Solvay (Formerly ACG) MTM45-1 7781 Glass Fabric Qualification Statistical Analysis Report

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N/C	Elizabeth Clarkson	03/20/2013	Document Initial Release
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1. Introduction

This report contains statistical analysis of ACG MTM45-1/GF0103-35%RW 7781 E glass fabric material property data published in "MTM45-1 GF0103 Data MH Cure Cycle Values Only 09-24-18.pdf" file. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP3505WI-Q, and retest material property data was generated with NCAMP oversight.

Basis values, A and B-basis estimates were computed using a variety of techniques that are detailed in section 2. Qualification material was procured in accordance with ACG material specification ACGM 1001-04. An equivalent NCAMP Material Specification NMS 451/4, which contains specification limits that are derived from guidelines in DOT/FAA/AR-03/19, has been created. The qualification test panels were fabricated per ACGP1001-02 using "MH" cure cycle. An equivalent NCAMP Process Specification, NPS 81451 baseline "MH" Cure Cycle, has been created. The panels were fabricated and the mechanical testing was performed at Advanced Composites Group, 5350 S 129th E. Ave, Tulsa, OK 74134

Basis numbers are labeled as 'values' when the data meets all the requirements of CMH-17 Rev G. When those requirements are not met, they will be labeled as 'estimates.' When the data does not meet all requirements, the failure to meet these requirements is reported and the specific requirement(s) the data fails to meet is identified. The method used to compute the basis value is noted for each basis value provided. When appropriate, in addition to the traditional computational methods, values computed using the modified coefficient of variation method is also provided.

The material property data acquisition process is designed to generate basic material property data with sufficient pedigree for submission to Complete Documentation sections of the Composite Materials Handbook (CMH-17 Rev G).

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.

The use of NCAMP material and process specifications do 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.

Part fabricators that wish to utilize the material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17 Rev G. The applicability of equivalency process must be evaluated on program-by-program basis by the applicant and certifying agency. The applicant and certifying agency must agree that the equivalency test plan along with the equivalency process described in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17 Rev G are adequate for the given program.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 451/4. NMS 451/4 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 451/4. NMS 451/4* which is a free, publicly available, non-proprietary aerospace industry material specification.

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1.1 Symbols and Abbreviations

Test Property	Abbreviation
Warp Compression	WC
Warp Tension	WT
Fill Compression	FC
Fill Tension	FT
In Plane Shear	IPS
Short Beam Strength	SBS
Open Hole Tension	OHT
Open Hole Compression	OHC
Filled Hole Tension	FHT
Filled Hole Compression	FHC
Laminate Short Beam Strength	LSBS
Interlaminate Tension Strength	ILT
Curved Beam Strength	CBS
Pin Bearing Strength	PB
Compression After Impact	CAI
Cured Ply Thickness	CPT

Table 1-1: Test Property Abbreviations

Test Property	Symbol
Warp Compression Strength	F_1^{cu}
Warp Compression Modulus	E_1^c
Warp Compression Poisson's Ratio	ν_{12}^c
Warp Tension Strength	F_1^{tu}
Warp Tension Modulus	E_1^t
Fill Compression Strength	F_2^{cu}
Fill Compression Modulus	E_2^c
Fill Tension Strength	F_2^{tu}
Fill Tension Modulus	E_2^t
In Plane Shear Strength at 5% strain	$F_{12}^{s5\%}$
In Plane Shear Strength at 0.2% offset	$F_{12}^{s0.2\%}$
In Plane Shear Modulus	G_{12}^s

Table 1-2: Test Property Symbols

Environmental Condition	Temperature	Abbreviation
Cold Temperature Dry	−65° F	CTD
Room Temperature Dry	70° F	RTD
Elevated Temperature Dry	200° F	ETD
Elevated Temperature Wet	200° F	ETW
Elevated Temperature Wet	250° F	ETW2

Table 1-3: Environmental Conditions Abbreviations

Tests with a number immediately after the abbreviation indicate the lay-up:

1 = "Quasi-Isotropic"
2 = "Soft"
3 = "Hard"

EX: OHT1 is an open hole tension test with a "Quasi-Isotropic layup

1.2 Pooling Across Environments

When pooling across environments was allowable, the pooled co-efficient of variation was used. ASAP (**A**GATE **S**tatistical **A**nalysis **P**rogram) 2008 version 1.0 was used to determine if pooling was allowable and to compute the pooled coefficient of variation for those tests. In these cases, the modified coefficient of variation (section 1.4) based on the pooled data was used to compute the basis values.

When pooling across environments was not allowable, (i.e. the data failed the Anderson-Darling test or normality tests and engineering judgment indicated there was no justification for overriding the result), B-Basis values were computed for each environment separately using Stat-17 version 5.

1.3 Basis Value Computational Process

The general form to compute engineering basis values is: basis value = $\bar{X} - kS$ where k is a factor based on the sample size and the distribution of the sample data. There are many different methods to determine the value of k in this equation, depending on the sample size and the distribution of the data. In addition, the computational formula used for the standard deviation, S may vary depending on the distribution of the data. The details of those different computations and when each should be used are in section 2.0.

1.4 Modified Coefficient of Variation (CV) Method

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 variability as measured in the qualification program is often lower than the actual material variability because of several reasons. The materials used in the qualification programs are usually manufactured within a short period of time, typically 2-3 weeks only, which is not representative of the production material. Some raw ingredients that are used to manufacture the multi-batch qualification materials may actually be from the same production batches or manufactured within a short period of time so the qualification materials, although regarded as multiple batches, may not truly be multiple batches so they are not representative of the actual production material variability.

The modified Coefficient of Variation (CV) used in this report is in accordance with section 8.4.4 of CMH-17 Rev G. 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%. The modified coefficient of variation (CV) method increases the measured coefficient of variation when it is below 8% prior to computing basis values. A higher CV will result in lower or more conservative basis values and lower specification limits. The use of the modified CV method is intended for a temporary period of time when there is minimal data available. When a sufficient number of production batches (approximately 8 to 15) have been produced and tested, the as-measured CV may be used so that the basis values and specification limits may be adjusted higher.

The material allowables in this report are calculated using both the as-measured CV and modified CV, so users have the choice of using either one. When the measured CV is greater than 8%, the modified CV method does not change the basis value. NCAMP recommended values make use the modified CV method when it is appropriate for the data.

When the data fails the Anderson-Darling K-sample test for batch to batch variability or when the data fails the normality test, the modified CV method is not appropriate and no modified CV basis value will be provided. When the ANOVA method is used, it may produce excessively conservative basis values.

In some cases a transformation of the data to fit the assumption of the modified CV resulted in the transformed data passing the ADK test and thus the data can be pooled only for the modified CV method.

NCAMP recommends that if a user decides to use the basis values that are calculated from as-measured CV, the specification limits and control limits be calculated with as-measured CV also. Similarly, if a user decides to use the basis values that are calculated from modified CV, the specification limits and control limits be calculated with modified CV also. This will ensure that the link between material allowables, specification limits, and control limits is maintained.

2. Background

Statistical computations are performed with AGATE Statistical Analysis Program (ASAP) when pooling across environments is permissible according to CMH-17 Rev G guidelines. If pooling is not permissible, a single point analysis using STAT-17 is performed for each environmental condition with sufficient test results. If the data does not meet CMH-17 Rev G requirements for a single point analysis, estimates are created by a variety of methods depending on which is most appropriate for the dataset available. Specific procedures used are presented in the individual sections where the data is presented.

2.1 ASAP Statistical Formulas and Computations

This section contains the details of the specific formulas ASAP uses in its computations.

2.1.1 Basic Descriptive Statistics

The basic descriptive statistics shown are computed according to the usual formulas, which are shown below:

Mean: $$\bar{X} = \sum_{i=1}^{n} \frac{X_i}{n}$$ **Equation 1**

Std. Dev.: $$S = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} \left(X_i - \bar{X} \right)^2}$$ **Equation 2**

% Co. Variation: $$\frac{S}{\bar{X}} \times 100$$ **Equation 3**

Where *n* refers to the number of specimens in the sample

2.1.2 Statistics for Pooled Data

Prior to computing statistics for the pooled dataset, the data is normalized to a mean of one by dividing each value by the mean of all the data for that condition. This transformation does not affect the coefficients of variation for the individual conditions.

2.1.2.1 Pooled Standard Deviation

The formula to compute a pooled standard deviation is given below:

Pooled Std. Dev. $$S_p = \sqrt{\frac{\sum_{i=1}^{k} \left(n_i - 1 \right) S_i^2}{\sum_{i=1}^{k} \left(n_i - 1 \right)}}$$ **Equation 4**

Where *k* refers to the number of batches and n_i refers to the number of specimens in the i^{th} sample

2.1.2.2 Pooled Coefficient of Variation

Since the mean for the normalized data is 1.0 for each condition, the pooled normalized data also has a mean of one. The coefficient of variation for the pooled normalized data is the pooled standard deviation divided by the pooled mean, as in equation 3. Since the mean for the pooled normalized data is one, the pooled coefficient of variation is equal to the pooled standard deviation of the normalized data.

$$\textbf{Pooled Coefficient of Variation} = \frac{S_p}{1} = S_p \qquad \textbf{Equation 5}$$

2.1.3 Basis Value Computations

Basis values are computed using the mean and standard deviation for that environment, as follows: The mean is always the mean for the environment, but if the data meets all requirements for pooling, S_p can be used in place of the standard deviation for the environment, S.

$$\textbf{Basis Values:} \quad \begin{aligned} A-basis &= \bar{X} - K_a S \\ B-basis &= \bar{X} - K_b S \end{aligned} \qquad \textbf{Equation 6}$$

2.1.3.1 K-factor computations

K_a and K_b are computed according to the methodology documented in section 8.3.5 of CMH-17 Rev G. The approximation formulas are given below:

$$K_a = \frac{2.3263}{\sqrt{q(f)}} + \sqrt{\frac{1}{c_A(f)\cdot n_j} + \left(\frac{b_A(f)}{2c_A(f)}\right)^2} - \frac{b_A(f)}{2c_A(f)} \qquad \textbf{Equation 7}$$

$$K_b = \frac{1.2816}{\sqrt{q(f)}} + \sqrt{\frac{1}{c_B(f)\cdot n_j} + \left(\frac{b_B(f)}{2c_B(f)}\right)^2} - \frac{b_B(f)}{2c_B(f)} \qquad \textbf{Equation 8}$$

Where

r = the number of environments being pooled together

n_j= number of data values for environment j

$$N = \sum_{j=1}^{r} n_j$$

$$f = N - r$$

$$q(f) = 1 - \frac{2.323}{\sqrt{f}} + \frac{1.064}{f} + \frac{0.9157}{f\sqrt{f}} - \frac{0.6530}{f^2}$$ **Equation 9**

$$b_B(f) = \frac{1.1372}{\sqrt{f}} - \frac{0.49162}{f} + \frac{0.18612}{f\sqrt{f}}$$ **Equation 10**

$$c_B(f) = 0.36961 + \frac{0.0040342}{\sqrt{f}} - \frac{0.71750}{f} + \frac{0.19693}{f\sqrt{f}}$$ **Equation 11**

$$b_A(f) = \frac{2.0643}{\sqrt{f}} - \frac{0.95145}{f} + \frac{0.51251}{f\sqrt{f}}$$ **Equation 12**

$$c_A(f) = 0.36961 + \frac{0.0026958}{\sqrt{f}} - \frac{0.65201}{f} + \frac{0.011320}{f\sqrt{f}}$$ **Equation 13**

2.1.4 Modified Coefficient of Variation

The coefficient of variation is modified according to the following rules:

Modified CV = $$CV^* = \begin{cases} .06 & if\ CV < .04 \\ \frac{CV}{2} + .04 & if\ .04 \le CV < .08 \\ CV & if\ CV \ge .08 \end{cases}$$ **Equation 14**

This is converted to percent by multiplying by 100%.

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

$$S^* = CV^* \cdot \bar{X}$$ **Equation 15**

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

$$S_p^* = \sqrt{\frac{\sum_{i=1}^{k}\left((n_i - 1)\left(CV_i^* \cdot \bar{X}_i\right)^2\right)}{\sum_{i=1}^{k}(n_i - 1)}}$$ **Equation 16**

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

2.1.4.1 Transformation of data based on Modified CV

In order to determine if the data would pass the diagnostic tests under the assumption of the modified CV, the data must be transformed such that the batch means remain the same while the standard deviation of transformed data (all batches) matches the modified standard deviation.

To accomplish this requires a transformation in two steps:

Step 1: Apply the modified CV rules to each batch and compute the modified standard deviation $S_i^* = CV^* \cdot \overline{X}_i$ for each batch. Transform the data in each batch as follows:

$$X'_{ij} = C_i\left(X_{ij} - \overline{X}_i\right) + \overline{X}_i \quad \textbf{Equation 17}$$

$$C_i = \frac{S_i^*}{S_i} \quad \textbf{Equation 18}$$

Run the Anderson-Darling k-sample test for batch equivalence (see section 2.1.6) on the transformed data. If it passes, proceed to step 2. If not, stop. The data cannot be pooled.

Step 2: Another transformation is needed as applying the modified CV to each batch leads to a larger CV for the combined data than when applying the modified CV rules to the combined data (due to the addition of between batch variation when combining data from multiple batches). In order to alter the data to match S^*, the transformed data is transformed again, this time setting using the same value of C′ for all batches.

$$X''_{ij} = C'\left(X'_{ij} - \overline{X}_i\right) + \overline{X}_i \quad \textbf{Equation 19}$$

$$C' = \sqrt{\frac{SSE^*}{SSE'}} \quad \textbf{Equation 20}$$

$$SSE^* = (n-1)\left(CV^* \cdot \overline{X}\right)^2 - \sum_{i=1}^{k} n_i\left(\overline{X}_i - \overline{X}\right)^2 \quad \textbf{Equation 21}$$

$$SSE' = \sum_{i=1}^{k}\sum_{j=1}^{n_i}\left(X'_{ij} - \overline{X}_i\right)^2 \quad \textbf{Equation 22}$$

Once this second transformation has been completed, the k-sample Anderson Darling test for batch equivalence can be run on the transformed data to determine if the modified co-efficient of variation will permit pooling of the data.

2.1.5 Determination of Outliers

Outliers are identified using the Maximum Normed Residual Test for Outliers as specified in CMH-17 Rev G.

$$MNR = \frac{\max_{all\ i} \left| X_i - \overline{X} \right|}{S}, i = 1 \ldots n$$ **Equation 23**

$$C = \frac{n-1}{\sqrt{n}} \sqrt{\frac{t^2}{n-2+t^2}}$$ **Equation 24**

where t is the $1-\frac{.05}{2n}$ quartile of a t distribution with n−2 degrees of freedom.

If MNR > C, then the X_i associated with the MNR is considered to be an outlier. If an outlier exists, then the X_i associated with the MNR is dropped from the dataset and the MNR procedure is applied again. This process is repeated until no outliers are detected. Additional information on this procedure can be found in references 1 and 2.

2.1.6 The k-Sample Anderson Darling Test for batch equivalency

The k-sample Anderson-Darling test is a nonparametric statistical procedure that tests the hypothesis that the populations from which two or more groups of data were drawn are identical. The distinct values in the combined data set are ordered from smallest to largest, denoted $z_{(1)}$, $z_{(2)}, \ldots z_{(L)}$, where L will be less than n if there are tied observations. These rankings are used to compute the test statistic.

The k-sample Anderson-Darling test statistic is:

$$ADK = \frac{n-1}{n^2(k-1)} \sum_{i=1}^{k} \left[\frac{1}{n_i} \sum_{j=1}^{L} h_j \frac{\left(nF_{ij} - n_i H_j\right)^2}{H_j\left(n-H_j\right) - \frac{nh_j}{4}} \right]$$ **Equation 25**

Where

n_i = the number of test specimens in each batch
$n = n_1 + n_2 + \ldots + n_k$
h_j = the number of values in the combined samples equal to $z_{(j)}$
H_j = the number of values in the combined samples less than $z_{(j)}$ plus ½ the number of values in the combined samples equal to $z_{(j)}$
F_{ij} = the number of values in the i^{th} group which are less than $z_{(j)}$ plus ½ the number of values in this group which are equal to $z_{(j)}$.

The critical value for the test statistic at 1−α level is computed:

$$ADC = 1 + \sigma_n \left[z_\alpha + \frac{0.678}{\sqrt{k-1}} - \frac{0.362}{k-1} \right].$$ **Equation 26**

This formula is based on the formula in reference 3 at the end of section 5, using a Taylor's expansion to estimate the critical value via the normal distribution rather than using the t distribution with k-1 degrees of freedom.

$$\sigma_n^2 = VAR(ADK) = \frac{an^3 + bn^2 + cn + d}{(n-1)(n-2)(n-3)(k-1)^2}$$ **Equation 27**

With

$$a = (4g-6)(k-1) + (10-6g)S$$
$$b = (2g-4)k^2 + 8Tk + (2g-14T-4)S - 8T + 4g - 6$$
$$c = (6T+2g-2)k^2 + (4T-4g+6)k + (2T-6)S + 4T$$
$$d = (2T+6)k^2 - 4Tk$$
$$S = \sum_{i=1}^{k} \frac{1}{n_i}$$
$$T = \sum_{i=1}^{n-1} \frac{1}{i}$$
$$g = \sum_{i=1}^{n-2} \sum_{j=i+1}^{n-1} \frac{1}{(n-i)j}$$

The data is considered to have failed this test (i.e. the batches are not from the same population) when the test statistic is greater than the critical value. For more information on this procedure, see reference 3.

2.1.7 The Anderson Darling Test for Normality

Normal Distribution: A two parameter (μ, σ) family of probability distributions for which the probability that an observation will fall between *a* and *b* is given by the area under the curve between a and b:

$$F(x) = \int_a^b \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} dx$$ **Equation 28**

A normal distribution with parameters (μ, σ) has population mean μ and variance σ^2.

The normal distribution is considered by comparing the cumulative normal distribution function that best fits the data with the cumulative distribution function of the data. Let

$$z_{(i)} = \frac{\overline{x}_{(i)} - \overline{x}}{s}, \quad \text{for i = 1,…,n}$$ **Equation 29**

where $x_{(i)}$ is the smallest sample observation, $\overline{x}$ is the sample average, and s is the sample standard deviation.

The Anderson Darling test statistic (AD) is:

$$AD = \sum_{i=1}^{n} \frac{1-2i}{n} \left\{ \ln\left[F_0(z_{(i)})\right] + \ln\left[1 - F_0\left(z_{(n+1-i)}\right)\right] \right\} - n$$ **Equation 30**

Where F_0 is the standard normal distribution function. The observed significance level (OSL) is

$$OSL = \frac{1}{1+e^{-0.48+0.78\ln(AD^*)+4.58AD^*}}, \quad AD^* = \left(1+\frac{0.2}{\sqrt{n}}\right)AD \qquad \textbf{Equation 31}$$

This OSL measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if, in fact, the data are a sample from a normal population. If OSL > 0.05, the data is considered sufficiently close to a normal distribution.

2.1.8 Graphical Test for Normality and Pearson's Coefficient

2.1.8.1 Normal Plots

2.1.8.1.1 Distribution of Data at Individual Test Conditions

The distribution for each environment data is graphed by taking the data, sorting it into ascending order and computing the percent of data that survived beyond that point.

$$x_{i(1)} \le x_{i(2)} \le \cdots \le x_{i(n_i)}$$

The probability of survival for $x_{i(j)}$ is computed:

$$\frac{n_i - j + 1}{n_i + 1}, j = 1, \cdots, n_i \qquad \textbf{Equation 32}$$

2.1.8.1.2 Distribution of Pooled Data

The distribution of pooled data is graphed by dividing each value by the mean for that environment, thus adjusting all environments to have a mean of 1: $\left(y_{ij} = \frac{x_{ij}}{\bar{x}_i} \Rightarrow \bar{y}_i = 1, i = 1, \ldots, k\right)$. Then the data is sorting into ascending order and the probability of survival is computed for each point.

$$y_{(1)} \le y_{(2)} \le \cdots \le y_{(n)}, n = \sum_{i=1}^{k} n_i$$

The probability of survival is computed:

$$\frac{n - j + 1}{n + 1}, j = 1, \cdots, n \qquad \textbf{Equation 33}$$

The normal curve and its ±10% bounds are computed as follows. A total of n points are computed and plotted for the normal curve and the +/− 10% normal curves.

S* = the standard deviation of the transformed data

Normal curves x-value:

$u_{(1)} = z_{(1)} - 0.05$, $u_{(n)} = z_{(n)} + 0.05$

$u_{(i)} = ((u_{(n)} - u_{(1)})/(n-1) + u_{(i-1)}$ for i = 2, …, n−1

Normal curve y-value: $v_{(i)} = \text{Prob}(t > u_{(i)})$, $u_{(i)} \sim N(1, S^*)$

+10% Normal curve y-value: $\max(v_{(i)} + 0.1, 0.1)$

−10% Normal curve y-value: max($v_{(i)}$ − 0.1, −.1)

2.1.8.2 Normal Pearson's r

The Normal Pearson's r statistic is the correlation coefficient of the actual data values with the predicted values computed assuming a normal distribution with the same mean and standard deviation as the original data and using the probability of survival as the percentile of the normal distribution.

Correlation Formula: $$r = \frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{x_i - \overline{x}}{S_x}\right)\left(\frac{y_i - \overline{y}}{S_y}\right)$$ **Equation 34**

2.1.9 Levene's test for Equality of Coefficient of Variation

Levene's test performs an Analysis of Variance on the absolute deviations from their sample medians. The absolute value of the deviation from the median is computed for each data value. $w_{ij} = \left|y_{ij} - \tilde{y}_i\right|$ An F-test is then performed on the transformed data values as follows:

$$F = \frac{\sum_{i=1}^{k} n_i\left(\overline{w}_i - \overline{w}\right)^2 /(k-1)}{\sum_{i=1}^{k}\sum_{j=1}^{n_i} {}_i\left(w_{ij} - \overline{w}_i\right)^2 /(n-k)}$$ **Equation 35**

If this computed F statistic is less than the critical value for the F-distribution having k-1 numerator and n-k denominator degrees of freedom at the 1-α level of confidence, then the data is not rejected as being too different in terms of the co-efficient of variation. ASAP provides the appropriate critical values for F at α levels of 0.10, 0.05, 0.025, and 0.01. For more information on this procedure, see references 4 and 5.

2.2 STAT-17

This section contains the details of the specific formulas STAT-17 uses in its computations.

The basic descriptive statistics, the maximum normed residual (MNR) test for outliers, and the Anderson Darling K-sample test for batch variability are the same as with ASAP – see sections 2.1.1, 2.1.3.1, and 2.1.5.

Outliers must be dispositioned before checking any other test results. The results of the Anderson Darling k-Sample (ADK) Test for batch equivalency must be checked. If the data passes the ADK test, then the appropriate distribution is determined. If it does not pass the ADK test, then the ANOVA procedure is the only approach remaining that will result in basis values that meet the requirements of CMH-17 Rev G.

2.2.1 Distribution tests

In addition to testing for normality using the Anderson-Darling test (see 2.1.7); Stat-17 also tests to see if the Weibull or Lognormal distribution is a good fit for the data.

Each distribution is considered using the Anderson-Darling test statistic which is sensitive to discrepancies in the tail regions. The Anderson-Darling test compares the cumulative distribution function for the distribution of interest with the cumulative distribution function of the data.

An observed significance level (OSL) based on the Anderson-Darling test statistic is computed for each test. The OSL measures the probability of observing an Anderson-Darling test statistic at least as extreme as the value calculated if the distribution under consideration is in fact the underlying distribution of the data. In other words, the OSL is the probability of obtaining a value of the test statistic at least as large as that obtained if the hypothesis that the data are actually from the distribution being tested is true. If the OSL is less than or equal to 0.05, then the assumption that the data are from the distribution being tested is rejected with at most a five percent risk of being in error.

If the normal distribution has an OSL greater than 0.05, then the data is assumed to be from a population with a normal distribution. If not, then if either the Weibull or lognormal distributions has an OSL greater than 0.05, then one of those can be used. If neither of these distributions has an OSL greater than 0.05, a non-parametric approach is used.

In what follows, unless otherwise noted, the sample size is denoted by n, the sample observations by $x_1, \ldots, x_n$, and the sample observations ordered from least to greatest by $x_{(1)}, \ldots, x_{(n)}$.

2.2.2 Computing Normal Distribution Basis values

Stat-17 uses a table of values for the k-factors (shown in Table 2-1) and a slightly different formula than ASAP to compute approximate k-values for the normal distribution when the sample size is larger than 15.

Norm. Dist. k Factors for N<16		
N	B-basis	A-basis
2	20.581	37.094
3	6.157	10.553
4	4.163	7.042
5	3.408	5.741
6	3.007	5.062
7	2.756	4.642
8	2.583	4.354
9	2.454	4.143
10	2.355	3.981
11	2.276	3.852
12	2.211	3.747
13	2.156	3.659
14	2.109	3.585
15	2.069	3.520

Table 2-1: K factors for normal distribution

2.2.2.1 One-sided B-basis tolerance factors, k_B, for the normal distribution when sample size is greater than 15.

The exact computation of k_B values is $1/\sqrt{n}$ times the 0.95th quantile of the noncentral t-distribution with noncentrality parameter $1.282\sqrt{n}$ and $n-1$ degrees of freedom. Since this in not a calculation that Excel can handle, the following approximation to the k_B values is used:

$$k_B \approx 1.282 + \exp\{0.958 - 0.520\ln(n) + 3.19/n\}$$ **Equation 36**

This approximation is accurate to within 0.2% of the tabulated values for sample sizes greater than or equal to 16.

2.2.2.2 One-sided A-basis tolerance factors, k_A, for the normal distribution

The exact computation of k_B values is $1/\sqrt{n}$ times the 0.95th quantile of the noncentral t-distribution with noncentrality parameter $2.326\sqrt{n}$ and $n-1$ degrees of freedom (Reference 11). Since this is not a calculation that Excel can handle easily, the following approximation to the k_B values is used:

$$k_A \approx 2.326 + \exp\{1.34 - 0.522\ln(n) + 3.87/n\}$$ **Equation 37**

This approximation is accurate to within 0.2% of the tabulated values for sample sizes greater than or equal to 16.

2.2.2.3 Two-parameter Weibull Distribution

A probability distribution for which the probability that a randomly selected observation from this population lies between *a* and *b* $(0 < a < b < \infty)$ is given by

$$e^{-(a/\alpha)^{\beta}} - e^{-(b/\alpha)^{\beta}}$$ **Equation 38**

where α is called the scale parameter and β is called the shape parameter.

In order to compute a check of the fit of a data set to the Weibull distribution and compute basis values assuming Weibull, it is first necessary to obtain estimates of the population shape and scale parameters (Section 2.2.2.3.1). Calculations specific to the goodness-of-fit test for the Weibull distribution are provided in section 2.2.2.3.2.

2.2.2.3.1 Estimating Weibull Parameters

This section describes the *maximum likelihood* method for estimating the parameters of the two-parameter Weibull distribution. The maximum-likelihood estimates of the shape and scale parameters are denoted $\hat{\beta}$ and $\hat{\alpha}$. The estimates are the solution to the pair of equations:

$$\hat{\alpha}\hat{\beta}\mathrm{n} - \frac{\hat{\beta}}{\hat{\alpha}^{\hat{\beta}-1}}\sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{x}_{\mathrm{i}}^{\hat{\beta}} = 0$$ **Equation 39**

$$\frac{n}{\hat{\beta}} - n\ln\hat{\alpha} + \sum_{i=1}^{n}\ln x_i - \sum_{i=1}^{n}\left[\frac{x_i}{\hat{\alpha}}\right]^{\hat{\beta}}\left(\ln x_i - \ln\hat{\alpha}\right) = 0$$

Equation 40

Stat-17 solves these equations numerically for $\hat{\beta}$ and $\hat{\alpha}$ in order to compute basis values.

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

The two-parameter Weibull distribution is considered by comparing the cumulative Weibull distribution function that best fits the data with the cumulative distribution function of the data. Using the shape and scale parameter estimates from section 2.2.2.3.1, let

$$z_{(i)} = \left[x_{(i)} / \hat{\alpha} \right]^{\hat{\beta}}, \quad \text{for } i = 1, \ldots, n$$ **Equation 41**

The Anderson-Darling test statistic is

$$\text{AD} = \sum_{i=1}^{n} \frac{1-2i}{n} \left[\ell n \left[1 - \exp(-z_{(i)}) \right] - z_{(n+1-i)} \right] - n$$ **Equation 42**

and the observed significance level is

$$\text{OSL} = 1 / \left\{ 1 + \exp[-0.10 + 1.24 \ln(\text{AD}^*) + 4.48 \text{AD}^*] \right\}$$ **Equation 43**

where

$$AD^* = \left(1 + \frac{0.2}{\sqrt{n}} \right) AD$$ **Equation 44**

This OSL measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if in fact the data is a sample from a two-parameter Weibull distribution. If OSL ≤ 0.05, one may conclude (at a five percent risk of being in error) that the population does not have a two-parameter Weibull distribution. Otherwise, the hypothesis that the population has a two-parameter Weibull distribution is not rejected. For further information on these procedures, see reference 6.

2.2.2.3.3 Basis value calculations for the Weibull distribution

For the two-parameter Weibull distribution, the B-basis value is

$$B = \hat{q} e^{\left(-V / \hat{\beta}\sqrt{n} \right)}$$ **Equation 45**

where

$$\hat{q} = \hat{\alpha} \left(0.10536 \right)^{1/\hat{\beta}}$$ **Equation 46**

To calculate the A-basis value, substitute the equation below for the equation above.

$$\hat{q} = \hat{\alpha}(0.01005)^{1/\beta}$$ **Equation 47**

V is the value in Table 2-2. when the sample size is less than 16. For sample sizes of 16 or larger, a numerical approximation to the V values is given in the two equations immediately below.

$$V_B \approx 3.803 + \exp\left[1.79 - 0.516\ln(n) + \frac{5.1}{n-1}\right]$$ **Equation 48**

$$V_A \approx 6.649 + \exp\left[2.55 - 0.526\ln(n) + \frac{4.76}{n}\right]$$ **Equation 49**

This approximation is accurate within 0.5% of the tabulated values for n greater than or equal to 16.

Weibull Dist. K Factors for N<16		
N	B-basis	A-basis
2	690.804	1284.895
3	47.318	88.011
4	19.836	36.895
5	13.145	24.45
6	10.392	19.329
7	8.937	16.623
8	8.047	14.967
9	7.449	13.855
10	6.711	12.573
11	6.477	12.093
12	6.286	11.701
13	6.127	11.375
14	5.992	11.098
15	5.875	10.861

Table 2-2: Weibull Distribution Basis Value Factors

2.2.2.4 Lognormal Distribution

A probability distribution for which the probability that an observation selected at random from this population falls between a and b $(0 < a < b < \infty)$ is given by the area under the normal distribution between ln(a) and ln(b).

The lognormal distribution is a positively skewed distribution that is simply related to the normal distribution. If something is lognormally distributed, then its logarithm is normally distributed. The natural (base e) logarithm is used.

2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

In order to test the goodness-of-fit of the lognormal distribution, take the logarithm of the data and perform the Anderson-Darling test for normality from Section 2.1.7. Using the natural logarithm, replace the linked equation above with linked equation below:

$$z_{(i)} = \frac{\ln\left(x_{(i)}\right) - \bar{x}_L}{s_L}, \quad \text{for } i = 1, \ldots, n \qquad \textbf{Equation 50}$$

where $x_{(i)}$ is the i^{th} smallest sample observation, $\bar{x}_L$ and s_L are the mean and standard deviation of the $\ln(x_i)$ values.

The Anderson-Darling statistic is then computed using the linked equation above and the observed significance level (OSL) is computed using the linked equation above . This **OSL** measures the probability of observing an Anderson-Darling statistic at least as extreme as the value calculated if in fact the data are a sample from a lognormal distribution. If **OSL ≤ 0.05**, one may conclude (at a five percent risk of being in error) that the population is not lognormally distributed. Otherwise, the hypothesis that the population is lognormally distributed is not rejected. For further information on these procedures, see reference 6.

2.2.2.4.2 Basis value calculations for the Lognormal distribution

If the data set is assumed to be from a population with a lognormal distribution, basis values are calculated using the equation above in section 2.1.3. However, the calculations are performed using the logarithms of the data rather than the original observations. The computed basis values are then transformed back to the original units by applying the inverse of the log transformation.

2.2.3 Non-parametric Basis Values

Non-parametric techniques do not assume any particularly underlying distribution for the population the sample comes from. It does require that the batches be similar enough to be grouped together, so the ADK test must have a positive result. While it can be used instead of assuming the normal, lognormal or Weibull distribution, it typically results in lower basis values. One of following two methods should be used, depending on the sample size.

2.2.3.1 Non-parametric Basis Values for large samples

The required sample sizes for this ranking method differ for A and B basis values. A sample size of at least 29 is needed for the B-basis value while a sample size of 299 is required for the A-basis.

To calculate a B-basis value for n > 28, the value of r is determined with the following formulas:

For B-basis values:

$$r_B = \frac{n}{10} - 1.645\sqrt{\frac{9n}{100}} + 0.23 \qquad \textbf{Equation 51}$$

For A-Basis values:

$$r_A = \frac{n}{100} - 1.645\sqrt{\frac{99n}{10,000}} + 0.29 + \frac{19.1}{n} \qquad \textbf{Equation 52}$$

The formula for the A-basis values should be rounded to the nearest integer. This approximation is exact for most values and for a small percentage of values (less than 0.2%), the approximation errs by one rank on the conservative side.

The B-basis value is the r_B^{th} lowest observation in the data set, while the A-basis values are the r_A^{th} lowest observation in the data set. For example, in a sample of size n = 30, the lowest (r = 1) observation is the B-basis value. Further information on this procedure may be found in reference 7.

2.2.4 Non-parametric Basis Values for small samples

The Hanson-Koopmans method (references 8 and 9) is used for obtaining a B-basis value for sample sizes not exceeding 28 and A-basis values for sample sizes less than 299. This procedure requires the assumption that the observations are a random sample from a population for which the logarithm of the cumulative distribution function is concave, an assumption satisfied by a large class of probability distributions. There is substantial empirical evidence that suggests that composite strength data satisfies this assumption.

The Hanson-Koopmans B-basis value is:

$$B = x_{(r)} \left[\frac{x_{(1)}}{x_{(r)}} \right]^k$$

Equation 53

The A-basis value is:

$$A = x_{(n)} \left[\frac{x_{(1)}}{x_{(n)}} \right]^k$$

Equation 54

where $x_{(n)}$ is the largest data value, $x_{(1)}$ is the smallest, and $x_{(r)}$ is the r^{th} largest data value. The values of r and k depend on n and are listed in Table 2-3. This method is not used for the B-basis value when $x_{(r)} = x_{(1)}$.

The Hanson-Koopmans method can be used to calculate A-basis values for n less than 299. Find the value k_A corresponding to the sample size n in Table 2-4. For an A-basis value that meets the requirements of CMH-17 Rev G there must be at least five batches represented in the data and at least 55 data points. For a B-basis value, there must be at least three batches represented in the data and at least 18 data points.

B-Basis Hanson-Koopmans Table		
n	r	k
2	2	35.177
3	3	7.859
4	4	4.505
5	4	4.101
6	5	3.064
7	5	2.858
8	6	2.382
9	6	2.253
10	6	2.137
11	7	1.897
12	7	1.814
13	7	1.738
14	8	1.599
15	8	1.540
16	8	1.485
17	8	1.434
18	9	1.354
19	9	1.311
20	10	1.253
21	10	1.218
22	10	1.184
23	11	1.143
24	11	1.114
25	11	1.087
26	11	1.060
27	11	1.035
28	12	1.010

Table 2-3: B-Basis Hanson-Koopmans Table

A-Basis Hanson-Koopmans Table					
n	k	n	k	n	k
2	80.00380	38	1.79301	96	1.32324
3	16.91220	39	1.77546	98	1.31553
4	9.49579	40	1.75868	100	1.30806
5	6.89049	41	1.74260	105	1.29036
6	5.57681	42	1.72718	110	1.27392
7	4.78352	43	1.71239	115	1.25859
8	4.25011	44	1.69817	120	1.24425
9	3.86502	45	1.68449	125	1.23080
10	3.57267	46	1.67132	130	1.21814
11	3.34227	47	1.65862	135	1.20620
12	3.15540	48	1.64638	140	1.19491
13	3.00033	49	1.63456	145	1.18421
14	2.86924	50	1.62313	150	1.17406
15	2.75672	52	1.60139	155	1.16440
16	2.65889	54	1.58101	160	1.15519
17	2.57290	56	1.56184	165	1.14640
18	2.49660	58	1.54377	170	1.13801
19	2.42833	60	1.52670	175	1.12997
20	2.36683	62	1.51053	180	1.12226
21	2.31106	64	1.49520	185	1.11486
22	2.26020	66	1.48063	190	1.10776
23	2.21359	68	1.46675	195	1.10092
24	2.17067	70	1.45352	200	1.09434
25	2.13100	72	1.44089	205	1.08799
26	2.09419	74	1.42881	210	1.08187
27	2.05991	76	1.41724	215	1.07595
28	2.02790	78	1.40614	220	1.07024
29	1.99791	80	1.39549	225	1.06471
30	1.96975	82	1.38525	230	1.05935
31	1.94324	84	1.37541	235	1.05417
32	1.91822	86	1.36592	240	1.04914
33	1.89457	88	1.35678	245	1.04426
34	1.87215	90	1.34796	250	1.03952
35	1.85088	92	1.33944	275	1.01773
36	1.83065	94	1.33120	299	1.00000
37	1.81139				

Table 2-4: A-Basis Hanson-Koopmans Table

2.2.5 Analysis of Variance (ANOVA) Basis Values

ANOVA is used to compute basis values when the batch to batch variability of the data does not pass the ADK test. Since ANOVA makes the assumption that the different batches have equal variances, the data is checked to make sure the assumption is valid. Levene's test for equality of variance is used (see section 2.1.9). If the dataset fails Levene's test, the basis values computed are likely to be conservative. Thus, this method can still be used but the values produced will be listed as estimates.

2.2.5.1 Calculation of basis values using ANOVA

The following calculations address batch-to-batch variability. In other words, the only grouping is due to batches and the k-sample Anderson-Darling test (Section 2.1.6) indicates that the batch to batch variability is too large to pool the data. The method is based on the one-way analysis of variance random-effects model, and the procedure is documented in reference 10.

ANOVA separates the total variation (called the sum of squares) of the data into two sources: between batch variation and within batch variation.

First, statistics are computed for each batch, which are indicated with a subscript $\left(n_i, \overline{x}_i, s_i^2\right)$ while statistics that were computed with the entire dataset do not have a subscript. Individual data values are represented with a double subscript, the first number indicated the batch and the second distinguishing between the individual data values within the batch. k stands for the number of batches in the analysis. With these statistics, the Sum of Squares Between batches (SSB) and the Total Sum of Squares (SST) are computed:

$$SSB = \sum_{i=1}^{k} n_i \overline{x}_I^2 - n\overline{x}^2 \qquad \textbf{Equation 55}$$

$$SST = \sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij}^2 - n\overline{x}^2 \qquad \textbf{Equation 56}$$

The within-batch, or error, sum of squares (SSE) is computed by subtraction

$$SSE = SST - SSB \qquad \textbf{Equation 57}$$

Next, the mean sums of squares are computed:

$$MSB = \frac{SSB}{k-1} \qquad \textbf{Equation 58}$$

$$MSE = \frac{SSE}{n-k} \qquad \textbf{Equation 59}$$

Since the batches need not have equal numbers of specimens, an 'effective batch size,' is defined as

$$n' = \frac{n - \frac{1}{n}\sum_{i=1}^{k} n_i^2}{k-1} \qquad \textbf{Equation 60}$$

Using the two mean squares and the effective batch size, an estimate of the population standard deviation is computed:

$$S = \sqrt{\frac{MSB}{n'} + \left(\frac{n'-1}{n'}\right) MSE} \qquad \textbf{Equation 61}$$

Two k-factors are computed using the methodology of section 2.2.2 using a sample size of n (denoted k_0) and a sample size of k (denoted k_1). Whether this value is an A- or B-basis value depends only on whether k_0 and k_1 are computed for A or B-basis values.

Denote the ratio of mean squares by

$$u = \frac{MSB}{MSE} \quad \textbf{Equation 62}$$

If u is less than one, it is set equal to one. The tolerance limit factor is

$$T = \frac{k_0 - \frac{k_1}{\sqrt{n'}} + \left(k_1 - k_0\right)\sqrt{\frac{u}{u + n' - 1}}}{1 - \frac{1}{\sqrt{n'}}} \quad \textbf{Equation 63}$$

The basis value is $\bar{x} - TS$.

The ANOVA method can produce extremely conservative basis values when a small number of batches are available. Therefore, when less than five (5) batches are available and the ANOVA method is used, the basis values produced will be listed as estimates.

2.3 Single Batch and Two Batch estimates using modified CV

This method has not been approved for use by the CMH-17 organization. Values computed in this manner are estimates only. It is used only when fewer than three batchs are available and no valid B-basis value could be computed using any other method. The estimate is made using the mean of the data and setting the coefficient of variation to 8 percent if it was less than that. A modified standard deviation (S_{adj}) was computed by multiplying the mean by 0.08 and computing the A and B-basis values using this inflated value for the standard deviation.

Estimated B-Basis = $\bar{X} - k_b S_{adj} = \bar{X} - k_b \cdot 0.08 \cdot \bar{X}$ **Equation 64**

2.4 Lamina Variability Method (LVM)

This method has not been approved for use by the CMH-17 organization. Values computed in this manner are estimates only. It is used only when the sample size is less than 16 and no valid B-basis value could be computed using any other method. The prime assumption for applying the LVM is that the intrinsic strength variability of the laminate (small) dataset is no greater than the strength variability of the lamina (large) dataset. This assumption was tested and found to be reasonable for composite materials as documented by Tomblin and Seneviratne [12].

To compute the estimate, the coefficients of variation (CVs) of laminate data are paired with lamina CV’s for the same loading condition and environmental condition. For example, the 0º compression lamina CV CTD condition is used with open hole compression CTD condition. Bearing and in-plane shear laminate CV’s are paired with 0º compression lamina CV’s. However, if the laminate CV is larger than the corresponding lamina CV, the larger laminate CV value is used.

The LVM B-basis value is then computed as:

LVM Estimated B-Basis = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot \max\left(CV_1, CV_2\right)$ **Equation 65**

When used in conjunction with the modified CV approach, a minimum value of 8% is used for the CV.

Mod CV LVM Estimated B-Basis = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot Max\left(8\%, CV_1, CV_2\right)$ **Equation 66**

With:

$\bar{X}_1$ the mean of the laminate (small dataset)

N_1 the sample size of the laminate (small dataset)

N_2 the sample size of the lamina (large dataset)

CV_2 is the coefficient of variation of the lamina (large dataset)

$K_{(N_1,N_2)}$ is given in Table 2-5

		N1													
		2	3	4	5	6	7	8	9	10	11	12	13	14	15
N1+N2-2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	4.508	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	3.827	3.607	0	0	0	0	0	0	0	0	0	0	0	0
	5	3.481	3.263	3.141	0	0	0	0	0	0	0	0	0	0	0
	6	3.273	3.056	2.934	2.854	0	0	0	0	0	0	0	0	0	0
	7	3.134	2.918	2.796	2.715	2.658	0	0	0	0	0	0	0	0	0
	8	3.035	2.820	2.697	2.616	2.558	2.515	0	0	0	0	0	0	0	0
	9	2.960	2.746	2.623	2.541	2.483	2.440	2.405	0	0	0	0	0	0	0
	10	2.903	2.688	2.565	2.484	2.425	2.381	2.346	2.318	0	0	0	0	0	0
	11	2.856	2.643	2.519	2.437	2.378	2.334	2.299	2.270	2.247	0	0	0	0	0
	12	2.819	2.605	2.481	2.399	2.340	2.295	2.260	2.231	2.207	2.187	0	0	0	0
	13	2.787	2.574	2.450	2.367	2.308	2.263	2.227	2.198	2.174	2.154	2.137	0	0	0
	14	2.761	2.547	2.423	2.341	2.281	2.236	2.200	2.171	2.147	2.126	2.109	2.093	0	0
	15	2.738	2.525	2.401	2.318	2.258	2.212	2.176	2.147	2.123	2.102	2.084	2.069	2.056	0
	16	2.719	2.505	2.381	2.298	2.238	2.192	2.156	2.126	2.102	2.081	2.063	2.048	2.034	2.022
	17	2.701	2.488	2.364	2.280	2.220	2.174	2.138	2.108	2.083	2.062	2.045	2.029	2.015	2.003
	18	2.686	2.473	2.348	2.265	2.204	2.158	2.122	2.092	2.067	2.046	2.028	2.012	1.999	1.986
	19	2.673	2.459	2.335	2.251	2.191	2.144	2.108	2.078	2.053	2.032	2.013	1.998	1.984	1.971
	20	2.661	2.447	2.323	2.239	2.178	2.132	2.095	2.065	2.040	2.019	2.000	1.984	1.970	1.958
	21	2.650	2.437	2.312	2.228	2.167	2.121	2.084	2.053	2.028	2.007	1.988	1.972	1.958	1.946
	22	2.640	2.427	2.302	2.218	2.157	2.110	2.073	2.043	2.018	1.996	1.978	1.962	1.947	1.935
	23	2.631	2.418	2.293	2.209	2.148	2.101	2.064	2.033	2.008	1.987	1.968	1.952	1.938	1.925
	24	2.623	2.410	2.285	2.201	2.139	2.092	2.055	2.025	1.999	1.978	1.959	1.943	1.928	1.916
	25	2.616	2.402	2.277	2.193	2.132	2.085	2.047	2.017	1.991	1.969	1.951	1.934	1.920	1.907
	26	2.609	2.396	2.270	2.186	2.125	2.078	2.040	2.009	1.984	1.962	1.943	1.927	1.912	1.900
	27	2.602	2.389	2.264	2.180	2.118	2.071	2.033	2.003	1.977	1.955	1.936	1.920	1.905	1.892
	28	2.597	2.383	2.258	2.174	2.112	2.065	2.027	1.996	1.971	1.949	1.930	1.913	1.899	1.886
	29	2.591	2.378	2.252	2.168	2.106	2.059	2.021	1.990	1.965	1.943	1.924	1.907	1.893	1.880
	30	2.586	2.373	2.247	2.163	2.101	2.054	2.016	1.985	1.959	1.937	1.918	1.901	1.887	1.874
	40	2.550	2.337	2.211	2.126	2.063	2.015	1.977	1.946	1.919	1.897	1.877	1.860	1.845	1.832
	50	2.528	2.315	2.189	2.104	2.041	1.993	1.954	1.922	1.896	1.873	1.853	1.836	1.820	1.807
	60	2.514	2.301	2.175	2.089	2.026	1.978	1.939	1.907	1.880	1.857	1.837	1.819	1.804	1.790
	70	2.504	2.291	2.164	2.079	2.016	1.967	1.928	1.896	1.869	1.846	1.825	1.808	1.792	1.778
	80	2.496	2.283	2.157	2.071	2.008	1.959	1.920	1.887	1.860	1.837	1.817	1.799	1.783	1.769
	90	2.491	2.277	2.151	2.065	2.002	1.953	1.913	1.881	1.854	1.830	1.810	1.792	1.776	1.762
	100	2.486	2.273	2.146	2.060	1.997	1.948	1.908	1.876	1.849	1.825	1.805	1.787	1.771	1.757
	125	2.478	2.264	2.138	2.051	1.988	1.939	1.899	1.867	1.839	1.816	1.795	1.777	1.761	1.747
	150	2.472	2.259	2.132	2.046	1.982	1.933	1.893	1.861	1.833	1.809	1.789	1.770	1.754	1.740
	175	2.468	2.255	2.128	2.042	1.978	1.929	1.889	1.856	1.828	1.805	1.784	1.766	1.750	1.735
	200	2.465	2.252	2.125	2.039	1.975	1.925	1.886	1.853	1.825	1.801	1.781	1.762	1.746	1.732

Table 2-5: B-Basis factors for small datasets using variability of corresponding large dataset

3. Summary of Results

The basis values for all tests are summarized in the following tables. The recommended B-basis values all meet the requirements of CMH-17 Rev G, and are compiled in
Table 3-1 and Table 3-2. However, not all test data meets those requirements. All basis values and estimates of basis values are shown in Table 3-3 and Table 3-4. When the data does not meet the requirements of CMH-17 Rev G the basis values are shown in shaded boxes and labeled as estimates. Basis values computed with the modified coefficient of variation (CV) are presented whenever possible. Basis values computed without that modification are presented for all tests. The modified CV basis values are recommended for use when available.

3.1 NCAMP Recommended B-basis Values

The following rules are used in determining what B-basis value, if any, is included in tables
Table 3-1and Table 3-2 of recommended values.

1. Recommended values are NEVER estimates. Only B-basis values that meet all requirements of CMH-17 Rev G are recommended.
2. Modified CV basis values are preferred. Recommended values will be the modified CV basis value when available. The CV provided with the recommended basis value will be the one used in the computation of the basis value.
3. Only normalized basis values are given for properties that are normalized.
4. ANOVA B-basis values are not recommended since only three batches of material are available and CMH-17 Rev G recommends that no less than five batches be used when computing basis values with the ANOVA method.
5. Caution is recommended with B-Basis values calculated from STAT17 when the B-basis value is 90% or more of the average value. Basis values of 90% or more of the mean value imply that the CV is unusually low and may not be conservative. Such values will be indicated.
6. If the data appear questionable (e.g. when the CTD-RTD-ETW trend of the basis values are not consistent with the CTD-RTD-ETW trend of the average values), then the B-basis values will not be recommended.

NCAMP Recommended B-basis Values for ACG MTM45-1/GF0103-35%RW 7781 glass fabric

All B-basis values in this table meet the standards for publication in CMH-17G Handbook
Values are for normalized data unless otherwise noted

Lamina Strength Tests

Environment	Statistic	WT	WC	FT	FC***	SBS*	IPS* 0.2% Offset	IPS* 5% Strain
CTD (-65 F)	B-basis	NA:A	94.48	61.18	80.68	10.82	6.12	NA:I
	Mean	80.89	104.11	68.69	91.85	12.29	6.93	13.00
	CV	7.07%	7.21%	6.06%	6.16%	6.06%	9.47%	3.30%
RTD (75 F)	B-basis	62.25	71.50	53.01	NA:A	9.89**	4.56	NA:I
	Mean	68.15	81.13	60.53	70.19	10.44	5.39	9.80
	CV	6.09%	6.94%	6.75%	6.61%	2.63%	9.35%	4.95%
ETD (200 F)	B-basis				53.34	8.19**		
	Mean				62.66	8.39		
	CV				7.54%	1.87%		
ETW (200 F)	B-basis	38.54	35.27	34.17	NA:A	4.57**	2.12	4.62
	Mean	44.46	44.90	38.76	45.74	4.86	2.94	5.30
	CV	6.37%	8.69%	6.00%	6.80%	6.89%	10.65%	6.53%
ETW2 (250 F)	B-basis	35.74	30.79	32.37	NA:A	3.59**	1.84	NA:I
	Mean	41.67	40.42	36.80	40.73	3.86	2.67	4.70
	CV	6.83%	10.65%	6.18%	5.79%	6.00%	7.82%	8.81%

Notes: The modified CV B-basis value is recommended when available.

The CV provided corresponds with the B-basis value given. If no B-basis value is provided, the as measured CV is given

NA implies that tests were run but data did not meet NCAMP recommended requirements.

"NA:A" indicates ANOVA with 3 batches, "NA:I" indicates insufficient data.

Shaded empty boxes indicate that no test data is available for that property and condition.

* Data is as measured rather than normalized

** Indicates the Stat17 B-basis value is greater than 90% of the mean value.

*** Fill Compression results are computed from retest data

Table 3-1 : NCAMP Recommended B-basis values for Lamina Test Data

NCAMP Recommended B-basis Values for
ACG MTM45-1/GF0103-35%RW 7781 glass fabric

All B-basis values in this table meet the standards for publication in CMH-17G Handbook
Values are for normalized data unless otherwise noted

Laminate Strength Tests

Lay-up	ENV	Statistic	OHT	OHC	FHT	FHC	UNT	UNC	PB 2% Offset	PB Ult. Str.	LSBS*
25/50/25	CTD (-65 F)	B-basis	29.95		31.47		56.73	NA:A			
		Mean	33.18		35.54		62.67	65.78			
		CV	6.00%		6.00%		6.00%	5.70%			
	RTD (75 F)	B-basis	22.92	31.24**	NA:I	NA:I	47.35	NA:I	58.22	84.86	8.74**
		Mean	26.11	34.22	28.83	54.69	53.29	35.51	67.73	98.29	9.58
		CV	6.00%	6.00%	1.64%	3.83%	6.00%	8.21%	9.67%	7.09%	6.15%
	ETW2 (250 F)	B-basis	15.05	17.65		NA:I	NA:I	NA:A	37.67	57.73	3.77
		Mean	17.07	20.63		36.24	32.42	32.77	47.18	65.45	4.61
		CV	6.00%	6.00%		7.91%	2.64%	10.49%	7.85%	6.12%	6.61%
10/80/10	CTD (-65 F)	B-basis	28.84								
		Mean	32.72								
		CV	6.00%								
	RTD (75 F)	B-basis		NA:I							
		Mean		30.97							
		CV		2.62%							
	ETW2 (250 F)	B-basis	NA:I	16.61							
		Mean	14.23	18.94							
		CV	3.80%	6.24%							
40/20/40	CTD (-65 F)	B-basis	33.66								
		Mean	38.30								
		CV	6.14%								
	RTD (75 F)	B-basis	NA:I	NA:I							
		Mean	30.30	37.10							
		CV	3.88%	1.99%							
	ETW2 (250 F)	B-basis	NA:I	20.69							
		Mean	19.97	23.47							
		CV	3.31%	6.00%							

Notes: The modified CV B-basis value is recommended when available.
The CV provided corresponds with the B-basis value given.
NA implies that tests were run but data did not meet NCAMP recommended requirements.
"NA: A" indicates ANOVA with 3 batches, "NA: I" indicates insufficient data,
Shaded empty boxes indicate that no test data is available for that property and condition.
* Data is as measured rather than normalized
** Indicates the Stat17 B-basis value is greater than 90% of the mean value.

Table 3-2 : NCAMP Recommended B-basis values for Laminate Test Data

3.2 Lamina and Laminate Summary Tables

ACG - MTM45-1/GF0103-35%RW 7781 glass fabric Lamina Properties Summary

Material: MTM45-1/GF0103-35%RW
Material Specificaton: ACGM1001-04 or NCAMP NMS 451/4.
Prepreg: MTM45-1/GF0103-35%RW
Fiber: BGF E-Glass ACDE75 1/0 Yarn **Resin:** MTM45-1

Tg(dry): 356°F **Tg(wet)** 320°F **Tg METHOD: SACMA SRM18R-94**

PROCESSING: ACGP 1001-02 Process Specification "MH" Cure Cycle

Date of fiber manufacture 10/21/2004; 3/31/2006; 1/14/2016
Date of resin manufacture 11/19/2004, 12/16/2004; 02/04/2006, 09/22/2006; 08/09/2016, 08/10/2016; 8/23/2016
Date of prepreg manufacture 11/19/2004, 12/16/2004, 2/4/2005, 09/22/2006; 8/10/2016; 8/24/2016
Date of composite manufacture 8/2/2005 - 4/13/2006; 11/1/2016 - 11/4/2016
Date of testing 8/2/2005 - 4/13/2006
Date of Retests 1/3/2017 - 3/31/2017
Date of data submittal 6/13/2006 - 8/13/2006; 5/15/2017
Date of analysis Sept 2008 - August 2009, May 2018

LAMINA MECHANICAL PROPERTY B-Basis SUMMARY for ACG - MTM45-1/GF0103-35%RW 7781 glass fabric
Data reported: As measured followed by normalized values in parentheses, normalizing tply: 0.0100 in

Values shown in shaded boxes do not meet all CMH-17G requirements and are estimates only
These values may not be used for certification unless specifically allowed by the certifying agency

	CTD			RTD			ETD			ETW			ETW2		
	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean
F_1^{cu}	98.00	96.98	106.42	74.35	73.32	82.76				37.78	36.75	46.19	32.68	31.65	41.09
(ksi)	(95.33)	(94.48)	(104.11)	(72.35)	(71.50)	(81.13)				(36.12)	(35.27)	(44.90)	(31.64)	(30.79)	(40.42)
E_1^c			4.40			3.56						3.94			NA
(Msi)			(4.30)			(3.48)						(3.82)			NA
ν_{12}^{cu}			0.153			0.123						0.119			NA
F_1^{tu}	63.47	70.03	80.11	62.72	60.19	68.32				38.99	39.12	44.54	38.84	36.72	41.66
(ksi)	(52.88)	69.59	(80.89)	(62.59)	(62.25)	(68.15)				(33.63)	(38.54)	(44.46)	(29.31)	(35.74)	(41.67)
E_1^t			3.78			3.64						3.40			4.18
(Msi)			(3.82)			(3.61)						(3.40)			(4.20)
F_2^{cu}	83.39	78.96	89.57	51.02	59.92	68.96	54.26	52.85	61.09	40.07	39.08	44.59	30.82	34.70	39.51
(ksi)	(84.01)	(80.68)	(91.85)	(43.86)	NA	(70.19)	(41.73)	53.34	(62.66)	(28.55)	NA	(45.74)	(26.55)	NA	(40.73)
E_2^c			3.61			3.39			3.28			3.37			3.04
(Msi)			(3.70)			(3.45)			(3.36)			(3.46)			(3.12)
F_2^{tu}	64.04	63.97	69.96	55.66	55.58	61.58				33.76	33.18	39.17	33.81	31.38	37.34
(ksi)	(63.06)	(61.18)	(68.69)	(54.90)	(53.01)	(60.53)				(36.40)	(34.17)	(38.76)	(33.67)	(32.37)	(36.80)
E_2^t			3.62			3.39						3.08			3.86
(Msi)			(3.56)			(3.33)						(3.05)			(3.80)
$F_{12}^{s5\%}$ (ksi)	11.37	NA	13.00	8.76	8.44	9.80				4.11	4.62	5.30	3.78	NA	4.70
$F_{12}^{s0.2\%}$ (ksi)	6.12	NA	6.93	4.56	NA	5.39				2.12	NA	2.94	1.84	NA	2.67
G_{12}^s (Msi)			0.64			0.54						0.34			0.33
SBS (ksi)	11.29	10.82	12.29	9.89	NA	10.44	8.19	NA	8.39	4.57	NA	4.86	3.59	NA	3.86

Strain data acquisition equipment calibrated by internal shunt method. Calibration traceable to NIST standard not available
Fill Compression results are computed from retest data

Table 3-3: Summary of Test Results for Lamina Data

Material:	MTM45-1/GF0103-35%RW		**ACG - MTM45-1/GF0103-35%RW 7781 glass fabric Laminate Properties Summary**
Material Specificaton:	ACGM1001-04 or NCAMP NMS 451/4.		
Prepreg:	MTM45-1/GF0103-35%RW		
Fiber:	BGF E-Glass ACDE75 1/0 Yarn	**Resin:** MTM45-1	
Tg(dry) 356°F	**Tg(wet)** 320°F	**Tg METHOD: SACMA SRM18R-94**	
PROCESSING: ACGP 1001-02 Process Specification "MH" Cure Cycle			
Date of fiber manufacture	10/21/2004; 3/31/2006	**Date of testing**	8/2/2005 - 4/13/2006
Date of resin manufacture	11/19/2004, 12/16/2004 02/04/2006, 09/22/2006	**Date of data submittal** **Date of analysis**	6/13/2006 - 8/13/2006 Sept 2008 - August 2009
Date of prepreg manufacture	11/19/2004, 12/16/2004, 02/04/2005, 09/22/2006		
Date of composite manufacture	8/2/2005 - 4/13/2006		

LAMINATE MECHANICAL PROPERTY B-Basis SUMMARY for ACG - MTM45-1/GF0103-35%RW 7781 glass fabric

Data reported as normalized used a normalizing t_{ply} of 0.0100 in

Values shown in shaded boxes do not meet all CMH-17G requirements and are estimates only

These values may not be used for certification unless specifically allowed by the certifying agency

Test	Property	Test Condition	Unit	Quasi Isotropic 25/50/25 B-value	Quasi Isotropic 25/50/25 Mod. CV B-value	Quasi Isotropic 25/50/25 Mean	"Soft" 10/80/10 B-value	"Soft" 10/80/10 Mod. CV B-value	"Soft" 10/80/10 Mean	"Hard" 40/20/40 B-value	"Hard" 40/20/40 Mod. CV B-value	"Hard" 40/20/40 Mean
OHT (normalized)	**Strength**	CTD	ksi	32.33	29.95	33.18	31.18	28.84	32.72	35.07	33.66	38.30
		RTD	ksi	25.28	22.92	26.11	---	---	---	27.58	25.10	30.30
		ETW	ksi	16.09	14.83	17.92	---	---	---	---	---	---
		ETW2	ksi	16.52	15.05	17.07	12.54	11.84	14.23	17.53	16.52	19.97
OHC (normalized)	**Strength**	RTD	ksi	32.85	31.24	34.22	27.23	25.88	30.97	32.40	30.70	37.10
		ETW	ksi	18.21	NA	22.41	---	---	---	---	---	---
		ETW2	ksi	19.26	17.65	20.63	14.57	16.61	18.94	20.73	20.69	23.47
UNT (normalized)	Strength	CTD	ksi	60.45	56.73	62.67						
	Modulus		Msi	---	---	2.98						
	Strength	RTD	ksi	51.07	47.35	53.29						
	Modulus		Msi	---	---	2.86						
	Strength	ETW2	ksi	28.56	25.76	32.42						
	Modulus		Msi	---	---	2.70						
UNC (normalized)	Strength	RTD	ksi	43.57	58.80	65.78						
	Modulus		Msi	---	---	3.07						
	Poisson's Ratio			---	---	0.31						
	Strength	ETW	ksi	28.86	27.47	35.51						
	Modulus		Msi	---	---	2.97						
	Poisson's Ratio			---	---	0.30						
	Strength	ETW2	ksi	12.13	25.75	32.77						
	Modulus		Msi	---	---	4.04						
	Poisson's Ratio			---	---	0.41						
FHT (normalized)	**Strength**	CTD	ksi	33.19	31.47	35.54						
		RTD	ksi	26.24	23.87	28.83						
FHC (normalized)	**Strength**	RTD	ksi	47.23	44.53	54.69						
		ETW2	ksi	30.88	NA	36.24						
Pin Bearing (normalized)	**2% Offset Strength**	RTD	ksi	55.12	58.22	67.73						
		ETW2	ksi	40.18	37.67	47.18						
	Ultimate Strength	RTD	ksi	86.59	84.86	98.29						
		ETW2	ksi	60.11	57.73	65.45						
LSBS (as measured)	**Strength**	RTD	ksi	7.27	8.74	9.58						
		ETW	ksi	4.85	4.83	5.83						
		ETW2	ksi	3.75	3.77	4.61						
CAI (normalized)	**Strength**	RTD	ksi	---	---	22.83						
ILT (as measured)	**Strength**	RTD	ksi	---	---	7.50						
		ETW2	ksi	---	---	2.11						
CBS (as measured)	**Strength**	RTD	lb	---	---	267.34	---	---	---	---	---	---
		ETW2	lb	---	---	82.21	---	---	---	---	---	---

Strain data acquisition equipment calibrated by internal shunt method. Calibration traceable to NIST standard not available

Table 3-4: Summary of Test Results for Laminate Data

4. Lamina Test Results, Statistics, Basis Values and Graphs

Test data for fiber dominated properties was normalized according to nominal cured ply thickness. Both normalized and as measured statistics were included in the tables, but only the normalized data values were graphed. Test failures, outliers and explanations regarding computational choices were noted in the accompanying text for each test.

All individual specimen results are graphed for each test by batch and environmental condition with a line indicating the recommended basis values for each environmental condition. The data is jittered (moved slightly to the left or right) in order for all specimen values to be clearly visible. The strength values are always graphed on the vertical axis with the scale adjusted to include all data values and their corresponding basis values. The vertical axis may not include zero. The horizontal axis values will vary depending on the data and how much overlapping there was of the data within and between batches. When there was little variation, the batches were graphed from left to right and the environmental conditions were identified by the shape and color of the symbol used to plot the data. Otherwise, the environmental conditions were graphed from left to right and the batches were identified by the shape and color of the symbol.

When a dataset fails the Anderson-Darling k-sample (ADK) test for batch-to-batch variation an ANOVA analysis is required. In order for B-basis values computed using the ANOVA method, data from five batches is required. Since this qualification dataset has only three batches, the basis values computed using ANOVA are considered estimates only. However, the basis values resulting from the ANOVA method using only three batches may be overly conservative. The ADK test is performed again after a transformation of the data according to the assumptions of the modified CV method (see section 2.1.4 for details). If the dataset still passes the ADK test at this point, modified CV basis values are provided. If the dataset does not pass the ADK test after the transformation, estimates may be computed using the modified CV method per the guidelines in CMH-17 Rev G section 8.3.10.

4.1 Warp (0º) Tension Properties (WT)

The RTD (both as measured and normalized) and the ETW2 (as measured only) datasets passed the Anderson-Darling k-sample test (ADK test) for batch-to-batch variation. The remaining datasets required the ANOVA method to compute basis values, which may result in overly conservative estimates of the basis values.

The normalized ETW and ETW2 data passes the ADK test with the modified CV transformation, so modified CV values are provided for those datasets. The ETW data fails the normality test, but the transformed pooled dataset passed the normality test, so the normalized RTD, ETW and ETW2 data could be pooled for the modified CV basis values. The normalized dataset had no outliers. Estimates were computed using the modified CV method for the CTD environment. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method.

For the as measured data all environments passed the ADK test with the modified CV transformation, but could not be pooled due to failure of Levene's test. There was one outlier. It was in the as measured data for the ETW environment on the high side of batch three. It was an outlier before pooling the three batches together. The outlier was retained for this analysis.

Statistics, estimates and basis values are given for warp tension strength data in Table 4-1. Statistics for the modulus data are given in Table 4-2. The normalized data, B-estimates and B-basis values are shown graphically in Figure 1.

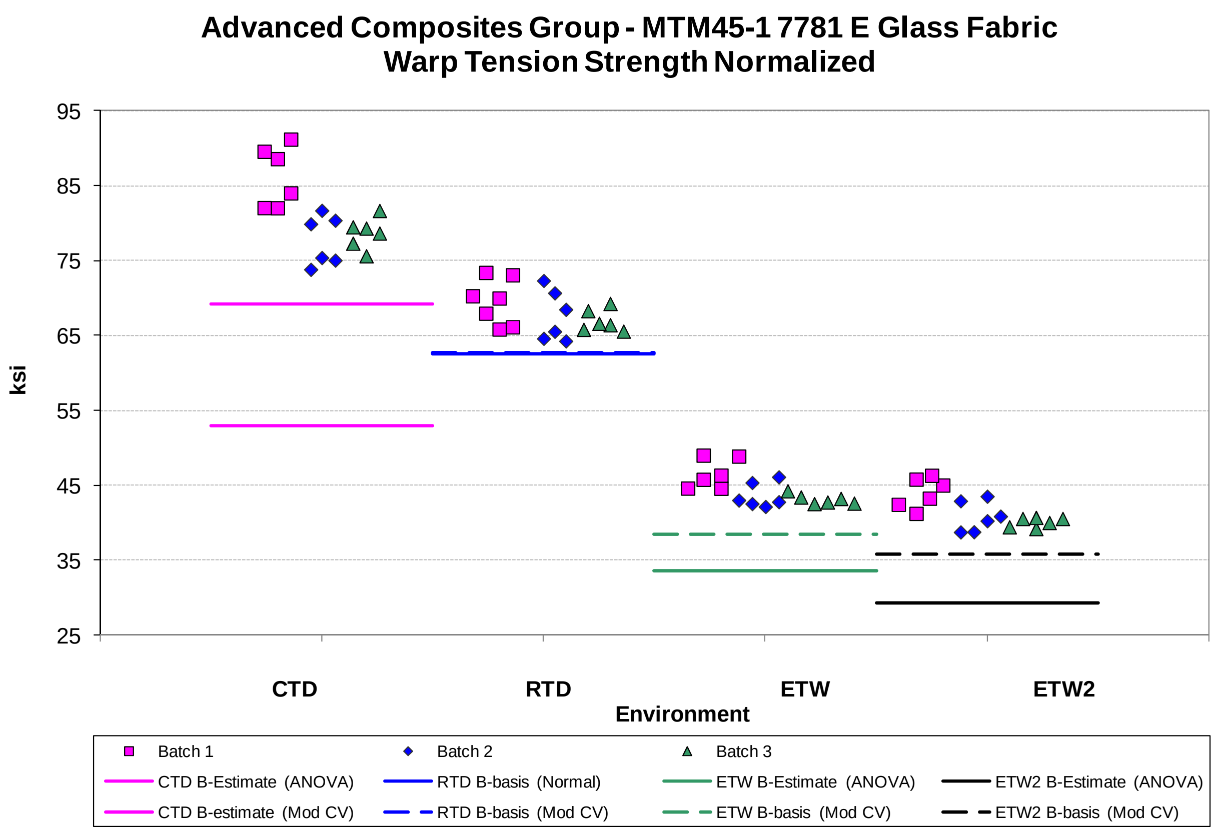

Figure 1: Batch Plot for WT Strength normalized

Warp Tension Strength (ksi) Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	80.89	68.15	44.46	41.67	80.11	68.32	44.54	41.66
Stdev	4.97	2.85	2.11	2.36	3.81	2.88	1.93	1.43
CV	6.15	4.18	4.74	5.66	4.75	4.21	4.33	3.43
Mod CV	7.07	6.09	6.37	6.83	6.38	6.10	6.17	6.00
Min	73.83	64.28	42.17	38.78	73.22	63.75	41.83	38.81
Max	91.20	73.42	49.03	46.33	87.08	72.74	48.19	43.64
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	19	18	18	18	19	18	18
Basis Values and/or Estimates								
B-basis Value		62.59				62.72		38.84
B-estimate	52.88		33.63	29.31	63.47		38.99	
A-estimate	32.90	58.65	25.90	20.49	51.61	58.74	35.04	36.84
Method	ANOVA	Normal	ANOVA	ANOVA	ANOVA	Normal	ANOVA	Normal
Modified CV Basis Values and/or Estimates								
B-basis Value		62.25	38.54	35.74	70.03	60.19	39.12	36.72
B-estimate	69.59							
A-estimate	61.60	58.29	34.58	31.79	62.90	54.43	35.28	33.23
Method	Normal	pooled	pooled	pooled	Normal	Normal	Normal	Normal

Table 4-1 : Statistics, Basis Values and/or Estimates for WT Strength data

Warp Tension Modulus (Msi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	3.82	3.61	3.40	4.20	3.78	3.64	3.40	4.18
Stdev	0.14	0.08	0.19	0.33	0.11	0.11	0.20	0.34
CV	3.74	2.29	5.49	7.93	2.98	3.09	5.94	8.10
Mod CV	6.00	6.00	6.75	7.97	6.00	6.00	6.97	8.10
Min	3.60	3.52	3.11	3.59	3.58	3.47	3.11	3.65
Max	4.10	3.88	3.94	4.75	3.98	3.94	4.01	4.83
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	14	18	18	18	14

Table 4-2 : Statistics ~~from~~ for WT modulus data

4.2 Fill (90º) Tension Properties (FT)

For the normalized data, all environments pass both the normality test and the ADK test, but the pooled dataset did not pass the normality test, so pooling all four environments was not appropriate. Only the CTD and RTD environments could be pooled together.

For the as measured data, the ETW environment did not pass the Anderson-Darling k-sample test for batch-to-batch variation. That dataset required the ANOVA method to compute basis values, which may result in overly conservative estimates of the basis values. Only the CTD and RTD environments could be pooled. The ETW data passed the ADK test with the modified CV transformation, so all four environments could be pooled for the modified CV basis values.

There were a total of four outliers in the normalized data. There were two outliers before pooling batches, RTD batch 3 and ETW2 batch 2, both on the low side. There were another two outliers after pooling batches, one each in ETW and ETW2, both in batch one and both on the low side. All outliers were retained for this analysis. There were no outliers in the as measured data.

Statistics, estimates and basis values are given for fill tension strength data in Table 4-3. Statistics for the modulus data are given in Table 4-4. The normalized data B-basis values are shown graphically in Figure 2.

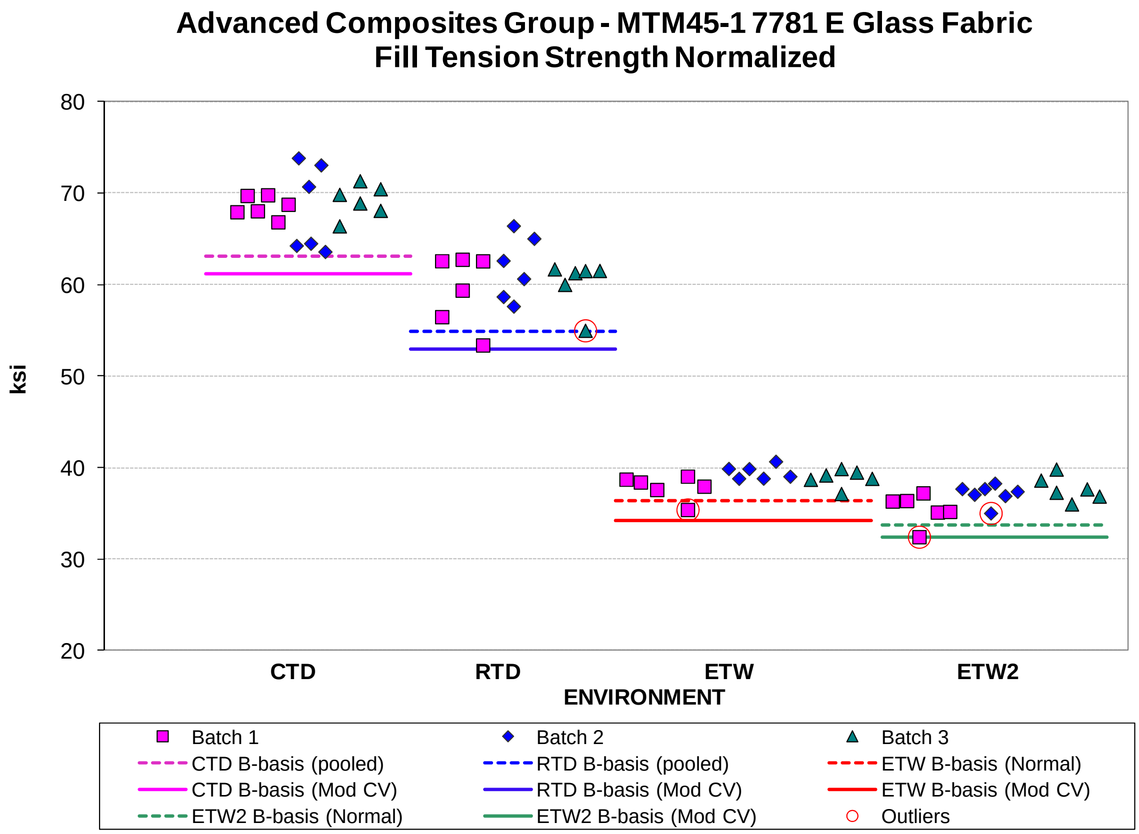

Figure 2: Batch Plot for FT Strength normalized

Fill Tension Strength (ksi) Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	68.69	60.53	38.76	36.80	69.96	61.58	39.17	37.34
Stdev	2.83	3.33	1.20	1.61	3.46	3.02	1.34	1.81
CV	4.13	5.50	3.08	4.36	4.95	4.91	3.41	4.86
Mod CV	6.06	6.75	6.00	6.18	6.47	6.45	6.00	6.43
Min	63.62	53.40	35.42	32.45	63.09	55.24	36.02	33.00
Max	73.85	66.44	40.69	39.84	74.84	67.00	40.91	41.21
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	19	18	18	18	19
Basis Values and/or Estimates								
B-basis Value	63.06	54.90	36.40	33.67	64.04	55.66		33.81
B-estimate							33.76	
A-estimate	59.23	51.07	34.73	31.45	60.01	51.63	29.91	31.30
Method	pooled	pooled	Normal	Normal	pooled	pooled	ANOVA	Normal
Modified CV Basis Values and/or Estimates								
B-basis Value	61.18	53.01	34.17	32.37	63.97	55.58	33.18	31.38
A-estimate	56.06	47.90	30.92	29.23	60.02	51.63	29.23	27.43
Method	pooled	pooled	normal	normal	pooled	pooled	pooled	pooled

Table 4-3 : Statistics, Basis Values and/or Estimates for FT Strength data

Fill Tension Modulus (Msi) Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	3.56	3.33	3.05	3.80	3.62	3.39	3.08	3.86
Stdev	0.07	0.11	0.07	0.31	0.12	0.11	0.07	0.32
CV	1.84	3.25	2.18	8.23	3.27	3.30	2.29	8.36
Mod CV	6.00	6.00	6.00	8.23	6.00	6.00	6.00	8.36
Min	3.37	3.15	2.93	3.37	3.37	3.18	2.93	3.35
Max	3.66	3.53	3.13	4.46	3.89	3.55	3.20	4.46
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	17	18	18	18	17	18

Table 4-4 : Statistics for FT Modulus data

4.3 Warp (0º) Compression Properties (WC)

The warp compression test data could be pooled across all environments. All environments passed the ADK test and the normality tests. There were no outliers. There is no modulus data available for the ETW2 environment.

Statistics, estimates and basis values are given for warp compression strength data in Table 4-5. Statistics for the modulus data are given in Table 4-6. The normalized data and B-basis values are shown graphically in Figure 3.

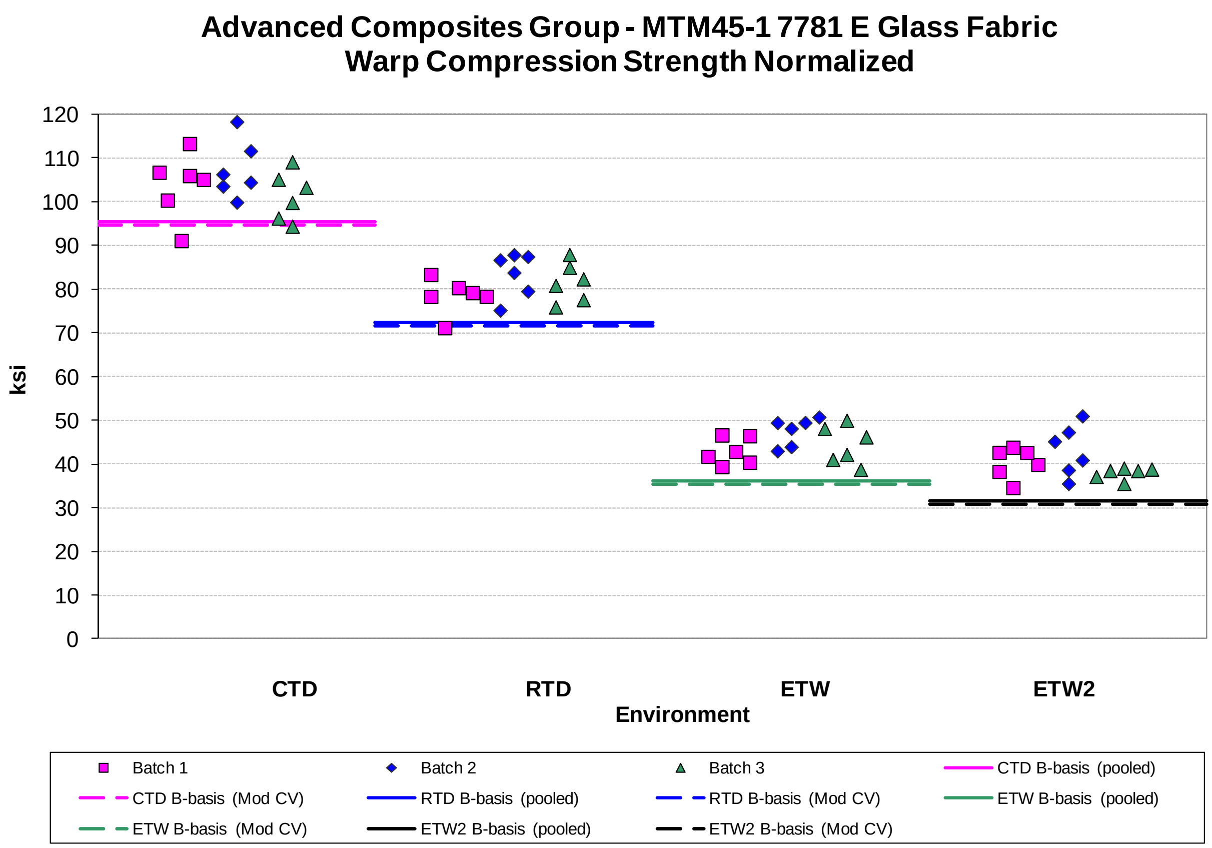

Figure 3: Batch Plot for WC Strength normalized

Warp Compression Strength (ksi) Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	104.11	81.13	44.90	40.42	106.42	82.76	46.19	41.09
Stdev	6.69	4.77	3.90	4.31	7.00	3.83	3.60	4.04
CV	6.42	5.88	8.69	10.65	6.58	4.63	7.80	9.83
Mod CV	7.21	6.94	8.69	10.65	7.29	6.31	7.90	9.83
Min	91.08	71.15	38.74	34.59	94.34	76.61	40.05	35.48
Max	118.27	87.87	50.72	50.97	124.50	90.08	52.03	50.97
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18	18	18
Basis Values and/or Estimates								
B-basis Value	95.33	72.35	36.12	31.64	98.00	74.35	37.78	32.68
A-estimate	89.54	66.56	30.33	25.85	92.46	68.80	32.23	27.13
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value	94.48	71.50	35.27	30.79	96.98	73.32	36.75	31.65
A-estimate	88.13	65.15	28.92	24.44	90.75	67.09	30.52	25.42
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-5 : Statistics, Basis Values and/or Estimates for WC Strength data

Warp Compression Modulus (Msi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	4.30	3.48	3.82	4.40	3.56	3.94
Stdev	0.36	0.12	0.24	0.36	0.19	0.29
CV	8.41	3.56	6.17	8.16	5.20	7.23
Mod CV	8.41	6.00	7.09	8.16	6.60	7.62
Min	3.76	3.31	3.35	3.73	3.32	3.41
Max	5.14	3.69	4.14	5.14	4.03	4.37
No. Batches	3	3	3	3	3	3
No. Spec.	18	17	17	18	17	17

Table 4-6 : Statistics for WC modulus data

4.4 Fill (90º) Compression Properties (FC)

This analysis is using Fill Compression re-test data. The RTD, ETD, ETW and ETW2 normalized and RTD and ETW2 as-measured strength data failed the Anderson-Darling k-sample test for batch to batch variability. The as-measured RTD and ETW2 datasets and the ETD normalized dataset passed the ADK test with the modified CV transform, but the RTD, ETW and ETW2 normalized datasets did not. Requirements for pooling data across environments were not met. There was one outlier. The largest value in batch one of the ETW2 condition was an outlier for batch one of both the normalized and as-measured datasets and an outlier for the ETW2 condition for the as-measured dataset only. Statistics, estimates and basis values are given for the fill compression strength data in Table 4-7. Statistics for the modulus data are given in Table 4-8. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4.

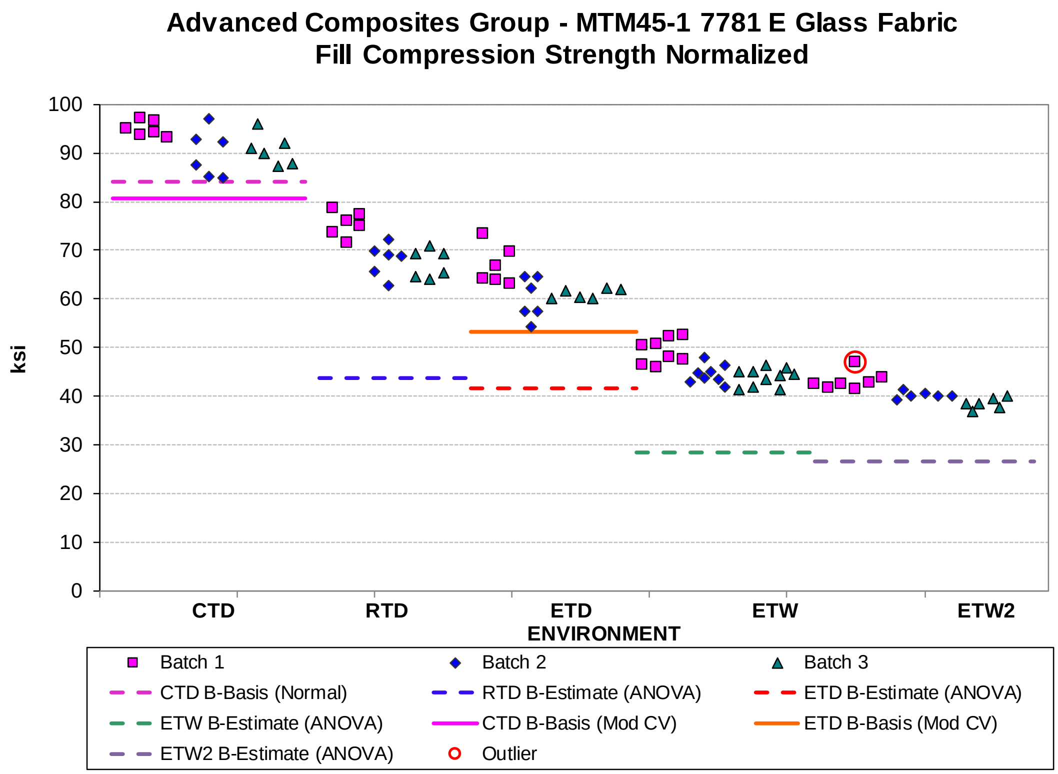

Figure 4: Batch Plot for FC Strength normalized

Fill Compression Strength (ksi) Basis Values and Statistics										
	Normalized					As Measured				
Env	CTD	RTD	ETD	ETW	ETW2	CTD	RTD	ETD	ETW	ETW2
Mean	91.845	70.194	62.659	45.741	40.726	89.573	68.964	61.095	44.588	39.509
Stdev	3.968	4.642	4.432	3.113	2.359	3.130	3.648	3.462	2.479	1.774
CV	4.320	6.613	7.073	6.805	5.792	3.495	5.289	5.666	5.561	4.489
Mod CV	6.160	7.307	7.536	7.402	6.896	6.000	6.645	6.833	6.780	6.245
Min	84.900	62.759	54.317	41.313	36.966	84.770	62.908	54.166	40.497	36.439
Max	97.094	78.659	73.399	52.436	47.002	95.898	74.479	68.946	49.716	44.359
No. Batches	3	3	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	26	19	18	18	18	26	19
Basis Values and/or Estimates										
B-basis Value	84.011					83.392		54.260	40.067	
B-estimate		43.861	41.726	28.549	26.549		51.022			30.823
A-estimate	78.460	25.074	26.801	16.264	16.431	79.013	38.229	49.417	36.815	24.627
Method	Normal	ANOVA	ANOVA	ANOVA	ANOVA	Normal	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and/or Estimates										
B-basis Value	80.676	NA	53.336	NA	NA	78.963	59.917	52.853	39.075	34.700
A-estimate	72.774	NA	46.742	NA	NA	71.457	53.518	47.023	35.110	31.291
Method	Normal	NA	Normal	NA	NA	Normal	Normal	Normal	Normal	Normal

Table 4-7 : Statistics, Basis Values and/or Estimates for FC Strength data

Fill Compression Modulus (Msi) Statistics										
	Normalized					As Measured				
Env	CTD	RTD	ETD	ETW	ETW2	CTD	RTD	ETD	ETW	ETW2
Mean	3.704	3.450	3.358	3.458	3.124	3.614	3.393	3.277	3.366	3.037
Stdev	0.055	0.033	0.045	0.179	0.090	0.094	0.067	0.082	0.151	0.091
CV	1.493	0.961	1.339	5.166	2.894	2.610	1.973	2.496	4.489	3.008
Mod CV	6.000	6.000	6.000	6.583	6.000	6.000	6.000	6.000	6.244	6.000
Min	3.602	3.400	3.262	3.201	2.989	3.408	3.236	3.101	3.101	2.894
Max	3.806	3.531	3.433	3.923	3.311	3.735	3.490	3.379	3.702	3.266
No. Batches	3	3	3	3	3	3	3	3	3	3
No. Spec.	18	18	18	20	18	18	18	18	20	18

Table 4-8 : Statistics for FC Modulus data

4.5 In-Plane Shear Properties (IPS)

In the 5% strain strength data, there were insufficient specimens in the CTD, RTD, and ETW2 environments to produce B-basis values that meet all CMH-17 Rev G requirements for publication, so only estimates of the basis values are available. The ETW data failed the ADK initially, but passes with the modified CV transform, so modified CV basis values are provided for that environment. The CTD data and the pooled dataset failed the normality test. This means the data could not be pooled and that modified CV basis values are not appropriate for the CTD environment. Modified CV basis values are not available for the ETW2 environment due to the large CV of the data for that condition. There were no outliers.

For the 0.2% offset strength data, all environments passed the ADK test. The RTD environment did not pass the normality test, but the pooled dataset did which means that pooling across all environments is appropriate. There was one outlier. It was an outlier after pooling the three batches in the RTD environment. It was on the high side of batch two. It was retained for this analysis. The modified CV method was not appropriate due to the large CV of the 2% offset data.

Statistics, estimates and basis values are given for the IPS strength data in Table 4-9. Statistics for the modulus data are given in Table 4-10. The data, B-estimates and the B-basis values are shown graphically for the 0.2% offset strength data in Figure 5 and for the 5% strain strength data in Figure 6.

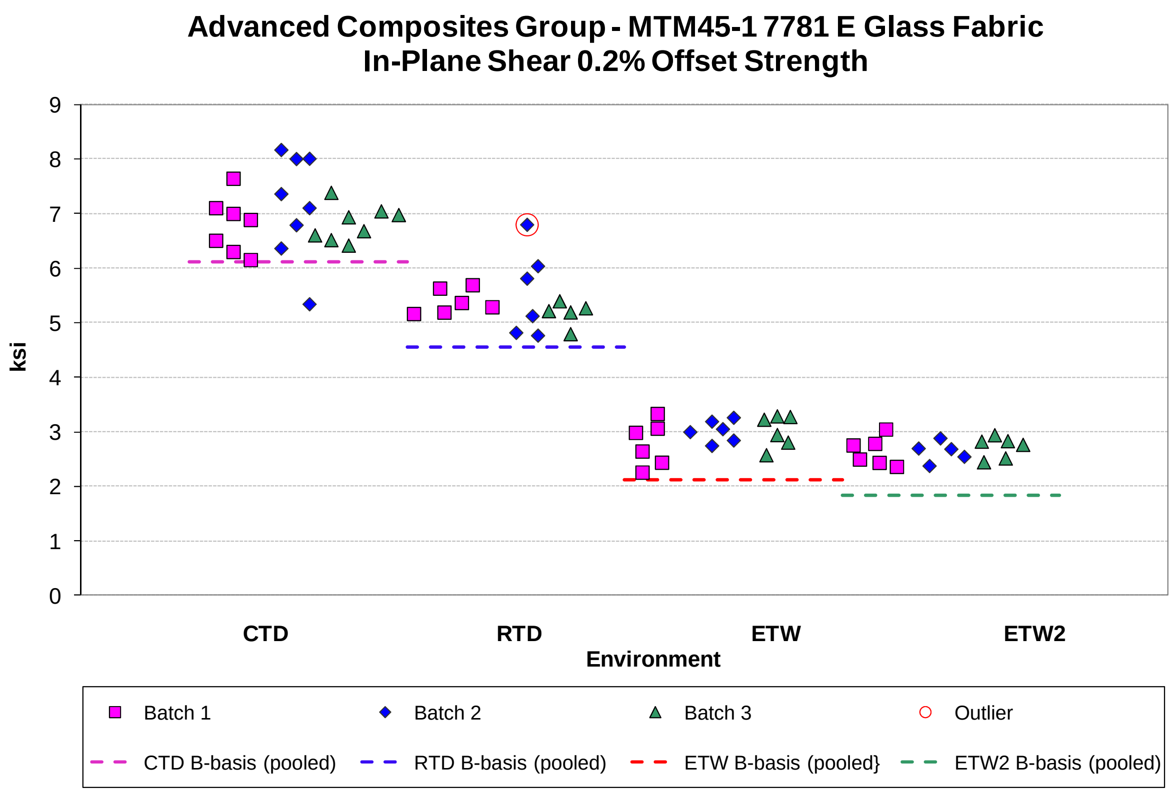

Figure 5: Batch plot for IPS 0.2% Offset Strength as measured

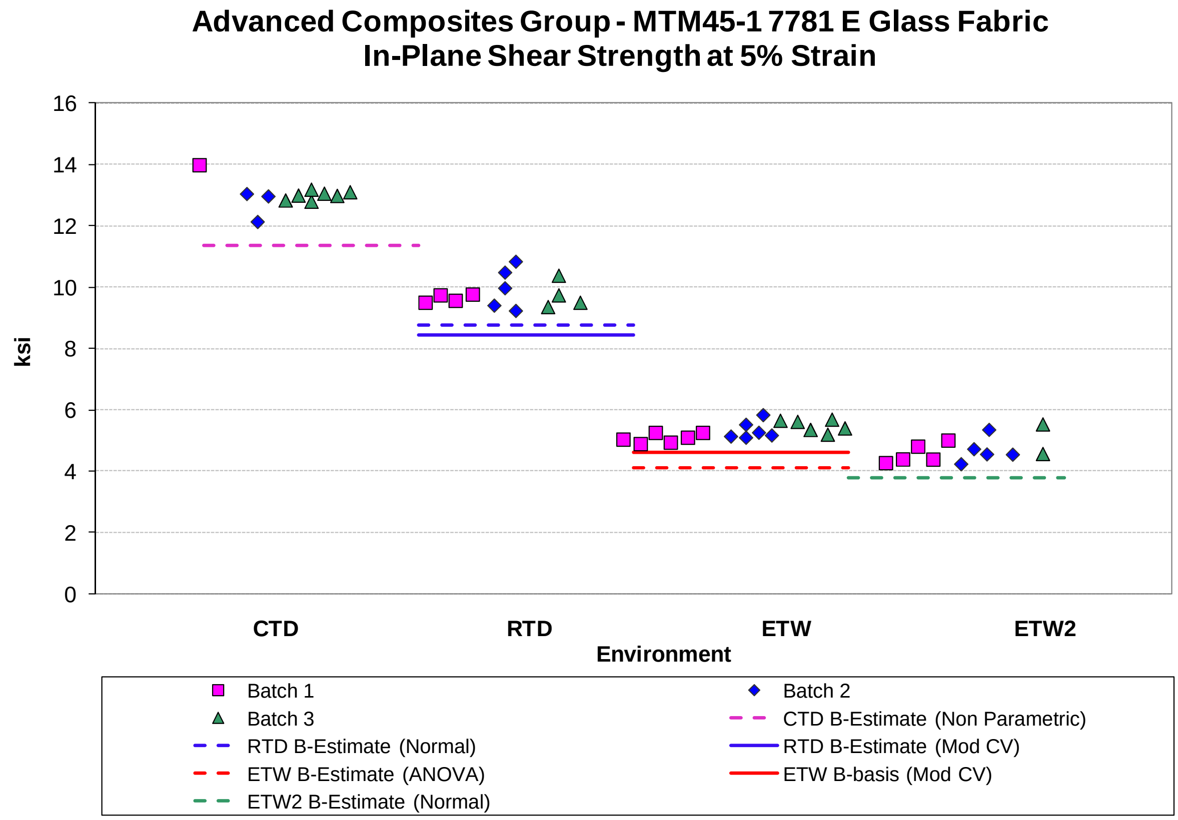

Figure 6: Batch plot for IPS 5% Shear Strain as measured

In-Plane Shear Strength (ksi) Basis Values and Statistics								
	Strength at 5% Strain				0.2% Offset Strength			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	13.00	9.80	5.30	4.70	6.93	5.39	2.94	2.67
Stdev	0.43	0.49	0.27	0.41	0.66	0.50	0.31	0.21
CV	3.30	4.95	5.07	8.81	9.47	9.35	10.65	7.82
Mod CV	6.00	6.47	6.53	8.81	9.47	9.35	10.65	7.91
Min	12.13	9.23	4.89	4.24	5.35	4.77	2.26	2.36
Max	13.98	10.83	5.83	5.53	8.17	6.80	3.34	3.05
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	11	13	18	12	23	17	18	17
Basis Values and/or Estimates								
B-basis Value					6.12	4.56	2.12	1.84
B-estimate	11.37	8.76	4.11	3.78				
A-estimate	8.70	8.03	3.27	3.15	5.58	4.02	1.58	1.30
Method	Non Para	Normal	ANOVA	Normal	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value			4.62	NA	NA	NA	NA	NA
B-estimate	NA	8.44						
A-estimate	NA	7.48	4.13	NA	NA	NA	NA	NA
Method	NA	normal	normal	NA	NA	NA	NA	NA

Table 4-9 : Statistics, Basis Values and/or Estimates for IPS Strength data

In-Plane Shear Modulus (Msi) Statistics				
Env	CTD	RTD	ETW	ETW2
Mean	0.64	0.54	0.34	0.33
Stdev	0.04	0.06	0.03	0.03
CV	6.01	10.25	7.49	7.89
Mod CV	7.00	10.25	7.75	7.95
Min	0.56	0.49	0.30	0.28
Max	0.72	0.74	0.41	0.38
No. Batches	3	3	3	3
No. Spec.	23	17	18	17

Table 4-10 : Statistics for IPS Modulus data

4.6 Short Beam Strength (SBS)

All environments pass the ADK test, but only the CTD environment passes the normality test. Pooling is not appropriate due to non-normality of the data. Since only the CTD environment passed the normality test, that is the only environment for which a modified CV basis value could be computed. There were two outliers. One was on the high side of batch three in the ETW environment. The other was on the high side of batch one in the ETD environment. Both were outliers for their respective batches, but not after pooling the three batches together. Both outliers were retained for this analysis.

Statistics, estimates and basis values are given for the SBS data in Table 4-11. The data and B-basis values are shown graphically in Figure 7.

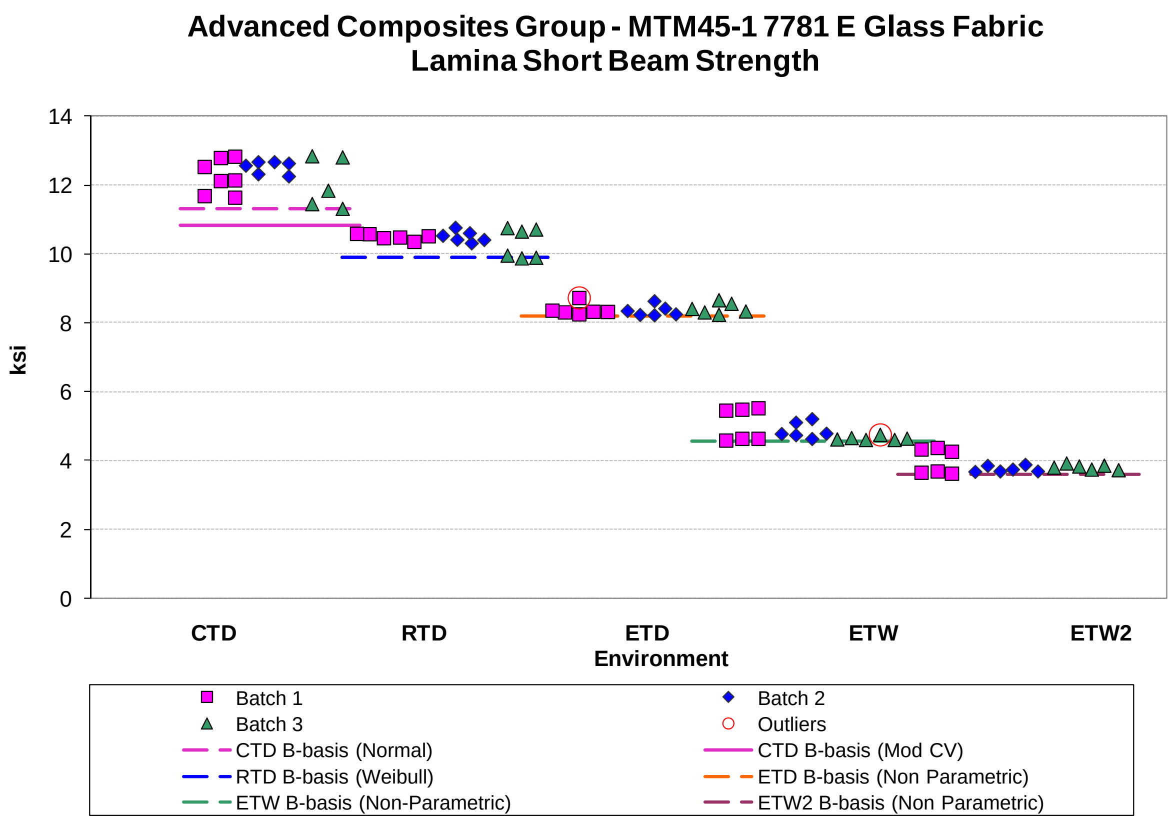

Figure 7: Batch plot for Short Beam Strength as measured

Short Beam Strength (ksi) Basis Values and Statistics					
Env	CTD	RTD	ETD	ETW	ETW2
Mean	12.29	10.44	8.39	4.86	3.86
Stdev	0.51	0.27	0.16	0.34	0.23
CV	4.11	2.63	1.87	6.89	6.00
Mod CV	6.06	6.00	6.00	7.44	7.00
Min	11.32	9.88	8.23	4.59	3.63
Max	12.85	10.77	8.73	5.53	4.38
No. Batches	3	3	3	3	3
No. Spec.	18	18	18	18	18
Basis Values and/or Estimates					
B-basis Value	11.29	9.89	8.19	4.57	3.59
A-estimate	10.58	9.28	7.53	3.48	2.74
Method	Normal	Weibull	Non Para	Non Para	Non Para
Modified CV Basis Values and/or Estimates					
B-basis Value	10.82	NA	NA	NA	NA
A-estimate	9.78	NA	NA	NA	NA
Method	normal	NA	NA	NA	NA

Table 4-11 : Statistics, Basis Values and/or Estimates for SBS Strength data

5. Laminate Test Results, Statistics and Basis Values

Some laminate tests were performed with one batch only. This is insufficient data to produce basis values that meet the requirements of CMH-17 Rev G, so only estimates are provided. Estimates were prepared using the lamina variability method documented in section 2.4 or by pooling with the other environments when appropriate. The more conservative of the LVM or pooled estimate was provided.

5.1 Quasi Isotropic Unnotched Tension (UNT1) Properties

The UNT1 data was pooled across the three environments. The ETW2 environment has only seven specimens available, so estimates only are provided. The ETW2 data was included in the pooled dataset, but because the LVM estimate was more conservative, the LVM estimate is provided. For the modified CV approach, the pooled estimate was more conservative than the LVM estimate, to the pooled estimate is provided as the ETW2 Mod CV estimate.

There was one outlier. It was on the high side of batch three in the CTD environment for the as measured data only. It was an outlier both before and after pooling. It was retained for this analysis.

Statistics, estimates and basis values are given for the UNT1 strength data in Table 5-1. Statistics for the modulus data are given in Table 5-2. The normalized data, B-estimates and B-basis values are shown graphically in Figure 8.

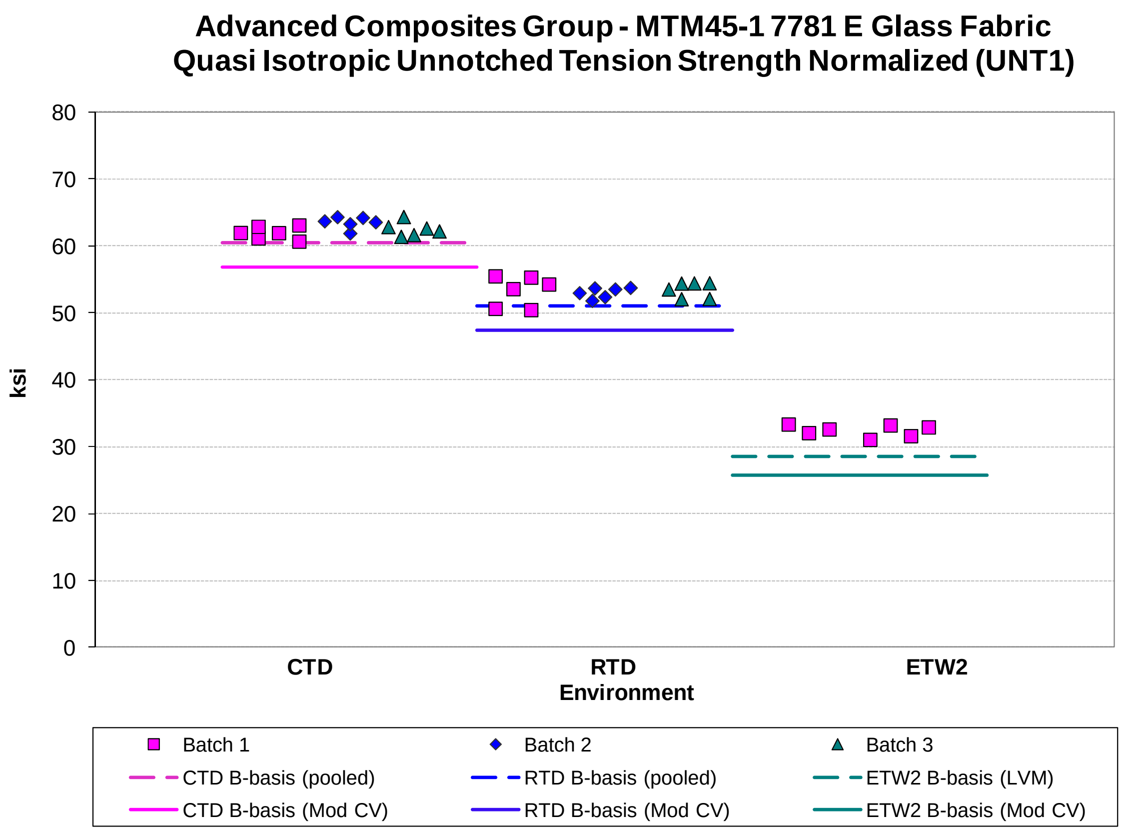

Figure 8: Batch plot for UNT1 Strength normalized

Quasi Isotropic Unnotched Tension Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	62.67	53.29	32.42	63.64	54.14	33.31
Stdev	1.12	1.44	0.86	1.60	1.99	1.19
CV	1.78	2.71	2.64	2.51	3.67	3.56
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	60.70	50.47	31.07	61.21	50.90	32.14
Max	64.36	55.50	33.37	68.58	58.42	35.28
No. Batches	3	3	1	3	3	1
No. Spec.	18	18	7	18	18	7
Basis Values and/or Estimates						
B-basis Value	60.45	51.07		60.53	51.04	
B-estimate			28.56			29.83
A-estimate	58.95	49.57	NA	58.44	48.94	27.80
Method	pooled	pooled	LVM	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	56.73	47.35		57.60	48.10	
B-estimate			25.76			26.54
A-estimate	52.72	43.33	21.86	53.52	44.02	22.58
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 5-1 : Statistics, Basis Values and/or Estimates for UNT1 Strength data

Quasi Isotropic Unnotched Tension Modulus (Msi) Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	2.98	2.86	2.70	3.02	2.92	2.77
Stdev	0.08	0.18	0.24	0.09	0.21	0.24
CV	2.77	6.41	8.90	3.13	7.19	8.74
Modified CV	6.00	7.20	8.90	6.00	7.59	8.74
Min	2.72	2.62	2.28	2.81	2.67	2.32
Max	3.07	3.28	2.96	3.18	3.34	3.04
No. Batches	3	3	1	3	3	1
No. Spec.	18	14	6	18	14	6

Table 5-2 : Statistics for UNT1 Modulus Data

5.2 Quasi Isotropic Un-notched Compression (UNC1) Properties

The RTD and ETW2 datasets did not pass the ADK test even with the modified CV transform. They required the ANOVA method to compute basis values which may result in overly conservative estimates of the basis values. Estimates were computed using the modified CV method. These are termed estimates due to the failure of the ADK test after the transformation for the modified CV method. Pooling was used to compute the Mod CV estimates.

There were no outliers. Statistics, A- and B-estimates are given for the UNC1 normalized strength data in Table 5-3. Statistics for the modulus data are given in Table 5-4. The normalized data and B-estimates are shown graphically in Figure 9.

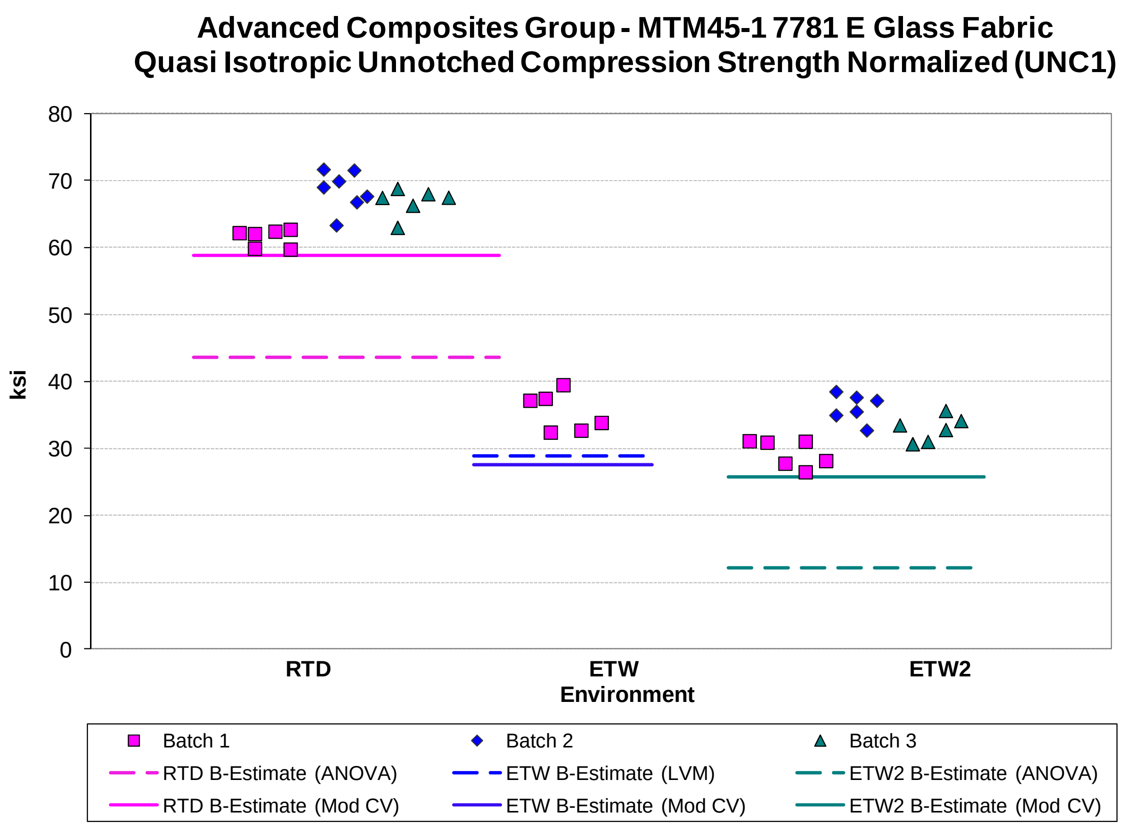

Figure 9: Batch plot for UNC1 Strength normalized

Quasi Isotropic Unnotched Compression Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	65.78	35.51	32.77	67.83	36.63	34.03
Stdev	3.75	2.91	3.44	3.62	2.91	3.18
CV	5.70	8.21	10.49	5.33	7.95	9.33
Modified CV	6.85	8.21	10.49	6.67	7.98	9.33
Min	59.74	32.41	26.50	61.80	33.54	28.14
Max	71.68	39.48	38.49	74.01	41.20	38.94
No. Batches	3	1	3	3	1	3
No. Spec.	19	6	18	19	6	18
Basis Values and/or Estimates						
B-estimate	43.57	28.86	12.13	45.09	30.35	14.95
A-estimate	27.71	NA	NA	28.86	NA	1.34
Method	ANOVA	LVM	ANOVA	ANOVA	LVM	ANOVA
Modified CV Basis Values and/or Estimates						
B-estimate	58.80	27.47	25.75	61.00	28.76	27.17
A-estimate	54.06	22.88	21.02	56.36	24.28	22.54
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 5-3 : Statistics, Basis Values and/or Estimates for UNC1 Strength data

Quasi Isotropic Unnotched Compression Modulus (Msi) Statistics						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	3.07	2.97	4.04	3.17	3.07	4.21
Stdev	0.26	0.25	0.28	0.27	0.30	0.30
CV	8.47	8.31	6.84	8.53	9.86	7.06
Modified CV	8.47	8.31	7.42	8.53	9.86	7.53
Min	2.79	2.65	3.33	2.91	2.71	3.47
Max	3.99	3.34	4.39	4.13	3.55	4.69
No. Batches	3	1	3	3	1	3
No. Spec.	19	6	15	19	6	15

Table 5-4 : Statistics for UNC1 Modulus data

5.3 Laminate Short Beam Strength (LSBS)

The RTD and ETW2 data failed the ADK initially, so they required the ANOVA method to compute basis values, which may result in overly conservative estimates of the basis values. Both environments passed the ADK test with the modified CV transform, so modified CV basis values are provided. ETW was included in the pooling, but the LVM method provided a more conservative B-estimate. There were no outliers.

Statistics, estimates and basis values are given for the LSBS strength data in Table 5-5. The data, B-estimates and B-basis values are shown graphically in Figure 10.

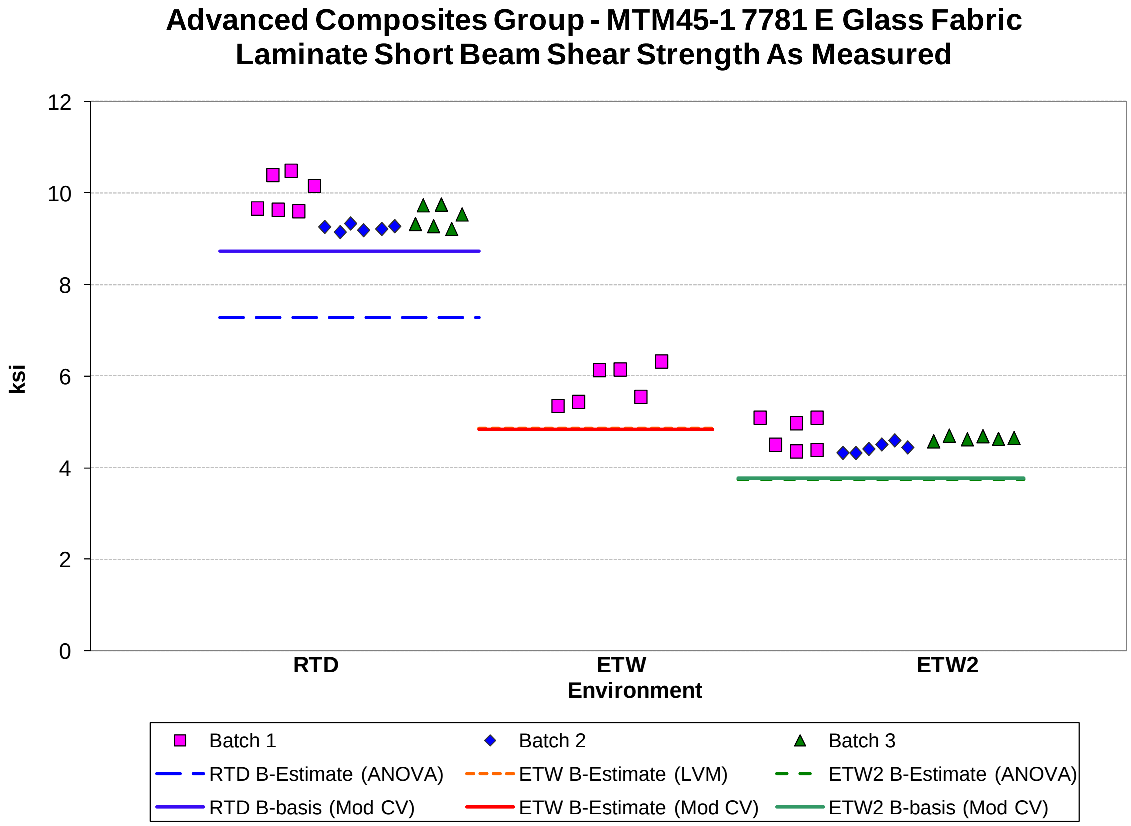

Figure 10: Batch plot for LSBS Strength as measured

Laminate Short Beam Strength (ksi) Basis Values and Statistics			
Env	RTD	ETW	ETW2
Mean	9.58	5.83	4.61
Stdev	0.41	0.42	0.24
CV	4.31	7.26	5.22
Modified CV	6.15	8.00	6.61
Min	9.16	5.36	4.33
Max	10.50	6.33	5.10
No. Batches	3	1	3
No. Spec.	18	6	18
Basis Values and/or Estimates			
B-estimate	7.27	4.85	3.75
A-estimate	5.63	NA	3.14
Method	ANOVA	LVM	ANOVA
Modified CV Basis Values and/or Estimates			
B-basis Value	8.74		3.77
B-estimate		4.83	
A-estimate	8.17	NA	3.21
Method	pooled	LVM	pooled

Table 5-5 : Statistics, Basis Values and/or Estimates for LSBS Strength data

5.4 Open Hole Tension (OHT1, OHT2, OHT3) Properties

5.4.1 Quasi Isotropic Open Hole Tension (OHT1)

The OHT1 datasets failed Levene's test for both the normalized and as measured data so pooling all environments was not appropriate. However, the CTD and RTD conditions could be pooled.

After transforming the data to meet the assumptions of the modified CV approach, the as measured data passed Levene's test, but the normalized data did not. Pooling the data to compute the modified CV basis values included all four environmental conditions for the as measured data but only the CTD and RTD could be pooled for the normalized data.

There was one outlier in the normalized RTD data. It was on the low side of batch two. It was an outlier before, but not after, pooling the three batches. It was retained for this analysis.

Statistics, estimates and basis values are given for the OHT1 strength data in Table 5-6. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 11.

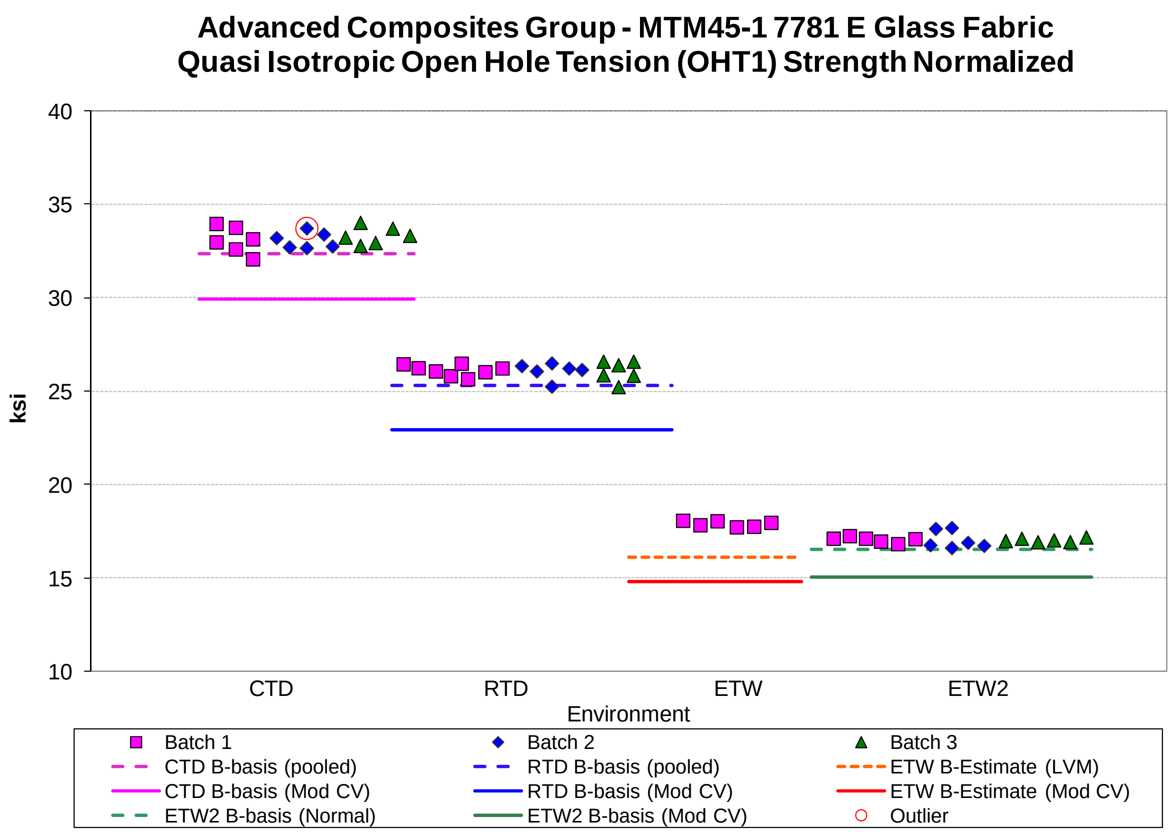

Figure 11: Batch plot for OHT1 Strength normalized

Quasi Isotropic Open Hole Tension Strength (ksi) Basis Values and Statistics								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	33.18	26.11	17.92	17.07	33.65	26.55	18.39	17.36
Stdev	0.53	0.40	0.15	0.28	1.03	0.66	0.31	0.44
CV	1.60	1.52	0.84	1.63	3.05	2.49	1.68	2.53
Modified CV	6.00	6.00	8.00	6.00	6.00	6.00	8.00	6.00
Min	32.08	25.25	17.75	16.63	32.18	25.06	18.07	16.58
Max	34.03	26.61	18.10	17.71	35.86	27.89	18.87	18.37
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	18	20	6	18	18	20	6	18
Basis Values and/or Estimates								
B-basis Value	32.33	25.28		16.52	32.10	25.02		16.49
B-estimate			16.09				16.67	
A-estimate	31.76	24.71	NA	16.13	31.05	23.97	NA	15.88
Method	pooled	pooled	LVM	Normal	pooled	pooled	LVM	Normal
Modified CV Basis Values and/or Estimates								
B-basis Value	29.95	22.92		15.05	30.90	23.83		14.61
B-estimate			14.83				15.21	
A-estimate	27.76	20.72	NA	13.62	29.07	22.00	13.44	12.78
Method	pooled	pooled	LVM	Normal	pooled	pooled	pooled	pooled

Table 5-6 : Statistics, Basis Values and/or Estimates for OHT1 Strength data

5.4.2 "Soft" Open Hole Tension (OHT2)

There was one outlier in the OHT2 CTD data. It was on the high side of batch two. It was an outlier only after pooling the three batches. It was retained for this analysis.

Statistics, estimates and basis values are given for the OHT2 strength data in Table 5-7. The normalized data, B-estimates and B-basis values are shown graphically in Figure 12.

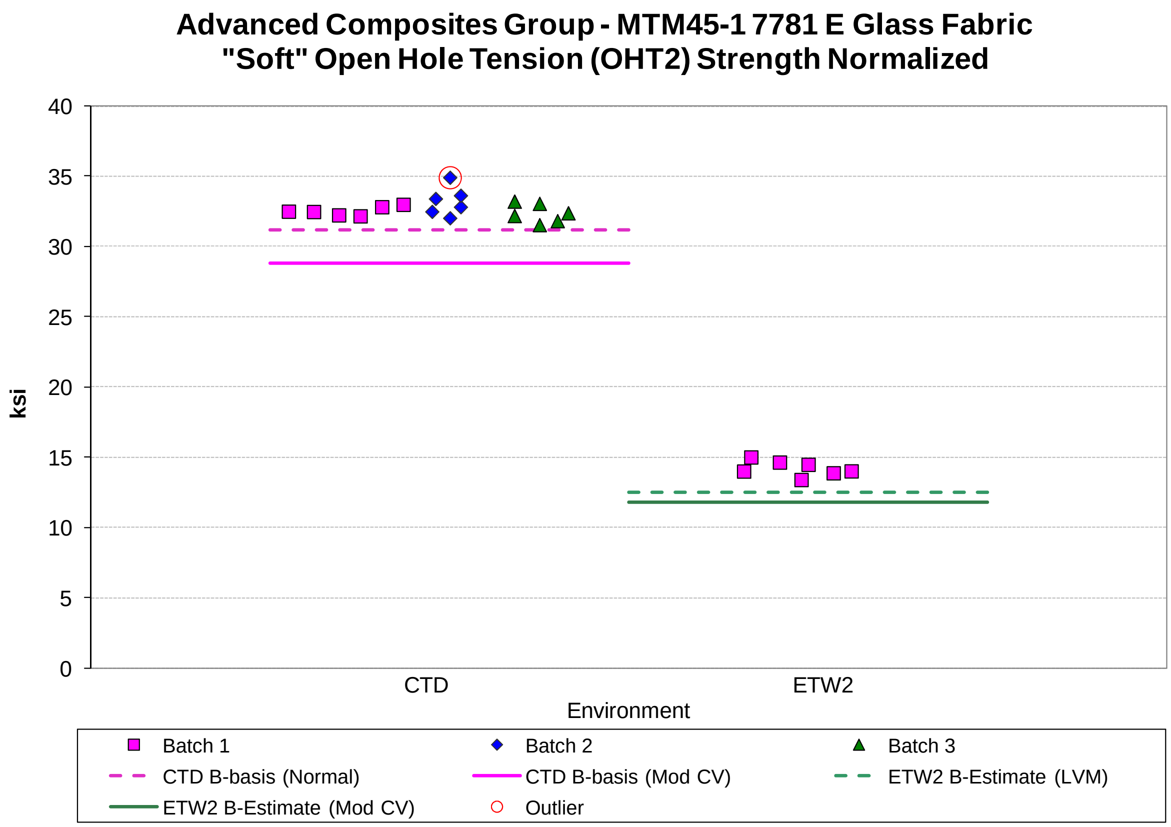

Figure 12: Batch plot for OHT2 Strength normalized

"Soft" Open Hole Tension Properties (OHT2) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	CTD	ETW2	CTD	ETW2
Mean	32.72	14.23	33.40	14.43
Stdev	0.78	0.54	1.20	0.48
CV	2.38	3.80	3.59	3.34
Modified CV	6.00	8.00	6.00	8.00
Min	31.56	13.42	31.56	13.70
Max	34.93	15.03	36.39	15.13
No. Batches	3	1	3	1
No. Spec.	18	7	18	7
Basis Values and/or Estimates				
B-basis Value	31.18		31.04	
B-estimate		12.54		13.39
A-estimate	30.09	NA	29.36	NA
Method	Normal	LVM	Normal	LVM
Modified CV Basis Values and/or Estimates				
B-basis Value	28.84		29.45	
B-estimate		11.84		12.01
A-estimate	26.10	NA	26.65	NA
Method	Normal	LVM	Normal	LVM

Table 5-7 : Statistics, Basis Values and/or Estimates for OHT2 Strength data

5.4.3 "Hard" Open Hole Tension 3 (OHT3)

There was one outlier in the OHT3 CTD data. It was on the high side of batch three in both the normalized and as measured data. It was an outlier before, but not after pooling the three batches. It was retained for this analysis.

Statistics, estimates and basis values are given for the OHT3 strength data in Table 5-8. The normalized data, B-estimates and B-basis values are shown graphically in Figure 13.

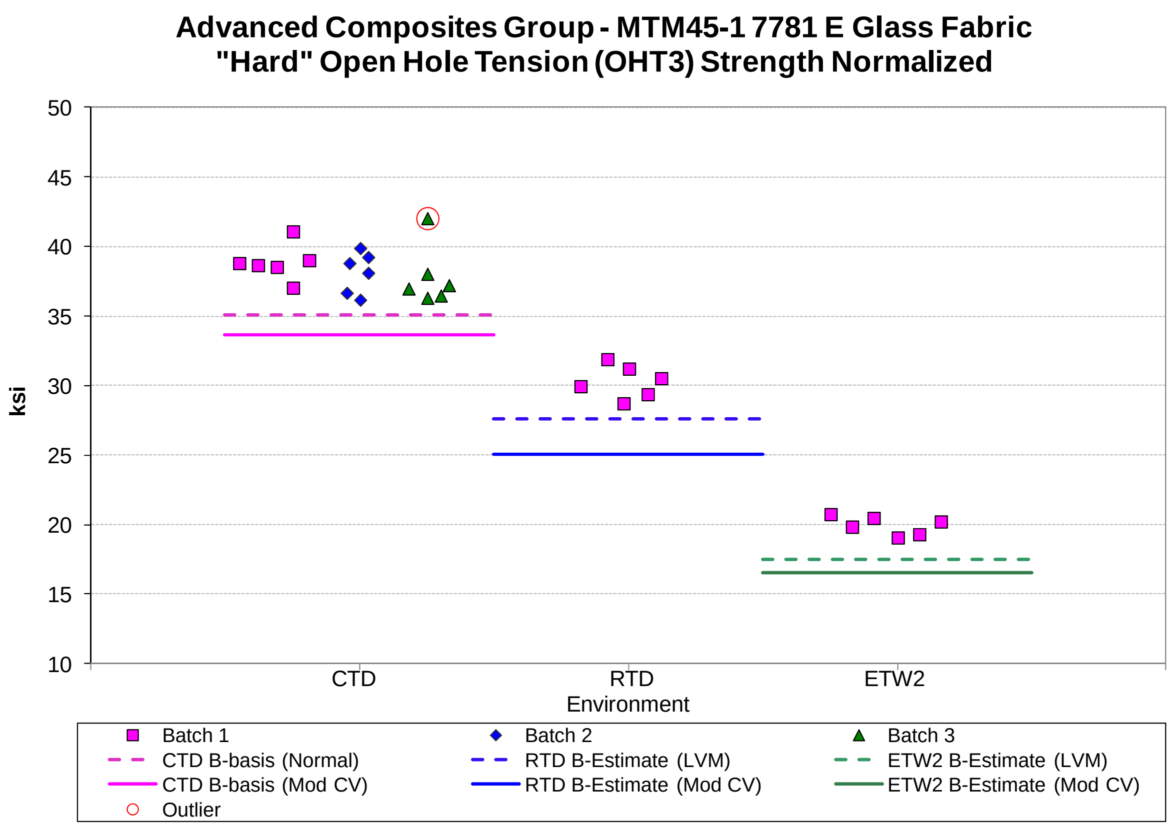

Figure 13: Batch plot for OHT3 Strength normalized

"Hard" Open Hole Tension Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	38.30	30.30	19.97	38.59	29.29	19.53
Stdev	1.64	1.18	0.66	1.70	0.87	0.33
CV	4.27	3.88	3.31	4.41	2.99	1.69
Modified CV	6.14	8.00	8.00	6.21	8.00	8.00
Min	36.19	28.74	19.10	35.71	28.09	18.97
Max	42.06	31.92	20.77	42.92	30.23	19.85
No. Batches	3	1	1	3	1	1
No. Spec.	18	6	6	18	6	6
Basis Values and/or Estimates						
B-basis Value	35.07			35.23		
B-estimate		27.58	17.53		26.64	18.09
A-estimate	32.78	NA	NA	32.85	NA	NA
Method	Normal	LVM	LVM	Normal	LVM	LVM
Modified CV Basis Values and/or Estimates						
B-basis Value	33.66			33.86		
B-estimate		25.10	16.52		24.26	16.16
A-estimate	30.38	NA	NA	30.52	NA	NA
Method	Normal	LVM	LVM	Normal	LVM	LVM

Table 5-8 : Statistics, Basis Values and/or Estimates for OHT3 Strength data

5.5 Open Hole Compression (OHC1, OHC2, OHC3) Properties

5.5.1 Quasi Isotropic Open Hole Compression 1 (OHC1)

The OHC1 data could be pooled across the three environments. The ETW environment has only six specimens available, so estimates only are provided. The ETW data was included in pooling but the LVM method provided a more conservative B-estimate. Modified CV basis values are not available for the normalized ETW environment data due to the large CV of WC lamina data for that condition. There were no outliers.

Statistics, estimates and basis values are given for the OHC1 strength data in Table 5-9. The normalized data, B-estimates and B-basis values are shown graphically in Figure 14.

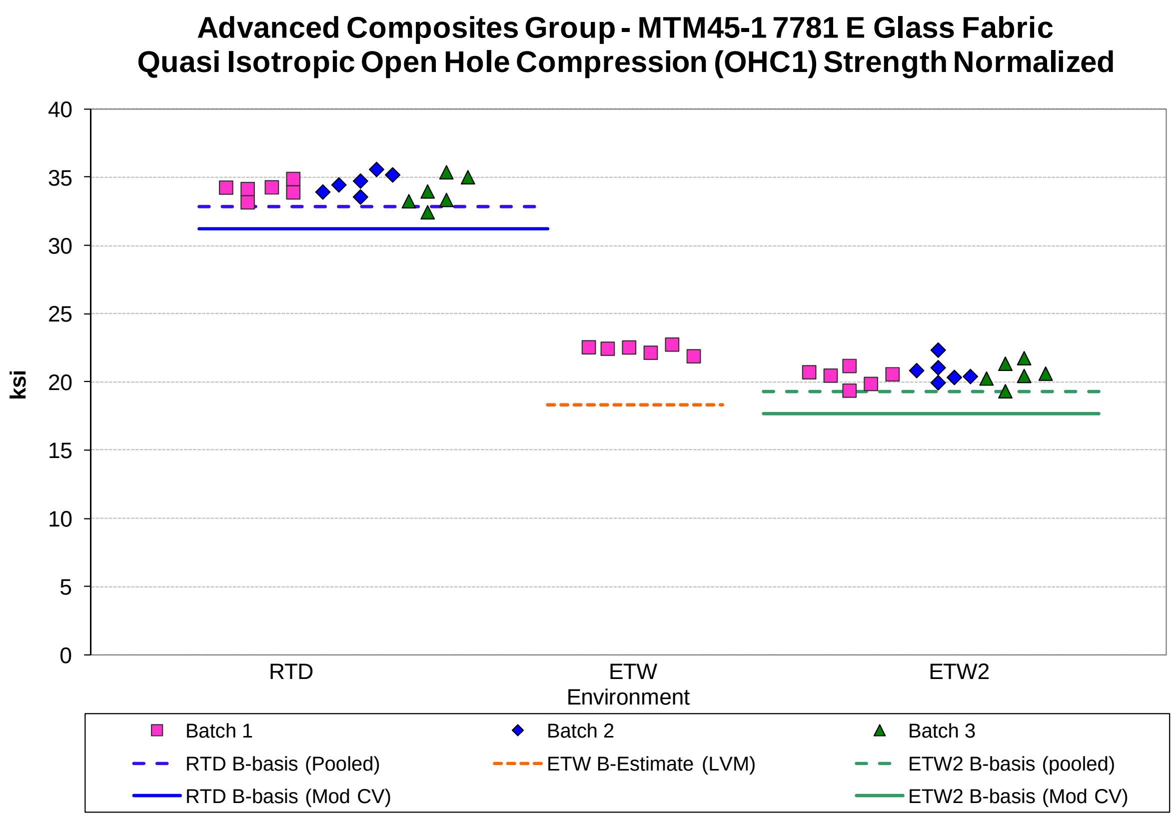

Figure 14: Batch plot for OHC1 Strength normalized

Quasi Isotropic Open Hole Compression Strength (ksi) Basis Values and Statistics						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	34.22	22.41	20.63	34.70	22.96	20.89
Stdev	0.84	0.31	0.76	0.93	0.53	0.69
CV	2.47	1.39	3.70	2.67	2.32	3.30
Modified CV	6.00	8.00	6.00	6.00	8.00	6.00
Min	32.47	21.91	19.35	32.79	22.36	19.78
Max	35.61	22.77	22.37	36.43	23.76	22.37
No. Batches	3	1	3	3	1	3
No. Spec.	18	6	18	18	6	18
Basis Values and/or Estimates						
B-basis Value	32.85		19.26	33.29		19.47
B-estimate		18.21			19.09	
A-estimate	31.92	NA	18.33	32.33	NA	18.52
Method	pooled	LVM	pooled	pooled	LVM	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	31.24		17.65	31.68		17.86
B-estimate		NA			18.99	
A-estimate	29.22	NA	15.63	29.64	NA	15.82
Method	pooled	NA	pooled	pooled	LVM	pooled

Table 5-9 : Statistics, Basis Values and/or Estimates for OHC1 Strength data

5.5.2 "Soft" Open Hole Compression (OHC2)

The OHC2 ETW2 data failed the ADK initially, but passes with the modified CV transform, so modified CV basis values are provided for that environment. There were no outliers. Statistics, estimates and basis values are given for the OHC2 strength data in Table 5-10. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 15.

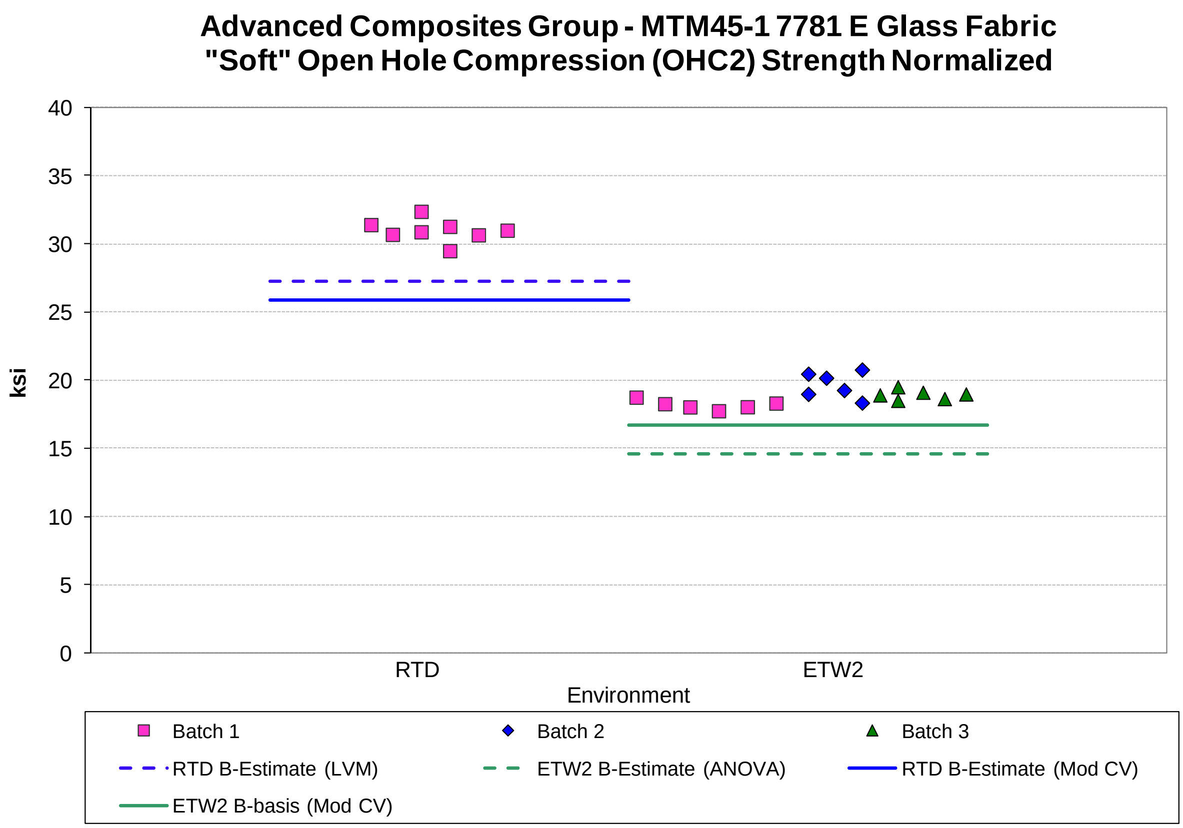

Figure 15: Batch plot for OHC2 Strength normalized

"Soft" Open Hole Compression Properties (OHC2) Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	30.97	18.94	31.80	19.31
Stdev	0.81	0.85	0.77	0.70
CV	2.62	4.47	2.41	3.64
Modified CV	8.00	6.24	8.00	6.00
Min	29.50	17.76	30.75	18.12
Max	32.38	20.77	33.10	20.64
No. Batches	1	3	1	3
No. Spec.	8	18	8	18
Basis Values and/or Estimates				
B-basis Value				17.92
B-estimate	27.23	14.57	28.77	
A-estimate	NA	11.45	NA	16.94
Method	LVM	ANOVA	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		16.61		17.02
B-estimate	25.88		26.57	
A-estimate	NA	14.96	NA	15.40
Method	LVM	Normal	LVM	Normal

Table 5-10 : Statistics, Basis Values and/or Estimates for OHC2 Strength data

5.5.3 “Hard” Open Hole Compression (OHC3)

The OHC3 ETW2 normalized data failed the ADK initially, but passes with the modified CV transform, so modified CV basis values are provided for that environment. There were no outliers. Statistics, estimates and basis values are given for the OHC3 strength data in Table 5-11. The normalized data, B-estimates and B-basis values are shown graphically in Figure 16.

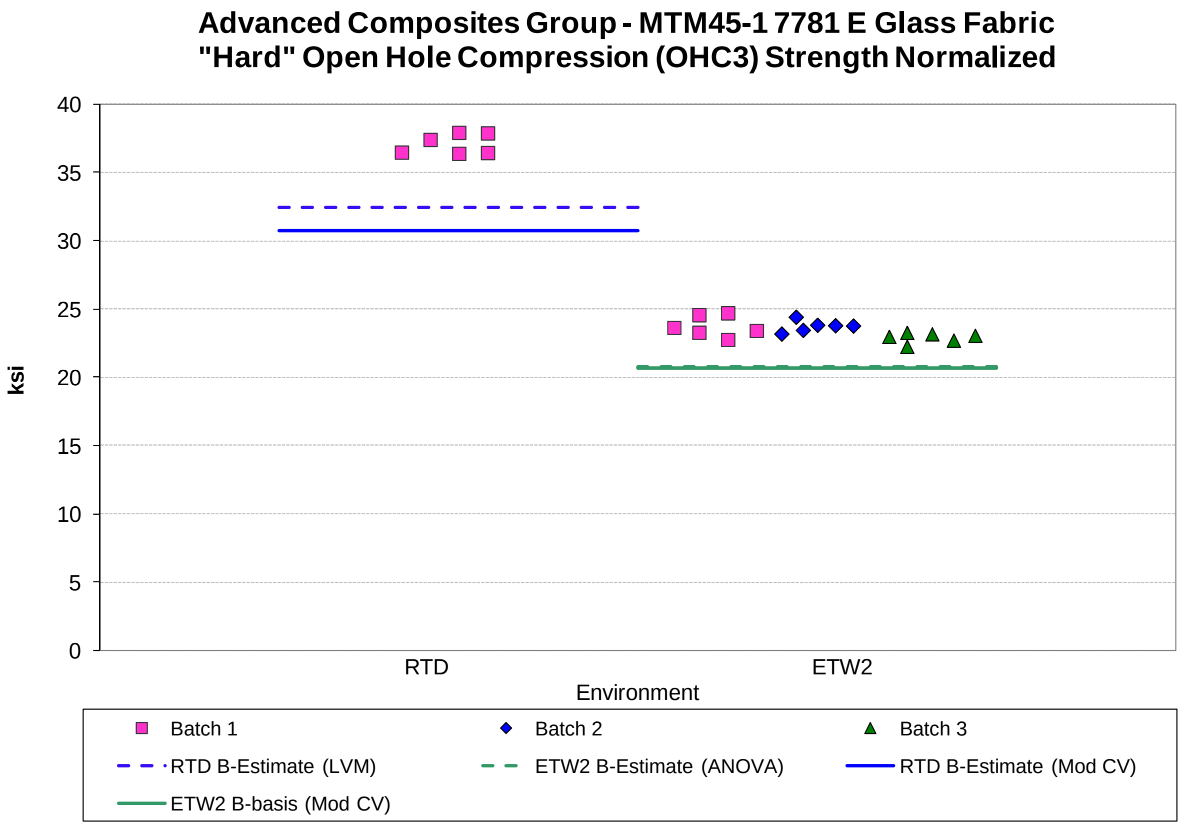

Figure 16: Batch plot for OHC3 Strength normalized

"Hard" Open Hole Compression Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	37.10	23.47	38.14	23.57
Stdev	0.74	0.65	1.08	0.84
CV	1.99	2.77	2.83	3.57
Modified CV	8.00	6.00	8.00	6.00
Min	36.40	22.27	37.04	22.28
Max	37.94	24.72	39.68	25.57
No. Batches	1	3	1	3
No. Spec.	6	18	6	18
Basis Values and/or Estimates				
B-basis Value				21.91
B-estimate	32.40	20.73	34.33	
A-estimate	NA	18.77	NA	20.74
Method	LVM	ANOVA	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		20.69		20.78
B-estimate	30.70		31.55	
A-estimate	NA	18.73	NA	18.80
Method	LVM	Normal	LVM	Normal

Table 5-11 : Statistics, Basis Values and/or Estimates for OHC3 Strength data

5.6 Quasi Isotropic Filled Hole Tension (FHT1) Properties

The FHT1 data had no outliers or test failures. Statistics, estimates and basis values are given for the FHT1 strength data in Table 5-12. The normalized data, B-estimates and B-basis values are shown graphically in Figure 17.

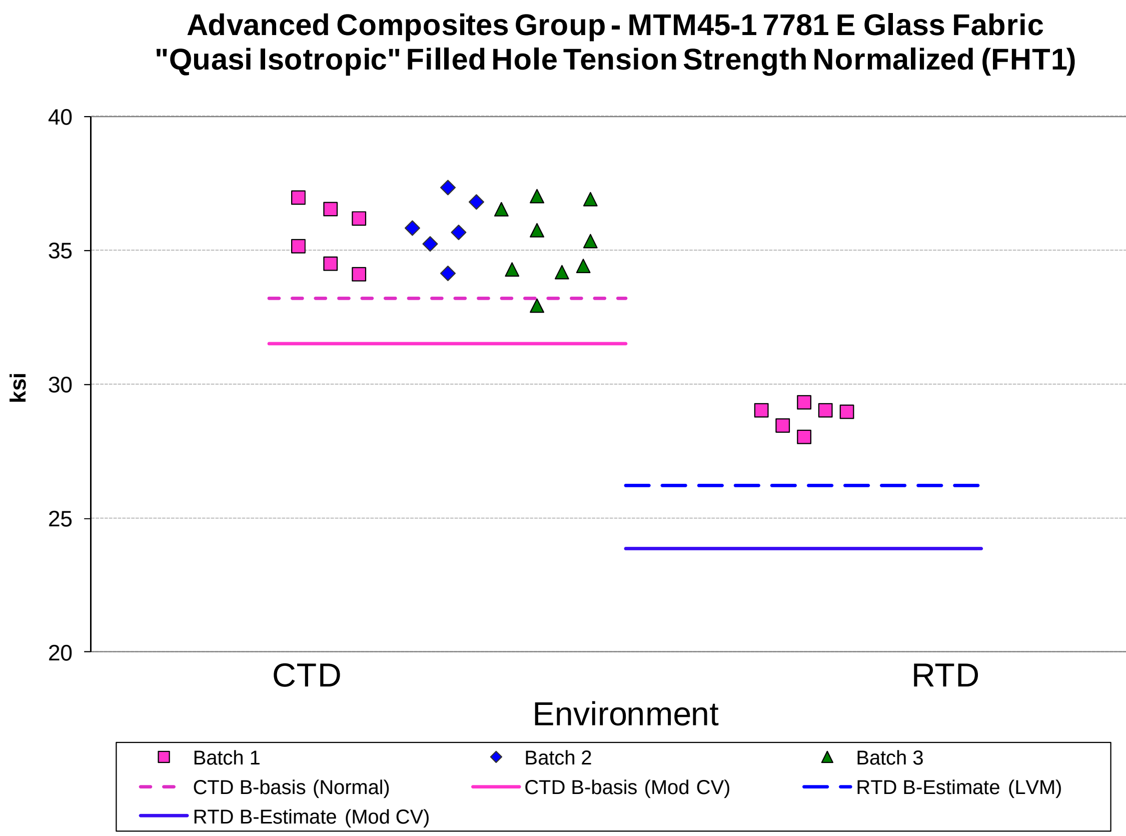

Figure 17: Batch plot for FHT1 Strength normalized

Quasi Isotropic Filled-Hole Tension Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	35.54	28.83	36.37	29.62
Stdev	1.23	0.47	1.69	0.39
CV	3.46	1.64	4.65	1.32
Modified CV	6.00	8.00	6.33	8.00
Min	32.96	28.05	34.41	29.21
Max	37.36	29.35	40.41	30.06
No. Batches	3	1	3	1
No. Spec.	21	6	21	6
Basis Values and/or Estimates				
B-basis Value	33.19		33.15	
B-estimate		26.24		26.94
A-estimate	31.52	NA	30.85	NA
Method	Normal	LVM	Normal	LVM
Modified CV Basis Values and/or Estimates				
B-basis Value	31.47		31.99	
B-estimate		23.87		24.53
A-estimate	28.58	NA	28.86	NA
Method	Normal	LVM	Normal	LVM

Table 5-12 : Statistics, Basis Values and/or Estimates for FHT1 Strength data

5.7 Quasi Isotropic Filled Hole Compression (FHC1) Properties

There was insufficient data to produce any basis values that would not be considered estimates. The FHC1 ETW2 data did not pass the normality test. The lognormal distribution was the best fit. There were no outliers. Statistics and A- and B-estimates are given for the FHC1 strength data in Table 5-13. The normalized data and B-estimates are shown graphically in Figure 18.

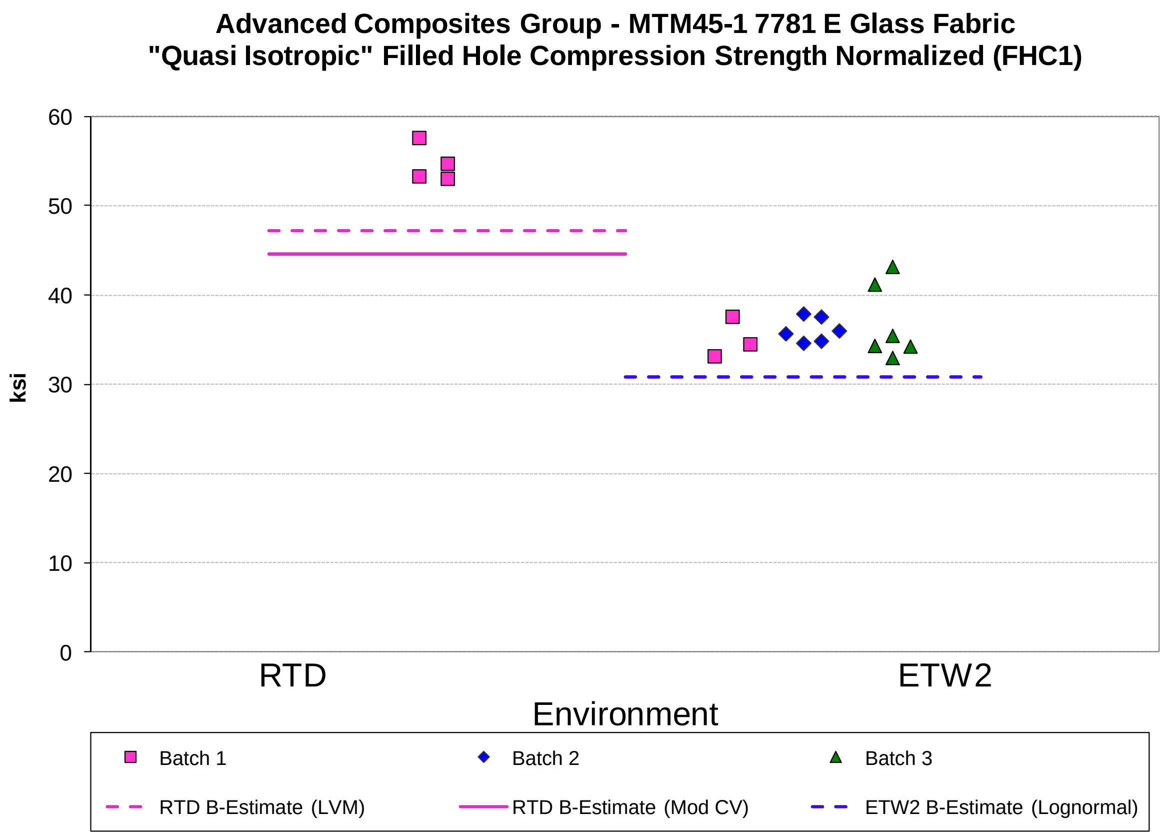

Figure 18: Batch plot for FHC1 Strength normalized

Quasi isotropic Filled-Hole Compression Strength (ksi) Basis Values and Statistics				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	54.69	36.24	56.88	37.14
Stdev	2.09	2.87	2.35	2.66
CV	3.83	7.91	4.14	7.16
Modified CV	8.00	7.96	8.00	7.58
Min	53.06	33.00	54.99	34.14
Max	57.63	43.20	59.98	43.20
No. Batches	1	3	1	3
No. Spec.	4	15	4	15
Basis Values and/or Estimates				
B-estimate	47.23	30.88	50.77	31.64
A-estimate	NA	27.65	NA	27.78
Method	LVM	Lognormal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-estimate	44.53	NA	46.31	31.32
A-estimate	NA	NA	NA	27.23
Method	LVM	NA	LVM	Normal

Table 5-13 : Statistics, Basis Values and/or Estimates for FHC1 Strength data

5.8 Quasi Isotropic Pin Bearing (PB1) Properties

The PB1 2% offset as measured data could be pooled across the two environments, but the normalized data could not due to failing Levene's test for equality of variance. However, after the modified CV transformation was applied to the normalized data, pooling the two environments was acceptable. The ultimate strength data could not be pooled due to non-normality of the pooled dataset, both normalized and as measured.

There were no outliers in the 2% offset data. There were two outliers in the ultimate strength data. One outlier was on the high side of batch one in the ETW2 environment. It was an outlier both before and after pooling across the three batches for the normalized data and only after pooling the three batches for the as measured data. The other outlier was on the low side of batch two in the RTD environment. It was an outlier only for the normalized data and only after pooling the three batches.

The normalized data and the B-basis values are shown graphically in Figure 19. Statistics and basis values are given for PB1strength data in Table 5-14. The normalized data and B-basis values are shown graphically in Figure 20.

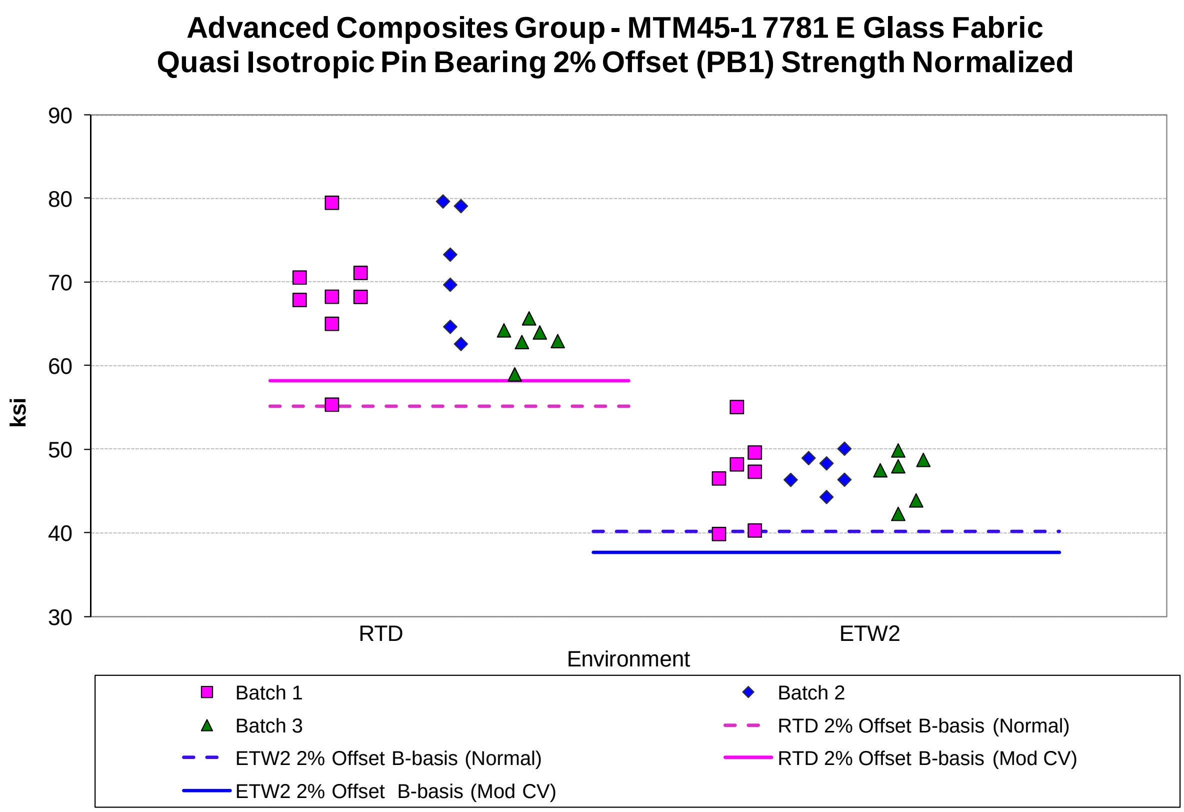

Figure 19: Batch plot for PB1 2% Offset Strength normalized

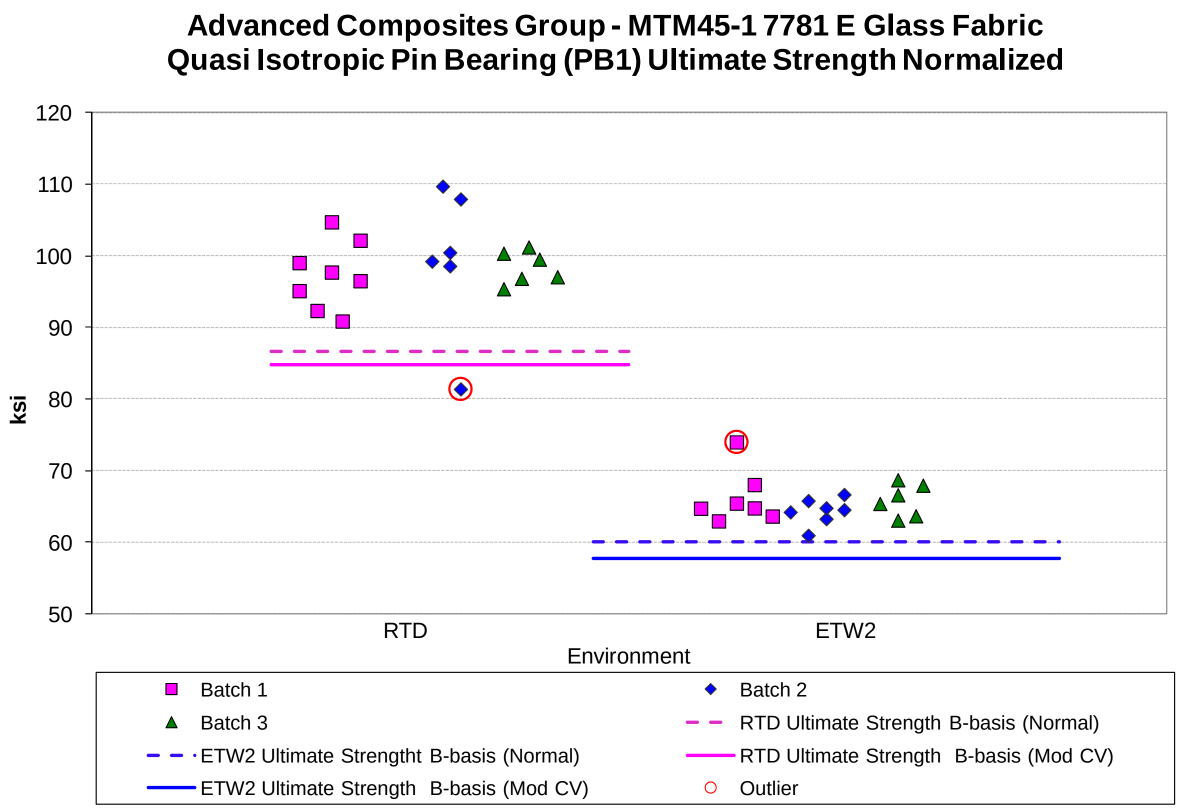

Figure 20: Batch plot for PB1 Ultimate Strength normalized

Quasi Isotropic Pin Bearing Strength (ksi) Basis Values and Statistics								
	Normalized				As measured			
	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW2	RTD	ETW2	RTD	ETW2	RTD	ETW2
Mean	67.73	47.18	98.29	65.45	67.98	47.39	98.61	65.75
Stdev	6.55	3.63	6.07	2.77	6.30	3.78	4.79	3.33
CV	9.67	7.70	6.18	4.24	9.26	7.98	4.85	5.07
Modified CV	9.67	7.85	7.09	6.12	9.26	7.99	6.43	6.53
Min	55.41	39.94	81.37	60.95	56.35	39.94	88.77	59.85
Max	79.71	55.12	109.68	73.98	80.38	56.05	107.89	75.23
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	20	20	20	20	20	20	20	20
Basis Values and/or Estimates								
B-basis Value	55.12	40.18	86.59	60.11	58.70	38.10	89.39	58.67
A-estimate	46.15	35.21	78.27	56.30	52.33	31.74	82.83	43.78
Method	Normal	Normal	Normal	Normal	pooled	pooled	Normal	Non-Parametric
Modified CV Basis Values and/or Estimates								
B-basis Value	58.22	37.67	84.86	57.73	58.69	38.10	86.40	NA
A-estimate	51.70	31.15	75.32	52.25	52.33	31.73	77.72	NA
Method	pooled	pooled	Normal	Normal	pooled	pooled	Normal	NA

Table 5-14 : Statistics, Basis Values and/or Estimates for PB1 Strength data

5.9 Compression After Impact (CAI) Data

Basis values are not computed for these properties. However, the summary statistics are presented in Table 5-15. The normalized data are shown graphically in Figure 21.

Figure 21: Batch plot for CAI Ultimate Strength normalized data

Compression After Impact Strength (ksi)		
RTD Environment	Normalized	As Measured
Mean	22.83	22.55
Stdev	0.74	0.70
CV	3.25	3.08
Modified CV	6.00	6.00
Min	21.36	21.01
Max	23.44	23.08
No. Batches	1	1
No. Spec.	7	7

Table 5-15 : Statistics for CAI Strength data

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

The ILT and CBS data is not normalized. Basis values are not computed for these properties. However, the summary statistics are presented in Table 5-16 and the data are displayed graphically in Figure 22. The lowest value of the CTD data is identified as an outlier. Only one batch of material was tested.

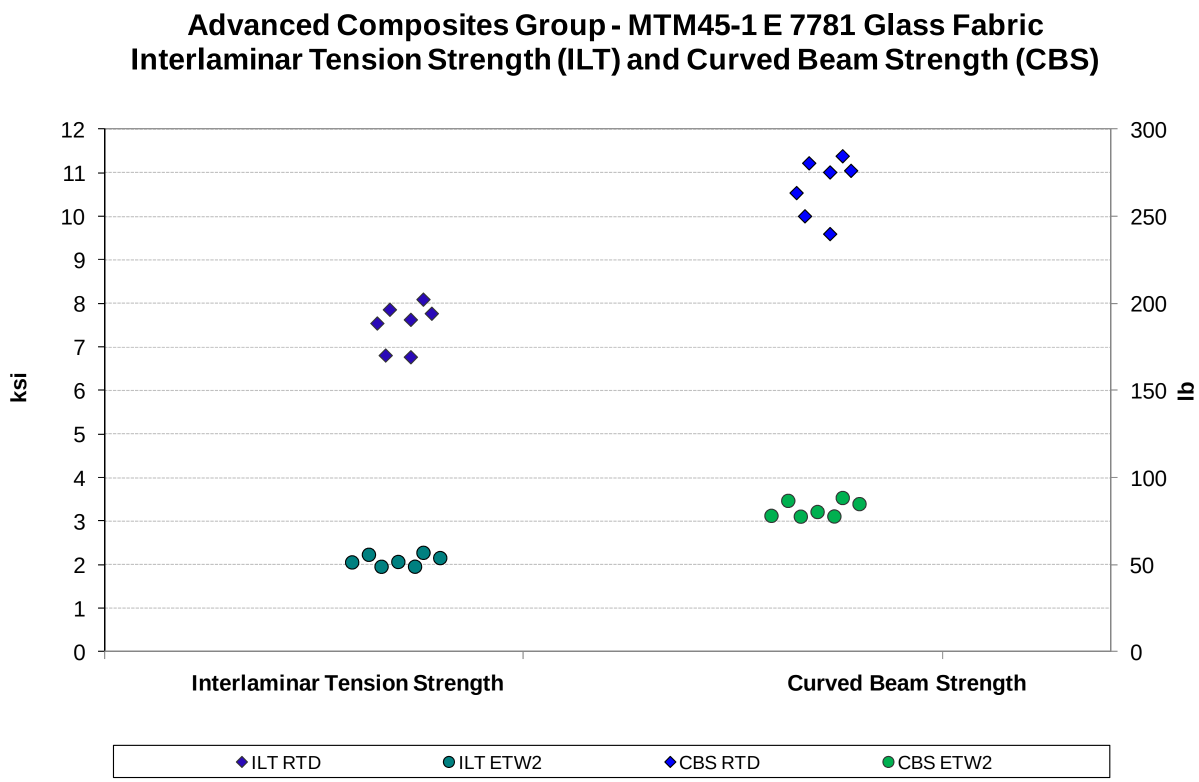

Figure 22: Plot for Interlaminar Tension and Curved Beam Strength

Property	ILT (ksi)		CBS (lb)	
Env	RTD	ETW2	RTD	ETW2
Mean	7.50	2.11	267.34	82.21
Stdev	0.51	0.13	16.74	4.58
CV	6.85	5.98	6.26	5.57
Mod CV	7.42	6.99	7.13	6.79
Min	6.78	1.96	240.08	77.88
Max	8.10	2.28	284.78	88.61
No. Batches	1	1	1	1
No. Spec.	7	7	7	7

Table 5-16: Statistics for ILT and CBS Strength Data

6. Outliers

Outliers were identified according to the standards documented in section 2.1.5, which are in accordance with the guidelines developed in CMH-17 Rev G section 8.3.3. An outlier may be an outlier in the normalized data, the as measured data, or both. A specimen may be an outlier for the batch only (before pooling the three batches within a condition together) or for the condition (after pooling the three batches within a condition together) or both.

Approximately 5 out of 100 specimens will be identified as outliers due to the expected random variation of the data. This test is used only to identify specimens to be investigated for a cause of the extreme observation. Outliers that have an identifiable cause are removed from the dataset as they inject bias into the computation of statistics and basis values. Specimens that are outliers for the condition and in both the normalized and as measured data are typically more extreme and more likely to have a specific cause and be removed from the dataset than other outliers. Specimens that are outliers only for the batch, but not the condition and specimens that are identified as outliers only for the normalized data or the as measured data but not both, are typical of normal random variation.

Outliers are listed in Table 6-1. These outliers were included in the analysis for their respective test properties.

Test	Condition	Batch	Specimen Number	Normalized Strength	Strength As Measured	High/ Low	Batch Outlier	Condition Outlier
WT	ETW	3	AITR1392-8HG-WT-C-MH2-ETW-3	Not an outlier	45.80	High	Yes	No
FT	RTD	3	AITR1392-8HG-FT-C-MH1-RTD-2	55.00	Not an outlier	Low	Yes	Yes
FT	ETW	1	AITR1392-8HG-FT-A-MH1-ETW-1	35.42	Not an outlier	Low	No	Yes
FT	ETW2	1	AITR1392-8HG-FT-A-MH2-ETW2-1	32.45	Not an outlier	Low	No	Yes
FT	ETW2	2	AITR1392-8HG-FT-B-MH1-ETW2-2	35.04	Not an outlier	Low	Yes	No
FC	ETW2	1	NTP AITR1392-CYT-8HG-NIAR-FC-A-MH2-1-ETW2-3	47.00	44.36	High	Yes	Yes - As Meas No - Norm
IPS 2% Offset	RTD	2	AITR1392-8HG-IPS-B-MH1-RTD-1	NA	6.80	High	No	Yes
SBS	ETD	1	AITR1392-8HG-SBS-A-MH1-ETD-1	NA	8.73	High	Yes	No
SBS	ETW	3	AITR1392-8HG-SBS-C-MH1-ETW-2	NA	4.76	High	Yes	No
UNT1	CTD	3	AITR1392-8HG-UNT1-C-MH1-CTD-1	Not an outlier	68.58	High	Yes	Yes
OHT1	RTD	2	AITR1392-8HG-OHT1-B-MH2-RTD-2	25.27	Not an outlier	Low	Yes	No
OHT2	CTD	2	AITR1392-8HG-OHT2-B-MH1-CTD-1	34.93	Not an outlier	High	No	Yes
OHT3	CTD	3	AITR1392-8HG-OHT3-C-MH2-CTD-3	42.06	42.92	High	Yes	No
PB1 - Ult. Str.	RTD	2	AITR1392-8HG-PB1-B-MH1-RTD-1	81.37	Not an outlier	Low	No	Yes
PB1 - Ult. Str.	ETW2	1	AITR1392-8HG-PB1-A-MH1-ETW2-4	73.98	75.23	High	Yes - Norm	Yes

Table 6-1 : List of outliers

7. References

1. Snedecor, G.W. and Cochran, W.G., *Statistical Methods*, 7th ed., The Iowa State University Press, 1980, pp. 252-253.
2. Stefansky, W., "Rejecting Outliers in Factorial Designs," *Technometrics*, Vol. 14, 1972, pp. 469-479.
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