RECERTIFICATION AND EQUIVALENCY TEST RESULTS FOR IM7/8552-1 FOLLOWING EXTENDED FREEZER STORAGE

Sandi G. Miller[1], Andrew F. Paddock[2], Dawn C. Jegley[2], Ray W. Grenoble[2], William E. Guin[3], Justin R. Jackson[3], Kenneth N. Segal[4],

[1]NASA Glenn Research Center, Cleveland, OH. 44135
[2]NASA Langley Research Center, Hampton, VA. 23681
[3]NASA Marshall Space Flight Center, Huntsville, AL. 35812
[4]NASA Goddard Space Flight Center, Greenbelt, MD. 20771

ABSTRACT

In 2015, the Composites for Exploration Upper Stage (CEUS) Project established an equivalency test program to reduce the scope of laminate coupon tests within the project. The material selected was IM7/8552-1, a variant of the IM7/8552 prepreg used to populate a National Center for Advanced Materials Performance (NCAMP) database. The CEUS successor program, Composites Technology for Exploration (CTE), kicked off in 2017 with the remaining CEUS prepreg planned for use. The IM7/8552-1 prepreg was recertified through an in-house defined set of pass/fail criteria then evaluated for equivalency to the NCAMP database. Over the course of recertification and equivalency panel fabrication, the time of freezer storage ranged from 19 – 22 months. Panels for recertification and equivalency tests were fiber placed at NASA Marshall Space Flight Center (MSFC) and NASA Langley Research Center (LARC).

1. INTRODUCTION

Epoxy resin is used extensively throughout the aerospace industry as the matrix material in carbon fiber reinforced composites. The epoxy is generally composed of a base resin and a curing agent; with the system engineered to cure under specified thermal conditions. Consequently the material is temperature sensitive and cure advancement occurs at ambient conditions which may alter material processability and the mechanical integrity of the composite. To slow ambient temperature cure prepreg is stored in a freezer, at or below 0°C, with a recommended freezer life provided by the manufacturer. Using material beyond its freezer life poses a risk of reduced processability and reduced composite thermal and mechanical properties.

As prepreg reaches the end of its recommended freezer life, the material may be 'recertified' through a user-defined set of chemical and mechanical tests. There are no community defined recertification standards, however, the tests should represent the quantifiable changes that would be expected as a material ages. For example, physical tests to evaluate changes to fiber volume or resin content and mechanical tests to evaluate changes to strength or modulus; particularly in resin dominated properties. Data generated on the expired material is compared to that of the 'as-received' material certification data.

Material recertification was required within the Composites Technology for Exploration (CTE) project for IM7/8552-1 prepreg that had been procured through a previous program. The prepreg was originally manufactured in July 2015 at Hexcel, Salt Lake City UT. Then it was shipped to Web Industries, Atlanta GA., where it was slit for fiber placement. The slit tape was received by NASA in Sept 2015 with a recommended freezer life of 1 year from the date of manufacture when stored at or below 0°C. This recertification effort provided a 12 month extension in freezer life of the material for use within the CTE project. The 12 month extension was deemed appropriate for a non-flight project. Past programs have shown excellent property retention in this material following extended freezer life and out time conditions.[1]

Table 1 outlines the recertification test matrix established for the CTE project; including lay-up, test method, and specimen count. Data used as the basis for comparison toward recertification was pulled from either vendor-generated certification data (Hexcel), or data generated during the CEUS project. As such, ply configuration and test standards were selected to repeat those used for baseline Hexcel or CEUS tests.

The material end-user has the flexibility to define its recertification test matrix, but should interrogate resin-dominated composite properties and retention of material processability. Table 1 identifies quantifiable resin dominated and process dependent properties. Qualitative properties such as tack and drape were not included in this test matrix, however these characteristics were noted during panel fabrication and considered to be consistent with that of the in-life material. Changes to tack and drape would result in processing challenges with the panel, i.e. stiffness in laying down plies or loss of tack between with consecutive plies.

Table 1: IM7/8552-1 requalification test matrix.

Panel	Lay-up	Test Standard	Batches	Panels/ Batch	Panel Total	Specimen/ Panel	Specimen Total
Compression Strength and Modulus	$[0]_{12}$	SACMA SRM 1	2	1	2	5	10
Fiber Volume	$[0]_{12}$		2	1	2	5	10
Short Beam Shear	[45/0/-45/90] 3s	ASTMD2 344	2	1	2	5	10
Tg by DMA	[45/0/-45/90] 3s	ASTM D7028	2	1	2	2	4

The 8552-1 epoxy resin procured for this program is a variant of the baseline 8552 resin reported within the NCAMP database. The 8552-1 variant demonstrates a lower tack, facilitating fiber placement as compared to the baseline 8552 prepreg. As data for the 8552 form of the material is available through the NCAMP database [2], the project adopted an accelerated building block approach in the form of an equivalency test matrix, to reduce schedule related risk. The Composite Material Handbook -17 (CMH-17) allows equivalency to be demonstrated for design allowables in the case where differences between the original and new material and/or process are minimal.[3] Test matrices defined for equivalency are provided in Tables 2 and 3 for lamina and laminate properties. This matrix expands upon equivalency tests performed under the CEUS program. Panels for equivalency tests were fiber placed at the Marshall Space Flight Center (MSFC) and the Langley Research Center (LARC) according to each matrix.

Table 2: Lamina level equivalency test matrix

	Design Property	Test	Layup	Coupon Size	Batches	Panels/ Batch	Specimens /panel	Environ ments	Per Center Total
Per Center Lamina-level Equivalency Tests	0° Tension (Modulus + Poisson's Ratio)	ASTM D3039	$[0]_6$	0.5 x 10	1	2	4	2	16
	90° Tension (Modulus)	ASTM D3039	$[90]_{11}$	1 x 10	1	2	4	2	16
	0° Comp. (Modulus + Poisson's Ratio)	ASTM D6641	$[0]_{14}$	0.5 x 5.5	1	2	4	2	16
	90° Comp. (Modulus)	ASTM D6641	$[90]_{14}$	0.5 x 5.5	1	2	4	2	16
	In-plane Shear (Modulus + Strength)	ASTM D3518	$[45/-45]_{3s}$	1 x 10	1	2	4	2	16

Table 3: Laminate level equivalency test matrix.

	Design Property[1]	Test	Layup	Coupon Size	Batches	Panels/ Batch	Specimens /Panel	Environ ments	Per Center Totals
Per Center Laminate-level Equivalency Tests	Laminate Tension[2,3]	ASTM D3039	$[+45/0/-45/90]_{2s}$	1 x 10	1	2	4	2	16
	Laminate Compression[2,3]	ASTM D6641	$[+45/0/-45/90]_{2s}$	0.5 x 5.5	1	2	4	2	16
	Open Hole Tension[4]	ASTM D5766	$[+45/0/-45/90]_{2s}$	1.5 x 12	1	2	4	2	16
	Open Hole Compression	ASTM D6484	$[+45/0/-45/90]_{3s}$	1.5 x 12	1	2	4	2	16
	Filled Hole Tension	ASTM D6742	$[+45/0/-45/90]_{2s}$	1.5 x 12	1	2	4	2	16
	Compression after Impact	ASTM D7136/ D7137	$[+45/0/-45/90]_{3s}$	4 x 6	1	2	4	1	8
	Single-shear Bearing	ASTM D5961	$[+45/0/-45/90]_{2s}$	1.5 x 6	1	2	4	2	16

Test coupons were machined, conditioned, and tested at the National Institute of Aviation Research (NIAR). Coupons were tested in room temperature/dry (RTD) and elevated temperature/wet (ETW) conditions. Statistical analysis methods were employed to establish equivalency of the remotely manufactured composite panels and equivalency of the IM7/8552-1 material to properties in the NCAMP database.

2. EXPERIMENTATION

2.1 Materials

IM7/8552-1 prepreg material was procured to Hexcel's internal specification HS-AD-971B and met the following:

- Fiber Areal Weight (FAW): 190 gsm
- Resin Content: 33 ± 2%
- IM7 12K –G sized fiber

The parent tape was fabricated at Hexcel Corp, Salt Lake City, UT, and slit at Web Industries, Atlanta, GA. The slit tape width specifications included a ¼" wide tape provided to LaRC and a ½" wide tape provided to MSFC.

2.2 Manufacturing

Fiber placement facilities at LARC and MSFC are shown in Figures 1 and 2, respectively. Fabrication for equivalency panels followed the processing conditions used to generate the NCAMP database[4]. This procedure included bagging materials, ply configuration and cure cycle. Ply configurations are provided within the respective tests matrices. The cure profile used was identified as 'baseline/medium cure cycle (M)', within the NCAMP processing specification and varied from the vendor recommended cycle.

An internal processing specification was established to ensure consistency of the lay-up and cure protocols used between remote manufacturing sites. Following autoclave cure, panels were inspected by ultrasonic scanning. In general, panels were indication free- however any indications noted by C-scan were avoided as coupons were machined. Panels from each center were shipped to the National Institute of Aviation Research (NIAR) where coupons were machined, conditioned, and tested.

Test and environmental conditions are defined as:

Cold Temperature Dry (CTD): -54±3^{o}C (-65±5 ^{o}F)
Room Temperature Dry (RTD): 21±6^{o}C (70±10 ^{o}F)
Elevated Temperature Wet (ETW): 121±3^{o}C (250±5 ^{o}F)

For wet conditioning, coupons were conditioned to equilibrium at 71±3^{o}C (160±5 ^{o}F) and 85% ± 5% humidity. Moisture equilibrium was considered achieved when the average moisture content of a coupon changed by less than 0.05% for three consecutive readings that are 7 days apart.[5]

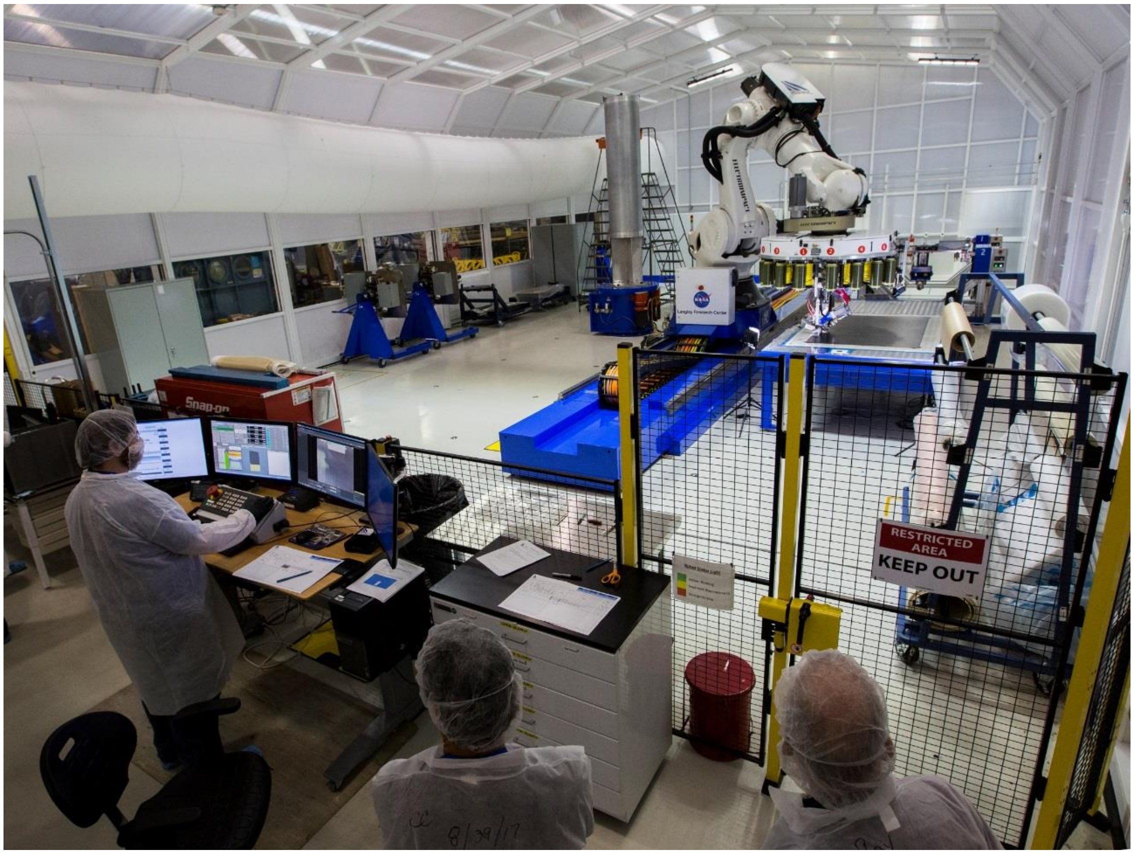

Figure 1: Equivalency panel fabrication with the ISAAC robot at LARC.

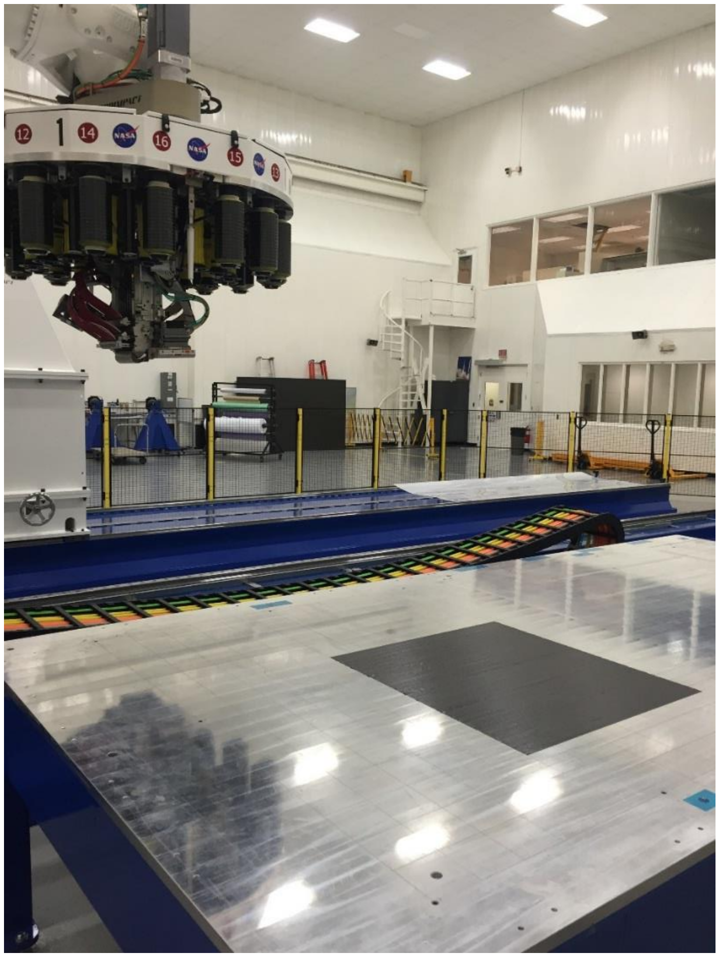

Figure 2: Equivalency panel fabrication at MSFC.

3. RESULTS

3.1 Recertification

The minimum pass/fail criteria for material recertification and test data are reported in Table 4. Minimum required values were determined statistically through application of the t- test. The t-test is a statistical tool used to calculate a confidence interval for data comparison; providing a probability that data will fall into a given range. A broader range imparts an increased probability that a data-point will fall between upper and lower bounds. The 95% confidence interval is a widely accepted conservative value.

The confidence interval of μ is given by

$$u = \overline{\bar{x} \pm \frac{ts}{\sqrt{n}}}$$

Where s is the measured standard deviation, n is the number of observations and t is a defined value based on the number of test data.

Pass/fail criteria was established based on comparison to as-manufactured data, with those values originating from either Hexcel certification tests or CEUS mechanical tests. This original data is listed in Table 4. Hexcel 1-4 represents separate test panels used for material certification. CEUS data calls out the NASA center at which the test panels were fabricated for that program.

Table 4: Recertification test matrix with baseline data, minimum required value for recertification and measured data.

Test- Lamina	Lay-up	Hexcel-1	Hexcel-2	Hexcel-3	Hexcel-4	Pass Re-Cert (Min Value, 95% conf)	CTE ReCert Measured Value	Comments
Compression Strength (ksi)	$[0]_{12}$	274	230	293	258	221	Avg. 224 ksi	LaRC: 216 MSFC: 225 MSFC: 231
Compression Modulus (msi)	$[0]_{12}$	21.5	21.5	21.3	21.0	20.95	Avg. 21.17 msi	LaRC: 21.12, MSFC: 20.68, MSFC: 21.71
		CEUS Data						
Short Beam Shear (ksi)	$[45/0/-45/90]_{3s}$	12.45 (GRC)	12.03 (LaRC)	12.40 (MSFC)		11.72	Avg. 11.76 ksi	LaRC: 12.59 MSFC: 11.49 MSFC: 11.19
Glass Transition Temp. (°C), E' shoulder in DMA	$[45/0/-45/90]_{2s}$	192, 191 (GRC)	194, 191 (LaRC)	190°C, 194°C (MSFC)		191	Avg. 189°C	
Fiber Volume (%)	$[45/0/-45/90]_{2s}$	56.6 (MSFC)	58.4 (LaRC)			56.2	57.2%	

The data generated for CTE recertification is consistent with material that has aged in that we see a reduction in all resin dominated properties measured. The measured glass transition temperature of the cured material failed to meet the recertification metric established by the project. However, CTE is a non-flight project focusing on composite joints. The IM7/8552-1 will be used to fabricate acreage panels for those joints. Therefore the material was recertified despite the low Tg measured during recertification.

3.2 Equivalency

The mechanical test data generated by NIAR is tabulated below, with the PASS/ FAIL column indicative of the equivalency metric. Statistical analysis for equivalency of composite materials utilizes a confidence level of 95%. This means that when stating two materials are not equivalent with respect to a particular test, the probability that this is a correct decision is no less than 95%.

In some cases, the NIAR report utilized a modified Coefficient of Variation (CV); in accordance with section 8.4.4 of CMH-17 Revision G. This is a method of adjusting the original basis values downward in anticipation of the expected additional variation. Composite materials are expected to have a CV of at least 6%. When the CV is less than 8%, a modification is made that adjusts the CV upwards.

Equivalency test data is presented in Tables 5, 6, and 7, with the mean value for each test tabulated and the standard deviation noted parenthetically. Key points to consider within this equivalency test program include the following:

1. Different matrix materials were used in this work and the NCAMP database; i.e. 8552-1 vs. 8552.
2. This material was aged beyond the recommended freezer life. Prepreg had been stored below 0°C for 19-23 months at the time of panel fabrication.
3. Reported data has been normalized to a cured ply thickness (CPT) of 0.0072 inch.
4. Any tests failing statistically by 1% or less were considered a 'pass'.
5. Any tests that failed because measured data was higher than qualification data was considered a 'pass'.
6. Any test that passed by the modified CV method was considered a 'pass'.
7. Data is presented as Pass/Fail. The relative severity of a failure is given by the below chart.[5]

Description	**Modulus**	**Strength**
Mild Failure	% fail ≤ 4%	% fail ≤ 5%
Mild to Moderate Failure	4% < % fail ≤ 8%	5% < % fail ≤ 10%
Moderate Failure	8% < % fail ≤ 12%	10%< % fail ≤ 15%
Moderate to Severe Failure	12% < % fail ≤ 16%	15% < % fail ≤ 20%
Severe Failure	16% < % fail ≤ 20%	20% < % fail ≤ 25%
Extreme Failure	20% < % fail	25% < % fail

Table 5: Lamina Strength and Modulus Data

	RTD		**ETW**	
Test/ Center	Normalized Data (std. dev.)	PASS/ FAIL	Normalized Data (std. dev.)	PASS/ FAIL
Longitudinal Tension $[0]_6$				
NCAMP				
Strength (ksi)	***362.7*** *(16.1)*		***333.5*** *(38.8)*	
Modulus (Msi)	***23.0*** *(0.8)*		***24.0*** *(0.6)*	
CTE-MSFC				
Strength (ksi)	**371.6** (20.8)	Pass	**354.4** (49.7)	Pass
Modulus (Msi)	**22.4** (0.3)	Pass	**22.7** (1.0)	Pass
CTE-LaRC				

Strength (ksi)	**359.8** (8.4)	Pass	**341.2** (12.4)	Pass
Modulus (Msi)	**21.8** (0.3)	Pass	**22.1** (0.3)	Mild Failure
Longitudinal Compression $[0]_{14}$				
NCAMP				
Modulus (Msi)	***20.0*** *(1.4)*		***20.4*** *(1.8)*	
CTE-MS FC				
Modulus (Msi)	**20.5** (0.6)	Pass	**20.7** (0.5)	Pass
CTE-LaRC				
Modulus (Msi)	**19.9** (0.4)	Pass	**19.6** (0.3)	Pass
Transverse Tension $[0]_{11}$				
NCAMP				
Strength (ksi)	***9.3*** *(0.9)*		***3.5*** *(0.2)*	
Modulus (Msi)	***1.3*** *(0.04)*		***0.8*** *(0.04)*	
CTE-MS FC				
Strength (ksi)	**10.4** (1.4)	Pass	**3.1** (0.8)	Pass
Modulus (Msi)	**1.3** (0.02)	Pass	**0.9** (0.1)	Pass
CTE-LaRC				
Strength (ksi)	**11.3** (0.7)	Pass	**3.3** (0.3)	Pass
Modulus (Msi)	**1.2** (0.01)	Pass	**0.8** (0.03)	Pass
Transverse Compression $[0]_{11}$				
NCAMP				
Strength (ksi)	***41.4*** *(1.9)*		***19.0*** *(1.0)*	
Modulus (Msi)	***1.4*** *(0.1)*		***1.2*** *(0.1)*	
CTE-MS FC				
Strength (ksi)	**39.6** (0.7)	Pass	**18.8** (0.3)	Pass
Modulus (Msi)	**1.4** (0.01)	Pass	**1.0** (0.04)	Moderate Failure
CTE-LaRC				
Strength (ksi)	**37.7** (1.3)	Mild Failure	**17.9** (0.9)	Mild Failure
Modulus (Msi)	**1.4** (0.02)	Pass	**1.0** (0.03)	Moderate Failure
In-Plane Shear $[45/-45]_{3s}$				
NCAMP				
0.2% Offset Strength (ksi)	***7.8*** *(0.2)*		***3.3*** *(0.2)*	
5% Offset Strength (ksi)	***13.2*** *(0.2)*		***5.5*** *(0.2)*	
Modulus (Msi)	***0.68*** *(0.02)*		***0.306*** *(0.01)*	
CTE-MS FC				
0.2% Offset Strength (ksi)	**7.2** (0.1)	Mild Failure	**3.6** (0.1)	Pass
5% Offset Strength (ksi)	**12.7** (0.2)	Pass	**5.9** (0.1)	Pass

Modulus (Msi)	**0.63** (0.01)	Mild Failure	**0.344** (0.01)	Pass
CTE-LaRC				
0.2% Offset Strength (ksi)	**7.2** (0.04)	Mild Failure	**3.5** (0.1)	Pass
5% Offset Strength (ksi)	**12.6** (0.04)	Pass	**5.8** (0.1)	Pass
Modulus (Msi)	**0.63** (0.01)	Mild Failure	**0.341** (0.01)	Pass

Table 6: Pristine Laminate Strength and Modulus Data

	RTD		**ETW**	
Test/Project/ Center	Normalized Data	PASS/FAIL	Normalized Data	PASS/ FAIL
Un-notched Tension [45/0/-45/90]$_{2s}$				
NCAMP				
Strength (ksi)	***104.7*** *(7.3)*		***112.5*** *(5.6)*	
Modulus (Msi)	***8.4*** *(0.5)*		***8.0*** *(0.4)*	
CTE-MSFC				
Strength (ksi)	**104.8** (2.0)	Pass	**112.7** (5.2)	Pass
Modulus (Msi)	**8.1** (0.1)	Pass	**7.9** (0.2)	Pass
CTE-LaRC				
Strength (ksi)	**106.5** (1.9)	Pass	**113.9** (2.7)	Pass
Modulus (Msi)	**7.9** (0.1)	Pass	**7.8** (0.1)	Pass
Un-notched Compression [45/0/-45/90]$_{2s}$				
NCAMP				
Strength (ksi)	***87.0*** *(8.1)*		***57.7*** *(6.4)*	
Modulus (Msi)	***7.9*** *(0.4)*		***7.1*** *(0.1)*	
CTE-MSFC				
Strength (ksi)	**82.9** (2.9)	Pass	**61.3** (4.2)	Pass
Modulus (Msi)	**7.4** (0.2)	Pass	**7.4** (0.1)	Pass
CTE-LaRC				
Strength (ksi)	**82.5** (3.9)	Pass	**61.1** (1.3)	Pass
Modulus (Msi)	**7.4** (0.1)	Pass	**7.2** (0.1)	Pass

Table 7: Open-Hole Strength Data

	RTD		**ETW**	
Test/ Center	Normalized Data	PASS/FAIL	Normalized Data	PASS/ FAIL
Open Hole Compression [45/0/-45/90]$_{3s}$				
NCAMP				

Strength (ksi)	***49.1*** *(3.7)*		***35.5*** *(1.4)*	
CTE-MS FC				
Strength (ksi)	**47.9** (3.3)	Pass	**37.1** (1.9)	Pass
CTE-LaRC				
Strength (ksi)	**47.7** (1.6)	Pass with Mod CV	**36.0** (1.0)	Pass
Open Hole Tension [45/0/-45/90]$_{2s}$				
NCAMP				
Strength (ksi)	***59.0*** *(4.0)*		***67.0*** *(2.9)*	
CTE-MS FC				
Strength (ksi)	**63.8** (2.7)	Pass	**68.3** (3.0)	Pass
CTE-LaRC				
Strength (ksi)	**63.8** (4.7)	Pass	**69.1** (1.1)	Pass
Filled Hole Tension [45/0/-45/90]$_{2s}$				
NCAMP				
Strength (ksi)	***65.9*** *(4.9)*		***70.3*** *(2.3)*	
CTE-MS FC				
Strength (ksi)	**67.7** (2.2)	Pass	**71.6** (1.9)	Pass
CTE-LaRC				
Strength (ksi)	**68.0** (2.4)	Pass	**71.8** (2.3)	Pass
Single Shear Bearing [45/0/-45/90]$_{2s}$				
NCAMP				
2% Strength (ksi)	***109.9*** *(5.5)*		***88.1*** *(8.9)*	
CTE-MS FC				
2% Strength (ksi)	**128.6** (3.1)	Pass	**104.1** (3.9)	Pass
CTE-LaRC				
2% Strength (ksi)	**125.7** (2.6)	Pass	**97.7** (4.7)	Pass

Under RTD conditions, panels fabricated from IM7/8552-1 following 19 months to 23 months of freezer storage, passed most equivalency metrics; with the exceptions being in-plane shear and transverse compression. Statistically mild failures were observed for these properties. Under ETW conditions, the aged material failed the metric for equivalency only in longitudinal tensile modulus, and transverse compression strength and modulus.

Tensile modulus, transverse compression and shear are resin dominated properties and a decline would be expected for 'aged' material. The marginal knock-down in shear performance was consistent with that measured for recertification.

3.3 Comparison to CEUS Data

The above data reports the test results from 'aged' IM7/8552-1 relative to NCAMP data for IM7/8552. It was of interest to compare these results to data collected during the CEUS program, generated from new material. A limited set of data was collected during the CEUS program and is presented in the tables below, along-side of CTE data. Through this comparison, as with the recertification data, we see a decrease in the lamina strength and modulus in the CTE material relative to the CEUS material. However, within the laminate configuration, room temperature compression strength was the only property decreased following 19-23 months of freezer storage.

Table 7: CEUS and CTE Lamina Data

	CTE RTD		CEUS RTD		CTE ETW		CEUS ETW	
Test/ Center	Normalized Data (std. dev.)	PASS/ FAIL	Normalized Data (std. dev.)	PASS/ FAIL	Normalized Data (std. dev.)	PASS/ FAIL	Normalized Data (std. dev.)	PASS/ FAIL
Longitudinal Tension $[0]_6$								
MSFC								
Strength (ksi)	**371.6** (20.8)	Pass	**397.1** (2.7)	Pass	**354.4** (49.7)	Pass	**366.5** (3.5)	Pass
Modulus (Msi)	**22.4** (0.3)	Pass	**22.6** (0.3)	Pass	**22.7** (1.0)	Pass	**22.8** (1.6)	Pass
LaRC								
Strength (ksi)	**359.8** (8.4)	Pass	**381.7** (14.2)	Pass	**341.2** (12.4)	Pass	**358.1** (3.7)	Pass
Modulus (Msi)	**21.8** (0.3)	Pass	**22.4** (2.4)	Pass	**22.1** (0.3)	Mild Failure	**23.2** (1.6)	Pass

Table 8: CEUS and CTE Laminate Data

	CTE RTD		CEUS RTD		CTE ETW		CEUS ETW	
Test/Project/ Center	Normalized Data (std. dev.)	PASS/ FAIL	Normalized Data (std dev.)	PASS/ FAIL	Normalized Data (std dev.)	PASS/ FAIL	Normalized Data (std dev.)	PASS/ FAIL
Un-notched Tension $[45/0/-45/90]_{2s}$								
MSFC								
Strength (ksi)	**104.8** (2.0)	Pass	**107.4** (1.5)	Pass	**112.7** (5.2)	Pass	**110.9** (2.5)	Pass
Modulus (Msi)	**8.1** (0.1)	Pass	**8.1** (1.2)	Pass	**7.9** (0.2)	Pass	**7.9** (1.6)	Pass
LaRC								
Strength (ksi)	**106.5** (1.9)	Pass	**108.0** (1.4)	Pass	**113.9** (2.7)	Pass	**116.1** (2.4)	Pass
Modulus (Msi)	**7.9** (0.1)	Pass	**8.2** (2.0)	Pass	**7.8** (0.1)	Pass	**8.0** (1.8)	Pass
Un-notched Compression $[45/0/-45/90]_{2s}$								
MSFC								
Strength (ksi)	**82.9** (2.9)	Pass	**95.0** (3.3)	Pass	**61.3** (4.2)	Pass	**60.3** (2.8)	Pass

Modulus (Msi)	**7.4** (0.2)	Pass	**7.7** (0.5)	Pass	**7.4** (0.1)	Pass	**7.5** (1.2)	Pass
LaRC								
Strength (ksi)	**82.5** (3.9)	Pass	**92.2** (2.3)	Pass	**61.1** (1.3)	Pass	**56.4** (7.5)	Pass
Modulus (Msi)	**7.4** (0.1)	Pass	**7.6** (1.3)	Pass	**7.2** (0.1)	Pass	**7.4** (0.8)	Pass

Table 9: CEUS and CTE Open-Hole Data

	CTE		CEUS		CTE		CEUS	
	RTD		RTD		ETW		ETW	
Test/ Center	Normalized Data (std. dev.)	PASS/ FAIL	Normalized Data (std dev.)	PASS/ FAIL	Normalized Data (std. dev.)	PASS/ FAIL	Normalized Data (std dev.)	PASS/ FAIL
Open Hole Compression [45/0/-45/90]$_{3s}$								
MSFC								
Strength (ksi)	**47.9** (3.3)	Pass	47.5 (3.7)	Pass	**37.1** (1.9)	Pass	33.2 (2.7)	Mild Failure
LaRC								
Strength (ksi)	**47.7** (1.6)	Pass with Mod CV	47.1 (2.9)	Pass	**36.0** (1.0)	Pass	32.2 (2.4)	Mild Failure
Open Hole Tension [45/0/-45/90]$_{2s}$								
MSFC								
Strength (ksi)	**63.8** (2.7)	Pass	64.1 (2.6)	Pass	**68.3** (3.0)	Pass	69.4 (3.4)	Pass
LaRC								
Strength (ksi)	**63.8** (4.7)	Pass	62.4 (1.8)	Pass	**69.1** (1.1)	Pass	69.0 (2.4)	Pass

4. CONCLUSIONS

A material recertification process and equivalency test plan was defined for IM7/8552-1 carbon fiber/epoxy prepreg that had exceed recommended freezer storage life. Recertification data reflected an advancement of resin cure, however material properties met the requirements for recertification set forth by the project. Panels for an equivalency program were fabricated and tested. The data was analyzed to establish statistical equivalence to the NCAMP database. The material passed the equivalency metric and was approved for continued use within the program. In addition, remotely manufactured panels for the equivalency test program yielded comparable mechanical properties. This is significant as acreage panels for CTE joint testing will be fabricated at both LaRC and MSFC.

5. REFERENCES

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