Report No: NCP-RP-2010-010 Rev N/C
Report Date: June 22, 2018

Solvay (Formerly Advanced Composites Group) – MTM45-1 CF0526A-36% RW 3K Plain Weave G30-500 Fabric, 193 gsm Equivalency Statistical Analysis Report – LH Cure Cycle

FAA Special Project Number: SP3505WI-Q

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Elizabeth Clarkson, Ph.D.
National Center for Advanced Materials Performance (NCAMP)
National Institute for Aviation Research
Wichita State University
Wichita, KS 67260-0093

Testing Facility:
National Institute for Aviation Research
Wichita State University
1845 N. Fairmount
Wichita, KS 67260-0093

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Prepared by:

Elizabeth Clarkson

Reviewed by:

Jonathan Tisack

Digitally signed by Jonathan Tisack
DN: cn=Jonathan Tisack, o=NIAR, ou=NCAMP, email=jtisack@niar.wichita.edu, c=US
Date: 2018.06.25 09:14:15 -05'00'

Jonathan Tisack

Katherine Carney

Digitally signed by Katherine Carney
DN: cn=Katherine Carney, o=NIAR/NCAMP, ou=NIAR/NCAMP, email=kcarney@niar.wichita.edu, c=US
Date: 2018.06.22 10:50:33 -05'00'

Katherine Carney

Approved by:

Royal Lovingfoss

Digitally signed by Royal Lovingfoss
DN: cn=Royal Lovingfoss, o=NIAR, ou=NCAMP, email=rlovingfoss@niar.wichita.edu, c=US
Date: 2018.06.24 10:02:32 -05'00'

Royal Lovingfoss

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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

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

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

One-sided tolerance factors for limits on sample minimum 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 t

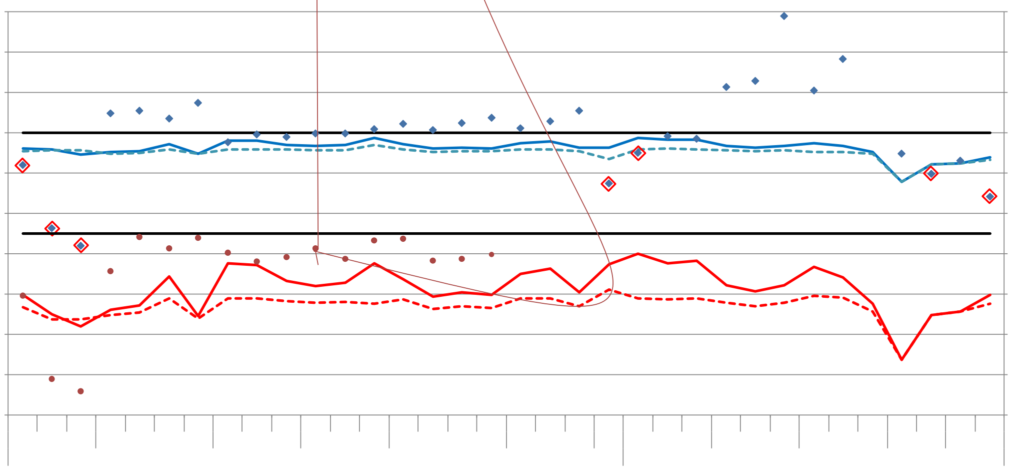
lues thatare unreualstic aly high. 1
e1(m wih 5)]TJ8.7359 -1.15 TD-.0001 Tc.0253 Tw(secation8.44.4 ofCMH-17-1G

June 22, 2018

EqTf1 816yv Tf-28.0431 -1.552 TD-.0077 Tc-42nTJTI

			CTD	RTD	ETD	ETW	ETW2
		Strength		Failed by 3.7%		Failed by 20.3%	Failed by 23.9%
		Modulus		Pass with Mod CV		Failed by 0.8%	
		Strength	Pass	Pass			Pass
		Modulus	Pass	Failed by 0.8%			
		Strength		Pass	Pass	Pass	Pass
		Modulus		Pass	Pass	Failed by 3.3%	
		Strength	Pass	Pass		Pass	Pass
		Modulus	Pass	Pass		Pass with Mod CV	
		0.2% Offset Strength	Pass	Pass			Pass
		5% Strain Strength	Pass Insufficient Data	Pass Insufficient Data			Pass Insufficient Data
		Modulus	Failed by 3.8%	Failed by 5.3%			Failed by 17.6%
Short Beam Strength	No	Strength	Failed by 1.0%	Pass			Pass
Open Hole Compression	Yes	Strength		Pass with Mod CV		Pass Insufficient Data	Pass
Open Hole Tension	Yes	Strength	Pass	Pass			Pass
Interlaminar Tension		Strength		Pass Insufficient Data			Failed by 2.5% Insufficient Data
Curved Beam Strength		Strength		Pass Insufficient Data			Failed by 9.7% Insufficient Data
Compression After Impact	Yes	Strength		Failed by 6.5% Insufficient Data			
Cured Ply Thickness	NA	NA					

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.



3.1 Warp Compression (WC)

The WC data is normalized by cured ply thickness. The WC strength data failed for all three environmental conditions. Modified CV results were not provided for the ETW2 strength data because the coefficient of variation was above 8% which means that the modified CV results were no different from the results shown.

The WC modulus data passed for the RTD condition with the use of the modified CV approach. The modulus data for the ETW conditions did not pass the equivalency test. ETW2 modulus data was not available for the MH cure cycle.

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	RTD		ETW		ETW2	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0079						
Mean Strength (ksi)	99.431	91.349	65.303	49.766	58.451	42.065
Standard Deviation	5.609	4.197	4.659	5.332	4.905	5.330
Coefficient of Variation %	5.641	4.594	7.135	10.714	8.392	12.671
Minimum	85.323	84.038	57.655	41.659	46.474	35.563
Maximum	108.069	96.922	75.378	56.324	64.558	50.878
Number of Specimens	21	8	26	11	18	9
RESULTS	FAIL		FAIL		FAIL	
Minimum Acceptable Equiv. Sample Mean	95.622		62.596		55.306	
Minimum Acceptable Equiv. Sample Min	84.286		52.213		45.006	
MOD CV RESULTS	FAIL		FAIL		NA	
Modified CV %	6.821		7.567			
Minimum Acceptable Equiv. Sample Mean	94.826		62.431			
Minimum Acceptable Equiv. Sample Min	81.120		51.420			

Table 3-3 Warp Compression Strength Results

Warp Compression (WC) Modulus	RTD		ETW		ETW2	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0079						
Mean Modulus (Msi)	8.321	8.069	8.329	7.839	NA	8.548
Standard Deviation	0.183	0.140	0.356	0.746		0.538
Coefficient of Variation %	2.196	1.740	4.280	9.517		6.299
Minimum	8.018	7.822	7.505	6.935		7.920
Maximum	8.671	8.237	9.220	9.668		9.364
Number of Specimens	21	8	26	11		9
RESULTS	FAIL		FAIL		NA	
Passing Range for Modulus Mean	8.173 to 8.468		7.964 to 8.694			
Student's t-statistic	-3.509		-2.727			
p-value of Student's t-statistic	0.002		0.010			
MOD CV RESULTS	PASS with MOD CV		FAIL			
Modified CV%	6.000		6.140			
Passing Range for Modulus Mean	7.949 to 8.692		7.899 to 8.758			
Modified CV Student's t-statistic	-1.392		-2.317			
p-value of Student's t-statistic	0.175		0.026			

Table 3-4 Warp Compression Modulus Results

The WC strength data for the RTD environment failed equivalence due to both the sample mean and sample minimum being too low. The equivalency sample mean (91.349) is 95.53% of the minimum acceptable mean value (95.622) and the equivalency sample minimum (84.038) is 99.71% of the lowest acceptable minimum value (84.286). Under the assumption of the modified CV method, the equivalency sample mean is 96.33% of the minimum acceptable mean value (94.826) and the equivalency sample minimum value is acceptable.

The WC strength data for the ETW environment failed equivalence due to both the mean and minimum being too low. Under the assumption of the modified CV method, the equivalency sample mean (49.766) is 79.71% of the minimum acceptable mean value (62.431) and the equivalency sample minimum (41.659) is 81.02% of the lowest acceptable minimum value (51.420).

The WC strength data for the ETW2 environment failed equivalence due to both the mean and minimum being too low. The modified CV method could not be used due to the CV of the ETW2 condition being greater

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.

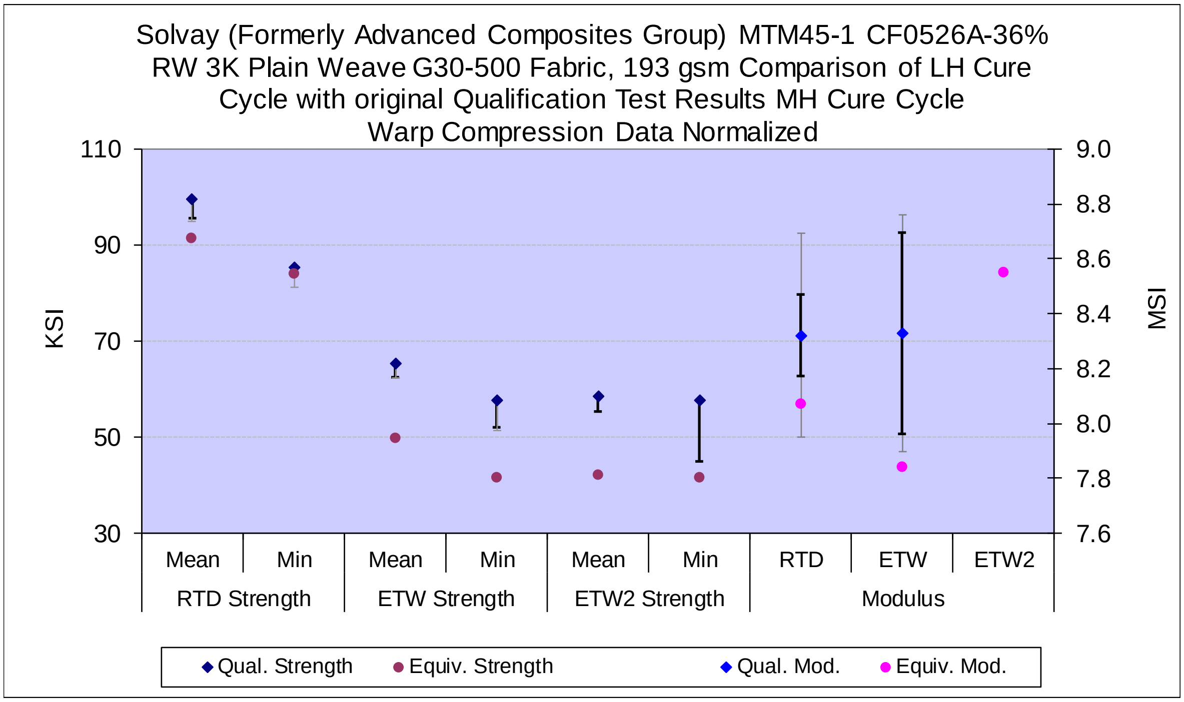


Figure 3-3 Warp Compression means, minimums and Equivalence limits

3.2 Warp Tension (WT)

The WT data is normalized by cured ply thickness. The WT strength data passed the equivalency tests for all the environmental conditions tested. The WT modulus data passed the equivalency test for the CTD condition but not for the RTD condition. ETW2 modulus data was not available for the MH

Figure 3-4 illustrates the 0º Tension str

3.3 Fill Compression (FC)

The FC data is normalized by cured ply thickness. The FC strength data passed the equivalency tests for all four environmental conditions tested. The FC modulus data passed the equivalency tests for the RTD and ETD conditions, but not the ETW condition. ETW2 modulus data was not available for the MH cure cycle. Statistics and analysis results are shown for the strength data in Table 3-7 and for the modulus data in Table 3-8.

	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0079								
Mean Strength (ksi)	88.677	92.933	75.424	79.548	58.307	60.410	51.854	55.759
Standard Deviation	6.210	6.985	4.981	4.057	2.323	2.899	3.938	2.689
Coefficient of Variation %	7.003	7.516	6.604	5.100	3.984	4.798	7.594	4.823
Minimum	80.354	80.342	65.296	74.720	53.132	56.103	44.472	51.271
Maximum	101.805	100.862	82.640	86.653	63.701	63.786	59.977	59.082
Number of Specimens	18	8	18	8	18	8	19	8
RESULTS								

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.

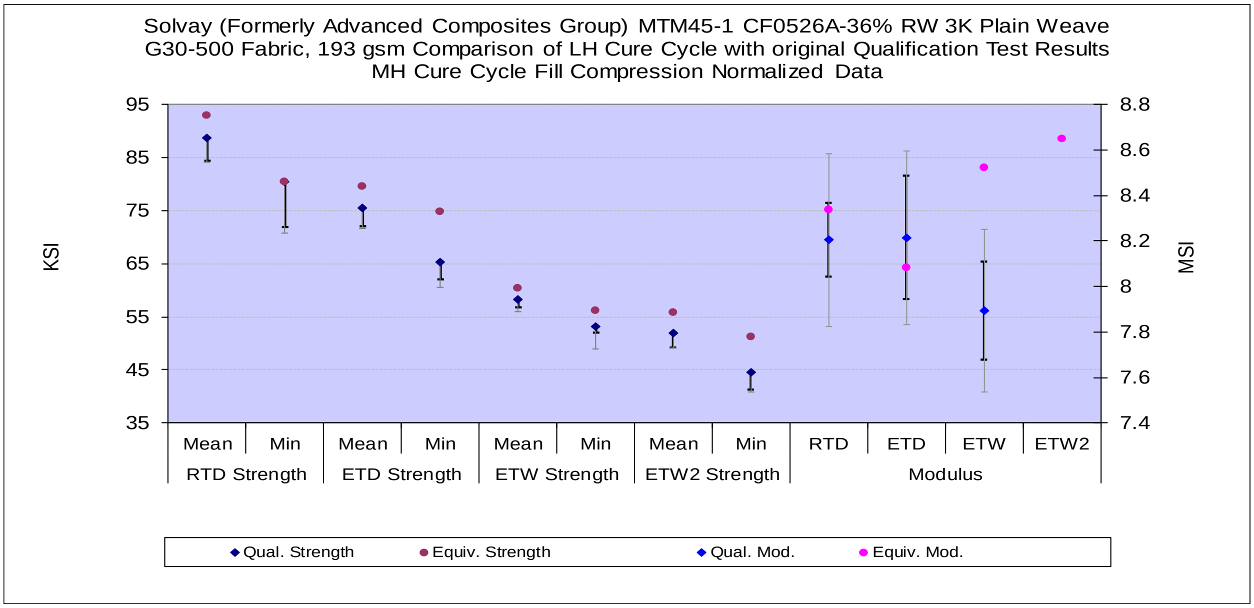


Figure 3-5 Fill Compression means, minimums and Equivalence limits

3.4 Fill Tension (FT)

The FT data is normalized by cured ply thickness. The FT strength data passed the equivalency tests for all four environmental conditions tested. The FT modulus data passed for all three conditions where data was available to compare, although the ETW condition passed only with the use of the modified CV approach. ETW2 modulus data was not available for the MH cure cycle. 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		ETW		ETW2	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0079								
Mean Strength (ksi)	125.639	128.393	128.257	129.199	117.184	120.060	110.443	114.670
Standard Deviation	5.232	3.330	7.500	4.489	6.342	5.949	6.282	4.537
Coefficient of Variation %	4.165	2.593	5.848	3.475	5.412	4.955	5.688	3.957
Minimum	118.178	123.984	111.989	119.645	108.885	109.781	101.609	104.596
Maximum	133.107	134.798	137.325	134.408	129.016	127.683	122.766	118.824
Number of Specimens	18	8	18	8	19	8	18	8
RESULTS	**PASS**		**PASS**		**PASS**		**PASS**	
Minimum Acceptable Equiv. Sample Mean	122.086		123.164		112.878		106.177	
Minimum Acceptable Equiv. Sample Min	111.511		108.006		100.061		93.481	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV %	6.082		6.924		6.706		6.844	
Minimum Acceptable Equiv. Sample Mean	120.450		122.227		111.849		105.310	
Minimum Acceptable Equiv. Sample Min	105.006		104.280		95.967		90.034	

Table 3-9 Fill Tension Strength Results

Fill Tension (FT) Modulus	CTD		RTD		ETW		ETW2	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0079								
Mean Modulus (Msi)	9.071	9.156	8.883	8.993	8.636	8.923	NA	9.483
Standard Deviation	0.272	0.216	0.284	0.090	0.192	0.118		0.365
Coefficient of Variation %	2.996	2.363	3.194	1.000	2.225	1.319		3.846
Minimum	8.599	8.861	8.035	8.852	8.258	8.758		9.069
Maximum	9.395	9.380	9.178	9.107	8.868	9.128		10.088
Number of Specimens	18	8	18	8	19	8		8
RESULTS	**PASS**		**PASS**		**FAIL**		NA	
Passing Range for Modulus Mean	8.846 to 9.297		8.669 to 9.097		8.485 to 8.788			
Student's t-statistic	0.774		1.065		3.890			
p-value of Student's t-statistic	0.447		0.298		0.001			
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	8.657 to 9.486		8.487 to 9.279		8.251 to 9.022			
Modified CV Student's t-statistic	0.420		0.575		1.529			
p-value of Student's t-statistic	0.678		0.571		0.139			

Table 3-10 Fill Tension Modulus Results

The FT modulus data for the ETW environment failed the equivalency test because the sample mean value (8.923) is above the upper acceptance limit (8.788). The equivalency sample mean value is 101.53% of the upper limit of acceptable values. Under the assumption of the modified CV method, the modulus data from the ETW environment passed the equivalence test.

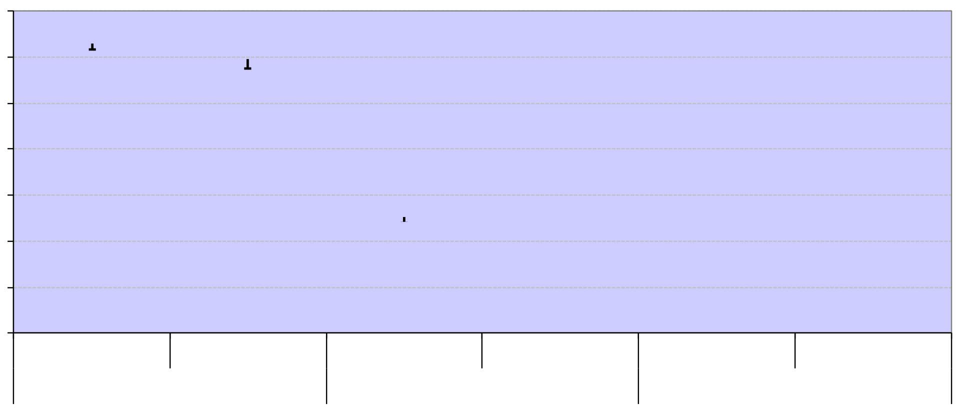
3.5 Lamina Short Beam Strength (SBS)

The Short Beam Strength data is not normalized. The SBS data passed for both the ETW and ETW2 environmental conditions, but not the RTD condition. Statistics and analysis results for the SBS data are shown in Table 3-11.

	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data as measured						
Mean Strength (ksi)	10.293	9.777	6.532	6.470	5.241	5.158
Standard Deviation	0.194	0.145	0.178	0.120	0.132	0.088
Coefficient of Variation %	1.888	1.485	2.729	1.852	2.515	1.704

M1.1s.D passed for both the

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.



3.6 In-Plane Shear (IPS)

The In-Plane Shear data is not normalized. The IPS strength data passes all equivalency tests. However, the strength at 5% strain datasets for all three conditions have insufficient data for the results to be considered conclusive. The IPS modulus data fails the equivalency test for all three environment conditions tested due to the mean modulus value being too high.

Statistics and analysis results 1.1(s)15 T1(r)37PS 1-1.12 550.8TD-9l.233 0.7Tw22esul)6 0 TD9.95001 Tc.0023 Tw(mean modul.280.

		Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data as measured							
	Mean Modulus (Msi)						

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.

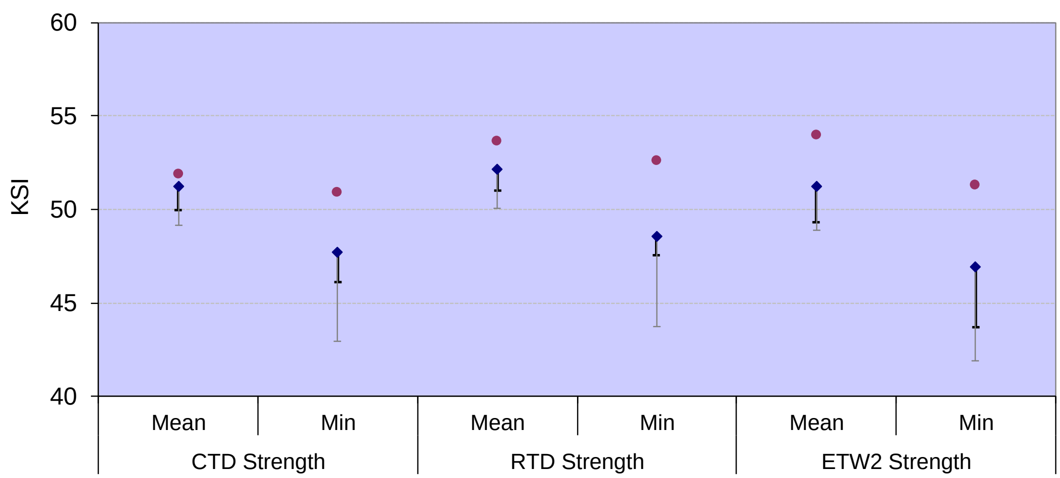
3.7 "25/50/25" Open Hole Tension 1 (OHT1)

The OHT1 data is normalized by cured ply thickness. The Open Hole Tension normalized strength data passes all equivalency tests. Statistics and analysis results for the OHT1 strength data are shown in Table 3-15.

Open Hole Tension (OHT1) Strength	CTD		RTD		ETW2	
	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0079						
Mean Strength (ksi)	51.269	51.862	52.164	53.668	51.214	53.983
Standard Deviation	1.897	0.560	1.701	0.644	2.770	1.409
Coefficient of Variation %	3.700	1.079	3.260	1.200	5.410	2.611
Minimum	47.691	50.886	48.549	52.577	46.921	51.297
Maximum	55.038	52.886	54.717	54.867	54.947	55.562
Number of Specimens	18	8	18	8	18	8
RESULTS	**PASS**		**PASS**		**PASS**	
Minimum Acceptable Equiv. Sample Mean	49.981		51.009		49.333	
Minimum Acceptable Equiv. Sample Min	46.147		47.573		43.734	
MOD CV RESULTS	**PASS with MOD CV**		**PASS with MOD CV**		**PASS with MOD CV**	
Modified CV %	6.000		6.000		6.705	
Minimum Acceptable Equiv. Sample Mean	49.180		50.039		48.883	
Minimum Acceptable Equiv. Sample Min	42.963		43.713		41.943	

Table 3-15 Open Hole Tension 1 Strength Results

Figure 3-9 illustrates the Open Hole Tension 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.

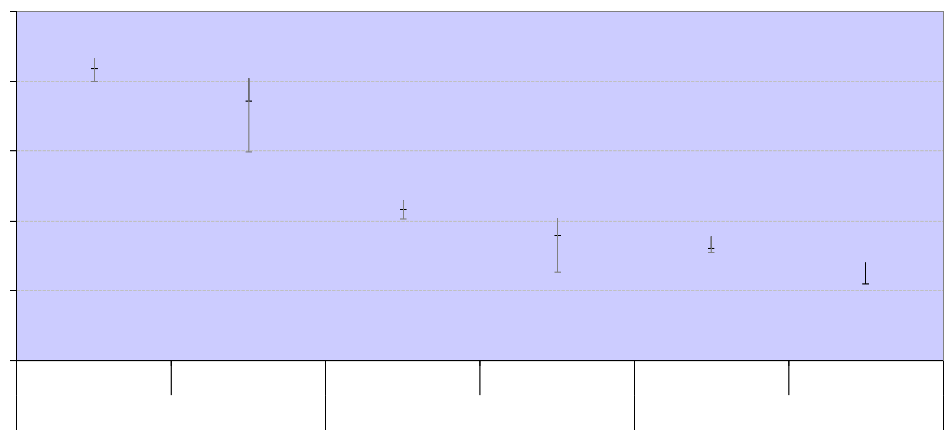


3.8 "25/50/25" Open Hole Compression 1 (OHC1)

The OHC1 data is normalized by cured ply thickness. The Open Hole Compression data passes all equivalency tests, although the RTD data requires the use of the modified CV approach and the ETW condition has insufficient data for the result to be considered conclusive. Statistics and analysis results for the OHC1 strength data are shown in Table 3-16.

	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Data normalized with CPT 0.0079						
Mean Strength (ksi)						

Figure 3-10 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.



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

The Interlaminar Tension and Curved Beam Strength data are not normalized. The ILT and CBS strength data passed equivalency tests for the RTD condition but not for the ETW2 condition. There was insufficient data for these results to be considered conclusive. Modified CV results were not provided for the ILT strength data because the coefficient of variation was above 8% which means that the modified CV results were no different from the results shown.

Statistics and analysis results are shown for the ILT data in Table 3-17 and for the CBS data in Table 3-18.

Interlaminar Tension (ILT) Strength	RTD		ETW2	
	Qual.	Equiv.	Qual.	Equiv.
Data as measured	Insufficient Data		Insufficient Data	
Mean Strength (ksi)	6.596	6.253	2.699	2.424
Standard Deviation	0.850	0.425	0.224	0.214
Coefficient of Variation %	12.885	6.796	8.289	8.839
Minimum	5.911	5.953	2.479	2.204
Maximum	8.131	6.876	2.984	2.650
Number of Specimens	6	4	6	4
RESULTS	**PASS**		**FAIL**	
Minimum Acceptable Equiv. Sample Mean	5.790		2.487	
Minimum Acceptable Equiv. Sample Min	4.521		2.153	

3.10 Compression After Impact 1 (CAI1)

The CAI1 data is normalized by cured ply thickness. The Compression After Impact normalized strength data was only tested at the RTD condition. The strength data failed the equivalency test, but there was insufficient data for the results to be considered conclusive. Statistics and analysis results for CAI strength data are shown in Table 3-19.

Compression After Impact (CAI) Strength	RTD	
	Qual.	Equiv.
Data normalized with CPT 0.0079	Insufficient Data	
Mean Strength (ksi)	33.844	29.576
Standard Deviation	1.126	0.354
Coefficient of Variation %	3.326	1.197
Minimum	31.920	29.218
Maximum	35.229	29.926
Number of Specimens	8	3
RESULTS	**FAIL**	
Minimum Acceptable Equiv. Sample Mean	32.620	
Minimum Acceptable Equiv. Sample Min	31.228	
MOD CV RESULTS	**FAIL**	
Modified CV %	6.000	
Minimum Acceptable Equiv. Sample Mean	31.637	
Minimum Acceptable Equiv. Sample Min	29.125	

Table 3-19 Compression After Impact 1 Strength Results

The CAI1 strength data for the RTD environment failed equivalence due to both the sample mean and sample minimum being too low. The equivalency sample mean (29.576) is 90.67% of the minimum acceptable mean value (32.620) and the equivalency sample minimum (29.218) is 93.56% of the lowest acceptable minimum value (31.228). Under the assumption of the modified CV method, the equivalency sample mean is 93.49% of the minimum acceptable mean value (31.637) and the equivalency sample minimum value is acceptable.

3.11 Dynamic Mechanical Analysis (DMA)

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. The DMA data from the LH cure cycle failed equivalency 95% t-tests in the dry condition, but passed equivalency with the use of the ±18°F criteria.

Statistics for both the original qualification material and the equivalency sample are shown in Table 3-20. The average DMA values from both the qualification sample and the equivalency sample are shown in Figure 3-13. 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.

	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.	Qual.	Equiv.
Mean (°F)	360.358	353.202	397.585	392.428	320.424	318.578	385.610	385.860
Standard Deviation	6.594	3.191	3.950	3.475	5.610	2.982	6.909	3.531
Coefficient of Variation %	1.830	0.904	0.994	0.886	1.751	0.936	1.792	0.915640 TD4CiQ

3.12 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. Both the MH (original qualification) and LH (equivalency) cure cycles are shown in Table 3-21. The average CPT with 95% standard error bars is shown in Figure 3-14. The longer, lighter colored error bars are for the modified CV computations.

Cured Ply Thickness (CPT)	**Qual.**	**Equiv.**
Average Cured Ply Thickness	0.008056	0.008014
Standard Deviation	0.00017	0.00011
Coefficient of Variation %	2.05131	1.43258
Minimum	0.00762	0.00783
Maximum	0.00855	0.00828
Number of Specimens	133	16
RESULTS	**PASS**	
Passing Range for CPT Mean	0.007972 to 0.008140	
Student's t-statistic		
p-value of Student's t-statistic		
MOD CV RESULTS	**PASS with MOD CV**	
Modified CV%	6.000	
Passing Range for CPT Mean	0.007816 to 0.008297	
Modified CV Student's t-statistic	-0.346	
p-value of Student's t-statistic	0.730	

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

4.2 Failures

The LH Cure Cycle material has sufficient test results for comparison with the original qualification material test results on a total of 38 different test types and conditions, not including the cured ply thickness and DMA tests.

Using the modified CV method, there were ten failures total. The Warp Compression strength failures in both ETW conditions and the In-Plane Shear Modulus in the ETW2 condition being classified as severe failures according to the scale presented Table 3-1.

1. Warp Compression Strength for the RTD condition failed by 3.7%.
2. Warp Compression Strength for the ETW condition failed by 20.3%.
3. Warp Compression Strength for the ETW2 condition failed by 23.9%.
4. Warp Compression Modulus for the ETW condition failed by 0.8%
5. Warp Tension Modulus for the RTD condition failed by 0.8%
6. Fill Compression Modulus for the ETW condition failed by 3.3%.
7. In-Plane Shear Modulus for the CTD condition failed by 3.8%
8. In-Plane Shear Modulus for the RTD condition failed by 5.3%
9. In-Plane Shear Modulus for the ETW2 condition failed by 17.6%
10. Short Beam Strength for the CTD condition failed by 1.0%

Those properties that did not pass equivalency tests should be evaluated regarding the needs of the application to determine if the test results for this equivalency sample will be sufficient for their design/build purposes.

4.3 Pass Rate

Ten failures out of 38 test conditions gives the LH cure cycle a pass rate of 73.68% for these tests. If the equivalency sample came from a material identical to the original qualification material and all tests were independent of all other tests, the expected pass rate would be 95%. This equates to 1.90 failures.

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 ten or more failures is 0.0010%. Figure 4-1 illustrates the probability of getting one or more failures, two or more failures, etc. for a set of 38 independent tests. If the two materials were equivalent, the probability of getting four or more failures is less than 5%. This means that the material could be considered as “not equivalent” with a 95% level of confidence if there were five or more failures out of 38 independent tests.

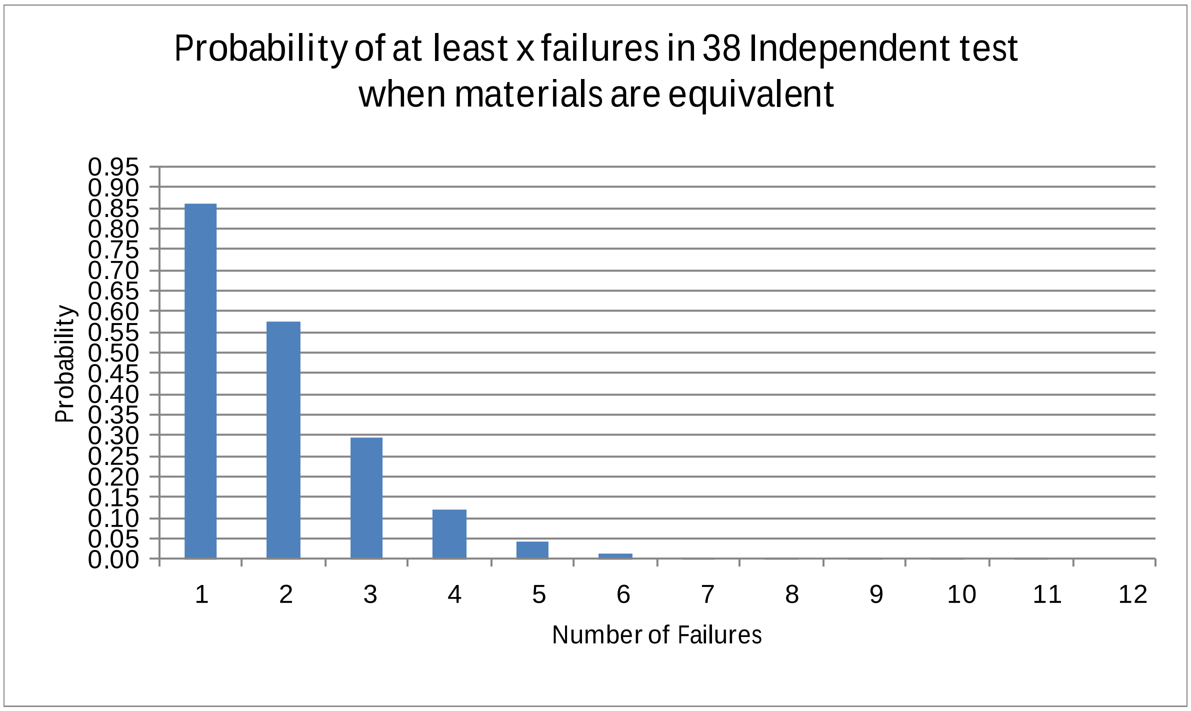


Figure 4-1 Probability of Number of Failures

5. References

1. CMH-17 Rev G, Volume 1, 2012. SAE International, 400 Commonwealth Drive, Warrendale, PA 15096
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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