Report No: NCP-RP-2008-009 Rev N/C
Report Date: July 18, 2018

Solvay (Formerly Advanced Composites Group) MTM45-1 / AS4145-32% RW Unitape (12K AS4 UNI) M cure cycle compared to MH cure cycle Equivalency Statistical Analysis Report

FAA Special Project Number: SP3505WI-Q

NCAMP Document: NCP-RP-2008-009 Rev N/C

Report Date: July 18, 2018

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1. Introduction

This report contains the equivalency test results for Solvay (formerly Advanced Composites Group) MTM45-1/12K AS4 145gsm 32%RW Unidirectional (12K AS4 UNI) “MH” cure cycle compared to the “M” cure cycle for the same material. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP3505WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

The material was procured to ACG Material Specification ACGM 1001-11. An equivalent NCAMP Material Specification NMS 451/11 which contains specification limits that are derived from guidelines in DOT/FAA/AR-03/19 has been created.

The original qualification data was published in “MTM45-1 AS4-145 CPT Normal Data MH Cure Cycle Values Only 7-16-09.pdf”. The qualification test panels were fabricated in accordance with ACG process specification ACGP 1001-02 Revision B “MH” cure cycle. The equivalency data was published in “MTM45-1 AS4-145 CPT Normal Data M Cure Cycle Values Only 2-1-08.pdf”. The test panels were fabricated in accordance with ACG process specification ACGP 1001-02 Revision B using “M” cure cycle. An equivalent NCAMP Process Specification, NPS 81451 with cure “M” has been created. ACG Test Plan AI/TR/1392 Rev E was used for this equivalency program.

These tests were performed by Solvay (formerly Advanced Composites Group) in Tulsa Oklahoma. The comparisons were performed according to CMH-17-1G section 8.4.1. The modified coefficient of variation (Mod CV) comparison tests were done in accordance with section 8.4.4 of CMH-17-1G.

Engineering basis values were reported in NCAMP Report NCP-RP-2008-004 Rev N/C which details the standards and methodology used for computing basis values as well as providing the B-basis values and A- and B- estimates computed from the test results for the original qualification panels.

The NCAMP shared material property database contains material property data of common usefulness to a wide range of aerospace projects. However, the data may not fulfill all the needs of a project. Specific properties, environments, laminate architecture, and loading situations that individual projects need may require additional testing.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 451/11. NMS 451/11 has additional requirements that are listed in its prepreg process control document (PCD), fiber specification, fiber PCD, and other raw material specifications and PCDs which impose essential quality controls on the raw materials and raw material manufacturing equipment and processes. *Aircraft companies and certifying agencies should assume that the material*

property data published in this report is not applicable when the material is not procured to NCAMP Material Specification NMS 451/11. NMS 451/11 is a free, publicly available, non-proprietary aerospace industry material specification.

The use of NCAMP material and process specifications does not guarantee material or structural performance. Material users should be actively involved in evaluating material performance and quality including, but not limited to, performing regular purchaser quality control tests, performing periodic equivalency/additional testing, participating in

2. Background

Equivalence tests are performed in accordance with section 8.4.1 of CMH-17-1G and section 6.1 of DOT/FAA/AR-03/19, “Material Qualification and Equivalency for Polymer Matrix Composite Material Systems: Updated Procedure.”

2.1 Results Codes

Pass

2.2.2 Type I and Type II Errors

	Materials are equal	*Materials are not equal*
Conclude materials are equal	*Correct Decision*	*Type II error*
Conclude materials are not equal	*Type I error*	

One-sided tolerance factors for limits on sample mean values									
n									
	0.25	**0.1**	**0.05**	**0.025**	**0.01**	**0.005**	**0.0025**	**0.001**	**0.0005**
2	0.6266	1.0539	1.3076	1.5266	1.7804	1.9528	2.1123	2.3076	2.4457
3	0.5421	0.8836	1.0868	1.2626	1.4666	1.6054	1.7341	1.8919	2.0035
4	0.4818	0.7744	0.9486	1.0995	1.2747	1.3941	1.5049	1.6408	1.7371
5	0.4382	0.6978	0.8525	0.9866	1.1425	1.2488	1.3475	1.4687	1.5546
6	0.4048	0.6403	0.7808	0.9026	1.0443	1.1411	1.2309	1.3413	1.4196
7	0.3782	0.5951	0.7246	0.8369	0.9678	1.0571	1.1401	1.2422	1.3145
8	0.3563	0.5583	0.6790	0.7838	0.9059	0.9893	1.0668	1.1622	1.2298
9	0.3379	0.5276	0.6411	0.7396	0.8545	0.9330	1.0061	1.0959	1.1596
10	0.3221	0.5016	0.6089	0.7022	0.8110	0.8854	0.9546	1.0397	1.1002
11	0.3084	0.4790	0.5811	0.6699	0.7735	0.8444	0.9103	0.9914	1.0490
12	0.2964	0.4593	0.5569	0.6417	0.7408	0.8086	0.8717	0.9493	1.0044
13	0.2856	0.4418	0.5354	0.6168	0.7119	0.7770	0.8376	0.9121	0.9651
14	0.2760	0.4262	0.5162	0.5946	0.6861	0.7488	0.8072	0.8790	0.9300
15	0.2673	0.4121	0.4990	0.5746	0.6630	0.7235	0.7798	0.8492	0.8985
16	0.2594	0.3994	0.4834	0.5565	0.6420	0.7006	0.7551	0.8223	0.8700
17	0.2522	0.3878	0.4692	0.5400	0.6230	0.6797	0.7326	0.7977	0.8440
18	0.2455	0.3771	0.4561	0.5250	0.6055	0.6606	0.7120	0.7753	0.8202
19	0.2394	0.3673	0.4441	0.5111	0.5894	0.6431	0.6930	0.7546	0.7984
20	0.2337	0.3582	0.4330	0.4982	0.5745	0.6268	0.6755	0.7355	0.7782
21	0.2284	0.3498	0.4227	0.4863	0.5607	0.6117	0.6593	0.7178	0.7594
22	0.2235	0.3419	0.4131	0.4752	0.5479	0.5977	0.6441	0.7013	0.7420
23	0.2188	0.3345	0.4041	0.4648	0.5359	0.5846	0.6300	0.6859	0.7257
24	0.2145	0.3276	0.3957	0.4551	0.5246	0.5723	0.6167	0.6715	0.7104
25	0.2104	0.3211	0.3878	0.4459	0.5141	0.5608	0.6043	0.6579	0.6960
26	0.2065	0.3150	0.3803	0.4373	0.5041	0.5499	0.5926	0.6451	0.6825
27	0.2028	0.3092	0.3733	0.4292	0.4947	0.5396	0.5815	0.6331	0.6698
28	0.1994	0.3038	0.3666	0.4215	0.4858	0.5299	0.5710	0.6217	0.6577
29	0.1961	0.2986	0.3603	0.4142	0.4774	0.5207	0.5611	0.6109	0.6463
30	0.1929	0.2936	0.3543	0.4073	0.4694	0.5120	0.5517	0.6006	0.6354

Table 2-1 One-sided tolerance factors for limits on sample mean values

n	0.25	0.1	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
2	1.2887	1.8167	2.1385	2.4208	2.7526	2.9805	3.1930	3.4549	3.6412
3	1.5407	2.0249	2.3239	2.5888	2.9027	3.1198	3.3232	3.5751	3.7550
4	1.6972	2.1561	2.4420	2.6965	2.9997	3.2103	3.4082	3.6541	3.8301
5	1.8106	2.2520	2.5286	2.7758	3.0715	3.2775	3.4716	3.7132	3.8864
6	1.8990	2.3272	2.5967	2.8384	3.1283	3.3309	3.5220	3.7603	3.9314
7	1.9711	2.3887	2.6527	2.8900	3.1753	3.3751	3.5638	3.7995	3.9690
8	2.0317	2.4407	2.7000	2.9337	3.2153	3.4127	3.5995	3.8331	4.0011
9	2.0838	2.4856	2.7411	2.9717	3.2500	3.4455	3.6307	3.8623	4.0292
10	2.1295	2.5250	2.7772	3.0052	3.2807	3.4745	3.6582	3.8883	4.0541
11	2.1701	2.5602	2.8094	3.0351	3.3082	3.5005	3.6830	3.9116	4.0765
12	2.2065	2.5918	2.8384	3.0621	3.3331	3.5241	3.7054	3.9328	4.0969
13	2.2395	2.6206	2.8649	3.0867	3.3558	3.5456	3.7259	3.9521	4.1155
14	2.2697	2.6469	2.8891	3.1093	3.3766	3.5653	3.7447	3.9699	4.1326
15	2.2975	2.6712	2.9115	3.1301	3.3959	3.5836	3.7622	3.9865	4.1485
16	2.3232	2.6937	2.9323	3.1495	3.4138	3.6007	3.7784	4.0019	4.1633
17	2.3471	2.7146	2.9516	3.1676	3.4306	3.6166	3.7936	4.0163	4.1772
18	2.3694	2.7342	2.9698	3.1846	3.4463	3.6315	3.8079	4.0298	4.1902
19	2.3904	2.7527	2.9868	3.2005	3.4611	3.6456	3.8214	4.0425	4.2025
20	2.4101	2.7700	3.0029	3.2156	3.4751	3.6589	3.8341	4.0546	4.2142
21	2.4287	2.7864	3.0181	3.2298	3.4883	3.6715	3.8461	4.0660	4.2252
22	2.4463	2.8020	3.0325	3.2434	3.5009	3.6835	3.8576	4.0769	4.2357
23	2.4631	2.8168	3.0463	3.2562	3.5128	3.6949	3.8685	4.0873	4.2457
24	2.4790	2.8309	3.0593	3.2685	3.5243	3.7058	3.8790	4.0972	4.2553
25	2.4941	2.8443	3.0718	3.2802	3.5352	3.7162	3.8889	4.1066	4.2644
26	2.5086	2.8572	3.0838	3.2915	3.5456	3.7262	3.8985	4.1157	4.2732
27	2.5225	2.8695	3.0953	3.3023	3.5557	3.7357	3.9077	4.1245	4.2816
28	2.5358	2.8813	3.1063	3.3126	3.5653	3.7449	3.9165	4.1328	4.2897
29	2.5486	2.8927	3.1168	3.3225	3.5746	3.7538	3.9250	4.1409	4.2975
30	2.5609	2.9036	3.1270	3.3321	3.5835	3.7623	3.9332	4.1487	4.3050

Table 2-2 One-sided tolerance factors for limits on sample minimum values

2.2.5 Modified Coefficient of Variation

A common problem with new material qualifications is that the initial specimens produced and tested do not contain all of the variability that will be encountered when the material is being produced in larger amounts over a lengthy period of time. This can result in setting basis values that are unrealistically high.

The modified Coefficient of Variation (CV) used in this report is in accordance with section 8.4.4 of CMH-17-1G. It 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.

$$\text{Modified CV} = CV^{*} \quad \begin{cases} .06 & \text{if } CV \quad .04 \\ \dfrac{CV}{2} \quad .04 & \text{if } .04 \quad CV \quad .08 \\ CV & \text{if } CV \quad .08 \end{cases} \qquad \text{Equation 1}$$

This is converted to percent by multiplying by 100%.

CV^* is used to compute a modified standard deviation S^*.

$$S^* \quad CV^* \quad \bar{X} \qquad \text{Equation 2}$$

To compute the pooled standard deviation based on the modified CV:

$$S_p^* \quad \sqrt{\frac{\sum_{i\ 1}^{k} n_i \quad 1 \quad CV_i^* \quad \bar{X}_i^{\ 2}}{\sum_{i\ 1}^{k} n_i \quad 1}} \qquad \text{Equation 3}$$

The A-basis and B-basis values under the assumption of the modified CV method are computed by replacing S with S^*.

When the basis values have been set using the modified CV method, we can use the modified CV to compute the equivalency test results.

			Environmental Condition			
			CTD	RTD	ETD	ETW
Longitudinal Compression	**Yes**	**Modulus**		Pass		Pass
Longitudinal Tension	**Yes**	**Modulus**	Pass	Pass		
		Strength		Failed by 0.6%		Pass with Mod CV
		Modulus		Failed by 5.1%		Pass
		Strength	Failed by 19.3%	Failed by 16.6%		Pass
		Modulus	Pass	Failed by 1.0%		Pass
		0.2% Offset Strength	Pass	Pass		Pass
		5% Strain Strength	Pass Insufficient Data	Pass		Pass
		Modulus	Failed by 1.8%	Failed by 2.9%		Failed by 1.8%
Short Beam Strength	**No**	**Strength**	Pass	Pass	Failed by 1.4%	Failed by 2.5%
		Strength		Failed by 1.2%		Failed by 2.4%
		Modulus		Pass		Pass
		Strength	Pass	Pass		
		Modulus	Pass	Pass with Mod CV		
Open Hole Compression	**Yes**	**Strength**		Pass		Pass with Mod CV Insufficient Data
Open Hole Tension	**Yes**	**Strength**	Pass	Pass		
Interlaminar Tension		**Strength**		Failed by 12.2% Insufficient Data		
Curved Beam Strength		**Strength**		Failed by 13.1% Insufficient Data		
Compression After Impact	**Yes**	**Strength**		Failed by 9.0% Insufficient Data		
Measured Ply Thickness	**NA**	**NA**				
				Failed by 4.0% Insufficient Data		

Table 3-2 Summary of Equivalency Test Results

Graphical presentations of all test results are shown in Figure 3-1 and Figure 3-2. In order to show different tests on the same graphical scale, all values are plotted as a percentage of the corresponding qualification mean. Figure 3-1 shows the strength means in the upper part of the chart using left axis and the strength minimums in the lower part of the chart using the right axis. This was done to avoid overlap of the two sets of data and equivalency criteria. Figure 3-2 shows the equivalency means plotted with the upper and lower equivalency criteria.

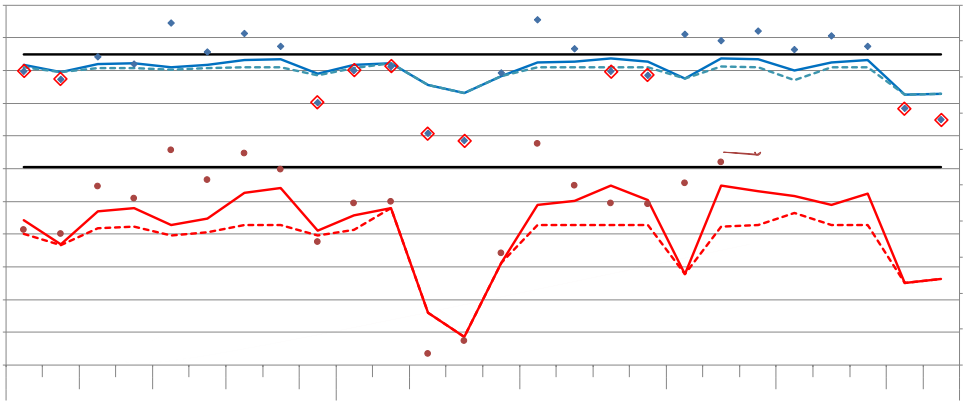

Figure 3-1 Summary of Strength means and minimums compared to their respective Equivalence limits

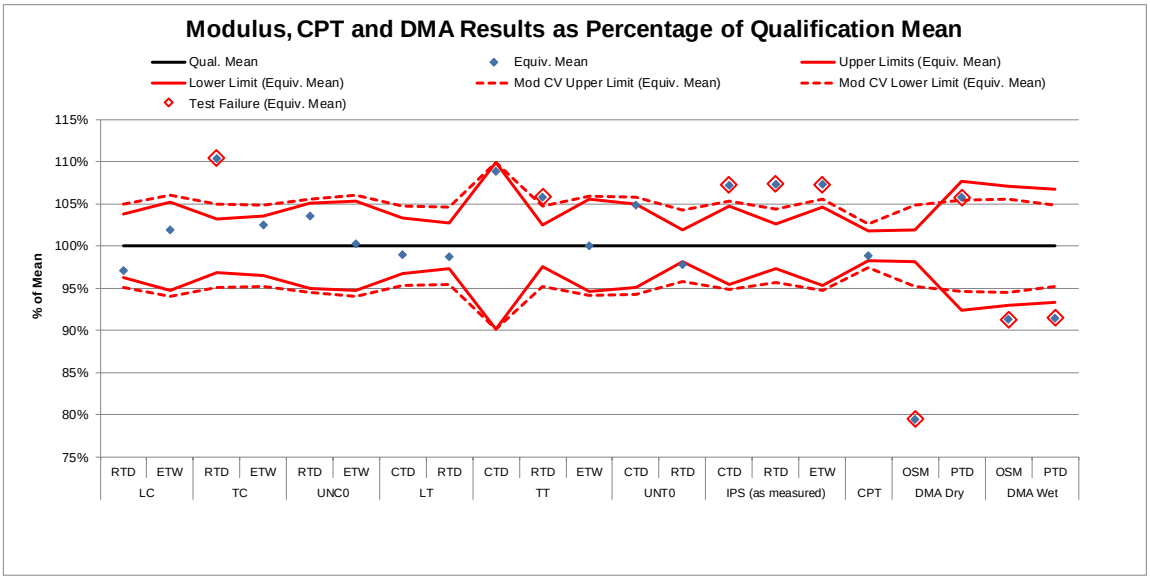

Figure 3-2 Summary of Modulus, CPT, and DMA means and Equivalence limits

3.1 Longitudinal Compression (LC)

The Longitudinal Compression Failure Strain is normalized by cured ply thickness.

3.2 Longitudinal Tension (LT)

The Longitudinal Tension data is normalized by cured ply thickness. There is no LT strength data available other than the values computed using the backout formula applied to the UNT0 data. Rather than compare the results of the UNT0 derived LT strength values, the UNT0 strength data is directly compared in section 3.8.

The LT normalized modulus data passed equivalency tests for both the CTD and RTD conditions. Statistics and analysis results are shown for the modulus data in Table 3-4.

	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0055				
Mean Modulus (Msi)	18.744	18.534	18.513	18.270
Standard Deviation	0.779	0.496	0.619	0.441
Coefficient of Variation %	4.157	2.676	3.342	2.415
Minimum	17.550	17.814	17.530	17.593
Maximum	20.217	19.389	20.227	19.206
Number of Specimens	18	8	18	8
RESULTS				
Passing Range for Modulus Mean	18.122 to 19.365		18.011 to 19.016	
Student's t-statistic				
p-value of Student's t-statistic				
MOD CV RESULTS				
Modified CV4-statistic				

Table 3-4 Longitudinal Tension Modulus Results

Figure 3-4 illustrates the 0º Tension modulus means for the qualification sample and the equivalency sample. The limits for equivalency samples are shown as error bars with the qualification data. The longer, lighter colored error bars are for the modified CV computations.

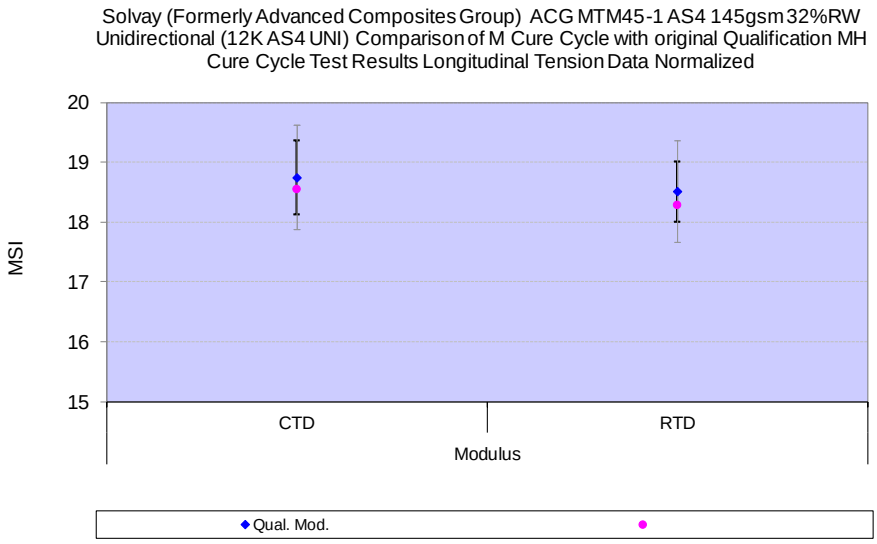

Figure 3-4 Longitudinal Tension Modulus means and Equivalence limits

is 97.79% of the lowest acceptable minimum value (3.655). The modified CV method could not be used due to the CV of the RTD condition being greater than 8%.

The TT modulus data for the RTD environment failed the equivalency test because the sample mean value (1.218) is above the upper acceptance limit (1.180). The equivalency sample mean value is 103.23% of the upper limit of acceptable values. Under the assumption of the modified CV method, the equivalency sample mean is 100.97% of the maximum acceptable mean value (1.206).

Figure 3-6 illustrates the Transverse Tension strength means and minimum values and modulus means for the qualification sample and the equivalency sample. The limits for equivalency samples are shown as error bars with the qualification data. The longer, lighter colored error bars are for the modified CV computations.

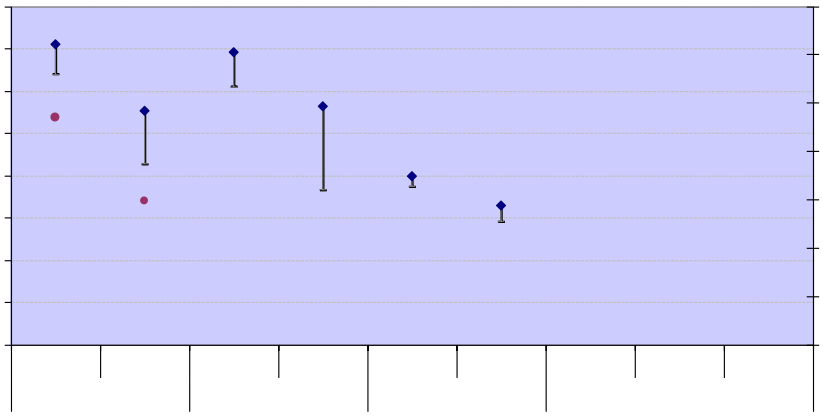

Figure 3-6 Transverse Tension means, minimums and Equivalence limits

3.5 Lamina Short Beam Strength (SBS)

The Short Beam Strength data is not normalized. The SBS data passed equivalency tests for the CTD and RTD conditions but not for the ETD and ETW conditions. Statistics and analysis results for the SBS data are shown in Table 3-9.

Short Beam Strength (SBS)	CTD		RTD		ETD		ETW	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data as measured								
Mean Strength (ksi)	16.351	18.070	12.661	12.859	9.872	9.341	8.307	7.774
Standard Deviation	0.636	0.585	0.443	0.521	0.187	0.220	0.280	0.274
Coefficient of Variation %	3.892	3.235	3.500	4.054	1.898	2.358	3.374	3.522
Minimum	15.251	17.419	11.828	12.021	9.468	8.885	7.730	7.461
Maximum	17.395	18.915	13.380	13.455	10.175	9.536	8.848	8.201
Number of Specimens	18	8	18	8	18	8	18	8
RESULTS	**PASS**		**PASS**		**FAIL**		**FAIL**	
Minimum Acceptable Equiv. Sample Mean	15.919		12.361		9.745		8.117	
Minimum Acceptable Equiv. Sample Min	14.632		11.465		9.366		7.551	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**FAIL**		**FAIL**	
Modified CV %	6.000		6.000		6.000		6.000	
Minimum Acceptable Equiv. Sample Mean	15.685		12.146		9.470		7.969	
Minimum Acceptable Equiv. Sample Min	13.702		10.610		8.273		6.962	

Table 3-9 Lamina Short Beam Strength Results

The SBS strength data for the ETD environment failed equivalence due to both the sample mean and sample minimum being too low. The equivalency sample mean (9.341) is 95.86% of the minimum acceptable mean value (9.745) and the equivalency sample minimum (8.885) is 94.86% of the lowest acceptable minimum value (9.366). Under the assumption of the modified CV method, the equivalency sample mean is 98.64% of the minimum acceptable mean value (9.470) and the equivalency sample minimum value is acceptable.

The SBS strength data for the ETW environment failed equivalence due to both the sample mean and sample minimum being too low. The equivalency sample mean (7.774) is 95.77% of the minimum acceptable mean value (8.117) and the equivalency sample minimum (7.461) is 98.82% of the lowest acceptable minimum value (7.551). Under the assumption of the modified CV method, the equivalency sample mean is 97.55% of the minimum acceptable mean value (7.969) and the equivalency sample minimum value is acceptable.

Figure 3-7 illustrates the Short Beam Strength means and minimum values for the qualification sample and the equivalency sample. The limits for equivalency samples are shown as error bars with the qualification data. The longer, lighter colored error bars are for the modified CV computations.

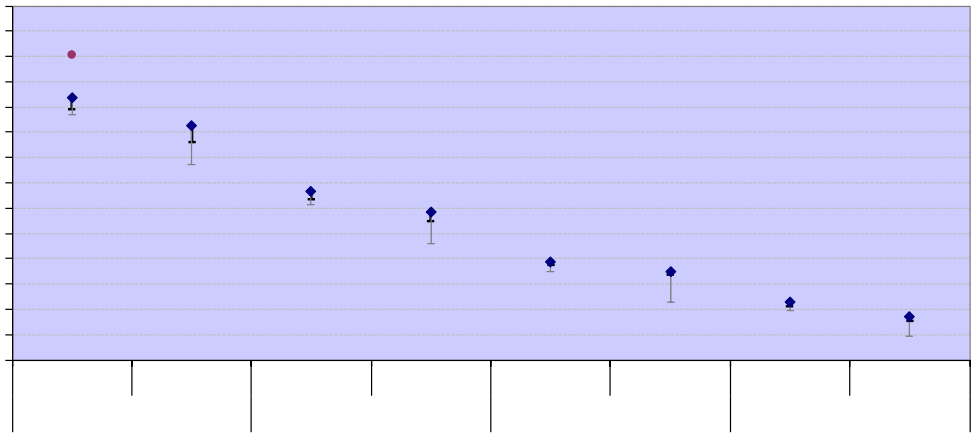

Figure 3-7 Lamina Short Beam Strength means, minimums and Equivalence limits

3.6 In-Plane Shear (IPS)

The In-Plane Shear data is not normalized. The IPS strength properties passed all equivalency tests for all three conditions tested. The IPS modulus datasets did not pass for any of the three conditions tested due to the modulus mean being too high. Statistics and analysis results are shown for 0.2% Offset Strength in Table 3-10, for Strength at 5% Strain in Table 3-11, and for Modulus in Table 3-12.

	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data as measured						

Table 3-10 In-Plane Shear 0.2% Offset Strength Results

	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data as measured						
Mean Strength 5% Strain (ksi)	13.138	13.320	9.357	9.880	5.308	5.439

Table 3-11 In-Plane Shear Strength at 5% Strain Results

Table 3-12 In-Plane Shear Modulus Results

The IPS modulus data for the CTD environment failed the equivalency test because the sample mean value (0.694) is above the upper acceptance limit (0.678). The equivalency sample mean value is 102.43% of the upper limit of acceptable values. Under the assumption of the modified CV method, the equivalency sample mean is 101.84% of the maximum acceptable mean value (0.682).

The IPS modulus data for the RTD environment failed the equivalency test because the sample mean value (0.565) is above the upper acceptance limit (0.540). The equivalency sample mean value is 104.61% of the upper limit of acceptable values. Under the assumption of the modified CV method, the equivalency sample mean is 102.92% of the maximum acceptable mean value (0.549).

The IPS modulus data for the ETW environment failed the equivalency test because the sample mean value (0.379) is above the upper acceptance limit (0.370). The equivalency sample mean value is 102.53% of the upper limit of acceptable values. Under the assumption of the modified CV method, the equivalency sample mean is 101.81% of the maximum acceptable mean value (0.373).

Figure 3-8 illustrates the In-Plane Shear strength means and minimum values and the modulus means for the qualification sample and the equivalency sample. The limits for equivalency samples are shown as error bars with the qualification data. The longer, lighter colored error bars are for the modified CV computations.

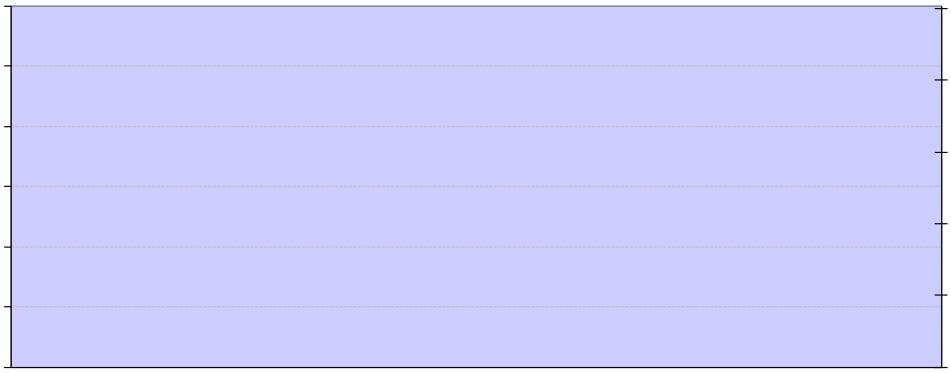

Figure 3-8 In-Plane Shear means, minimums and Equivalence limits

(72.053). Under the assumption of the modified CV method, the equivalency sample mean is 97.63% of the minimum acceptable mean value (72.049).

Figure 3-9 illustrates the Unnotched Compression strength means and minimum values and modulus means for the qualification sample and the equivalency sample. The limits for equivalency samples are shown as error bars with the qualification data. The longer, lighter colored error bars are for the modified CV computations.

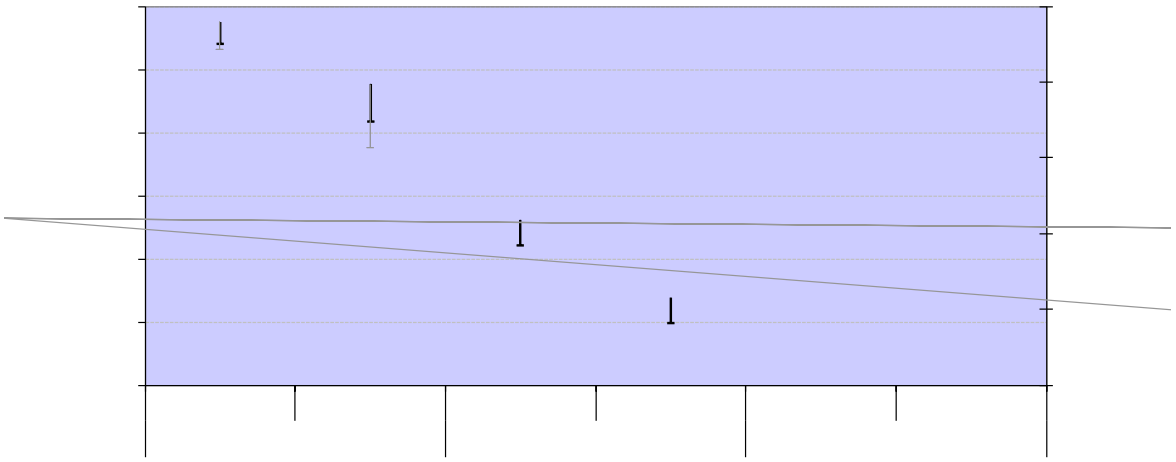

Figure 3-9 Unnotched Compression 0 means, minimums and Equivalence limits

3.8 3 /0/ ´ 8 Q Q R W F K H G (UNT0) Q V L R Q

The Unnotched Tension data is normalized by cured ply thickness. The UNT0 data passed all equivalency tests for both strength and modulus in both the CTD and RTD conditions, although the modulus RTD dataset required the use of the modified CV method. Statistics and analysis results are shown for strength in Table 3-15 and for modulus in Table 3-16.

Unnotched Tension (UNT0) Strength	CTD		RTD	
	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0055				
Mean Strength (ksi)	141.409	154.714	144.688	145.690
Standard Deviation	8.488	3.691	7.554	4.147
Coefficient of Variation %	6.003	2.386	5.221	2.846
Minimum	124.829	148.134	120.235	139.424
Maximum	157.668	159.157	154.907	151.929
Number of Specimens	21	8	19	9
RESULTS	**PASS**		**PASS**	
Minimum Acceptable Equiv. Sample Mean	135.645		139.845	
Minimum Acceptable Equiv. Sample Min	118.490		123.982	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV %	7.001		6.610	
Minimum Acceptable Equiv. Sample Mean	134.686		138.557	
Minimum Acceptable Equiv. Sample Min	114.677		118.471	

Table 3-15 Unnotched Tension 0 Strength Results

	Qual.	Equiv.	Qual.	Equiv.

Table 3-16 Unnotched Tension 0 Modulus Results

The UNT0 modulus data for the RTD environment failed the equivalency test because the sample mean value (9.671) is below the lower acceptance limit (9.712). The equivalency sample mean value is 99.58% of the lower limit of acceptable values. Under the assumption of the modified CV method, the modulus data from the RTD environment passed the equivalence test.

3.10 3 ´ 2SHQ +ROH &RPSUHVVLRQ (OHC1)

The Open Hole Compression data is normalized by cured ply thickness. The OHC1 strength data passed equivalency tests for both the RTD and ETW conditions although the ETW condition required the use of the modified CV method. The ETW condition had insufficient data in the qualification sample for the result to be considered conclusive. Statistics and analysis results for the OHC1 strength data are shown in Table 3-18.

	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0055				
Mean Strength (ksi)	43.760	43.364	37.991	36.807
Standard Deviation	1.998			

Table 3-18 Open Hole Compression 1 Strength Results

The OHC1 strength data for the ETW environment failed equivalence due to the sample mean being below the acceptance limit. The sample minimum value is acceptable. The equivalency sample mean (36.807) is 99.75% of the minimum acceptable mean value (36.898). Under the assumption of the modified CV method, the strength data from the ETW environment passed the equivalence test.

Figure 3-12 illustrates the Open Hole Compression strength means and minimum values for the qualification sample and the equivalency sample. The limits for equivalency samples are shown as error bars with the qualification data. The longer, lighter colored error bars are for the modified CV computations.

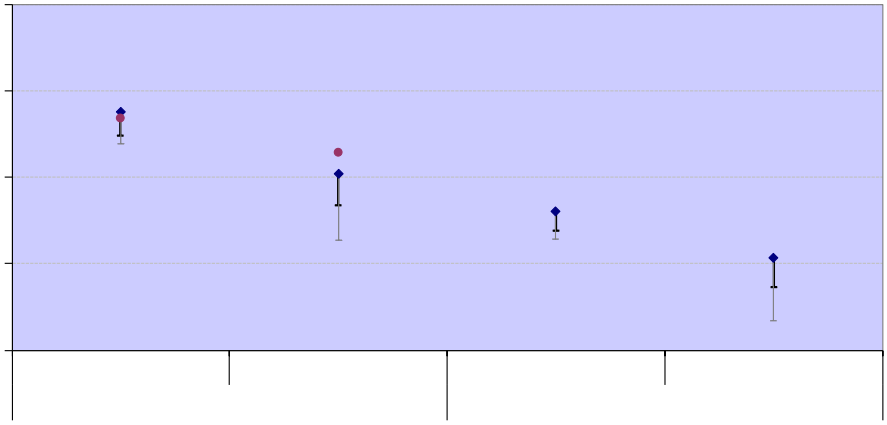

Figure 3-12 Open Hole Compression 1 means, minimums and Equivalence limits

3.11 Interlaminar Tension (ILT) and Curved Beam Strength (CBS)

The Interlaminar Tension and Curved Beam Strength data are not normalized. Modified CV results were not provided because the coefficient of variation was above 8% which means that the modified CV resultsf variaed

Figure 3-13 illustrates the Interlaminar Tension and Curved Beam Strength means and minimum values for the qualification sample and the equivalency sample. Due to the large CV of the qualification sample, the modified CV approach does not change the limits.

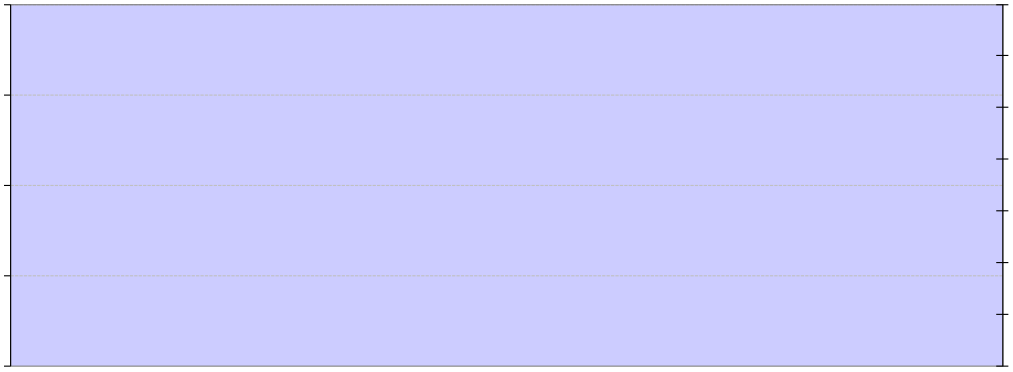

Figure 3-13 Interlaminar Tension and Curved Beam Strength means, minimums and Equivalence limits

Figure 3-14 illustrates the Compression After Impact strength means and minimum values for the qualification sample and the equivalency sample. The limits for equivalency samples are shown as error bars with the qualification data. The longer, lighter colored error bars are for the modified CV computations.

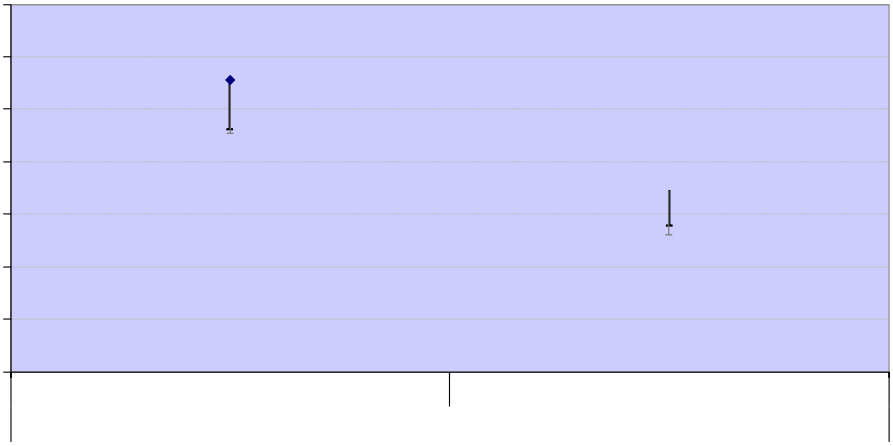

Figure 3-14 Compression After Impact means, minimums and Equivalence limits

3.13 Cured Ply Thickness (CPT)

The Cured Ply Thickness can be considered equivalent according to the results of a pooled two-sample double-sided t-test at a 95% confidence level. Statistics for both the original qualification material MH cure cycle and the M cure cycle equivalency sample are shown in Table 3-21. The average CPT with 95% standard error bars is shown in Figure 3-15. The longer, lighter colored error bars are for the modified CV computations.

Cured Ply Thickness (CPT)	Qual.	Equiv.
Average Cured Ply Thickness	0.005478	0.005413
Standard Deviation	0.00021	0.00010
Coefficient of Variation %	3.76079	1.81878
Minimum	0.00458	0.00525
Maximum	0.00588	0.00573
Number of Specimens	40	22
RESULTS	**PASS**	
Passing Range for CPT Mean	0.005384 to 0.005571	
Student's t-statistic	-1.382	
p-value of Student's t-statistic	0.1720	
MOD CV RESULTS	**PASS with MOD CV**	
Modified CV%	6.000	
Passing Range for CPT Mean	0.005334 to 0.005622	
Modified CV Student's t-statistic	-0.897	
p-value of Student's t-statistic	0.373	

Table 3-21 Cured Ply Thickness Results

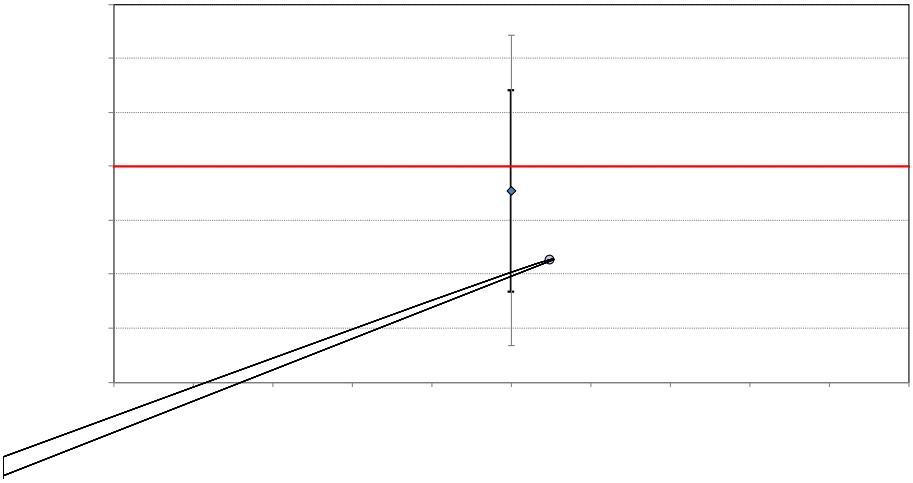

Figure 3-15 CPT means, 95% standard error bars and nominal value

3.14 Dynamic Mechanical Analysis (DMA)

DMA is compared for two measurements, the onset of storage modulus and the peak of tangent delta for both dry and wet conditions. These are tested for equivalency using a pooled two-sample double-sided t-test at a 95% confidence level. The modified CV method is not applied to DMA, but an additional analysis is also made with the allowable range for DMA being set to ±18°F. This equivalency criterion for evaluating glass transition temperature is not a statistically-based criterion but is generally more stringent than that based on α=5% with modified coefficient of variation but less stringent that that based on α=5% with as-measured coefficient of variation. This criterion is added to the test on Tg to aid the decision making process because the statistically-based methods are often too stringent (when as-measured coefficient of variation is used) or too lax (when modified coefficient of variation is used).

Only the Dry Peak of Tangent Delta dataset passed the equivalency test. There was insufficient data for the results to be considered conclusive. Statistics for both the original qualification material and the equivalency sample are shown in Table 3-22.

Table 3-22 DMA Results

The Onset Storage Modulus for dry data failed the equivalency test because the sample mean value (293.818) is beyond the acceptance limit (

Figure 3-16 illustrates the average DMA values for both the qualification sample and the equivalency sample. The limits for equivalency samples are shown as error bars with the qualification data. The longer, lighter colored error bars are for the range equal to ±18°F computations.

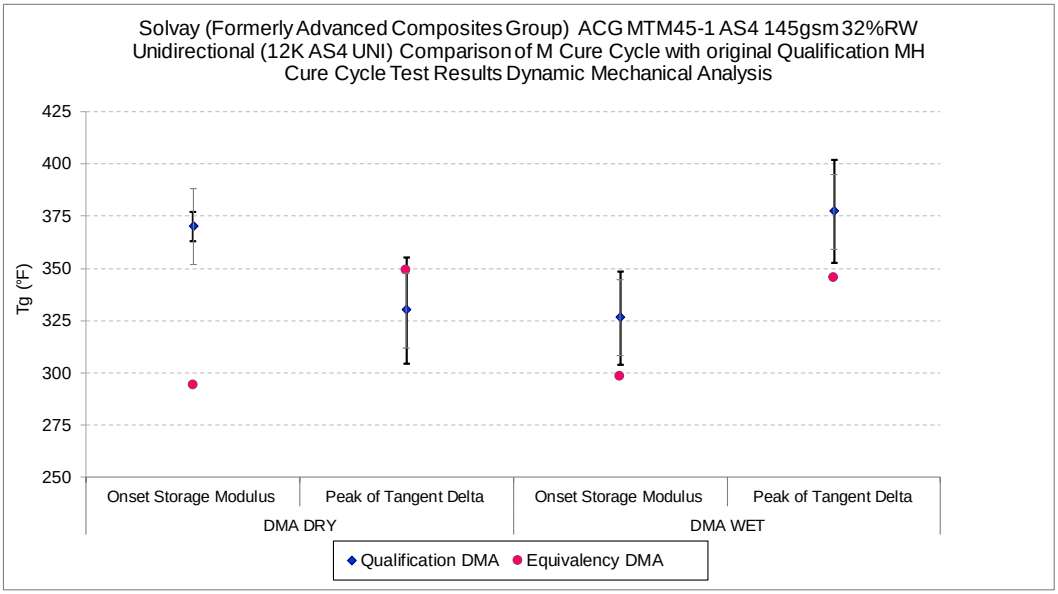

Figure 3-16 DMA Means and Equivalence limits

4. Summary of Results

All the equivalency comparisons are conducted with Type I error probability (α) of 5% in accordance with FAA/DOT/AR-03/19 report and CMH-17-1G section 8.4.1. It is common to obtain a few or even several failures in a typical equivalency program involving multiple independent property comparisons. In theory, if the equivalency dataset is truly identical to the qualification dataset, we expect to obtain approximately 5% failures. Since the equivalency test panels were fabricated by a different company, the test panel quality is expected to differ at least marginally; so, we expect to obtain slightly higher failure rates than 5% because the equivalency dataset may not be truly identical to the qualification dataset. However, a failure rate that is significantly higher than 5% is an indication that equivalency should not be assumed and some retesting is justified.

In addition to the frequency of failures, the severity of the failures (i.e. how far away from the pass/fail threshold) and any pattern of failures should be taken into account when making a determination of overall equivalency. Severity of failure can be determined using the graphs accompanying the individual test results. Whether or not a pattern of failures exists is a subjective evaluation to be made by the original equipment manufacturer or certifying agency. The question of how close is close enough is often difficult to answer, and may depend on specific application and purpose of equivalency. NCAMP does not make a judgment regarding the overall equivalence; the following information is provided to aid the original equipment manufacturer or certifying agency in making that judgment.

4.1 The assumption of Independence

The following computations are based on the assumption that the tests are independent. The DMA and CPT tests are not included in this part of the analysis because the results of multiple other tests may be dependent or correlated with those tests.

While the tests are all conducted independently, measurements for strength and modulus are made from a single specimen. For the In-Plane Shear tests, both the 0.2% offset strength and the strength at 5% strain as well as the modulus measurements are made on a single specimen. While modulus measurements are generally co

4.2 Failures

The M cure cycle panels have sufficient test results for comparison with the original qualification material test results on a total of 37 different test types and conditions, not including the cured ply thickness or the DMA comparison. Using the modified CV method, there were twelve failures.

July 18, 2018