinfectant Type					
	D0	D1	D2	D3	D4	D5
Kydex 6565	x 13	x 3	x 3	x 3	x 3	x 3
Boltaron 9815E	x 13	x 3	x 3	x 3	x 3	x 3
Lexan XHR	N/A*					
Boltaron 9815N						

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

*Limited availability of material did not permit machining of additional specimens. Statistical evaluation for these two plastics were conducted based on reduced data set

Results Summary: Plastics

Mechanical Properties

Tension Properties: Statistical Evaluation Summary					
Plastic Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
Kydex 6565					
Boltaron 9815E					
Lexan XHR					
Boltaron 9815N					

Equivalent to unconditioned specimens

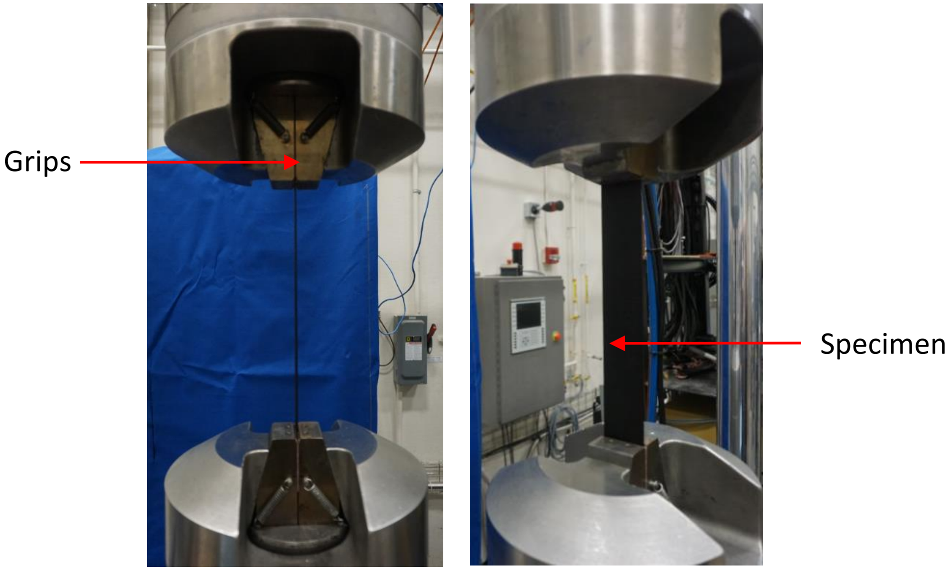
Not equivalent to unconditioned specimens

Equivalent to unconditioned specimens based on reduced testing

Test Details: SCHROTH Webbing

Mechanical Properties

Seat Belt Webbing Tensile Test Setup



SCHROTH Webbing

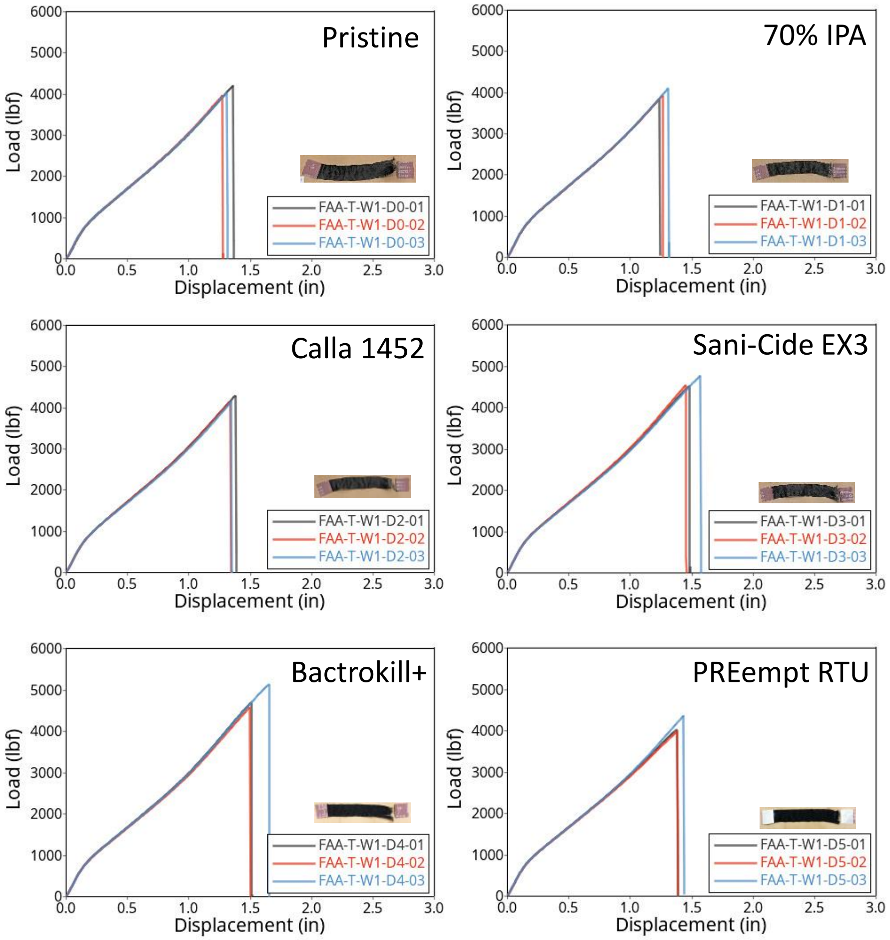
- Test Reference: DOT/FAA/TC-15/29
- Test Apparatus: Servo-Hydraulic frame; 55 kip
- Grip pressure: 3000 psi
- Stroke rate: 3 in/min

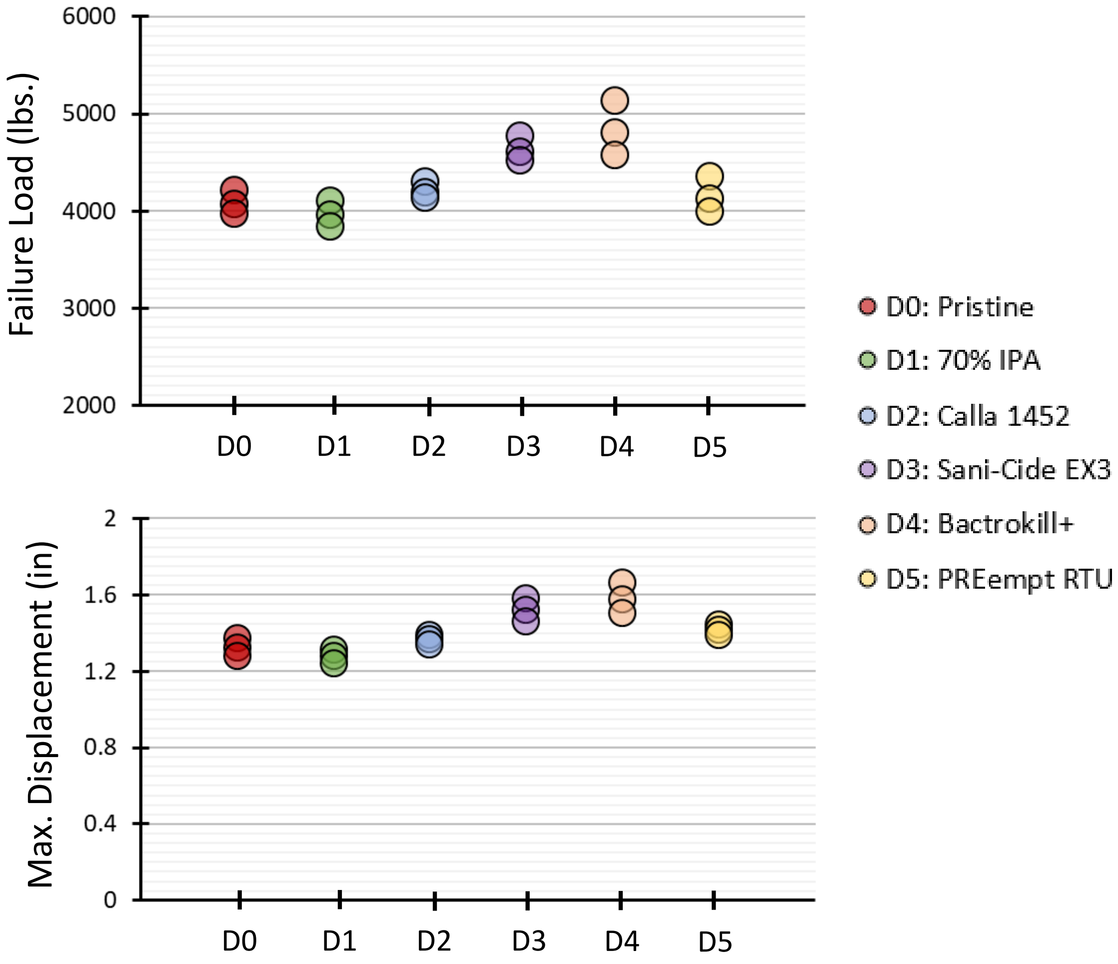
Seatbelt Webbing Tension Test Matrix (SCHROTH)						
Webbing Type	Liquid Disinfectant Type					
	D0	D1	D2	D3	D4	D5
SCHROTH	x 3	x 3	x 3	x 3	x 3	x 3

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Test Results: SCHROTH Webbing

Mechanical Properties





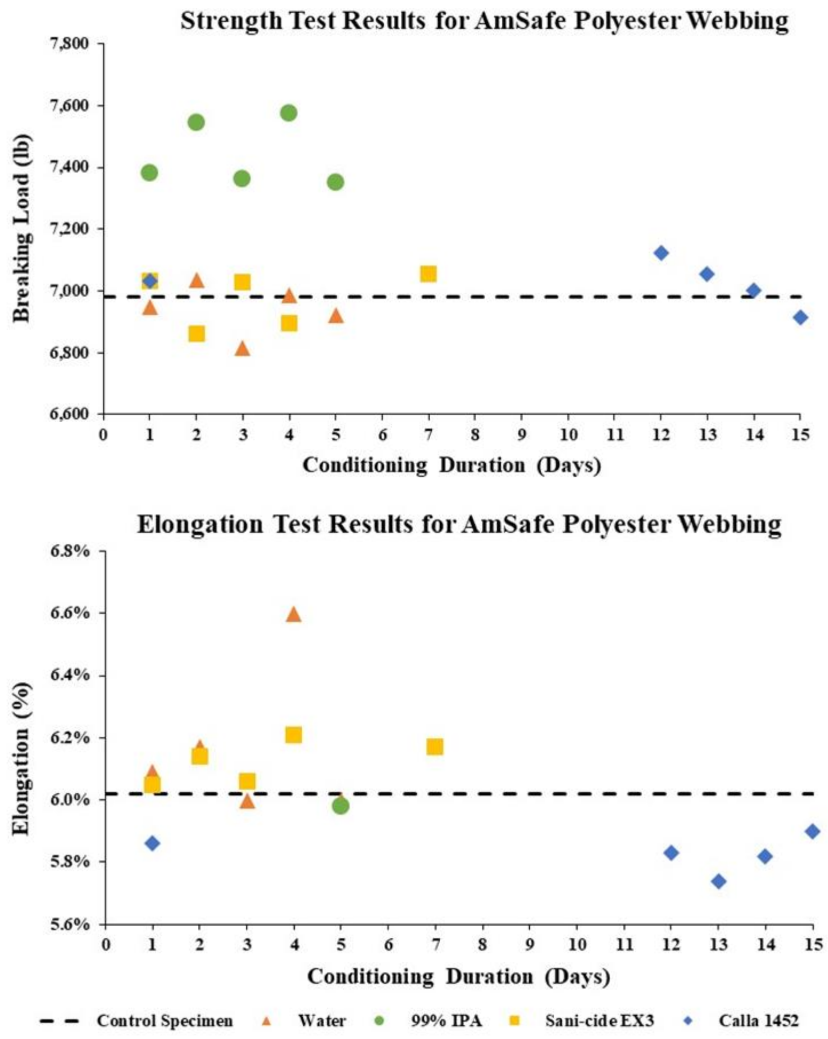
D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Test Details and Results: AmSafe Webbing

Mechanical Properties

- Tests conducted at AmSafe facility
- Standard: SAE AS8043B
- Specimen conditioning: 1 day to longer duration
- Conditioning: Water, 99% IPA, Sani-Cide EX3, Calla 1452

Disinfectants Type	Conditioning Duration (Days)										
	0	1	2	3	4	5	7	12	13	14	15
No Conditioning	x1	-	-	-	-	-	-	-	-	-	-
Water	-	x1	x1	x1	x1	x1	-	-	-	-	-
99% IPA	-	x1	x1	x1	x1	x1	-	-	-	-	-
Sani-Cide EX3	-	x1	x1	x1	x1	-	x1	-	-	-	-
Calla 1452	-	x1	-	-	-	-	-	x1	x1	x1	x1



Graphical plots provided by AmSafe

Results Summary: Seatbelt Webbing

Mechanical Properties

Failure Load: Statistical Evaluation Summary					
Seatbelt Webbing Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
SCHROTH					
AmSafe					

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

No Reduction in failure load

Reduction in failure load less than 5%

Testing data not available

Flammability Properties

Phase-I: Effect of Liquid Disinfectants on Aircraft Seating

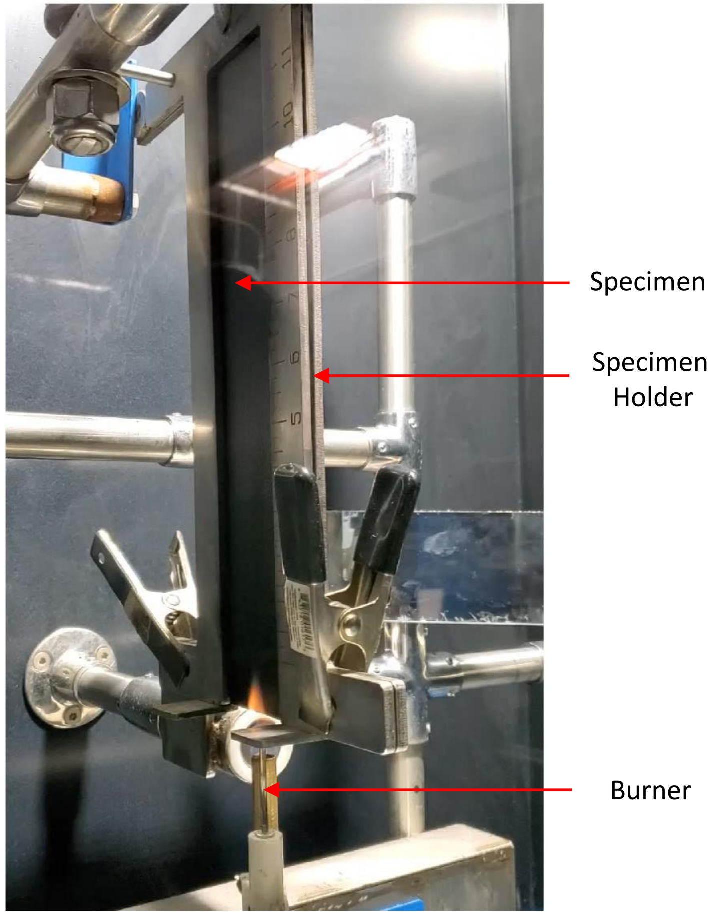
Test Details

Flammability Properties



- Vertical Bunsen burn tests were conducted per Title 14, Code of Federal Regulations (14 CFR) 25.853 Appendix F
- Purpose of the test was to expose likely differences between conditioned and unconditioned specimens
- For seatbelt webbing, 12-second test was conducted; whereas,
- For plastics, leather and fabric materials 60-second test were conducted

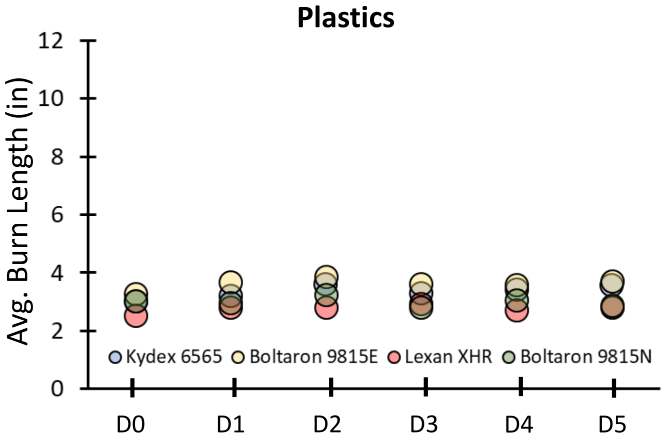
Material Type	Material Name	Flammability Evaluation: Disinfectant Type					
		Pristine	70% IPA	Calla 1452	Sani-Cide EX3	BactroKill+	PREempt RTU
Plastic	Kydex 6565	x3	x3	x3	x3	x3	x3
	Boltaron 9815E	x3	x3	x3	x3	x3	x3
	Lexan XHR	x3	x3	x3	x3	x3	x3
	Boltaron 9815N	x3	x3	x3	x3	x3	x3
Webbing	SCHROTH	x3	x3	x3	x3	x3	x3
Synthetic Leather	E-Leather CL280	x3	x3	x3	x3	x3	x3
	Ultrafabric 492-6579FR12	x3	x3	x3	x3	x3	x3
	TapiSuede TSFRC0961	x3	x3	x3	x3	x3	x3
	Ultraleather ULFRB971-1363	x3	x3	x3	x3	x3	x3
Wool/Nylon Blend	Lantal	x3	x3	x3	x3	x3	x3
	Rohi Beach	x3	x3	x3	x3	x3	x3
	Sheepskin	x3	x3	x3	x3	x3	x3
	Botany Fabric	x3	x3	x3	x3	x3	x3
Leather	Murihead	x3	x3	x3	x3	x3	x3
	Pewter BC (Perrone)	x3	x3	x3	x3	x3	x3
	Perrone Feather Weight	x3	x3	x3	x3	x3	x3

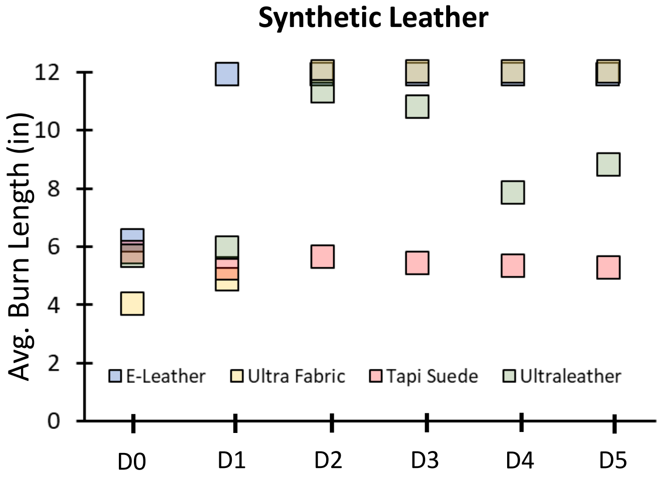


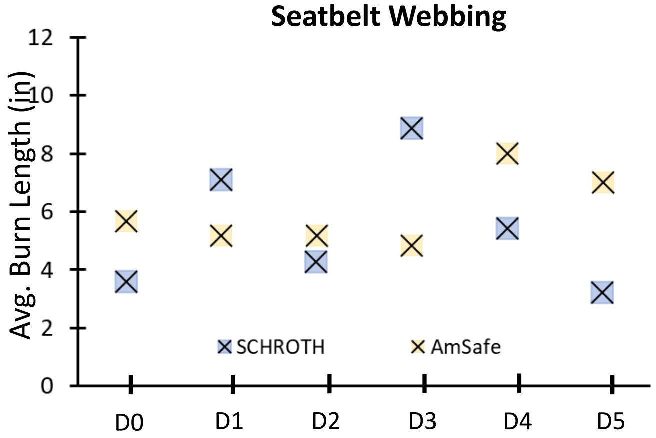
Video provided by ACES
(speed scaled for presentation)

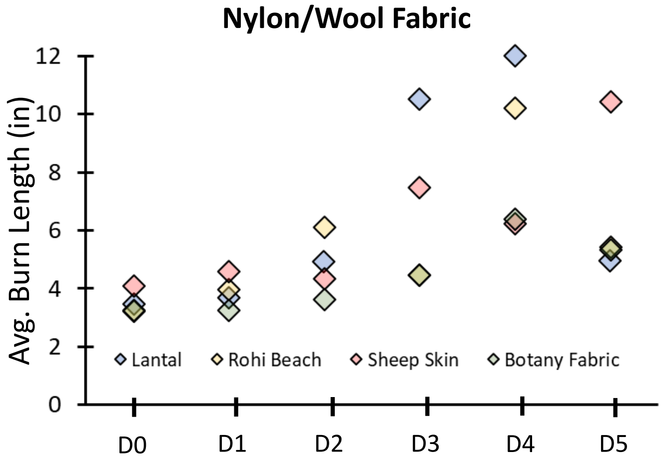
Burn Length Comparison

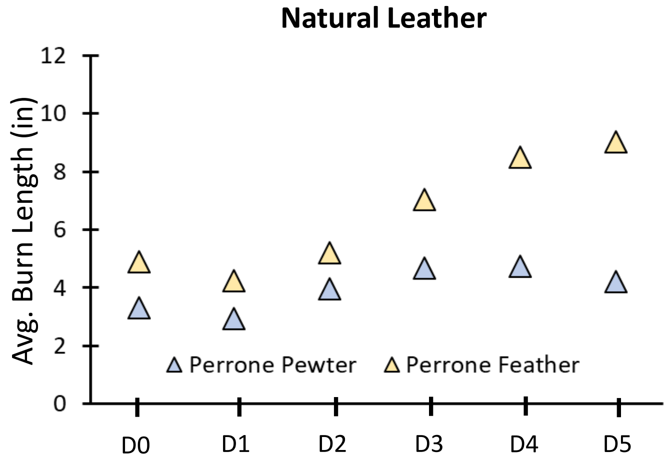
Flammability Properties











D0: Pristine, D1: 70% IPA; D2: Calla 1452;
D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Flammability Results Summary

Flammability Properties

Flammability Results: Submersion Conditioning						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Plastic	Kydex 6565					
	Boltaron 9815E					
	Lexan XHR					
	Boltaron 9815N					
Synthetic Leather	E-Leather CL280					
	Ultrafabric 492-6579FR12					
	TapiSuede TSFRC0961					
	Ultraleather ULFRB971-1363					
Wool/Nylon Blend	Lantal					
	Rohi Beach					
	Sheep Skin					
	Botany Fabric					
Leather	Pewter BC (Perrone)					
	Perrone Feather Weight					
Webbing	SCHROTH					
	AmSafe Polyester					

D0: Pristine; D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Increase in avg. burn length less than 50% in comparison to unconditioned specimens

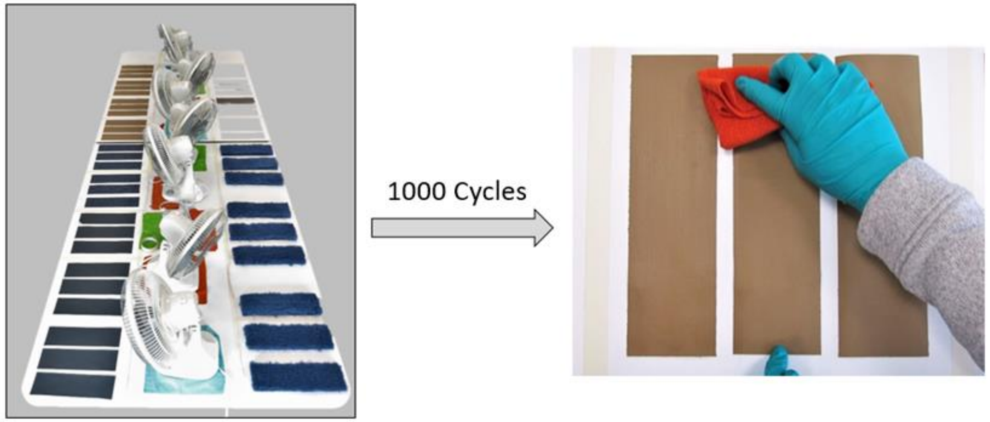
Increase in avg. burn length greater than 50% in comparison to unconditioned specimens

Increase in avg. burn length less is less than 6" in comparison to unconditioned specimens

Wiping Conditioning

Flammability Properties

- Materials for which the flammability results were significantly different, following submersion method, were revaluated by conditioning them with wiping method
- Wiping conditioning simulated the real world application of the liquid disinfectants
- Specimens were arranged on a flat surface and wiped by hand for 1000 cycles
- Only the passenger facing side of the specimen was conditioned

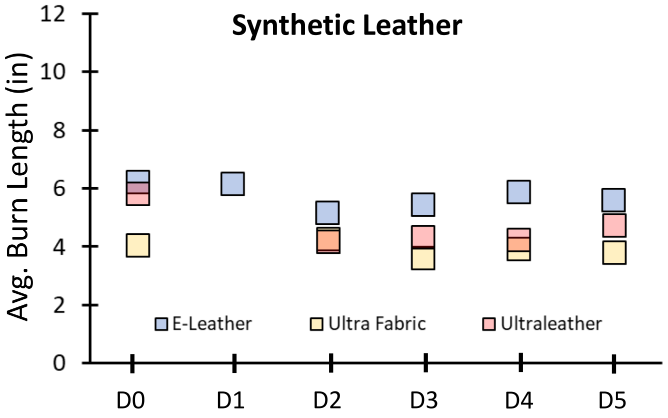


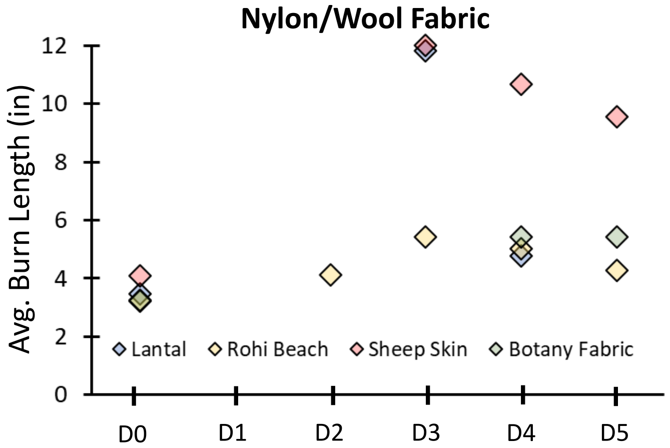
Material Type	Material Name	Flammability Evaluation: Disinfectant Type				
		70% IPA	Calla 1452	Sani-Cide EX3	BactroKill+	PREempt RTU
Synthetic Leather	E-Leather CL820	x3	x3	x3	x3	x3
	Ultrafabric 492-6579FR12	-	x3	x3	x3	x3
	Ultraleather ULFRB971-1363	-	x3	x3	x3	x3
Wool/Nylon Blend	Lantal	-	-	X3	x3	-
	Rohi Beach	-	X3	X3	x3	X3
	Sheepskin	-	-	X3	x3	X3
	Botany Fabric	-	-	-	x3	X3
Leather	Murihead DF602	x3	X3	X3	x3	x3
	Pewter BC (Perrone)	-	x3	x3	x3	x3
	Perrone Feather Weight	-	-	x3	x3	x3

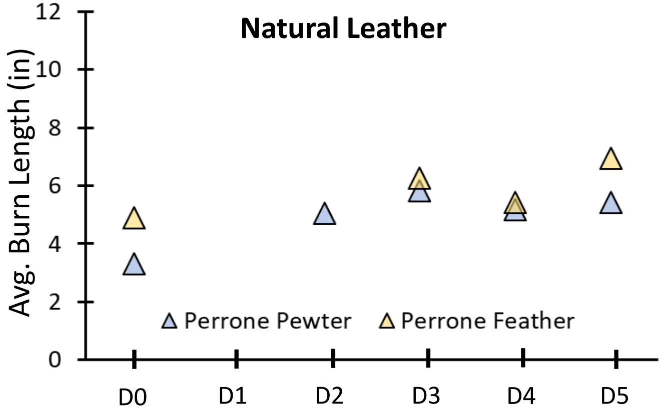
NIAR

Burn Length Comparison: Wiping

Flammability Properties







D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Synthetic Leather (E-leather)

Conditioned with 'D1'

Pristine Submersion Wiping

Lantal (Nylon/Wool Fabric)

Conditioned with 'D3'

Pristine Submersion Wiping

Flammability Results Summary: Wiping

Flammability Properties

Flammability Results: Wiping Conditioning						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Synthetic Leather	E-Leather CL280					
	Ultrafabric 492-6579FR12					
	Ultraleather ULFRB971-1363					
Wool/Nylon Blend	Lantal					
	Rohi Beach					
	Sheep Skin					
	Botany Fabric					
Leather	Pewter BC (Perrone)					
	Perrone Feather Weight					

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Increase in avg. burn length less than 50% in comparison to unconditioned specimens

Increase in avg. burn length greater than 50% in comparison to unconditioned specimens

Normally equivalent results obtained when conditioned using submersion method

Physical Properties

Phase-I: Effect of Liquid Disinfectants on Aircraft Seating

Change in Weight: Submersion

Physical Properties

Change in Weight: Submersion Conditioning						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Plastic	Kydex 6565					
	Boltaron 9815E					
	Lexan XHR					
	Boltaron 9815N					
Synthetic Leather	E-Leather CL280					
	Ultrafabric 492-6579FR12					
	TapiSuede TSFRC0961					
	Ultraleather ULFRB971-1363					
Wool/Nylon Blend	Lantal					
	Rohi Beach					
	Sheep Skin					
	Botany Fabric					
Leather	Pewter BC (Perrone)					
	Perrone Feather Weight					
Webbing	SCHROTH					
	AmSafe Polyester					

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Increase in avg. weight less than 5%

Increase in avg. weight more than 5%

Change in Weight: Wiping

Physical Properties

Change in Weight: Wiping Conditioning						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Synthetic Leather	E-Leather CL280					
	Ultrafabric 492-6579FR12					
	Ultraleather ULFRB971-1363					
Wool/Nylon Blend	Lantal					
	Rohi Beach					
	Sheep Skin					
	Botany Fabric					
Leather	Pewter BC (Perrone)					
	Perrone Feather Weight					

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

- Increase in avg. weight less than 5%
- Increase in avg. weight more than 5%
- Wiping conditioning not conducted

Color Change – Submersion

Physical Properties

Qualitative Color Change: Submersion Conditioning						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Plastic	Kydex 6565					
	Boltaron 9815E					
	Lexan XHR					
	Boltaron 9815N					
Synthetic Leather	E-Leather CL280					
	Ultrafabric 492-6579FR12					
	TapiSuede TSFRC0961					
	Ultraleather ULFRB971-1363					
Wool/Nylon Blend	Lantal					
	Rohi Beach					
	Sheep Skin					
	Botany Fabric					
Leather	Pewter BC (Perrone)					
	Perrone Feather Weight					
Webbing	SCHROTH					

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Boltaron 9815N (D0)

Boltaron 9815N (D4)

Rohi Beach (D0)

Rohi Beach (D5)

Perrone Feather Weight (D0)

Perrone Feather Weight (D4)

No change in color or texture

Change in color

Change in color and texture

Color Change – Wiping

Physical Properties

Change in Weight: Wiping Conditioning						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Synthetic Leather	E-Leather CL280					
	Ultrafabric 492-6579FR12					
	Ultraleather ULFRB971-1363					
Wool/Nylon Blend	Lantal					
	Rohi Beach					
	Sheep Skin					
	Botany Fabric					
Leather	Pewter BC (Perrone)					
	Perrone Feather Weight					

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

No change in color or texture

Change in color

Change in color and texture


Rohi Beach (D0)


Rohi Beach (D2)


Lantal (D0)


Lantal (D3)


Ultrafabric (D0)

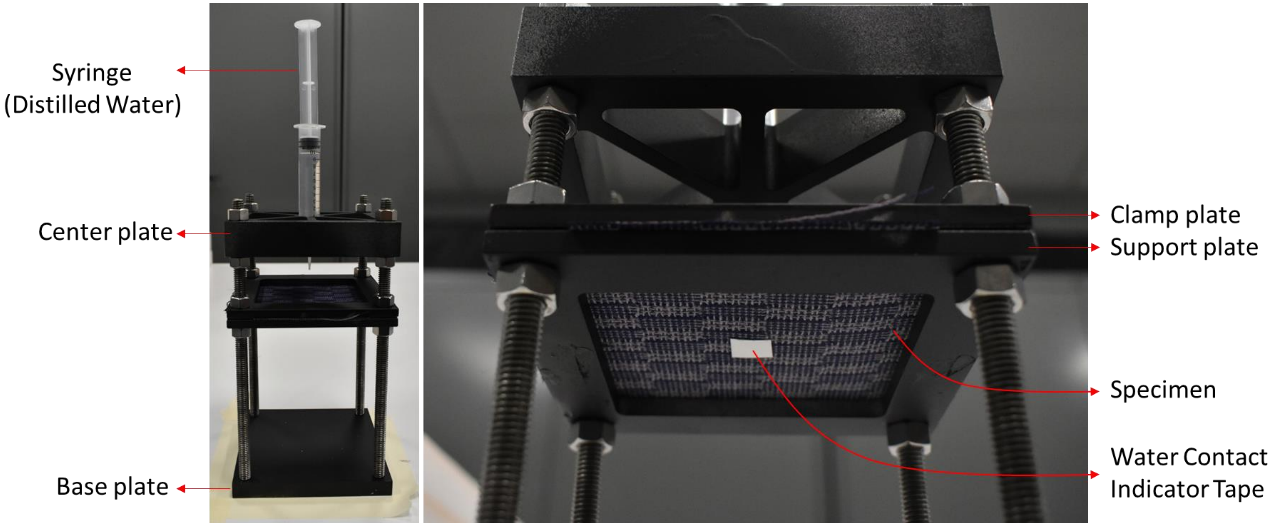

Lantal (D3)

Permeability Evaluation – Test Details

Physical Properties

- NIAR conducted a rapid evaluation of permeability of materials used for this study
- This was done by securing the specimen in a custom fixture and applying 10ml of distilled water at the center of the sample.
- Water indicating tape was attached to the back face of the specimen. Upon direct contact with liquid, the tape turns red in color. It was determined that the color change occurs within 3s of the initial contact.
- The test time was considered to be the time it took for the tape to start coloring. If 15minutes elapsed with visible coloration, test was terminated.
- For control purposes weight of the specimen was measured before and after conducting the test.
- The test setup is shown right.

Material Type	Material Name	Distilled Water
Leather	Pewter BC (Perrone)	x 3
	Perrone WA9374	x 3
Synthetic Leather	E-Leather CL280	x 3
	Ultrafabric 492-6579FR12	x 3
	TapiSuede TSFRC0961	x 3
	Ultraleather ULFRB971-1363	x 3
Nylon/Wool	Lantal	x 3
	Rohi Beach	x 3
	Botany Fabric	x 3



Permeability Evaluation – Results

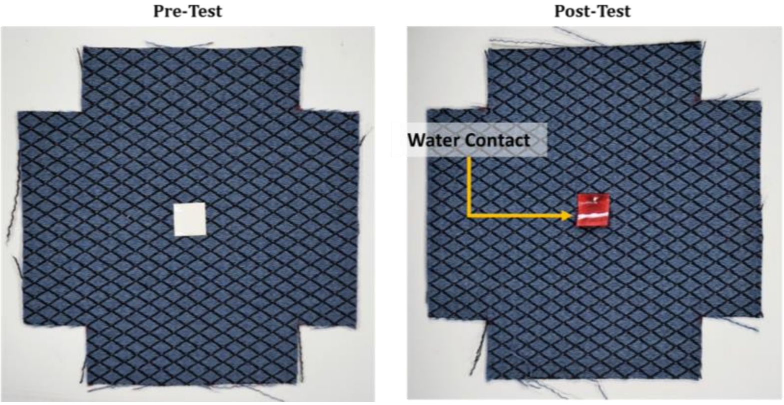
Physical Properties

Permeability Evaluation: Distilled Water		
Material Type	Material Name	Permeation
Synthetic Leather	E-Leather CL280	
	Ultrafabric 492-6579FR12	
	TapiSuede 492-6579FR12	
	Ultraleather ULFRB971-1363	
Wool/Nylon Blend	Lantal	
	Rohi Beach	
	Botany Fabric	
Leather	Pewter BC (Perrone)	
	Perrone Feather Weight	

No permeation observed for all specimens

Permeation observed for at least 1 specimen

Permeation observed for all 3 specimen



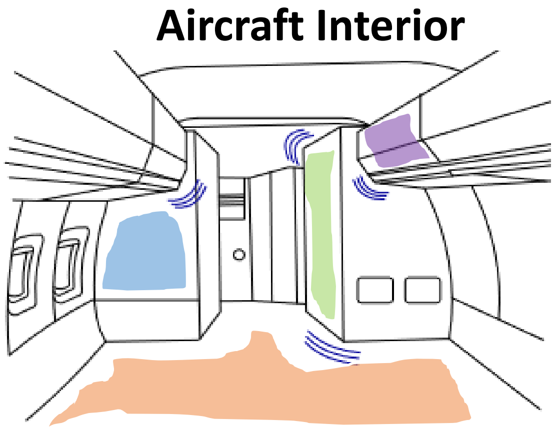
Botany Fabric (Nylon/Wool Fabric)

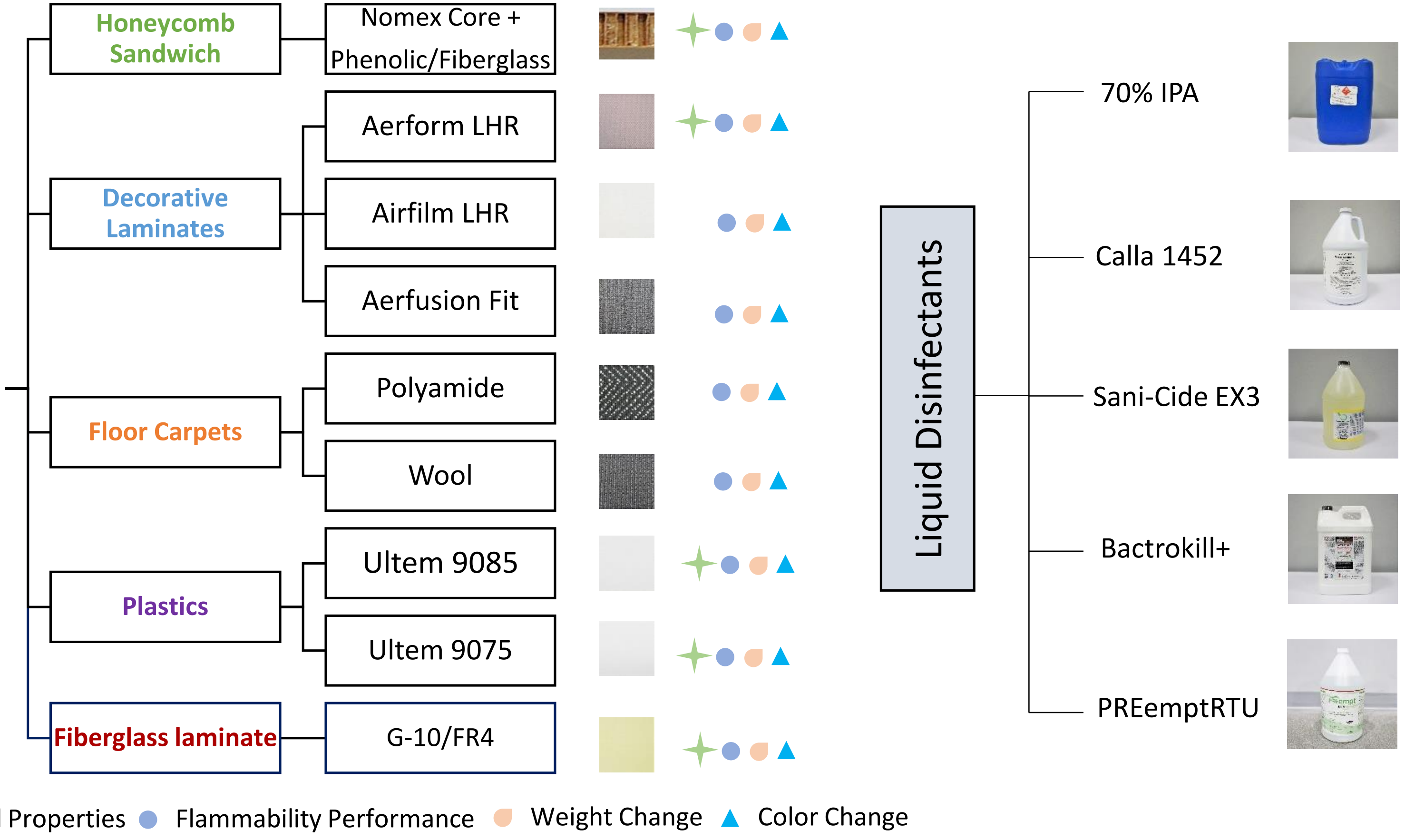
Phase-III: Effect of Liquid Disinfectants on Cabin Interior

Effects of Liquid Disinfectants on Aircraft Cabin Interior Materials

Selected Materials

Phase-III: Effect of Liquid Disinfectants on Cabin Interior





Conditioning Method: Wiping

Phase-III: Effect of Liquid Disinfectants on Cabin Interior

Wiping conditioning for flammability and flatwise compression

1000 cycles on Face #1

1000 cycles on Face #2

Mechanical Properties

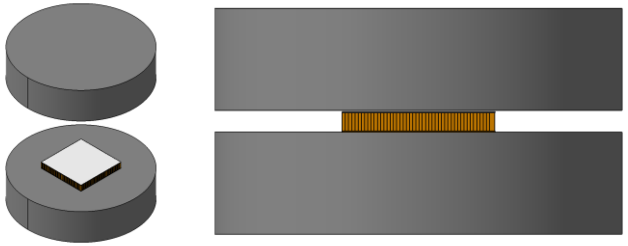
Phase-III: Effect of Liquid Disinfectants on Cabin Interior

Honeycomb Sandwich: Test Matrix

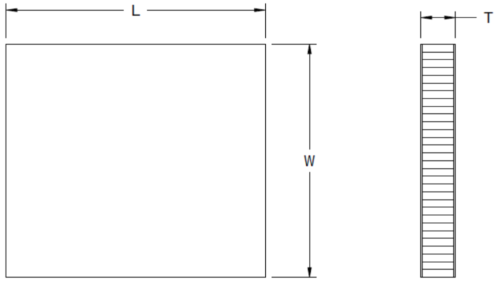
Mechanical Properties

Honeycomb Sandwich Test Matrix						
Loading Condition	Liquid Disinfectant Type					
	D0	D1	D2	D3	D4	D5
Flatwise Compression	x 5	x 5	x 5	x 5	x 5	x 5
Drum Peel	x 5	x 5	x 5	x 5	x 5	x 5
Flexure	x 5	x 5	x 5	x 5	x 5	x 5

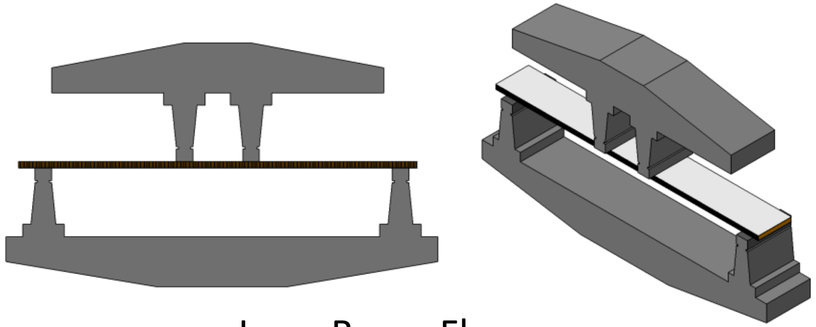
D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU



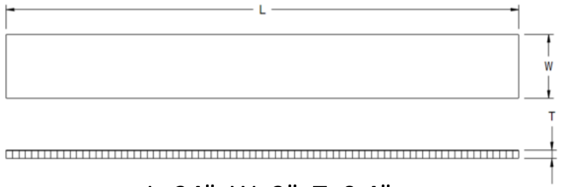
Flatwise Compression



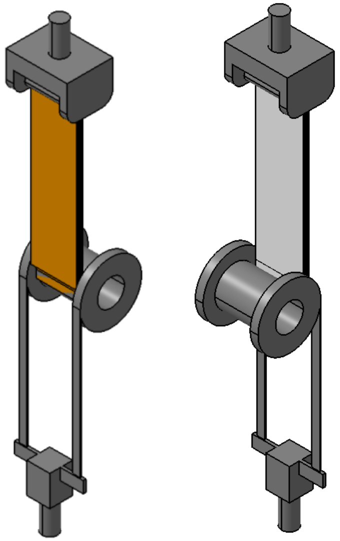
L=3”; W=3”; T=0.4”



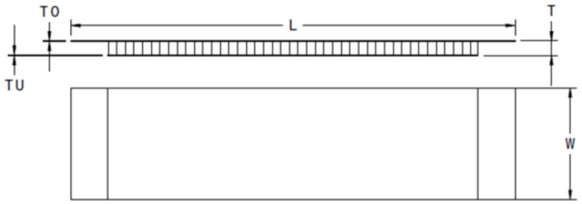
Long Beam Flexure



L=24”; W=3”; T=0.4”



Climbing Drum Peel

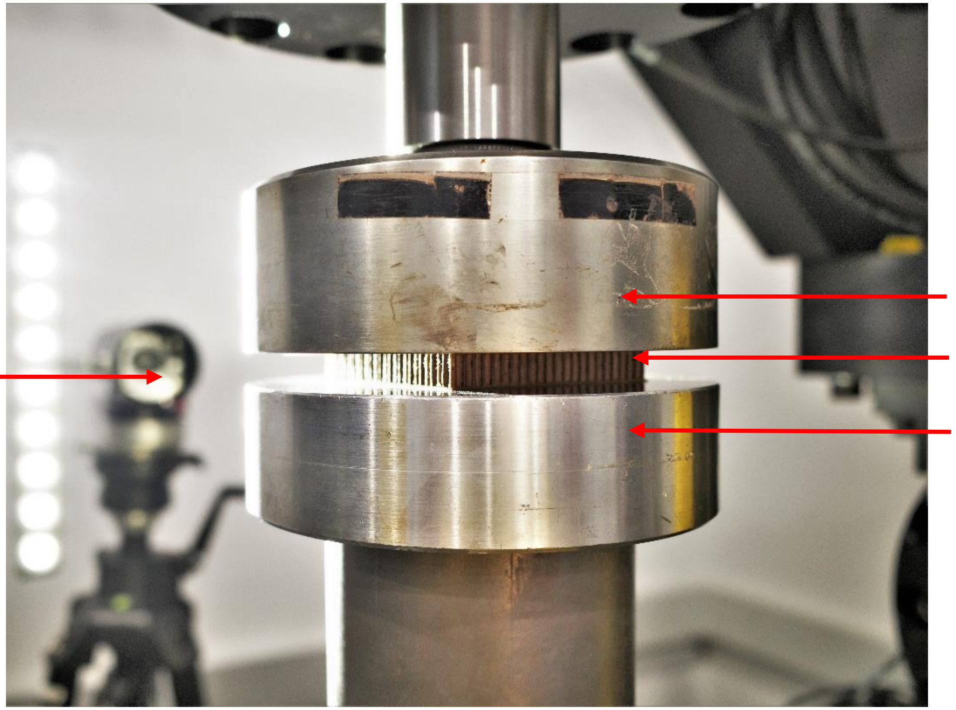


L=12”; W=3”; T=0.4”

Honeycomb Sandwich: Compression

Mechanical Properties

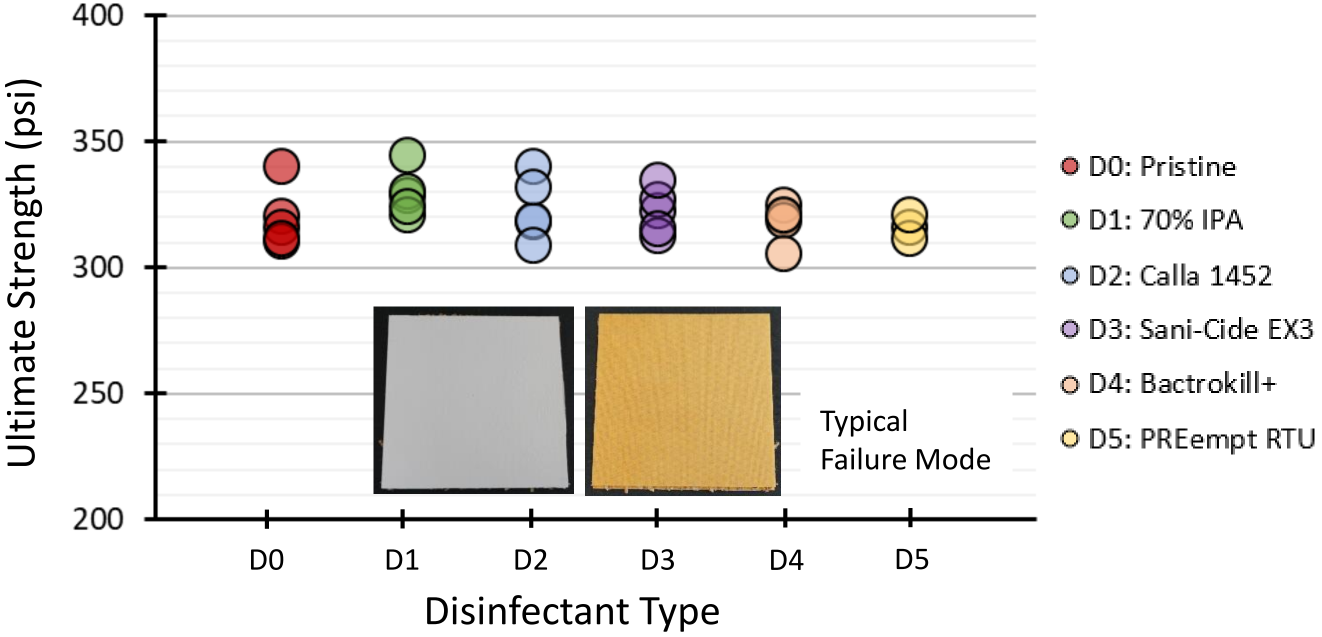
Flatwise Compression Test Setup



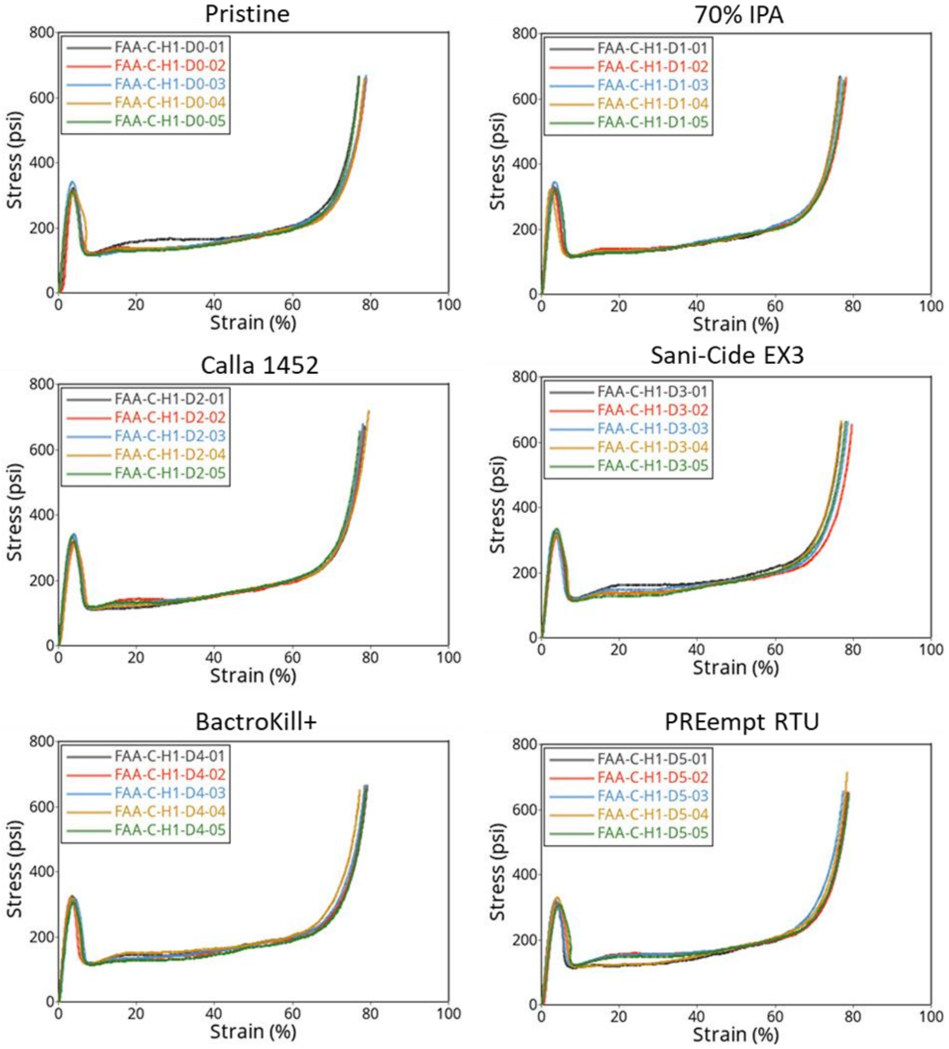
- Mechanical Test Method: Flatwise compression
- Test Standard: ASTM C365
- Test Equipment: Servo hydraulic biaxial test frame
- Instrumentation: Video extensometer for relative disp.

Results: Compression (Honeycomb Sandwich)

Mechanical Properties



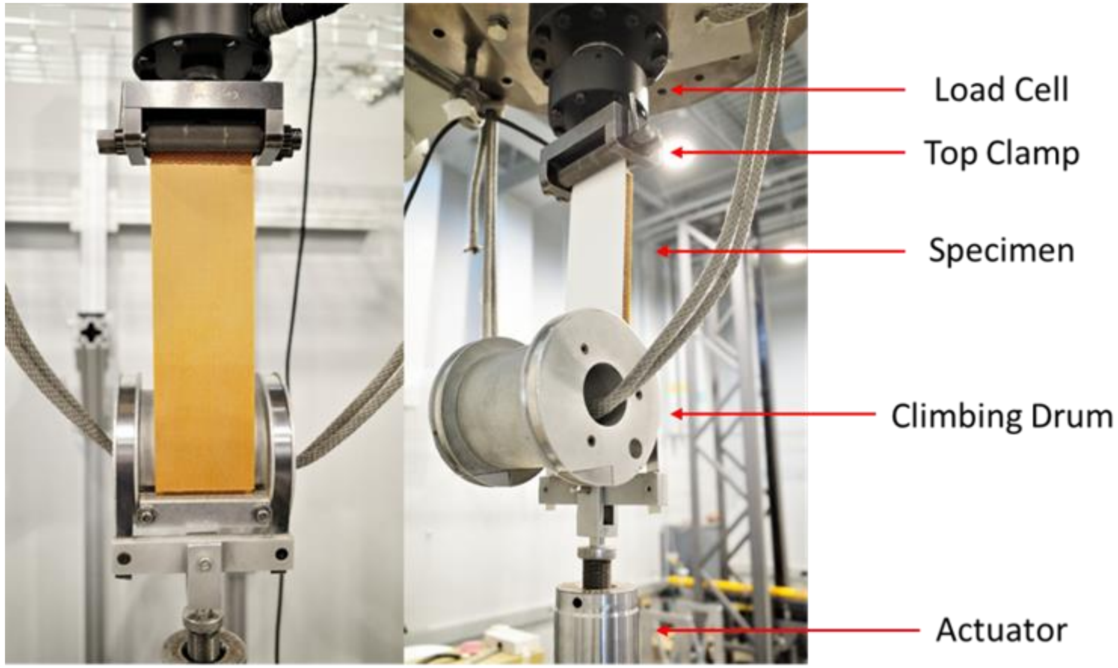
D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU



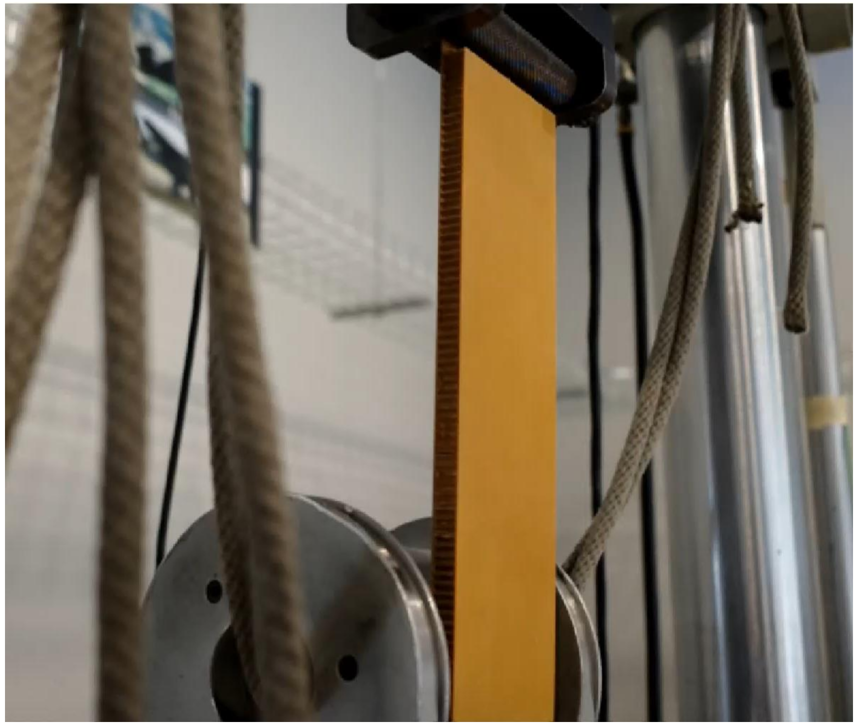
Honeycomb Sandwich: Peel

Mechanical Properties

Climbing Drum Peel Test Setup



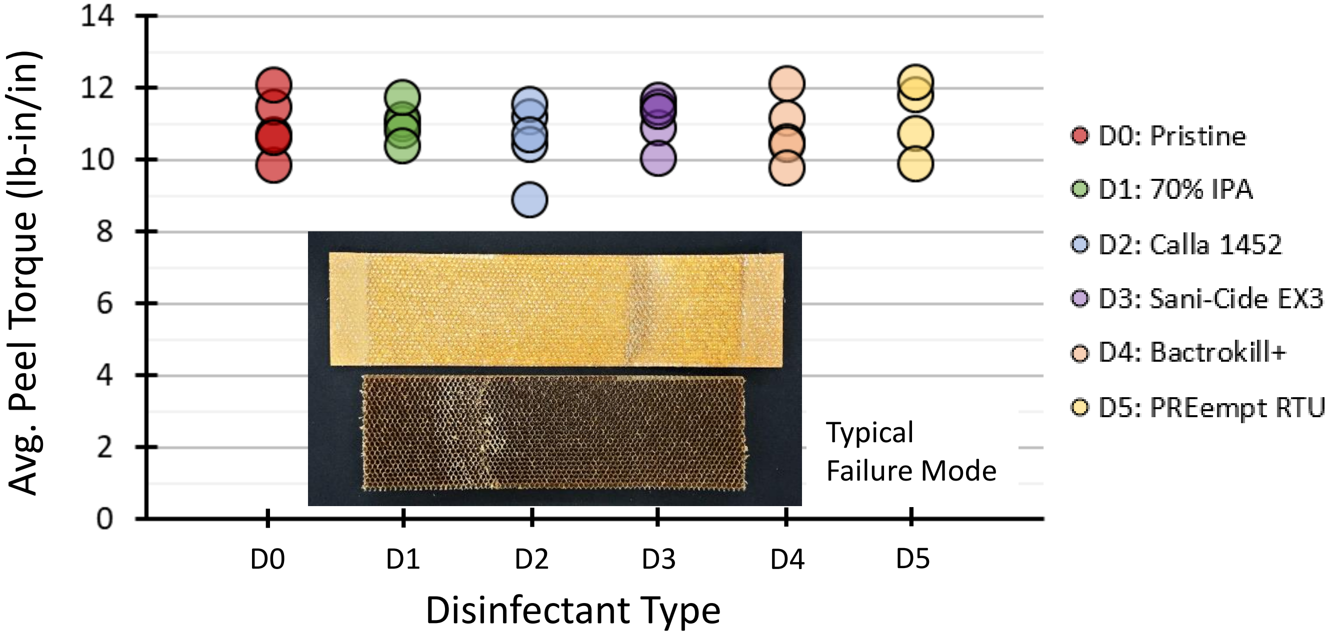
- Mechanical Test Method: Climbing Drum Peel
- Test Standard: ASTM D1781
- Test Equipment: Servo hydraulic test frame



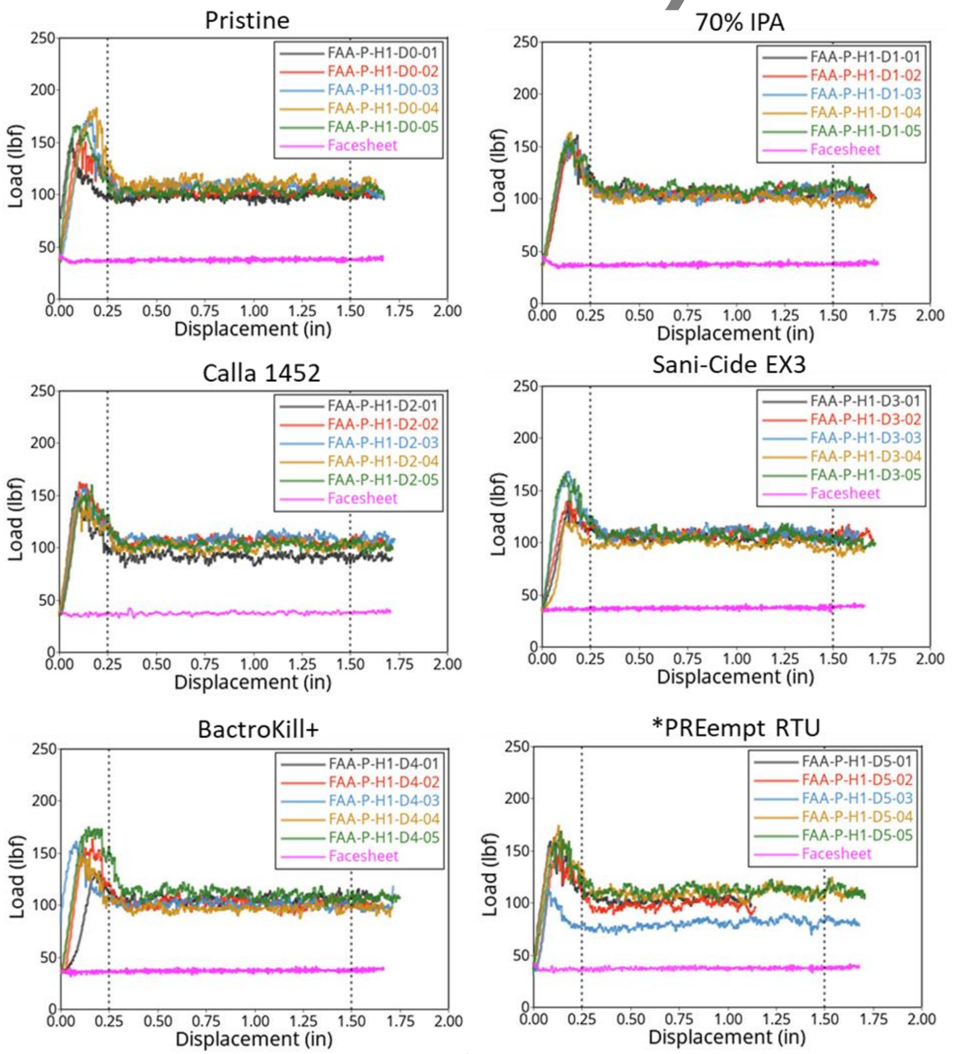
(speed scaled for presentation)

Results: Peel Torque (Honeycomb Sandwich)

Mechanical Properties



D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

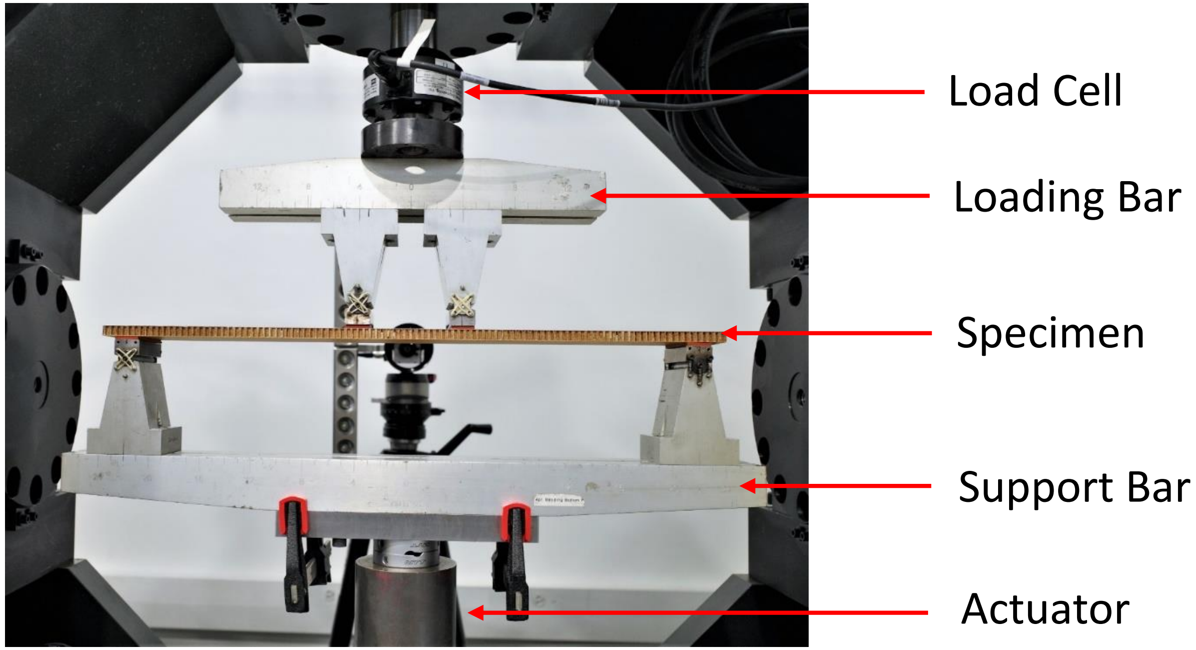


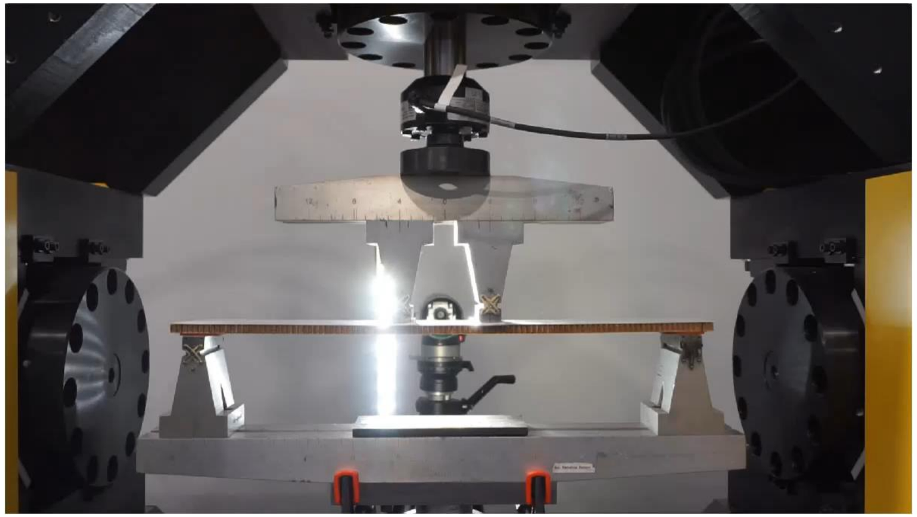
*Specimen FAA-P-H1-D5-03 is considered as an outlier

Honeycomb Sandwich: Long Beam Flexure

Mechanical Properties

Flexure Test Setup



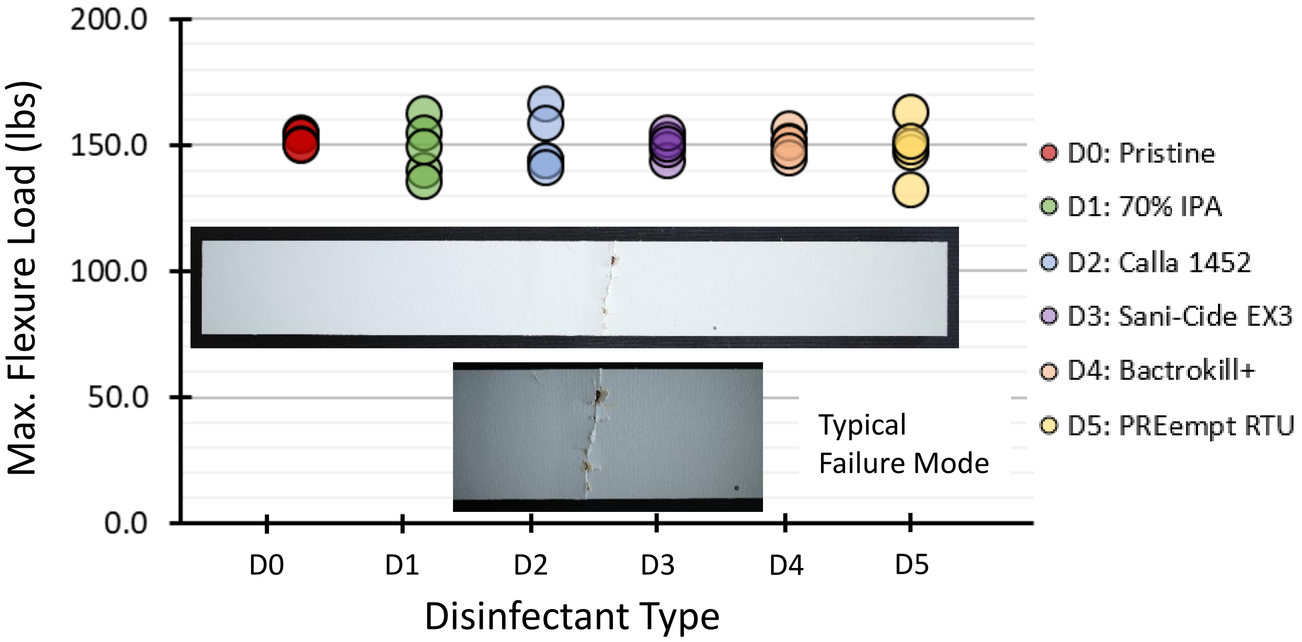


(speed scaled for presentation)

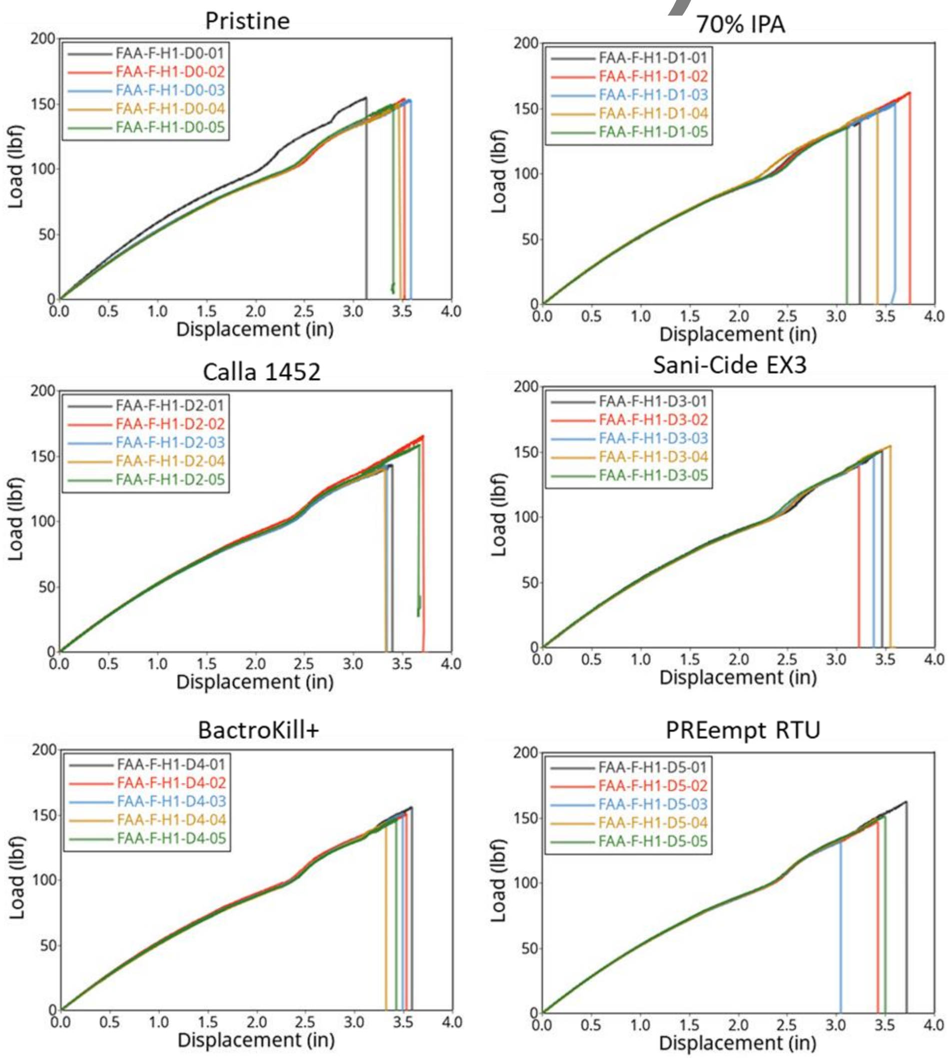
- Mechanical Test Method: Long beam flexure
- Test Standard: ASTM D7249
- Test Equipment: Servo hydraulic biaxial test frame

Results: Flexure (Honeycomb Sandwich)

Mechanical Properties



D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU



Results Summary: Honeycomb Sandwich

Mechanical Properties

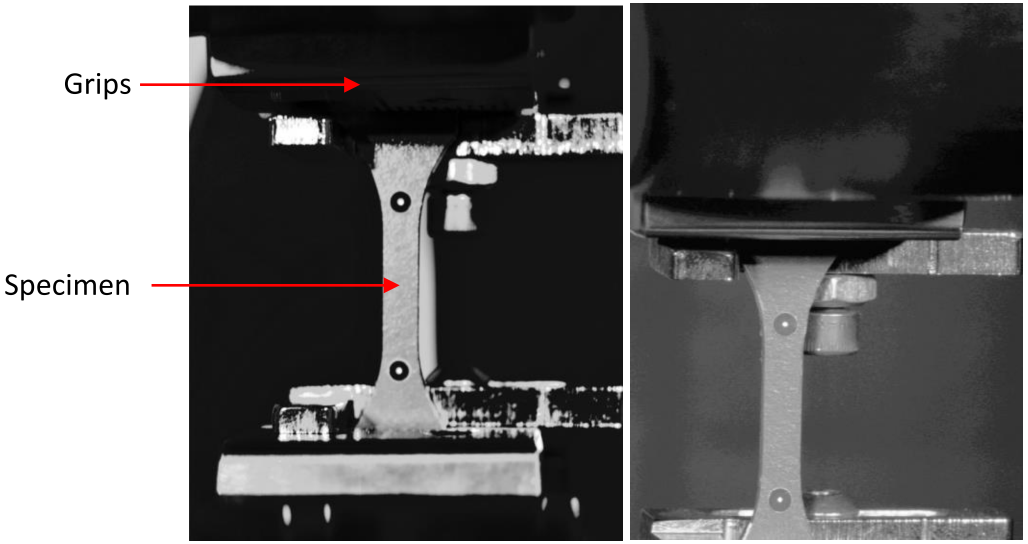
Mechanical Properties: Statistical Evaluation Summary					
Property Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
Compressive Strength					
Average Peel Torque					
Maximum Flexure Load					

Equivalent to unconditioned specimens based on reduced testing

Test Details: Decorative Laminate

Mechanical Properties

Test Setup



Aerform LHR (front and back view)

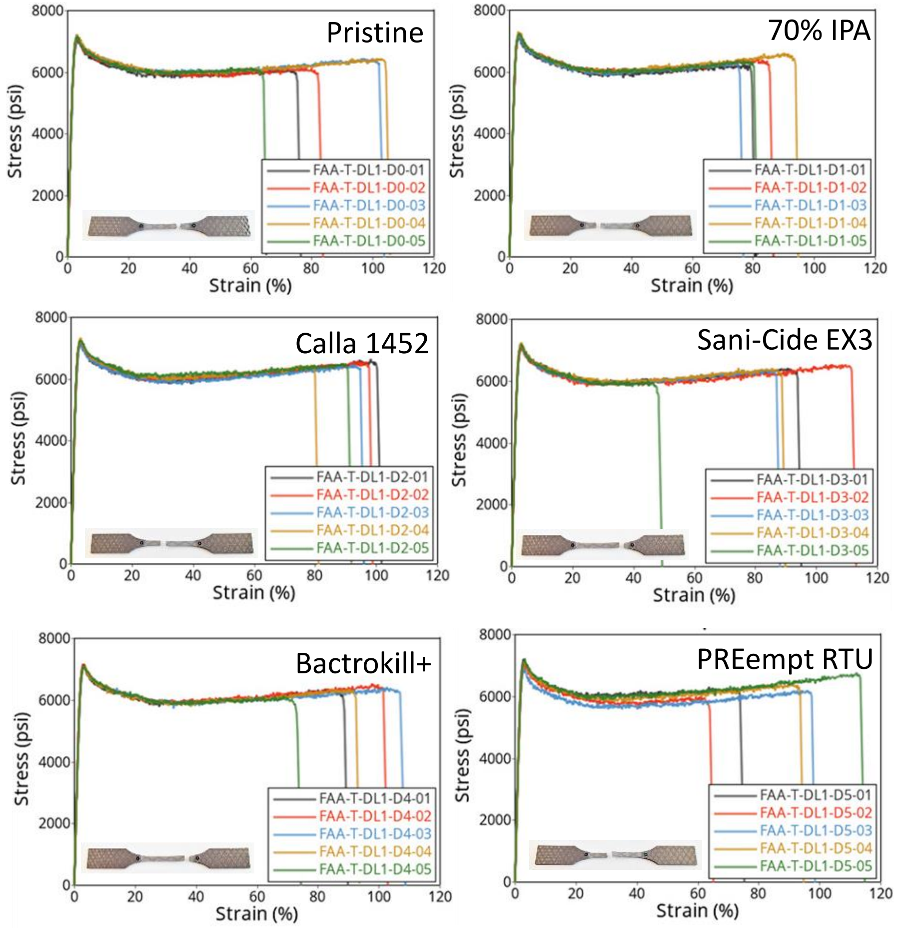
- Mechanical Test Method: Uniaxial tension experiments
- Test Standard: ASTM D638
- Test Equipment: MTS electrodynamic test frame
- Instrumentation: DIC for elongation measurements

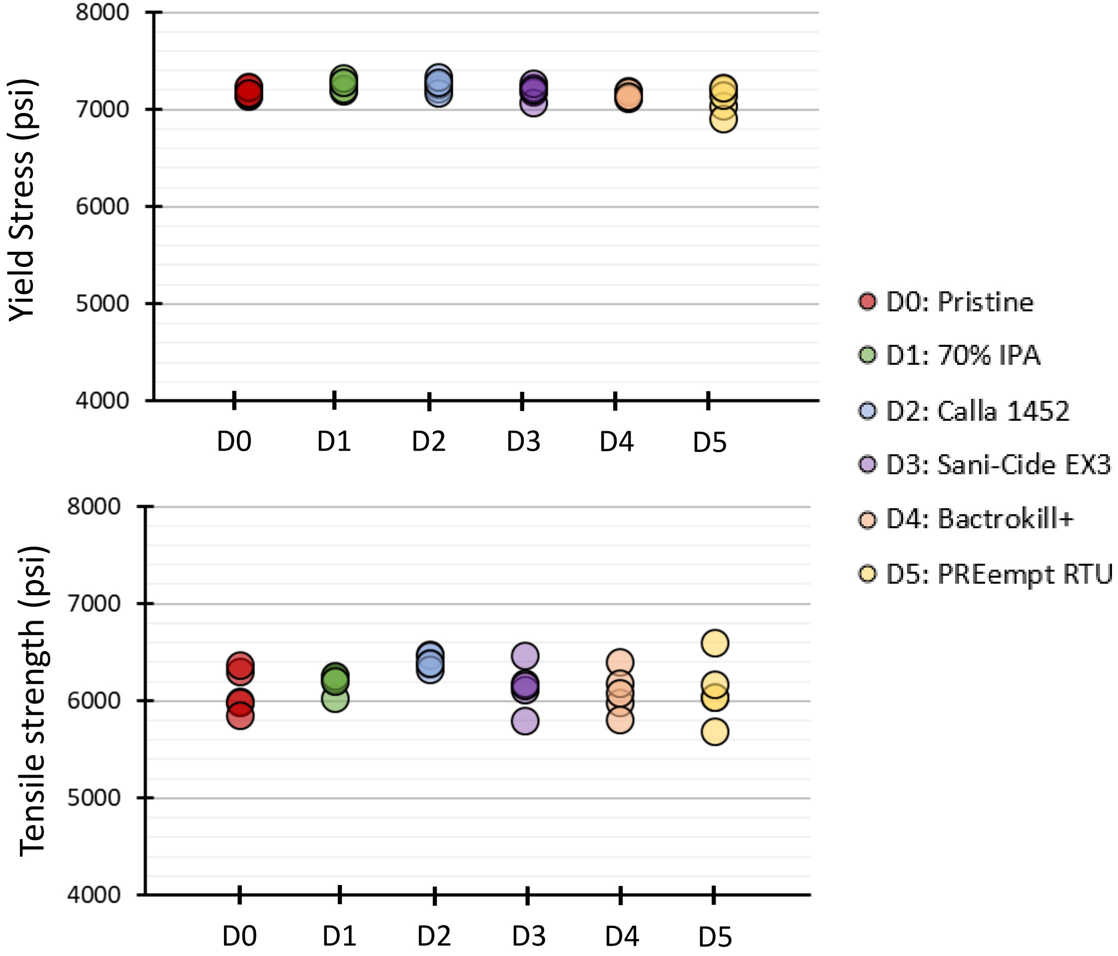
Tensile Test Matrix						
Decorative Laminate Type	Liquid Disinfectant Type					
	D0	D1	D2	D3	D4	D5
Aerform LHR	x 5	x 5	x 5	x 5	x 5	x 5

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Test Results: Decorative Laminate

Mechanical Properties





Results Summary: Decorative Laminate

Mechanical Properties

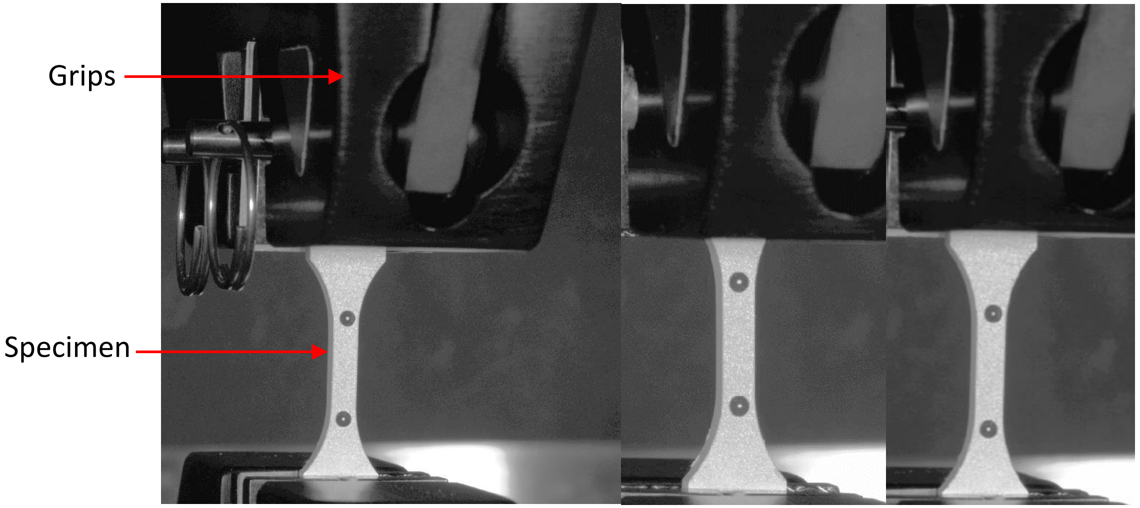
Mechanical Properties: Statistical Evaluation Summary					
Property Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
Yield Stress					
Tensile Strength					

Equivalent to unconditioned specimens based on reduced testing

Test Details: ULTEM 9075 and ULTEM 9085

Mechanical Properties

Test Setup | ULTEM 9075 | ULTEM 9085



ULTEM 9075

ULTEM 9085

- Mechanical Test Method: Uniaxial tension experiments
- Test Standard: ASTM D638
- Test Equipment: MTS electrodynamic test frame
- Instrumentation: DIC for elongation measurements

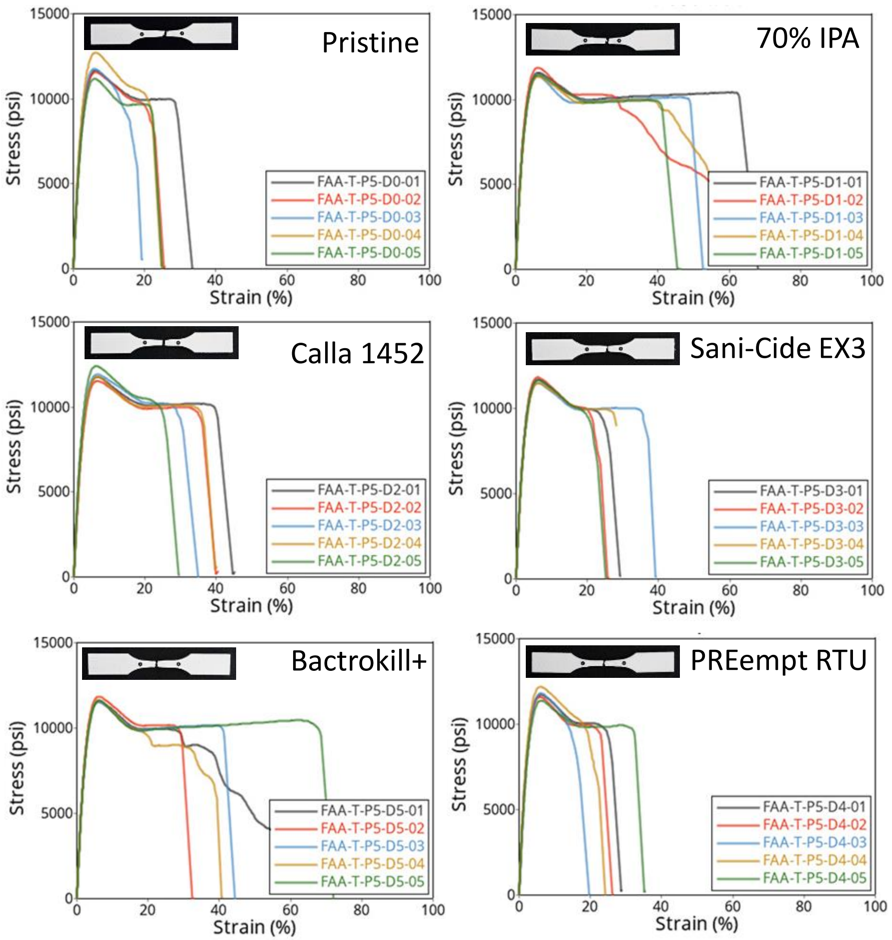
Tensile Test Matrix

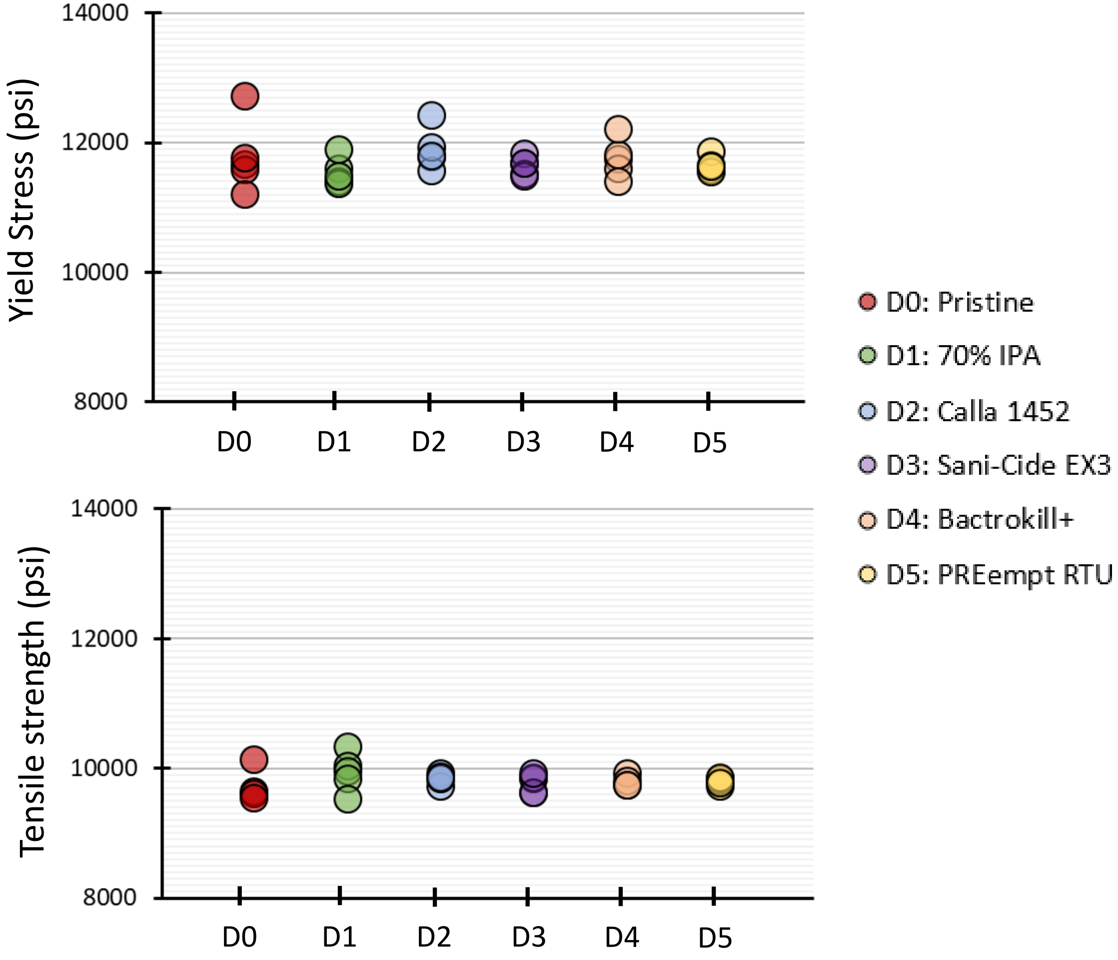
Decorative Laminate Type	Liquid Disinfectant Type					
	D0	D1	D2	D3	D4	D5
ULTEM 9075	x 5	x 5	x 5	x 5	x 5	x 5
ULTEM 9085	x 5	x 5	x 5	x 5	x 5	x 5

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Test Results: ULTEM 9075

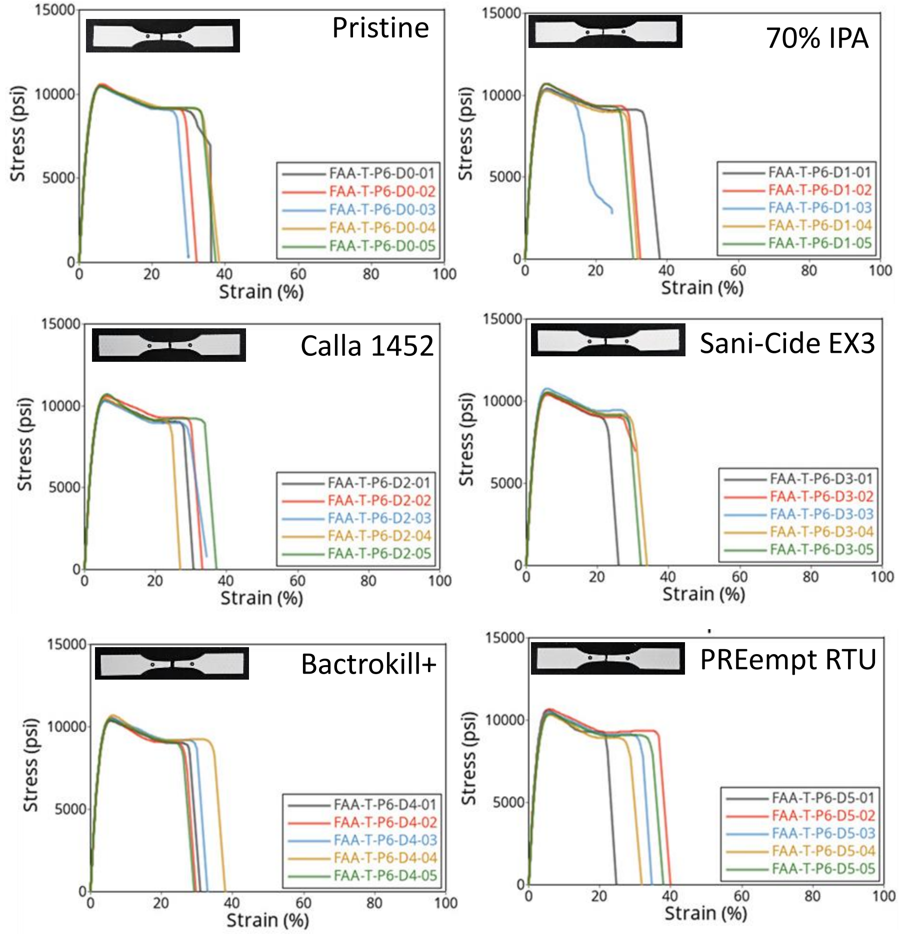
Mechanical Properties

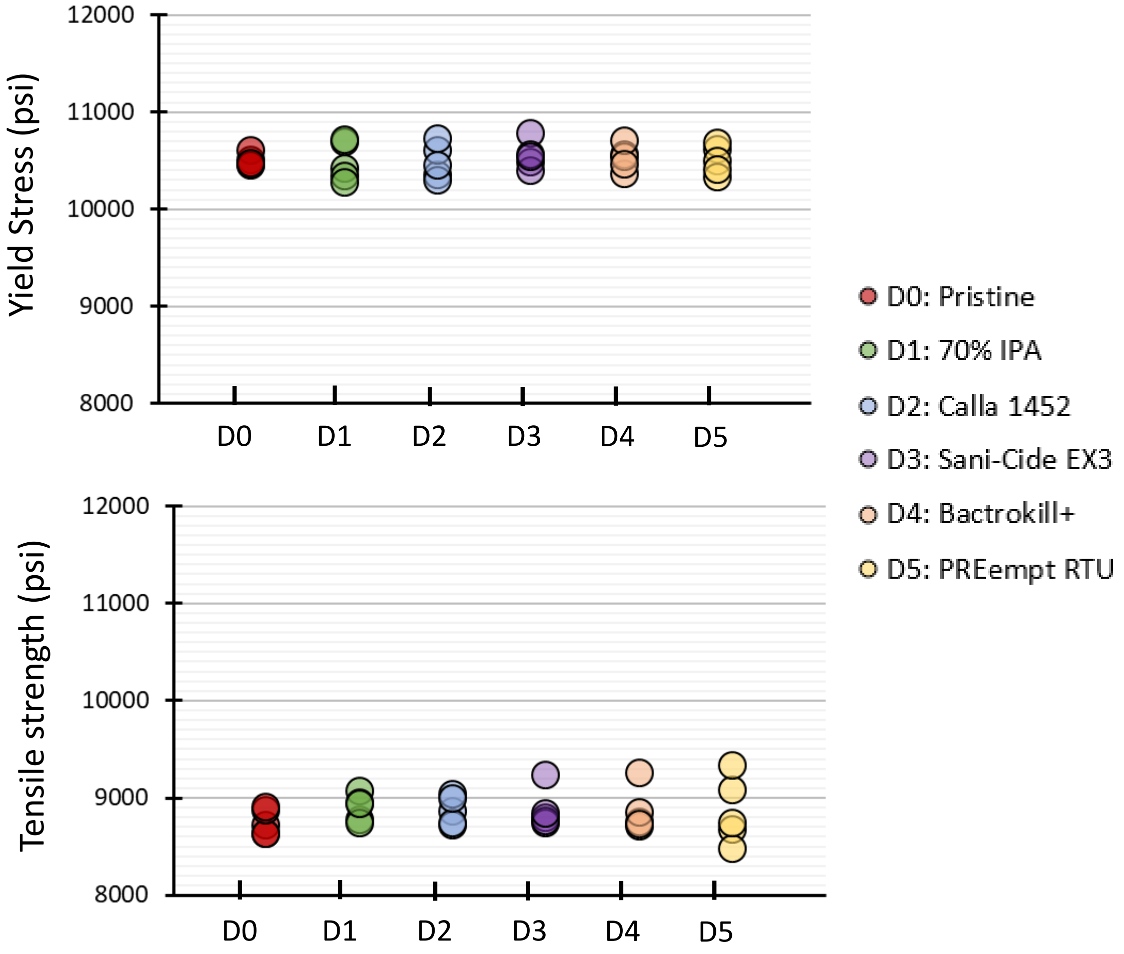




Test Results: ULTEM 9085

Mechanical Properties





Results Summary: ULTEM 9075 and ULTEM 9085

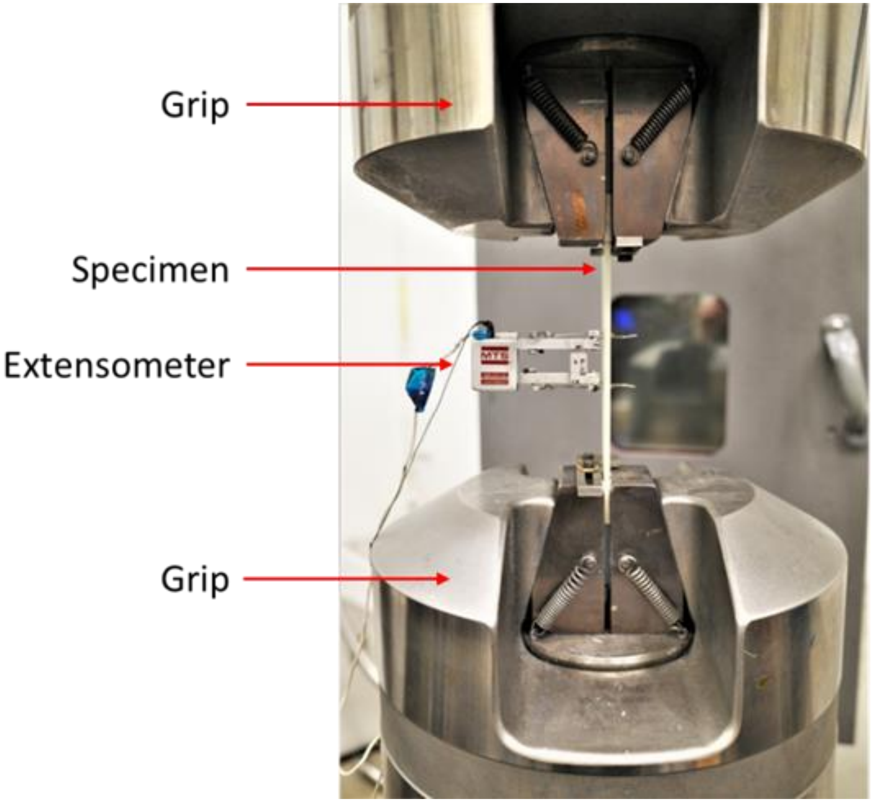
Mechanical Properties

Mechanical Properties: Statistical Evaluation Summary					
Property Type	Liquid Disinfectant Type				
	D1	D2	D3	D4	D5
Yield Stress					
Tensile Strength					

Equivalent to unconditioned specimens based on reduced testing

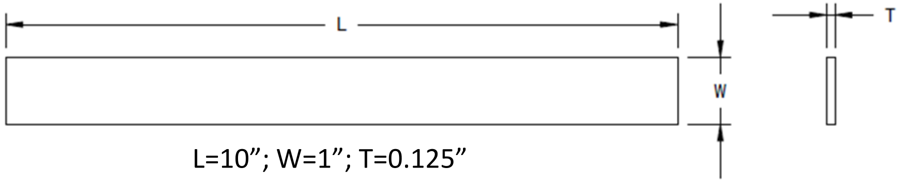
Fiberglass Laminate: Uniaxial Tension

Mechanical Properties



- Mechanical Test Method: Tensile properties of composites
- Test Standard: ASTM D3039
- Test Equipment: Servo hydraulic test frame
- Instrumentation: Extensometer

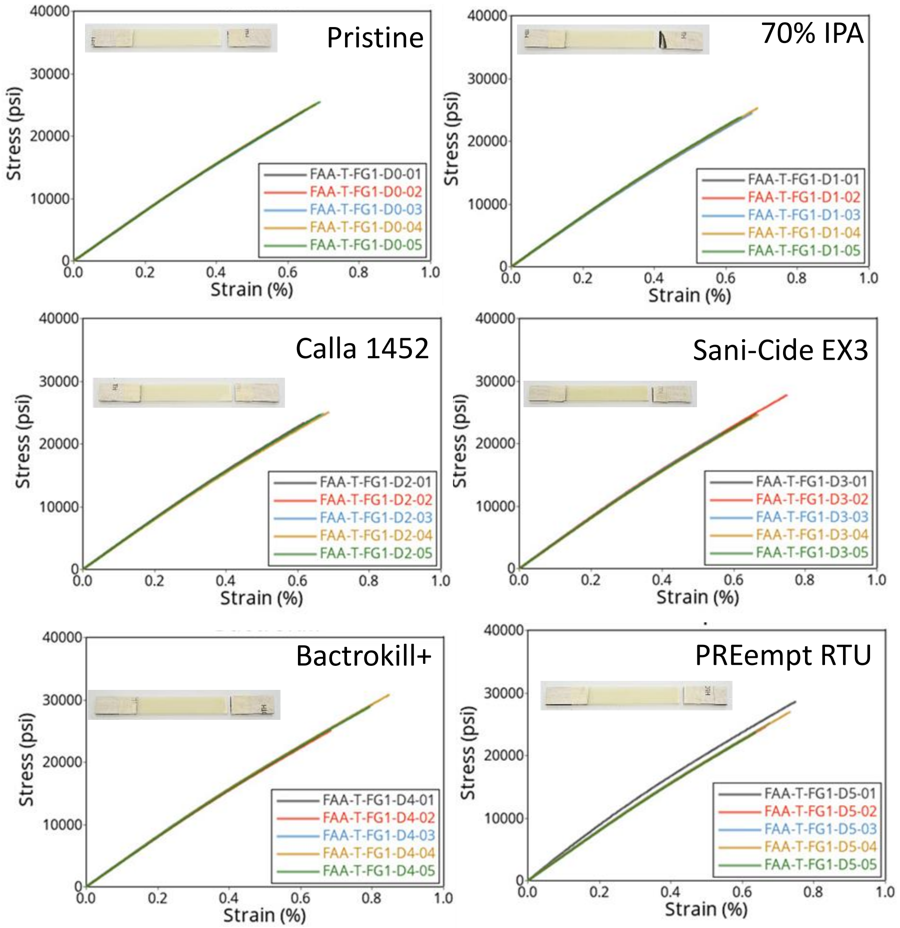
Tension Test Matrix						
Fiberglass Laminate	Liquid Disinfectant Type					
	D0	D1	D2	D3	D4	D5
G-10/FR4	x 5	x 5	x 5	x 5	x 5	x 5

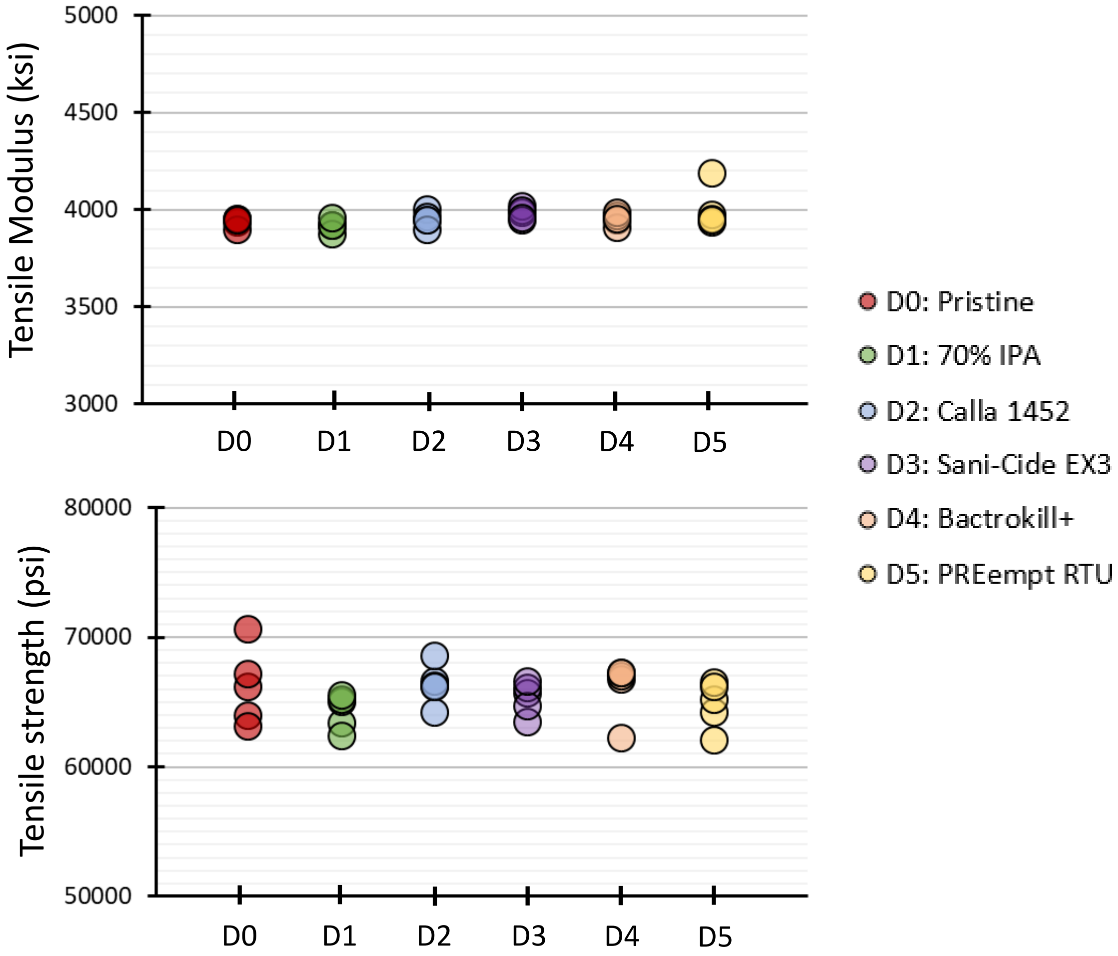


L=10”; W=1”; T=0.125”

Test Results: Uniaxial Tension

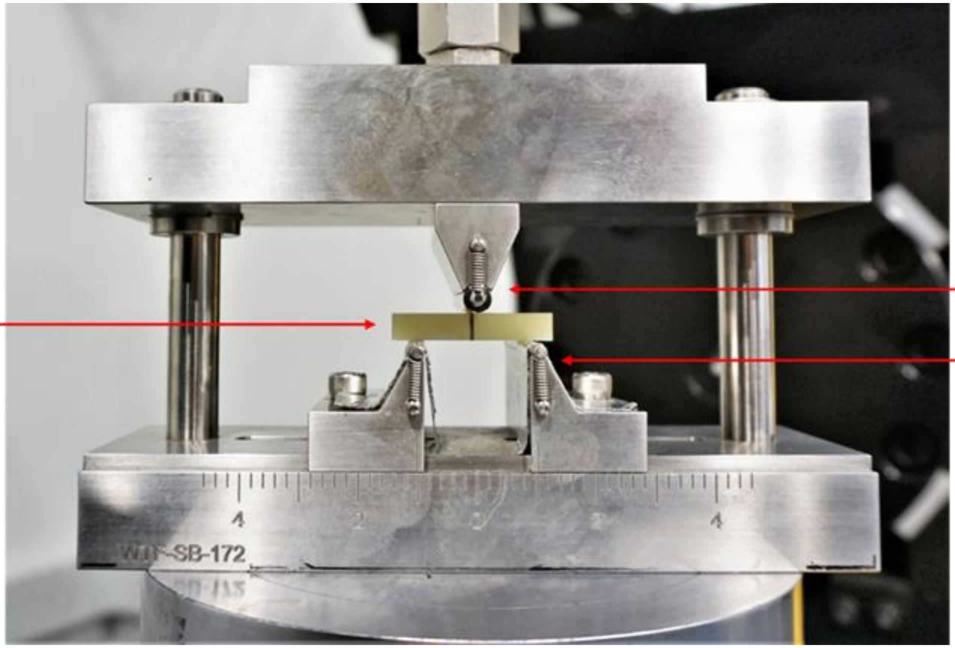
Mechanical Properties





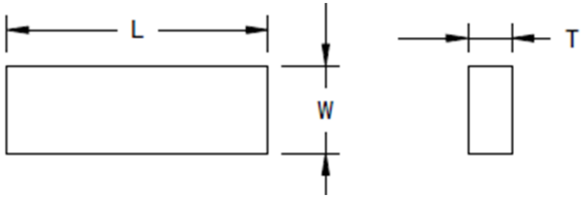
Fiberglass Laminate: Short beam Shear

Mechanical Properties



- Mechanical Test Method: Short beam shear
- Test Standard: ASTM D2344
- Test Equipment: Servo hydraulic biaxial test frame

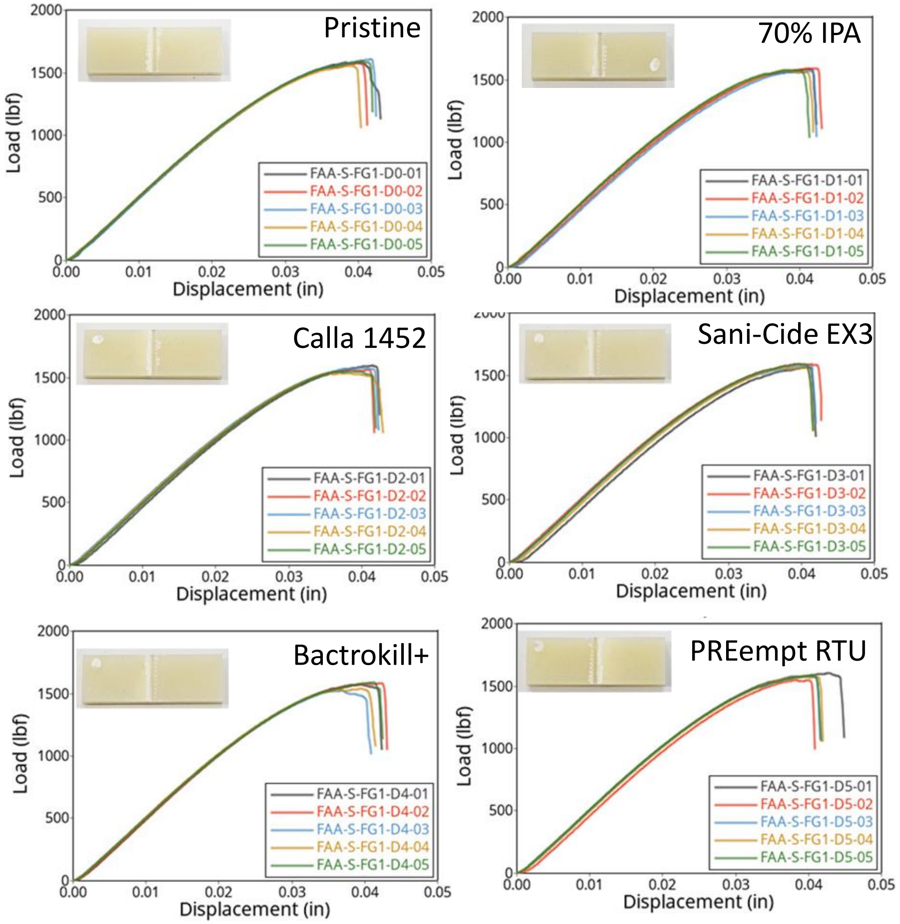
Short Beam Shear Test Matrix						
Fiberglass Laminate	Liquid Disinfectant Type					
	D0	D1	D2	D3	D4	D5
G-10/FR4	x 5	x 5	x 5	x 5	x 5	x 5

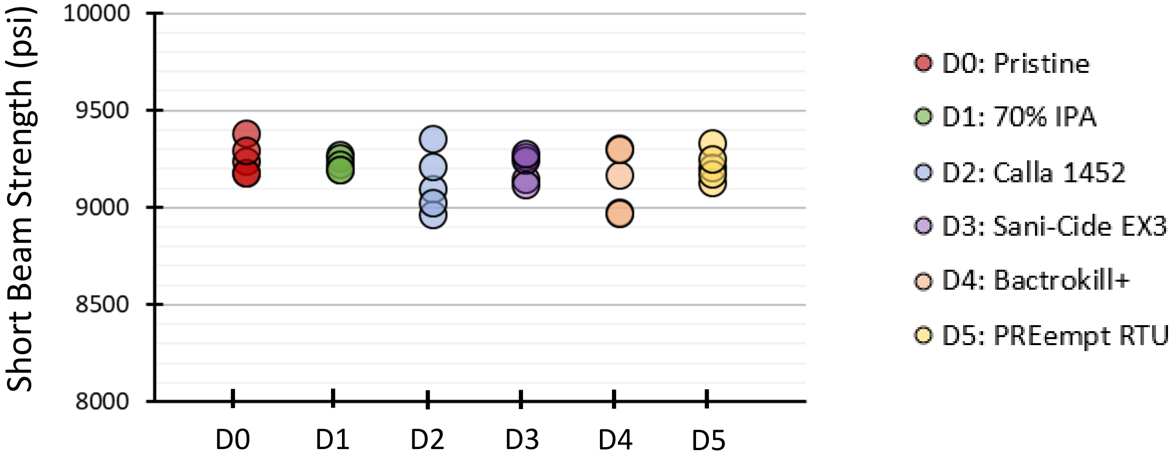


L=1.50”; W=0.50”; T=0.25”

Test Results: Short Beam Shear

Mechanical Properties





Flammability Properties

Phase-III: Effect of Liquid Disinfectants on Cabin Interior

Test Details

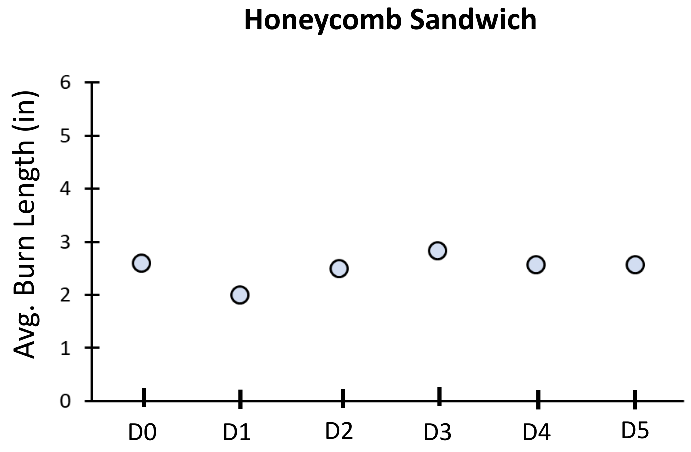
Flammability Properties

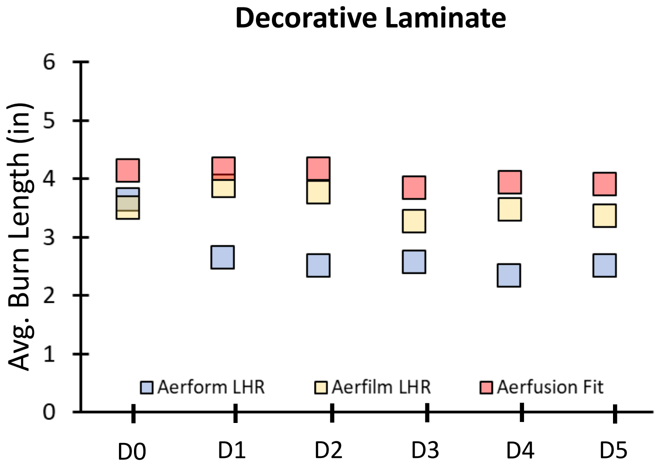
- Vertical Bunsen burn tests were conducted per Title 14, Code of Federal Regulations (14 CFR) 25.853 Appendix F
- Purpose of the test was to expose likely differences between conditioned and unconditioned specimens
- For all selected material types, 60-second test were conducted

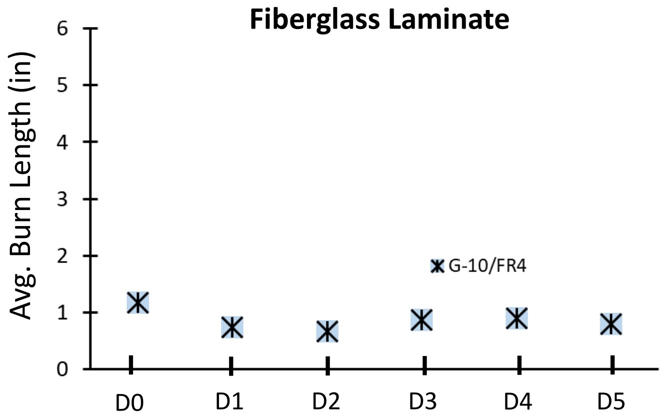
Flammability Evaluation: Test Matrix						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Honeycomb Sandwich	Nomex Core + fiberglass/phenolic	x3	x3	x3	x3	x3
Decorative Laminate	Aerform LHR	x3	x3	x3	x3	x3
	Aerfilm LHR	x3	x3	x3	x3	x3
	Aerfusion fit	x3	x3	x3	x3	x3
Floor Carpet	Polyamide	x3	x3	x3	x3	x3
	Wool	x3	x3	x3	x3	x3
ULTEM	ULTEM 9075	x3	x3	x3	x3	x3
	ULTEM 9085	x3	x3	x3	x3	x3
Fiberglass	G-10/FR4	x3	x3	x3	x3	x3

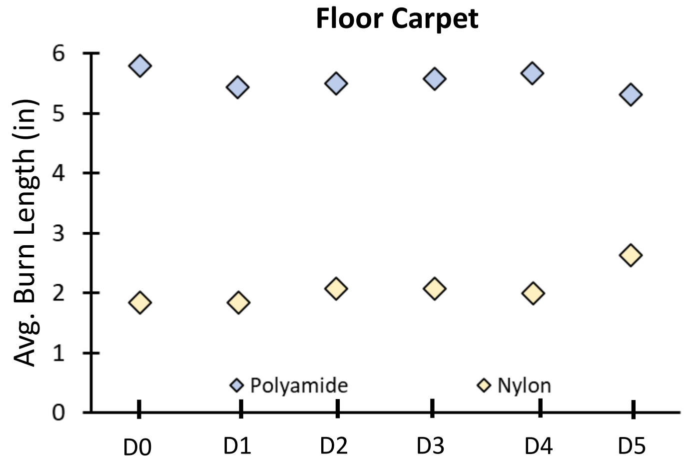
Burn Length Comparison

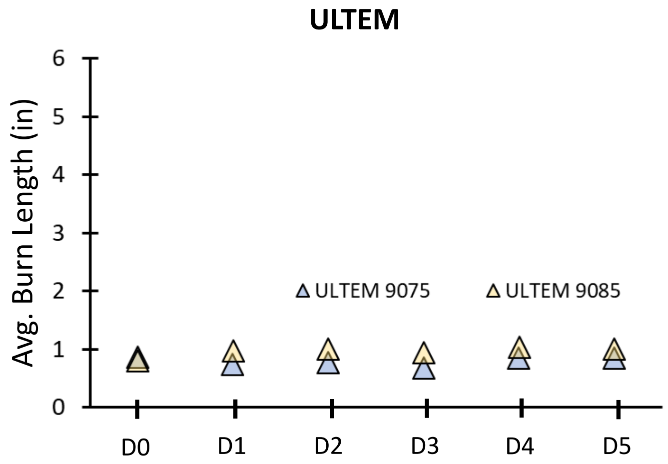
Flammability Properties











D0: Pristine, D1: 70% IPA; D2: Calla 1452;
D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Flammability Results Summary

Flammability Properties

Flammability Results for Cabin Materials: Summary						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Honeycomb Sandwich	Nomex Core + fiberglass/phenolic					
Decorative Laminate	Aerform LHR					
	Aerfilm LHR					
	Aerfusion fit					
Floor Carpet	Polyamide					
	Wool					
ULTEM	ULTEM 9075					
	ULTEM 9085					
Fiberglass	G-10/FR4					

Increase in avg. burn length less than 50% in comparison to unconditioned specimens

D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Physical Properties

Phase-III: Effect of Liquid Disinfectants on Cabin Interior

Change in Weight

Physical Properties

Change in Weight: Cabin Materials						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Honeycomb Sandwich	Nomex Core + fiberglass/phenolic					
Decorative Laminate	Aerform LHR					
	Aerfilm LHR					
	Aerfusion fit					
Floor Carpet	Polyamide					
	Wool					
ULTEM	ULTEM 9075					
	ULTEM 9085					
Fiberglass	G-10/FR4					

D0: Pristine; D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: [illegible]

Increase in avg. weight less than 5%

Increase in avg. weight more than 5%

Change in Color

Physical Properties

Change in Color: Cabin Materials						
Material Type	Material Name	Liquid Disinfectant Type				
		D1	D2	D3	D4	D5
Honeycomb Sandwich	Nomex Core + fiberglass/phenolic					
Decorative Laminate	Aerform LHR					
	Aerfilm LHR					
	Aerfusion fit					
Floor Carpet	Polyamide					
	Wool					
ULTEM	ULTEM 9075					
	ULTEM 9085					
Fiberglass	G-10/FR4					

No change in color or texture

Change in color

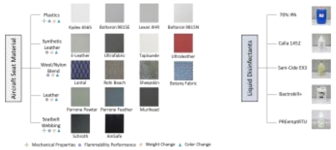
D0: Pristine, D1: 70% IPA; D2: Calla 1452; D3: Sani-Cide EX3; D4: Bactrokill+; D5: PREempt RTU

Summary and Conclusion

Effects of Liquid Disinfectants on Aircraft Cabin Interior Materials

Project Summary

Summary and Conclusion

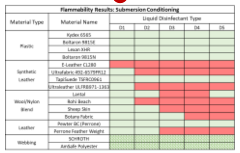


* Identify different materials used in aircraft seat
* Identify different liquid disinfectants being used

* Material traceability and documentation
* Specimen preparation

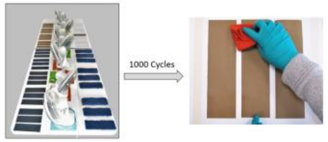
* Condition the specimens with conservative submersion method
* Number of days material conditioned dependent on material type

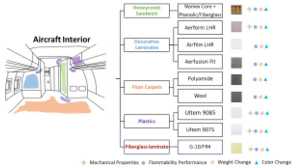
* Conduct experiments to obtain mechanical, flammability and physical properties of conditioned specimens and unconditioned specimens



* Evaluate the change in flammability and mechanical properties based on defined criterion

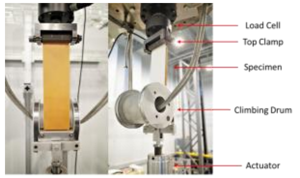
* Condition specimens using wiping method, real world application
*Revaluate change in the flammability properties

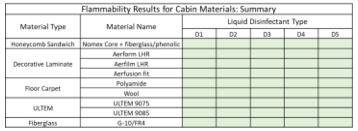




* Continue the research effort for materials used in cabin
* Identify different materials in conjunction with the SAE committee

* Conduct experiments to obtain mechanical, flammability and physical properties of cabin materials





* Evaluate the change in flammability and mechanical properties based on defined criterion

* Write technical reports and recommended practices for aerospace community
*Define steps for future work

Results Summary: Seat Material

Summary and Conclusion

Effect of Liquid Disinfectants on Aircraft Seat Material					
Material Type	Material Name	Property Type			
		Mechanical	Flammability	Color	Weight
Plastic	Kydex 6565				
	Boltaron 9815E				
	Lexan XHR				
	Boltaron 9815N				
Synthetic Leather	E-Leather CL280	N/A			
	Ultrafabric 492-6579FR12	N/A			
	TapiSuede TSFRC0961	N/A			
	Ultraleather ULFRB971-1363	N/A			
Wool/Nylon Blend	Lantal	N/A			
	Rohi Beach	N/A			
	Sheep Skin	N/A			
	Botany Fabric	N/A			
Leather	Pewter BC (Perrone)	N/A			
	Perrone Feather Weight	N/A			
Webbing	SCHROTH				

- Equivalency between conditioned and unconditioned specimen for all liquid disinfectants
- Equivalency not obtained between conditioned and unconditioned specimen for some liquid disinfectants
- Equivalency not obtained between conditioned and unconditioned specimen for all liquid disinfectants

Results Summary: Cabin Material

Summary and Conclusion

Effect of Liquid Disinfectants on Aircraft Cabin Material					
Material Type	Material Name	Property Type			
		Mechanical	Flammability	Color	Weight
Honeycomb Sandwich	Nomex Core/phenolic				
Decorative Laminate	Aerform LHR				
	Aerfilm LHR	N/A			
	Aerfusion fit	N/A			
Floor Carpet	Polyamide	N/A			
	Wool	N/A			
ULTEM	ULTEM 9075				
	ULTEM 9085				
Fiberglass	G-10/FR4				

Equivalency between conditioned and unconditioned specimen for all liquid disinfectants

Equivalency not obtained between conditioned and unconditioned specimen for some liquid disinfectants

Equivalency not obtained between conditioned and unconditioned specimen for all liquid disinfectants

Ongoing & Future Work

Summary and Conclusion

- Other materials currently being evaluated from aircraft cabin and flight deck
- Report for Phase I already published: DOT/FAA/TC-21/18
- Report for Phase II and Phase III under review and to be published by FAA.

AVET LABORATORIES