7781 E765 Glass 293gsm Prepreg at 38% Equivalency Statistical Analysis Report for Park Aerospace Corp.

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1. Introduction

This report contains the equivalency test results for Park Aerospace Corp. 7781 E765 Glass 293gsm Prepreg at 38% produced panels compared to the original qualification panels of the same material. The lamina and laminate material property data have been generated with NCAMP oversight in accordance with NSP 100 NCAMP Standard Operating procedures; the test panels and test specimens have been inspected by NCAMP Authorized Inspection Representatives (AIR) and the testing has been witnessed by NCAMP Authorized Engineering Representatives (AER). However, the data may not fulfill all the needs of any specific company's program; specific properties, environments, laminate architecture and loading situations may require additional testing. This report was updated with Phase 3 new data for WT and FT methods.

NCAMP test plan NTP 7653E1 Rev D was used for this equivalency program. The Park Aerospace material was procured to Park Aerospace Corp. E-765 MS1001 Rev 5 Type 1 Grade A which is equivalent to NCAMP material specification NMS 765/5. NMS 765/5 shall be used for future procurement. The Park Aerospace panels were fabricated using three batches of material per Park Aerospace Corp. process specification E-765 PS1000 Rev. 5 using Section 3.7 bagging "Option 2" and Section 4.0 cure cycle which is equivalent to NCAMP Process Specification NPS 81765 Rev – using cure cycle "O" and bagging scheme "Option 2". Qualification panels were fabricated with bagging scheme "Option 1".

The tests on the equivalency specimens were performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas and at Park Aerospace Corp in Newton, Kansas. 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.

The material property data for the qualification panels is published in AGATE-WP3.3-033051-105. The material property data for Park Aerospace Corp equivalence panels is in NCAMP Test Report CAM-RP-2023-010 Rev N/C. Engineering basis values generated from material qualification testing can be obtained from AGATE-WP3.3-033051-105.

Aircraft companies should not use the data published in this report without specifying Park Aerospace Corp. E-765 MS1001 or NMS 765/5. Park Aerospace Corp. E-765 MS1001 or NMS 765/5 have 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 Park Aerospace Corp. E-765 MS1001 or NMS 765/5. Park Aerospace Corp. E-765 MS1001 and NMS 765/5* are 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 material change management activities, conducting statistical process control, and conducting regular supplier audits.

The applicability and accuracy of NCAMP material property data, material allowables, and specifications must be evaluated on case-by-case basis by aircraft companies and certifying agencies. NCAMP assumes no liability whatsoever, expressed or implied, related to the use of the material property data, material allowables and specifications.

1.1 Symbols and Abbreviations

Test Method	Abbreviation
Warp Compression	WC
Warp Tension	WT
Fill Compression	FC
Fill Tension	FT
In-Plane Shear	IPS
Short Beam Strength	SBS
Cured Ply Thickness	CPT
Dynamic Mechanical Analysis	DMA

Table 1-1 Test Method Abbreviations

Environmental Condition	Temperature	Abbreviation
Cold Temperature Ambient	−65ºF±5ºF	CTD
Room Temperature Ambient	70ºF±10ºF	RTD
Elevated Temperature Ambient	180ºF±5ºF	ETD
Elevated Temperature Wet	180ºF±5ºF	ETW

Table 1-2 Environmental Conditions Abbreviations

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 indicates that the test results are equivalent for that environment under both computational methods.

Fail indicates that the test results are NOT equivalent under both computational methods.

Pass with Mod CV indicates the test results are equivalent under the assumption of the modified CV method that the coefficient of variation is at least 6 but the test results fail without the use of the modified CV method.

2.2 Equivalency Computations

Equivalency tests are performed to determine if the differences between test results can be reasonably explained as due to the expected random variation of the material and testing processes. If so, we can conclude the two sets of tests are from ‘equivalent’ materials.

2.2.1 Hypothesis Testing

This comparison is performed using the statistical methodology of hypothesis testing. Two mutually exclusive hypotheses are set up, termed the null (H_0) and the alternative (H_1). The null hypothesis is assumed true and must contain the equality. For equivalency testing, they are set up as follows, with M_1 and M_2 representing the two materials being compared:

$$H_0 : M_1 = M_2$$
$$H_1 : M_1 \neq M_2$$

Samples are taken of each material and tested according to the plan. A test statistic is computed using the data from the sample tests. The probability of the actual test result is computed under the assumption of the null hypothesis. If that result is sufficiently unlikely then the null is rejected and the alternative hypothesis is accepted as true. If not, then the null hypothesis is retained as plausible.

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*	*Correct Decision*

Figure 2-1 Type I and Type II errors

As illustrated in **Figure 2-1**, there are four possible outcomes: two correct conclusions and two erroneous conclusions. The two wrong conclusions are termed type I and type II errors to distinguish them. The probability of making a type I error is specified using a parameter called alpha (α), while the type II error is not easily computed or controlled. The term 'sufficiently unlikely' in the previous paragraph means, in more precise terminology, the probability of the computed test statistic under the assumption of the null hypothesis is less than α.

For equivalency testing of composite materials, α is set at 0.05 which corresponds to a confidence level of 95%.This means that if we reject the null and say the two materials are not equivalent with respect to a particular test, the probability that this is a correct decision is no less than 95%.

2.2.3 Cumulative Error Probability

Each characteristic (such as Longitudinal Tension strength or In-Plane Shear modulus) is tested separately. While the probability of a Type I error is the same for all tests, since many different tests are performed on a single material, each with a 5% probability of a type I error, the probability of having one or more failures in a series of tests can be much higher.

If we assume the two materials are identical, with two tests the probability of a type I error for the two tests combined is $1 - .95^2 = .0975$. For four tests, it rises to $1 - .95^4 = 0.1855$. For 25 tests, the probability of a type I error on 1 or more tests is $1 - .95^{25} =$

0.7226. With a high probability of one or more equivalence test failures due to random chance alone, a few failed tests should be allowed and equivalence may still be presumed provided that the failures are not severe.

2.2.4 Strength and Modulus Tests

For strength test values, we are primarily concerned only if the equivalence sample shows lower strength values than the original qualification material. This is referred to as a ‘one-sided’ hypothesis test. Higher values are not considered a problem, though they may indicate a difference between the two materials. The equivalence sample mean and sample minimum values are compared against the minimum expected values for those statistics, which are computed from the qualification test result.

The expected values are computed using the values listed in **Table 2-1** and **Table 2-2** according to the following formulas:

> The mean must exceed $\bar{X} - k_n^{table\,2.1} \cdot S$ where $\bar{X}$ and S are, respectively, the mean and the standard deviation of the qualification sample.
>
> The sample minimum must exceed $\bar{X} - k_n^{table\,2.2} \cdot S$ where $\bar{X}$ and S are, respectively, the mean and the standard deviation of the qualification sample.

If either the mean or the minimum falls below the expected minimum, the sample is considered to have failed equivalency for that characteristic and the null hypothesis is rejected. The probability of failing either the mean or the minimum test (the α level) is set at 5%.

For Modulus values, failure occurs if the equivalence sample mean is either too high or too low compared to the qualification mean. This is referred to as a ‘two-sided’ hypothesis test. A standard two-sample two-tailed t-test is used to determine if the mean from the equivalency sample is sufficiently far from the qualification sample mean to reject the null hypothesis. The probability of a type I error is set at 5%.

These tests are performed with the HYTEQ spreadsheet, which was designed to test equivalency between two materials in accordance with the requirements of CMH-17-1G section 8.4.1: Tests for determining equivalency between an existing database and a new dataset for the same material. Details about the methods used are documented in the references listed in Section 5.

One-sided tolerance factors for limits on sample mean values									
n	α								
	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	α								
	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

One-sided tolerance factors for limits on sample minimum values

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.

$$\text{Modified CV} = CV^* = \begin{cases} .06 & if\ CV < .04 \\ \frac{CV}{2} + .04 & if\ .04 \le CV < .08 \\ CV & if\ CV \ge .08 \end{cases} \qquad \text{Equation 1}$$

This is converted to percent by multiplying by 100%.

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

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

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

$$S_p^* = \sqrt{\frac{\sum_{i=1}^{k}\left((n_i - 1)\left(CV_i^* \cdot \bar{X}_i\right)^2\right)}{\sum_{i=1}^{k}(n_i - 1)}} \qquad \text{Equation 3}$$

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.

3. Equivalency Test Results

There were a total of 23 different tests of equivalency run with sufficient data according to the recommendations of CMH-17-1G. All tests were performed with an α level of 5%. Four significant digits are provided for the qualification values for all test properties. The Park Aerospace test data and the computations to determine equivalency are given to four significant digits.

The results of the equivalency comparisons are listed as ‘Pass’ or ‘Fail’, or ‘Pass with Mod CV’. ‘Pass with Mod CV’ refers to cases where the equivalency fails unless the modified coefficient of variation method is used. A minimum of eight samples from two separate panels and processing cycles is required for strength properties and a minimum of four specimens for modulus comparison. If the sample does not have an adequate number of specimens, this will be indicated with ‘Insufficient Data’. A summary of all results is shown in Table 3-1.

Failures in Table 3-1 are reported as "Failed by _._%". This percentage was computed by taking the ratio of the equivalency mean or minimum value to the modified CV limit for that value. Table 3-2 gives a rough scale for the relative severity of those failures.

Equivalency Test Results for Park Aerospace Technologies Corp. "C" Cure Cycle compared with 7781 E765 Glass 293gsm Prepeg at 38% Cure Cycle						
Test	**Normalized Data**	**Property**	**Enviromental Condition**			
			CTD	RTD	ETD	ETW
Warp Compression	**Yes**	**Strength**	Insufficient Data	Pass	Pass	Pass
		Modulus	Insufficient Data	Pass	Pass	Pass
Warp Tension	**Yes**	**Strength**	Insufficient Data	Pass	Pass	
		Modulus	Insufficient Data	Pass	Pass with Mod CV	
Fill Compression	**Yes**	**Strength**	Insufficient Data	Pass	Pass	Pass
		Modulus	Insufficient Data	Pass	Pass with Mod CV	Pass
Fill Tension	**Yes**	**Strength**	Pass	Pass	Pass	
		Modulus	Pass	Pass	Pass	
Short Beam Strength	**No**	**Strength**		Pass		
Cured Ply Thickness	**NA**	**NA**	Pass with Mod CV			
Dynamic Mechanical Analysis	**Onset Storage Modulus - Dry**		Pass			
	Peak of Tangent Delta - Dry		Pass with ±18°F Results			
	Onset Storage Modulus - Wet		Pass with ±18°F Results			
	Peak of Tangent Delta - Wet		Pass			

Table 3-1 Summary of Equivalency Test Results

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 3-2 "% Failed" Results Scale

A graphical presentation of all test results is 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.

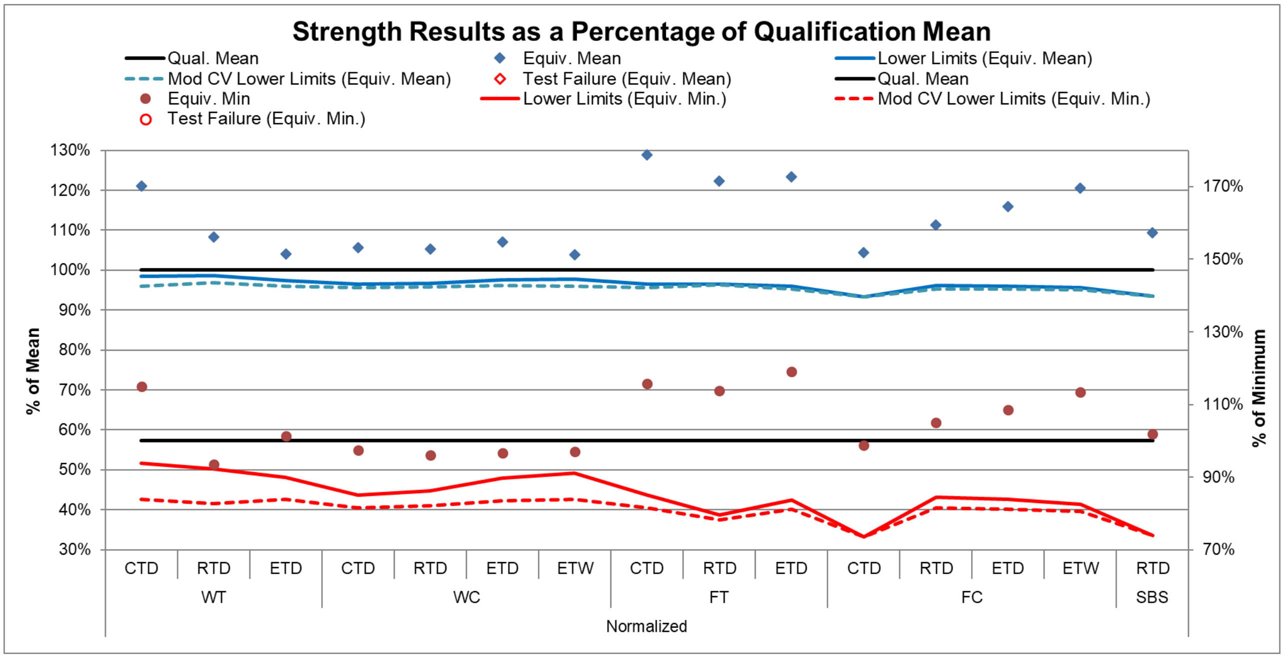

Figure 3-1 Summary of Strength means and minimums compared to their respective Equivalence limits

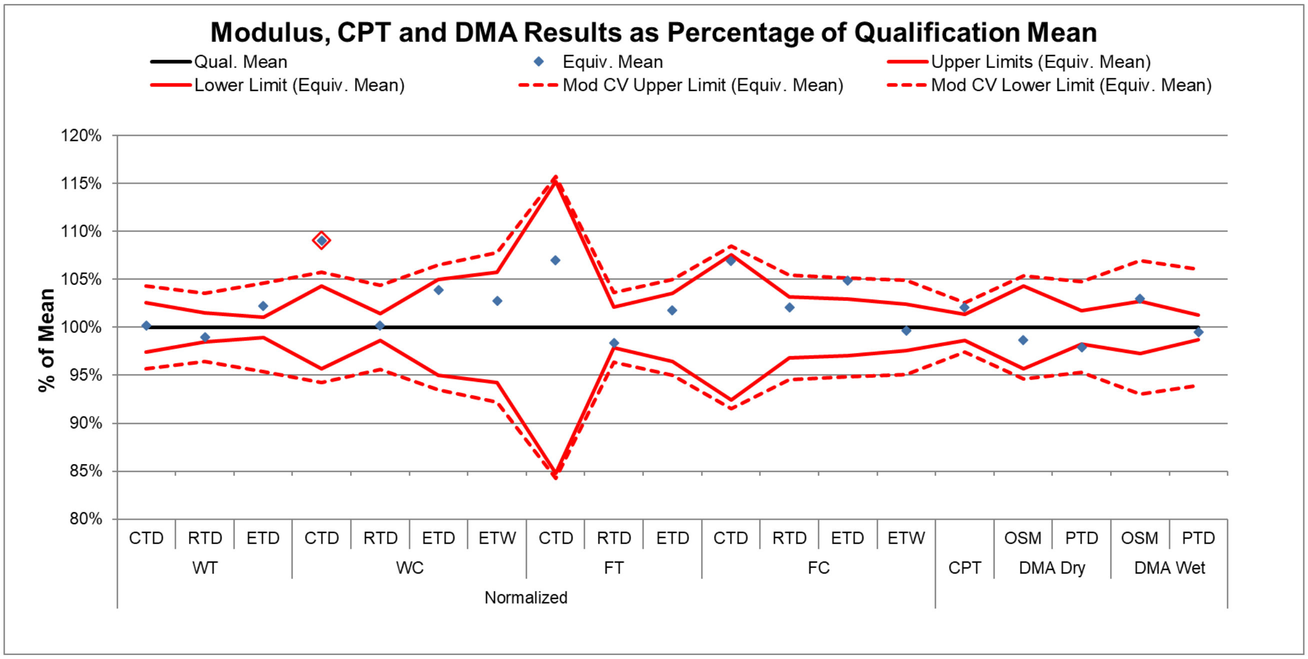

Figure 3-2 Summary of Modulus means and Equivalence limits

3.1 Warp Compression (WC)

The WC data is normalized. Equivalency specimens were tested in four environmental conditions, CTD, RTD, ETD and ETW with two properties, strength and modulus reported. The WC strength data passed equivalency for all tested conditions while the WC modulus data failed equivalency for CTD condition, with modulus values being too high.

Statistics and analysis results are shown for the strength data in **Table 3-3** and for the modulus data in **Table 3-4**.

Warp Compression (WC) Strength	CTD Qual.	CTD Equiv.	RTD Qual.	RTD Equiv.	ETD Qual.	ETD Equiv.	ETW Qual.	ETW Equiv.
Data normalized with CPT 0.0098	Insufficient Data							
Mean Strength (ksi)	87.59	92.60	75.07	79.01	62.29	66.65	52.96	55.01
Standard Deviation	4.790	6.899	3.780	5.434	2.334	5.409	1.748	3.690
Coefficient of Variation %	5.469	7.450	5.036	6.877	3.748	8.115	3.300	6.708
Minimum	81.06	85.29	69.01	72.09	57.46	60.21	49.83	51.34
Maximum	94.84	103.2	81.17	85.94	67.58	74.72	56.07	60.02
Number of Specimens	7	9	18	9	18	9	20	8
RESULTS	**PASS**		**PASS**		**PASS**		**PASS**	
Minimum Acceptable Equiv. Sample Mean	84.52		72.65		60.79		51.77	
Minimum Acceptable Equiv. Sample Min	74.46		64.71		55.89		48.24	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV %	6.734		6.518		6.000		6.000	
Minimum Acceptable Equiv. Sample Mean	83.81		71.94		59.89		50.80	
Minimum Acceptable Equiv. Sample Min	71.42		61.66		52.04		44.38	

Table 3-3 Warp Compression Strength Results

Warp Compression (WC) Modulus	CTD Qual.	CTD Equiv.	RTD Qual.	RTD Equiv.	ETD Qual.	ETD Equiv.	ETW Qual.	ETW Equiv.
Data normalized with CPT 0.0098	Insufficient Data							
Mean Modulus (Msi)	3.889	4.241	3.785	3.791	3.716	3.859	3.742	3.846
Standard Deviation	0.04962	0.09656	0.04342	0.04854	0.03387	0.2061	0.05566	0.2300
Coefficient of Variation %	1.276	2.277	1.147	1.281	0.9117	5.339	1.488	5.979
Minimum	3.854	4.071	3.731	3.699	3.660	3.562	3.662	3.594
Maximum	3.924	4.356	3.842	3.871	3.756	4.148	3.821	4.120
Number of Specimens	2	8	6	9	6	9	6	6
RESULTS	**FAIL**		**PASS**		**PASS**		**PASS**	
Passing Range for Modulus Mean	3.721 to 4.056		3.732 to 3.838		3.530 to 3.901		3.526 to 3.957	
Student's t-statistic	4.850		0.2436		1.673		1.079	
p-value of Student's t-statistic	0.001271		0.8113		0.1182		0.3061	
MOD CV RESULTS	**FAIL**		**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV%	6.000		6.000		6.000		6.000	
Passing Range for Modulus Mean	3.666 to 4.112		3.619 to 3.951		3.474 to 3.958		3.449 to 4.034	
Modified CV Student's t-statistic	3.648		0.07789		1.282		0.7941	
p-value of Student's t-statistic	0.006510		0.9391		0.2223		0.4456	

Table 3-4 Warp Compression Modulus Results

The WC modulus data for the CTD environment failed the equivalency test because the sample mean value (4.241) is above the upper acceptance limit (4.056). The equivalency sample mean value is 104.6% of the upper limit of acceptable values. Under the assumption of the modified CV method, the equivalency sample mean is 103.2% of the maximum acceptable mean value (4.112).

However, CTD environment has insufficient data for both Strength and Modulus properties, therefore the results are not statistically significant for these environments.

Figure 3-3 illustrates the 0º Compression 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.

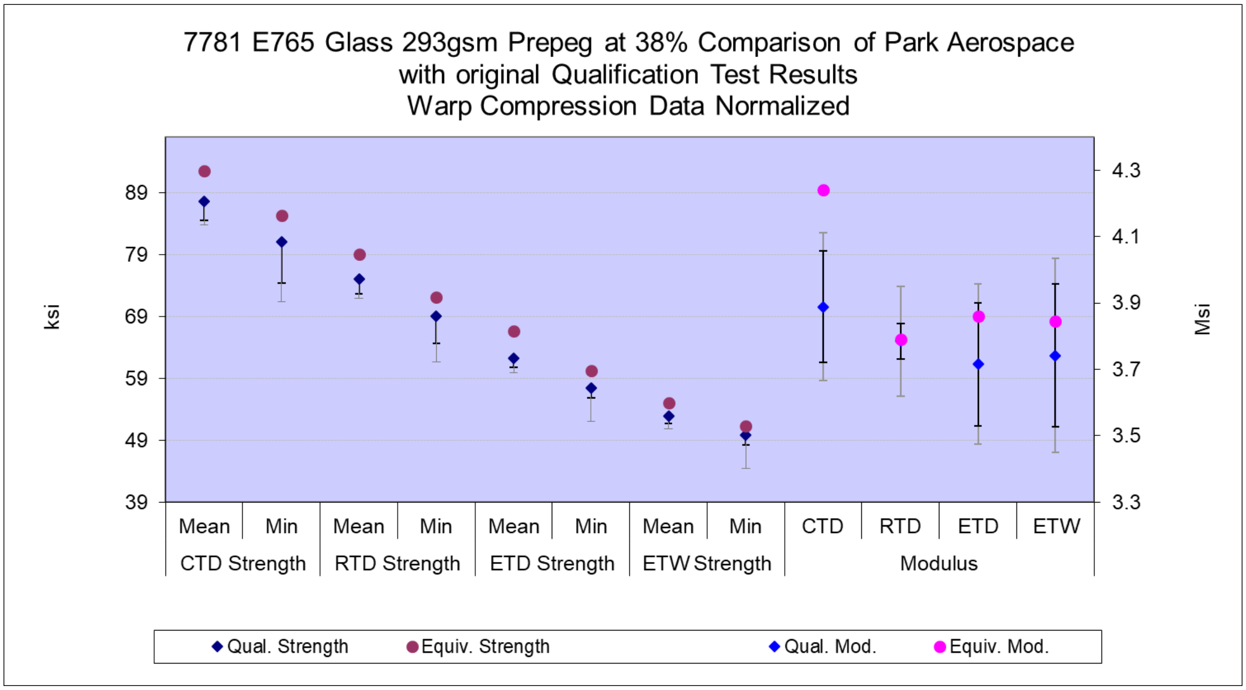

Figure 3-3 Warp Compression means, minimums and Equivalence limits

3.2 Warp Tension (WT)

The WT data is normalized. Equivalency specimens were tested in the CTD, RTD and ETD conditions with two properties, strength and modulus reported. The WT strength data passed equivalency for all three conditions. For Modulus property CTD and RTD conditions passed the equivalence test while ETD failed but passed with Mod CV. Statistics and analysis results are shown for the strength data in **Table 3-5** and for the modulus data in **Table 3-6**.

Warp Tension (WT) Strength	CTD		RTD		ETD	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0098	Insufficient Data					
Mean Strength (ksi)	70.15	84.92	64.39	69.77	59.97	62.44
Standard Deviation	1.617	2.424	1.730	4.205	2.256	1.225
Coefficient of Variation %	2.306	2.855	2.686	6.027	3.761	1.962
Minimum	68.44	80.63	61.65	60.24	55.03	60.76
Maximum	71.74	89.01	67.69	75.97	64.58	65.02
Number of Specimens	6	8	18	14	24	8
RESULTS	**PASS**		**PASS**		**PASS**	
Minimum Acceptable Equiv. Sample Mean	69.05		63.50		58.44	
Minimum Acceptable Equiv. Sample Min	65.78		59.39		53.88	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV %	6.000		6.000		6.000	
Minimum Acceptable Equiv. Sample Mean	67.29		62.40		57.53	
Minimum Acceptable Equiv. Sample Min	58.79		53.23		50.26	

Table 3-5 Warp Tension Strength Results

Warp Tension (WT) Modulus	CTD		RTD		ETD	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0098	Insufficient Data					
Mean Modulus (Msi)	3.833	3.840	3.721	3.683	3.510	3.589
Standard Deviation	0.1047	0.04304	0.04017	0.06073	0.04181	0.02740
Coefficient of Variation %	2.733	1.121	1.080	1.649	1.191	0.7634
Minimum	3.759	3.788	3.672	3.576	3.451	3.556
Maximum	3.907	3.920	3.789	3.758	3.561	3.643
Number of Specimens	2	8	6	14	8	8
RESULTS	**PASS**		**PASS**		**FAIL**	
Passing Range for Modulus Mean	3.733 to 3.932		3.664 to 3.778		3.472 to 3.548	
Student's t-statistic	0.1743		-1.395		4.445	
p-value of Student's t-statistic	0.8660		0.1799		0.0005544	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV%	6.000		6.000		6.000	
Passing Range for Modulus Mean	3.667 to 3.998		3.589 to 3.853		3.349 to 3.671	
Modified CV Student's t-statistic	0.1051		-0.6057		1.046	
p-value of Student's t-statistic	0.9189		0.5523		0.3132	

Table 3-6 Warp Tension Modulus Results

The WT modulus data for the ETD environment failed the equivalency test because the sample mean value (3.589) is higher than the upper acceptance limit for the mean (3.548). The equivalency sample mean value is 101.1% of the upper limit of acceptable values. Under the assumption of the modified CV method, the equivalency sample mean is 97.75% of the acceptable upper limit for the mean value (3.671).

However, CTD environment has insufficient data for Strength property and Modulus property, therefore the results are not statistically significant for these cases.

Figure 3-4 illustrates the 0º Tension 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.

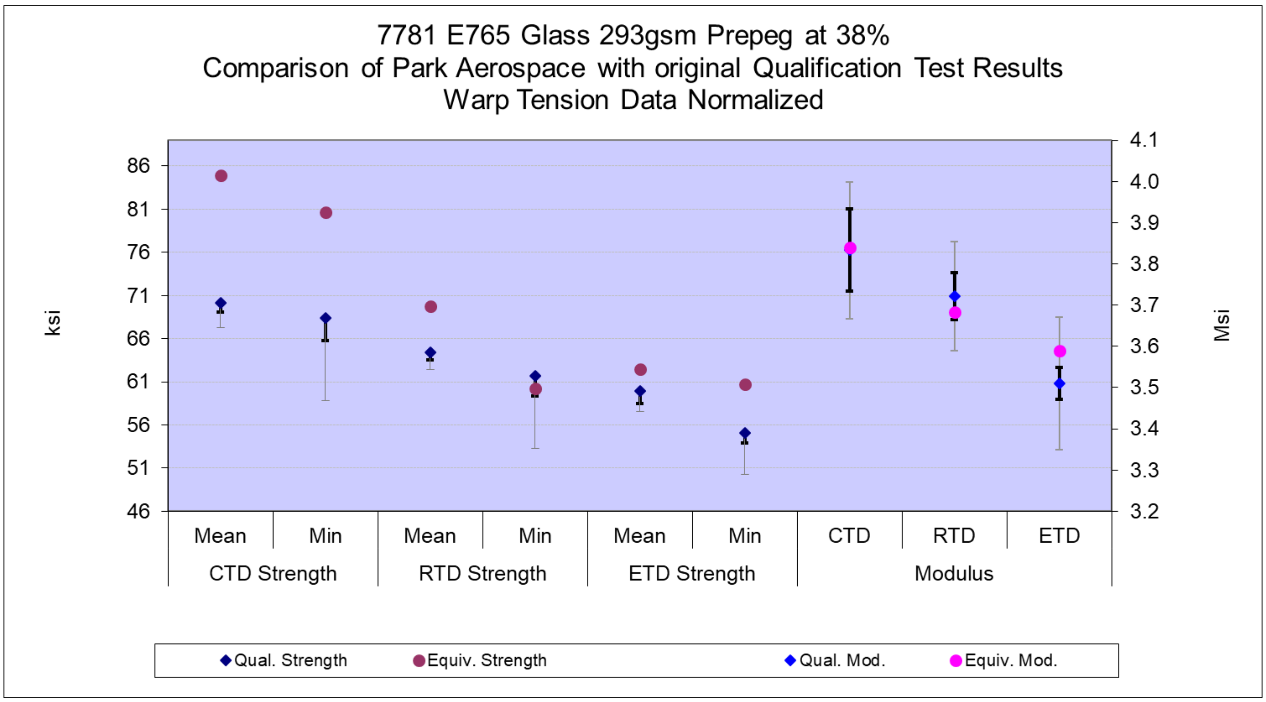

Figure 3-4 Warp Tension means, minimums and Equivalence limits

3.3 Fill Compression (FC)

The FC data is normalized. Equivalency specimens were tested in four environmental conditions, CTD, RTD, ETD and ETW with two properties, strength and modulus reported. The FC strength data passed equivalency for all tested conditions while the FC modulus data failed equivalency for ETD condition, with modulus values being too high. Under modified CV assumption, ETD condition passed the equivalency test for modulus property.

Statistics and analysis results are shown for the strength data in **Table 3-7** and for the modulus data in **Table 3-8**.

Fill Compression (FC) Strength	CTD		RTD		ETD		ETW	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0098	Insufficient Data							
Mean Strength (ksi)	66.61	69.57	58.57	65.19	47.05	54.52	39.17	47.24
Standard Deviation	6.526	2.743	3.366	1.980	2.809	2.716	2.529	1.786
Coefficient of Variation %	9.797	3.943	5.748	3.037	5.970	4.981	6.456	3.780
Minimum	57.09	65.80	52.20	61.53	40.15	51.06	33.64	44.43
Maximum	74.22	74.31	64.41	67.78	51.22	58.42	43.06	49.92
Number of Specimens	6	8	18	8	18	8	29	8
RESULTS	**PASS**		**PASS**		**PASS**		**PASS**	
Minimum Acceptable Equiv. Sample Mean	62.18		56.28		45.14		37.45	
Minimum Acceptable Equiv. Sample Min	48.99		49.48		39.46		32.34	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV %	CV > 8		6.874		6.985		7.228	
Minimum Acceptable Equiv. Sample Mean	62.18		55.84		44.82		37.25	
Minimum Acceptable Equiv. Sample Min	48.99		47.70		38.18		31.53	

Table 3-7 Fill Compression Strength Results

Fill Compression (FC) Modulus	CTD		RTD		ETD		ETW	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0098	Insufficient Data							
Mean Modulus (Msi)	3.715	3.973	3.635	3.711	3.547	3.720	3.529	3.518
Standard Deviation	0.02309	0.1652	0.04806	0.1229	0.02611	0.1143	0.06822	0.07670
Coefficient of Variation %	0.6216	4.159	1.322	3.313	0.7362	3.074	1.933	2.180
Minimum	3.699	3.795	3.584	3.513	3.520	3.545	3.418	3.338
Maximum	3.731	4.333	3.697	3.899	3.579	3.901	3.618	3.601
Number of Specimens	2	8	6	8	6	9	6	8
RESULTS	**PASS**		**PASS**		**FAIL**		**PASS**	
Passing Range for Modulus Mean	3.433 to 3.997		3.519 to 3.751		3.443 to 3.650		3.443 to 3.615	
Student's t-statistic	2.112		1.422		3.606		-0.2867	
p-value of Student's t-statistic	0.06771		0.1805		0.003193		0.7793	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV%	6.000		6.000		6.000		6.000	
Passing Range for Modulus Mean	3.399 to 4.031		3.436 to 3.834		3.365 to 3.728		3.354 to 3.704	
Modified CV Student's t-statistic	1.884		0.8310		2.060		-0.1413	
p-value of Student's t-statistic	0.09635		0.4222		0.06000		0.8900	

Table 3-8 Fill Compression Modulus Results

The FC modulus data for the ETD environment failed the equivalency test because the sample mean value (3.720) is above the upper acceptance limit (3.650). The equivalency sample mean value is 101.9% of the upper limit of acceptable values.

Under the assumption of the modified CV method, the equivalency sample mean is 99.77% of the maximum acceptable mean value (3.728).

However, CTD environment has insufficient data for Strength and Modulus properties, therefore the results are not statistically significant for this environment.

Figure 3-5 illustrates the 90º Compression 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.

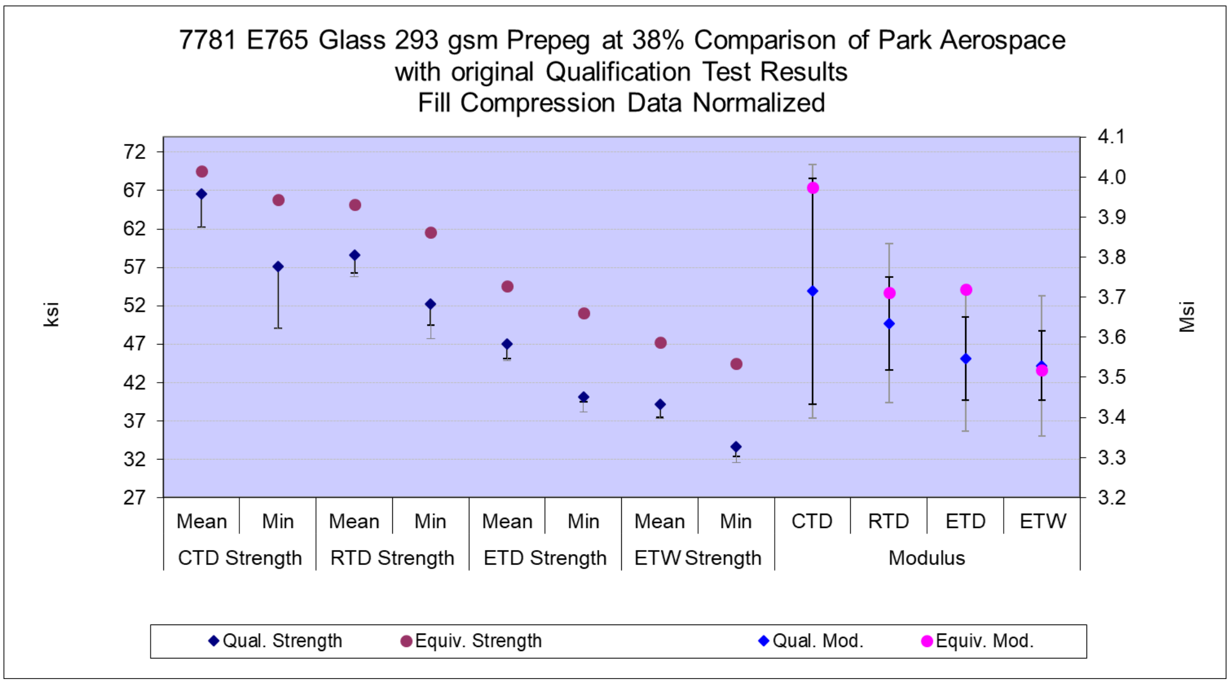

Figure 3-5 Fill Compression means, minimums and Equivalence limits

3.4 Fill Tension (FT)

The FT data is normalized. Equivalency specimens were tested in three environmental conditions, CTD, RTD and ETD, with two properties, strength and modulus reported. The FT strength data passed equivalency for all three tested conditions while the FT modulus data also passed equivalency for all three tested conditions.

Statistics and analysis results are shown for the strength data in **Table 3-9** and for the modulus data in **Table 3-10**.

Fill Tension (FT) Strength	CTD		RTD		ETD	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0098						
Mean Strength (ksi)	59.23	76.30	52.76	64.49	49.53	61.07
Standard Deviation	3.223	4.693	3.694	2.238	2.977	1.153
Coefficient of Variation %	5.441	6.151	7.001	3.470	6.010	1.889
Minimum	54.92	68.60	46.95	60.02	43.13	59.02
Maximum	63.43	82.03	59.09	68.08	54.63	62.80
Number of Specimens	8	9	18	15	18	8
RESULTS	**PASS**		**PASS**		**PASS**	
Minimum Acceptable Equiv. Sample Mean	57.17		50.92		47.51	
Minimum Acceptable Equiv. Sample Min	50.40		42.01		41.49	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV %	6.721		7.501		7.005	
Minimum Acceptable Equiv. Sample Mean	56.68		50.79		47.17	
Minimum Acceptable Equiv. Sample Min	48.32		41.24		40.16	

Table 3-9 Fill Tension Strength Results

Fill Tension (FT) Modulus	CTD		RTD		ETD	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0098						
Mean Modulus (Msi)	3.601	3.853	3.538	3.482	3.297	3.355
Standard Deviation	0.1051	0.4756	0.06321	0.07751	0.1235	0.07644
Coefficient of Variation %	2.917	12.35	1.786	2.226	3.746	2.279
Minimum	3.456	3.473	3.417	3.363	3.198	3.199
Maximum	3.697	4.924	3.589	3.596	3.540	3.450
Number of Specimens	4	8	6	15	6	8
RESULTS	**PASS**		**PASS**		**PASS**	
Passing Range for Modulus Mean	3.053 to 4.150		3.463 to 3.613		3.180 to 3.413	
Student's t-statistic	1.021		-1.583		1.091	
p-value of Student's t-statistic	0.3315		0.1300		0.2967	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV%	6.000		6.000		6.000	
Passing Range for Modulus Mean	3.035 to 4.168		3.409 to 3.667		3.131 to 3.462	
Modified CV Student's t-statistic	0.9884		-0.9180		0.7678	
p-value of Student's t-statistic	0.3463		0.3701		0.4575	

Table 3-10 Fill Tension Modulus Results

Figure 3-6 illustrates the 90º Tension 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.

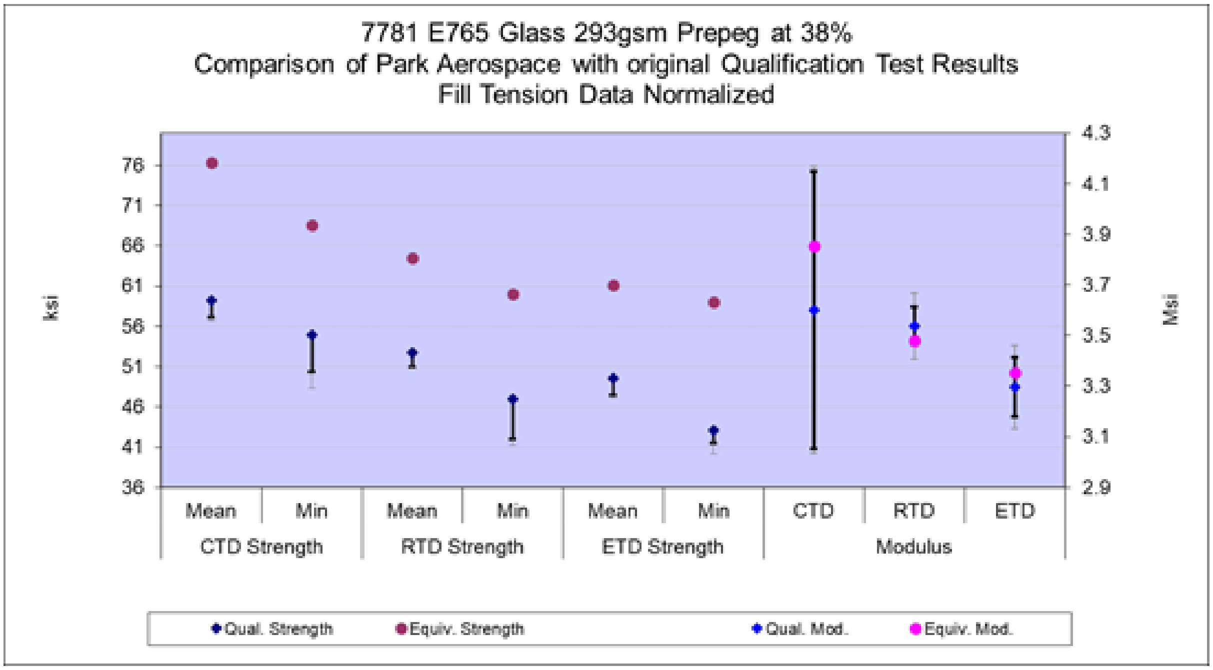

Figure 3-6 Fill Tension means, minimums and Equivalence limits

3.5 Lamina Short Beam Strength (SBS)

The SBS data is not normalized. The SBS specimens were tested in only RTD condition and values reported for one property, short beam strength. The data passed equivalency for this test property. Statistics and analysis results for the SBS data are shown in **Table 3-11**.

Short Beam Strength (SBS)	RTD	
	Qual.	**Equiv.**
Data as measured		
Mean Strength (ksi)	8.096	8.850
Standard Deviation	0.7836	0.5650
Coefficient of Variation %	9.679	6.385
Minimum	7.095	8.253
Maximum	9.448	9.770
Number of Specimens	21	8
RESULTS	**PASS**	
Minimum Acceptable Equiv. Sample Mean	7.564	
Minimum Acceptable Equiv. Sample Min	5.980	
MOD CV RESULTS	**PASS with MOD CV**	
Modified CV %	CV > 8	
Minimum Acceptable Equiv. Sample Mean	7.564	
Minimum Acceptable Equiv. Sample Min	5.980	

Table 3-11 Lamina Short Beam Strength Results

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.

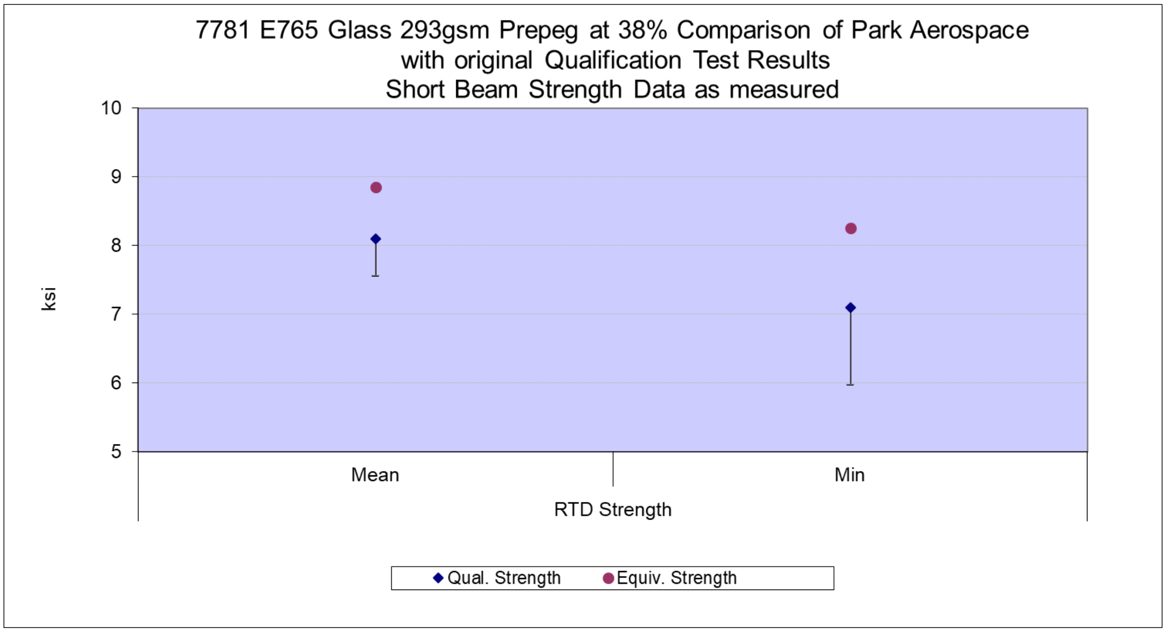

Figure 3-7 Lamina Short Beam Strength means, minimums and Equivalence limits

3.6 In-Plane Shear (IPS)

V-notch ASTM D5379 In-Plane Shear properties listed in AGATE-WP3.3-033051-105 is not reproducible based on Park Aerospace Corp historical data. Therefore, In-Plane Shear properties were retested with ASTM D3518 with the intention to supersede In-Plane Shear property in AGATE-WP3.3-033051-105. So, we removed V-notch ASTM D5379 IPS from Equivalency and added ASTM D3518 IPS for Qualification allowables.

The dataset for IPS includes three properties, 0.2% offset strength, strength at 5% strain and modulus.

Modulus general statistics

The data is as measured. The specimens were tested in four environmental conditions, CTD, RTD, ETD and ETW. General statistics are shown for the modulus data in **Table 3-12.**

In-Plane Shear (IPS) Modulus	CTD	RTD	ETD	ETW
Mean Modulus [Msi]	0.8490	0.6857	0.5423	0.3193
Standard Deviation	0.05006	0.03881	0.03134	0.07074
Coefficient of Variation %	5.897	5.660	5.779	22.15
Minimum	0.7810	0.6152	0.4916	0.2309
Maximum	0.9138	0.7550	0.6184	0.4273
Number of Specimens	18	18	18	18

Table 3-12 In-Plane Shear Modulus

Strength properties qualification allowables

The IPS test method was performed in CTD, RTD, ETD and ETW conditions for the 0.2% offset strength and strength at 5% strain data properties. For 0.2% offset strength conditions CTD and RTD passed all pooling tests, so pooling method was used for computing design values, while conditions ETD and ETW failed ADK test so ANOVA method was used. For modified CV data, conditions CTD, RTD and ETD passed all pooling tests, so pooling method was used while condition ETW has no available method (NA).

For strength at 5% strain, conditions RTD, ETD and ETW passed pooling tests, so pooling method was used, while condition CTD passed normality test, so normal method was used to compute design values. For modified CV data, conditions RTD, ETD and ETW passed pooling tests, so pooling method was used, while condition CTD passed normality test, so normal method was used.

Two statistical outliers were detected. A condition lower outlier (specimen NTP7653E1-PAC-P03-PAC-IPS-C-C1-1-RTD-2) for 0.2% offset strength in condition RTD and batch C. A batch lower outlier (specimen NTP7653E1-PAC-P03-PAC-IPS-A-C1-1-ETD-3) for

5% offset strength in condition ETD and batch A. All statistical outliers were retained for computations.

Statistics are given for the 0.2% offset strength in **Table 3-13** and for strength at 5% strain in **Table 3-14**. The data for 0.2% offset strength are shown graphically in **Figure 3-8** and for strength at 5% strain in **Figure 3-9**.

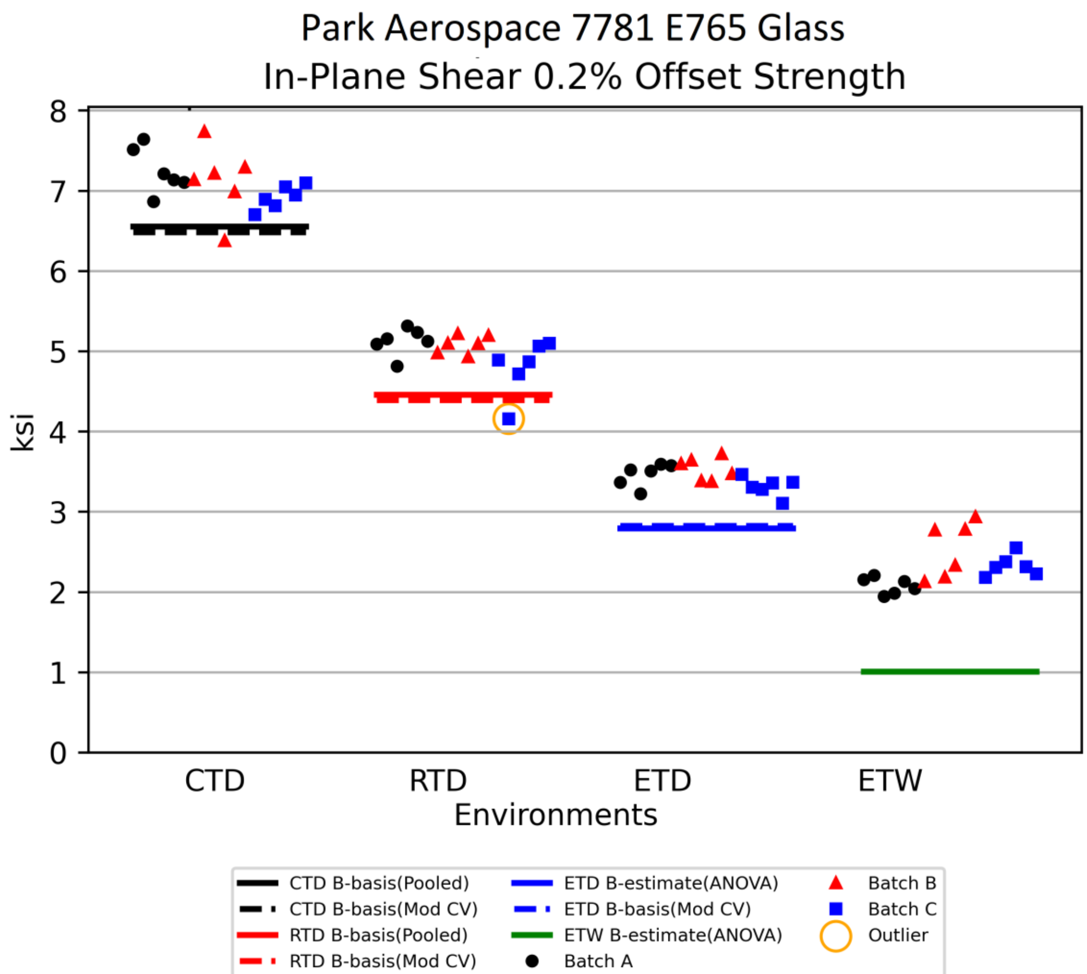

Figure 3-8 IPS 0.2% offset strength data and basis values

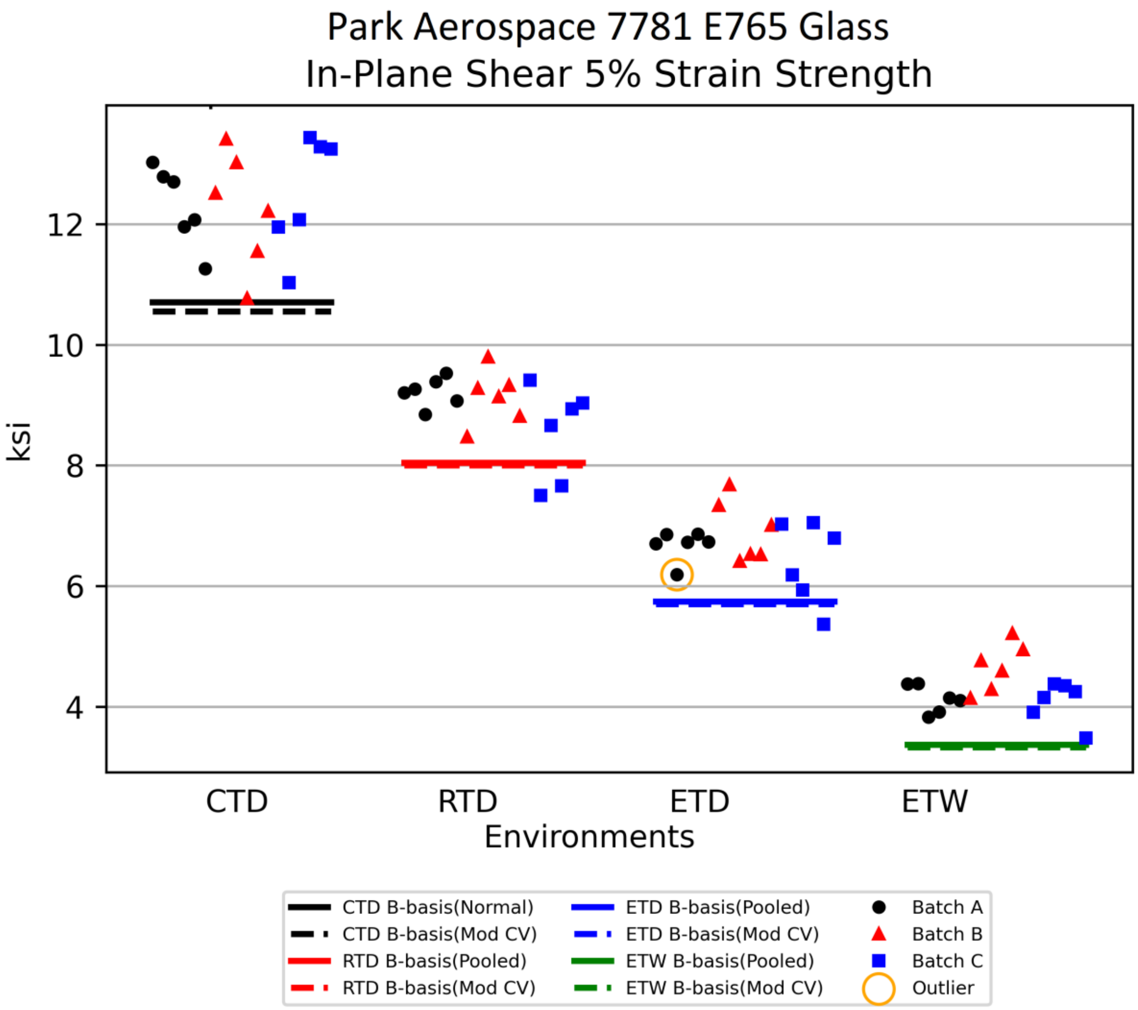

Figure 3-9 IPS strength at 5% strain data and basis values

In-Plane Shear Basis Values and Statistics				
	0.2% Offset Strength			
Env	CTD(-65)	RTD(70)	ETD(180)	ETW(180)
Mean	7.095	5.002	3.436	2.308
Stdev	0.3288	0.2633	0.1595	0.2810
CV	4.634	5.265	4.640	12.17
Mod CV	6.317	6.632	6.320	12.17
Min	6.378	4.158	3.103	1.943
Max	7.737	5.315	3.722	2.937
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-Basis	6.553	4.459		
B-Estimate			2.838	1.110
A-Estimate	6.183	4.090	2.365	0.1474
Method	Pooled	Pooled	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-Basis	6.483	4.390	2.824	NA
A-Estimate	6.075	3.982	2.416	
Method	Pooled	Pooled	Pooled	

Table 3-13 IPS 0.2% offset strength basis values and statistics

In-Plane Shear Basis Values and Statistics				
	Strength at 5% Strain			
Env	CTD(-65)	RTD(70)	ETD(180)	ETW(180)
Mean	12.35	8.962	6.661	4.288
Stdev	0.8322	0.5952	0.5287	0.4110
CV	6.739	6.640	7.938	9.585
Mod CV	7.370	7.320	7.969	9.585
Min	10.77	7.504	5.366	3.480
Max	13.43	9.796	7.678	5.212
No. Batches	3	3	3	3
No. Spec.	18	18	18	18
Basis Values and Estimates				
B-Basis	10.71	8.047	5.745	3.372
A-Estimate	9.541	7.436	5.134	2.761
Method	Normal	Pooled	Pooled	Pooled
Modified CV Basis Values and Estimates				
B-Basis	10.55	8.003	5.701	3.329
A-Estimate	9.281	7.363	5.061	2.688
Method	Normal	Pooled	Pooled	Pooled

Table 3-14 IPS strength at 5% strain basis values and statistics

3.7 Cured Ply Thickness (CPT)

The Cured Ply Thickness cannot be considered equivalent according to the results of a pooled two-sample double-sided t-test at a 95% confidence level. After modifying the data for the modified CV assumptions, the data passed the equivalency test. Statistics for both the original qualification material and the Park Aerospace equivalency sample are shown in **Table 3-15**

Cured Ply Thickness (CPT)	Qual.	Equiv.
Average Cured Ply Thickness (inch)	0.009787	0.009986
Standard Deviation	0.0003033	0.0004616
Coefficient of Variation %	3.099	4.623
Minimum	0.008761	0.009286
Maximum	0.01042	0.01108
Number of Specimens	587	23
RESULTS	**FAIL**	
Passing Range for CPT Mean	0.009658 to 0.009917	
Student's t-statistic	3.019	
p-value of Student's t-statistic	0.002638	
MOD CV RESULTS	**PASS with MOD CV**	
Modified CV%	6.000	
Passing Range for CPT Mean	0.009544 to 0.01003	
Modified CV Student's t-statistic	1.607	
p-value of Student's t-statistic	0.1085	

Table 3-15 Cured Ply Thickness Results

The CPT data failed the equivalency test because the average CPT (0.009986) is slightly above the upper acceptance limit (0.009917). The equivalency average CPT is 100.7% of the upper limit of acceptable values. However, under the assumption of the modified CV method, the CPT passed the test.

The average CPT with 95% standard error bars is shown in **Figure 3-10** The longer, lighter colored error bars are for the modified CV computations.

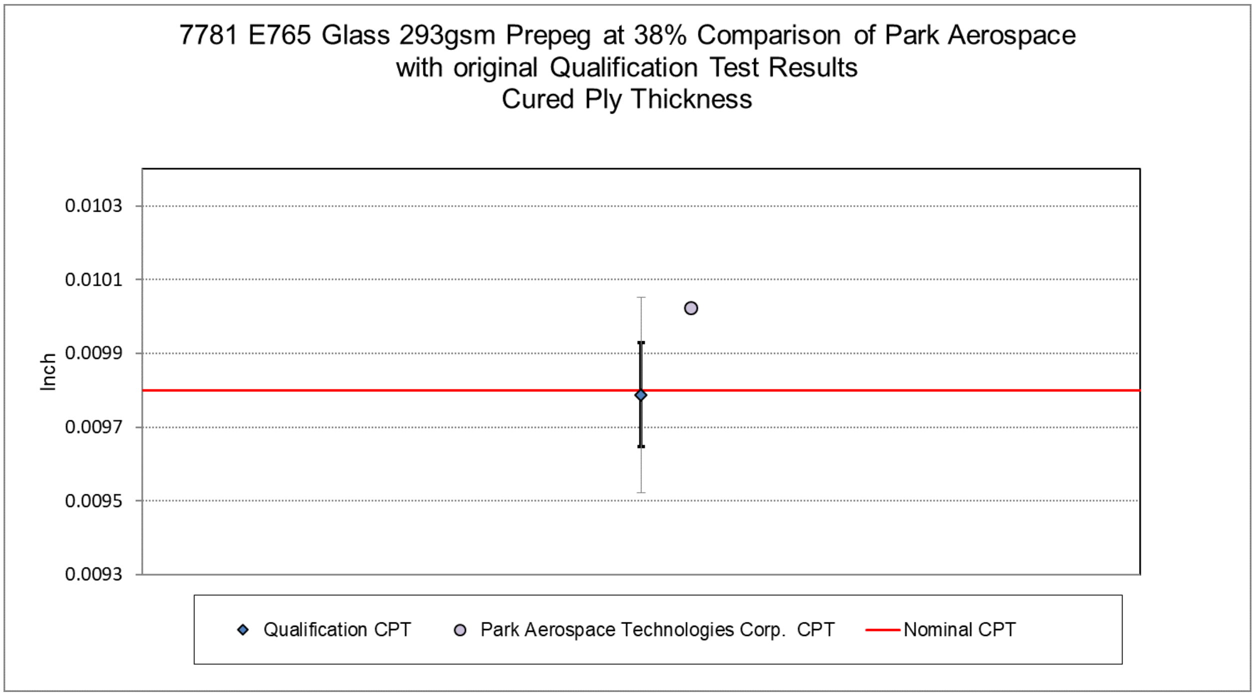

Figure 3-10 CPT means, 95% standard error bars and nominal value

3.8 Dynamic Mechanical Analysis (DMA)

Dynamic Mechanical Analysis (DMA) is compared for two measurements, the Onset of Storage Modulus and the Peak of Tangent Delta, taken under both wet and dry conditions. These are each 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 onα=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).

The Onset Storage Modulus – Dry and Peak of Tangent Delta – Wet data passed the equivalency test, while the Onset Storage Modulus – Wet and Peak of Tangent Delta – Dry failed the test. However the Onset Storage Modulus - Wet and Peak of Tangent Delta - Dry datasets passed the test for the ±18°F range.

Statistics for both the original qualification material and the equivalency sample are shown in **Table 3-16**.

Dynamic Mechanical Analysis (DMA)	Onset Storage Modulus - Dry		Peak of Tangent Delta - Dry		Onset Storage Modulus - Wet		Peak of Tangent Delta - Wet	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Mean (°F)	335.2	330.6	380.3	372.3	258.2	265.9	296.0	294.5
Standard Deviation	7.093	19.26	3.915	8.802	7.555	5.987	4.576	2.133
Coefficient of Variation %	2.116	5.825	1.029	2.365	2.926	2.252	1.546	0.7242
Minimum	323.7	293.4	372.6	362.5	247.4	257.4	289.9	291.2
Maximum	345.1	344.4	384.4	390.0	272.7	272.7	304.0	297.5
Number of Specimens	9	10	9	10	9	8	9	8
RESULTS	**PASS**		**FAIL**		**FAIL**		**PASS**	
Passing Range for DMA Mean	320.8 to 349.6		373.6 to 387.0		251.1 to 265.3		292.2 to 299.8	
Student's t-statistic	-0.6654		-2.520		2.307		-0.8493	
p-value of Student's t-statistic	0.5148		0.02201		0.03572		0.4090	
Range = ±18°F RESULTS	**PASS Range = ±18°F**		**PASS Range = ±18°F**		**PASS Range = ±18°F**		**PASS Range = ±18°F**	
Passing Range for DMA Mean	317.2 to 353.2		362.3 to 398.3		240.2 to 276.2		278.0 to 314.0	

Table 3-16 DMA results

The DMA Onset Storage Modulus - Wet data failed the equivalency test because the equivalency sample mean (265.9) is above the upper acceptance limit (265.3). The equivalency sample mean is 100.2% of the upper limit of acceptable values. With the allowable range set to ±18°F, the DMA Onset Storage Modulus - Wet data passed the equivalency test.

The DMA Peak of Tangent Delta - Dry data failed the equivalency test because the equivalency sample mean (372.3) is below the lower acceptance limit (373.6). The equivalency sample mean is 99.65% of the lower limit of acceptable values. With the allowable range set to ±18°F, the DMA Peak of Tangent Delta - Dry data passed the equivalency test.

The average DMA values from both the qualification sample and the equivalency sample are shown in **Figure 3-11**. 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.

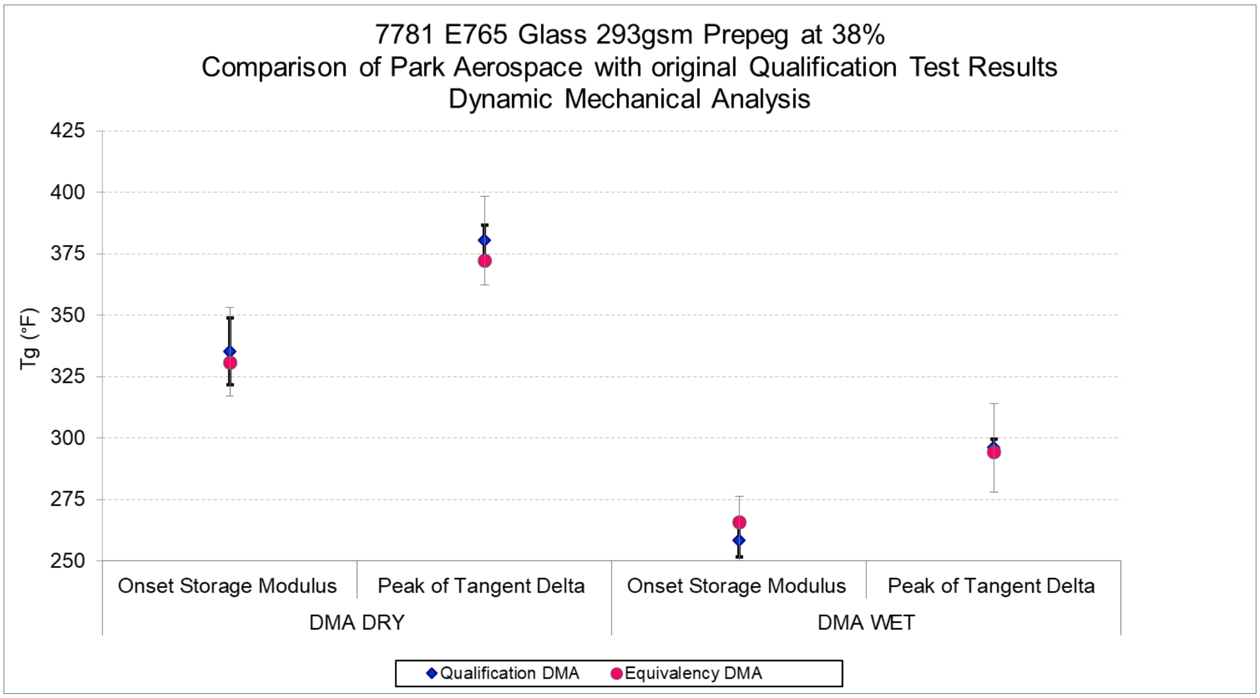

Figure 3-11 DMA Means and Equivalence limits

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 considered to be independent of the strength measurements, the IPS strength measurements are expected to be positively correlated.

However the computations can be considered conservative. If the tests are not independent and a failure in IPS 0.2% offset strength is correlated with a failure in IPS 5% strain strength, the probability of both failures occurring together should be higher than predicted with the assumption of independence, thus leading to a conservative overall judgment about the material.

4.2 Failures

The Park Aerospace Corp. produced specimens that had sufficient data for comparison with the original qualification material on a total of 23 different test types and conditions.

Using the modified CV method, there were 0 failures.

4.3 Pass Rate

Zero failures out of 23 test conditions gives Park Aerospace Corp. a pass rate of 100% for these tests. If the materials are equivalent, we would expect 1.4 failures in average.

4.4 Probability of Failures

If the equivalency sample came from a material with characteristics identical to the original qualification material and all tests were independent of all other tests, the chance of having three or more failures is p-value = 74.97%. **Figure 4-1** illustrates the probability of getting one or more failures, two or more failures, etc. for a set of 23 independent tests. In this case, since the p-value is greater than 5%, we would consider the materials to be equivalent with 95% of confidence.

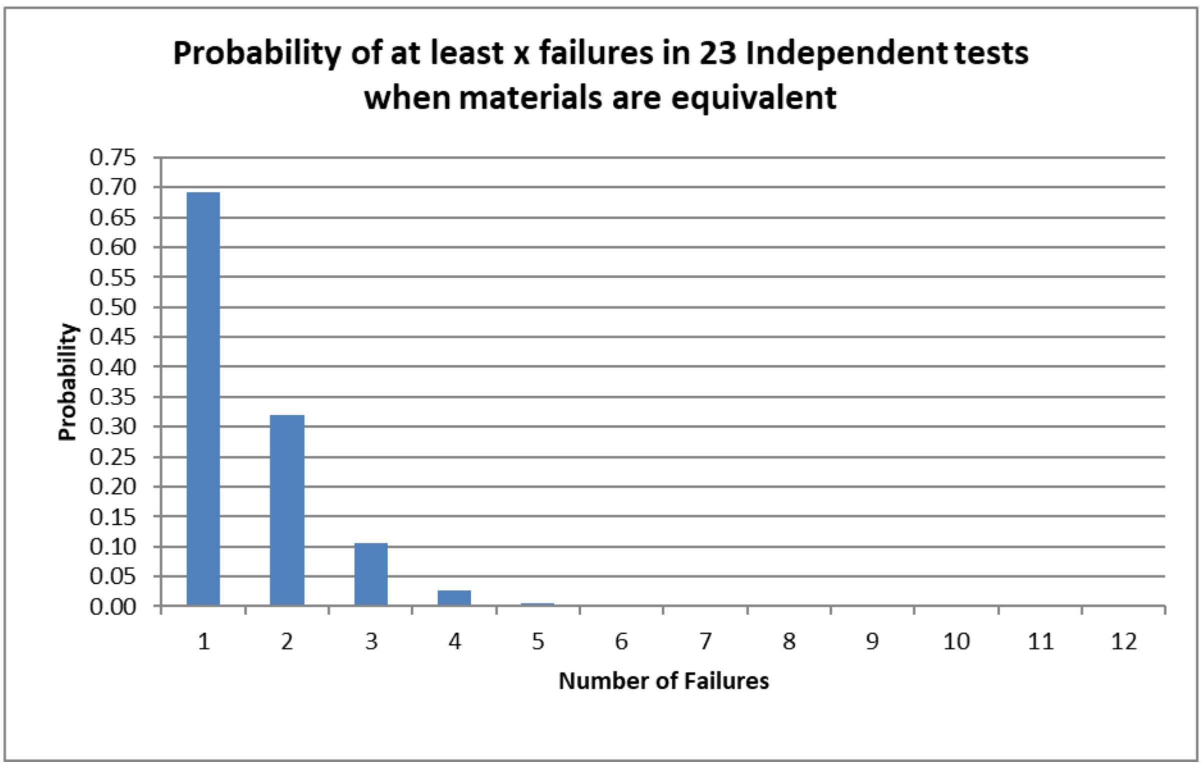

Figure 4-1 Probability of Number of Failures

5. References

1. CMH-17 Rev G, Volume 1, 2012. SAE International, 400 Commonwealth Drive, Warrendale, PA 15096
2. John Tomblin, Yeow C. Ng, and K. Suresh Raju, "*Material Qualification and Equivalency for polymer Matrix Composite Material Systems: Updated Procedure*", National Technical Information Service (NTIS), Springfield, Virginia 22161
3. Vangel, Mark, "Lot Acceptance and Compliance Testing Using the Sample Mean and an Extremum", Technometrics, Vol 44, NO. 3, August 2002, pp. 242-249