Report No: NCP-RP-2009-008 N/C
Report Date: March 25, 2016

CYTEC
(Formerly Advanced Composites Group)
MTM45-1/ 12K HTS5631 145gsm
32%RW Unidirectional
Qualification Statistical Analysis Report

FAA Special Project Number SP3505WI-Q

NCAMP Report Number: NCP-RP-2009-008 N/C

Report Date: March 25, 2016

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REVISIONS:

Rev	By	Date	Rev App By	Pages Revised or Added
N/C	Elizabeth Clarkson	3/25/2016	Royal Lovingfoss	Document Initial Release

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1. Introduction

This report contains statistical analysis of ACG MTM45-1 HTS(12K) Unitape material property data published in NCAMP Test Report CAM-RP-2009-010 Rev B. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP3505WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

B-Basis values and estimates were calculated using a variety of techniques that are detailed in section two. Qualification material was procured in accordance with ACG material specification ACGM 1001-14 Revision A dated May 25, 2006. An equivalent NCAMP Material Specification NMS 451/14 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 with baseline "MH" cure cycle has been created. The panels were fabricated at Bell Helicopter Textron lnc., 600 East Hurst Blvd. Hurst, TX 76053. The ACG Test Plan AI/TR/1392 Revision E was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

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 along with the specific requirement(s) the data fails to meet. 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 Composite Materials Handbook 17 (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 451/14. NMS 451/14 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 451/14.* NMS 451/14 is a free, publicly available, non-proprietary aerospace industry material specification.

This report is intended for general distribution to the public, either freely or at a price that does not exceed the cost of reproduction (e.g. printing) and distribution (e.g. postage).

1.1 Symbols and Abbreviations

Test Property	Abbreviation
Longitudinal Compression	LC
Longitudinal Tension	LT
Transverse Compression	TC
Transverse Tension	TT
In Plane Shear	IPS
Unnotched Tension	UNT
Unnotched Compression	UNC
Short Beam Strength	SBS
Open Hole Tension	OHT
Open Hole Compression	OHC
Filled Hole Tension	FHT
Filled Hole Compression	FHC
Pin Bearing Strength	PB
Curved Beam Strength	CBS
Interlaminar Tension	ILT
Compression After Impact	CAI

Table 1-1: Test Property Abbreviations

Test Property	Symbol
Longitudinal Compression Strength	F_1^{cu}
Longitudinal Compression Modulus	E_1^{c}
Longitudinal Compression Poisson's Ratio	ν_{12}^{c}
Longitudinal Tension Strength	F_1^{tu}
Longitudinal Tension Modulus	E_1^{t}
Transverse Compression Strength	F_2^{cu}
Transverse Compression Modulus	E_2^{c}
Transverse Compression Poisson's Ratio	ν_{21}^{c}
Transverse Tension Strength	F_2^{tu}
Transverse 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	Abbreviation
Cold Temperature Dry (−65°)	CTD
Room Temperature Dry (75°)	RTD
Elevated Temperature Dry (200°)	ETD
Elevated Temperature Wet (200°)	ETW
Elevated Temperature Wet (250°)	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.

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2009-010 Rev B.

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 based on the pooled data was used to compute the basis values.

When pooling across environments was not advisable because the data was not eligible for pooling and engineering judgment indicated there was no justification for overriding the result, then B-Basis values were computed for each environmental condition separately using Stat17 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. When appropriate, a single batch or two batch estimate may be provided in addition to the ANOVA estimate.

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 the requirements of CMH-17 Rev G 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 and X_i refers to the individual specimen measurements.

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. $$S_p = \sqrt{\frac{\sum_{i=1}^{k}(n_i - 1)S_i^2}{\sum_{i=1}^{k}(n_i - 1)}}$$ **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.

Pooled Coefficient of Variation $$= \frac{S_p}{1} = S_p$$ **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.

Basis Values: $$A-basis = \overline{X} - K_a S$$ $$B-basis = \overline{X} - K_b S$$ **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:

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

$$K_b = \frac{1.2816}{\sqrt{q(f)}} + \sqrt{\frac{1}{c_B(f)\cdot n_j} + \left(\frac{b_B(f)}{2c_B(f)}\right)^2} - \frac{b_B(f)}{2c_B(f)}$$ **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 = $$CV^* = \begin{cases} .06 & \text{if } CV < .04 \\ \frac{CV}{2} + .04 & \text{if } .04 \le CV < .08 \\ CV & \text{if } CV \ge .08 \end{cases}$$ **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 $S_i^* = CV^* \cdot \bar{X}_i$ for each batch. Transform the data in each batch as follows:

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

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

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.

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

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

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

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

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.

$$MNR = \frac{\max\limits_{all\ i}\left|X_i - \bar{X}\right|}{S}, i = 1 \ldots n \quad \textbf{Equation 23}$$

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

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

$$OSL = \frac{1}{1+e^{-0.48+0.78\ln(AD^*)+4.58AD^*}}, \quad AD^* = \left(1 + \frac{0.2}{\sqrt{n}}\right) AD$$ **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 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 32

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 STAT17

This section contains the details of the specific formulas STAT17 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); Stat17 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 $x_1, ..., x_n$, and the sample observations ordered from least to greatest by $x_{(1)}, ..., x_{(n)}$.

2.2.2 Computing Normal Distribution Basis Values

Stat17 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:

$$k_B \approx 1.282 + \exp\{0.958 - 0.520\ln(n) + 3.19/n\} \quad \textbf{Equation 33}$$

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 34**

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

$$e^{-\left(a/\alpha\right)^{\beta}} - e^{-\left(b/\alpha\right)^{\beta}}$$ **Equation 35**

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 36**

$$\frac{n}{\hat{\beta}} - n\ln\hat{\alpha} + \sum_{i=1}^{n}\ln x_i - \sum_{i=1}^{n}\left[\frac{x_i}{\hat{\alpha}}\right]^{\hat{\beta}}\left(\ln x_i - \ln\hat{\alpha}\right) = 0$$ **Equation 37**

Stat17 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 38**

The Anderson-Darling test statistic is

$$\mathrm{AD} = \sum_{i=1}^{n} \frac{1-2i}{n} \left[\ell n \left[1 - \exp(-z_{(i)}) \right] - z_{(n+1-i)} \right] - n$$ **Equation 39**

and the observed significance level is

$$\mathrm{OSL} = 1/\left\{ 1 + \exp[-0.10 + 1.24 \ln(\mathrm{AD}^*) + 4.48 \mathrm{AD}^*] \right\}$$ **Equation 40**

where $$AD^* = \left(1 + \frac{0.2}{\sqrt{n}} \right) AD$$ Equation 41

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 42**

where

$$\hat{q} = \hat{\alpha} \left(0.10536 \right)^{1/\hat{\beta}}$$ **Equation 43**

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

$$\hat{q} = \hat{\alpha}(0.01005)^{1/\beta}$$ **Equation 44**

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 45**

$$V_A \approx 6.649 + \exp\left[2.55 - 0.526\ln(n) + \frac{4.76}{n}\right]$$ **Equation 46**

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:

$$z_{(i)} = \frac{\ln\left(x_{(i)}\right) - \bar{x}_L}{s_L}, \quad \text{for } i = 1, \ldots, n$$ **Equation 47**

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 be 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:

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

Equation 48

For A-Basis values:

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

Equation 49

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.

2.2.3.2 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:

$$B = x_{(r)}\left[\frac{x_{(1)}}{x_{(r)}}\right]^k \qquad \textbf{Equation 50}$$

The A-basis value is:

$$A = x_{(n)}\left[\frac{x_{(1)}}{x_{(n)}}\right]^k \qquad \textbf{Equation 51}$$

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

2.2.4 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 2.1.8). 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.

2.2.4.1 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 $\left(n_i, \bar{x}_i, s_i^2\right)$ 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:

$$SSB = \sum_{i=1}^{k} n_i \bar{x}_I^2 - n\bar{x}^2$$ **Equation 52**

$$SST = \sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij}^2 - n\bar{x}^2$$ **Equation 53**

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

$$SSE = SST - SSB$$ **Equation 54**

Next, the mean sums of squares are computed:

$$MSB = \frac{SSB}{k-1}$$ **Equation 55**

$$MSE = \frac{SSE}{n-k}$$ **Equation 56**

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

$$n' = \frac{n - \frac{1}{n}\sum_{i=1}^{k} n_i^2}{k-1}$$ **Equation 57**

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

$$S = \sqrt{\frac{MSB}{n'} + \left(\frac{n'-1}{n'}\right)MSE}$$ **Equation 58**

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

$$u = \frac{MSB}{MSE}$$ **Equation 59**

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

$$T = \frac{k_0 - \frac{k_1}{\sqrt{n'}} + \left(k_1 - k_0\right)\sqrt{\frac{u}{u + n' - 1}}}{1 - \frac{1}{\sqrt{n'}}}$$ **Equation 60**

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 batches 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 61**

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 62**

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 63**

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													
N1+N2-2	2	3	4	5	6	7	8	9	10	11	12	13	14	15
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

2.5 0º Lamina Strength Derivation

Lamina strength values in the 0º direction were not obtained directly for any conditions during compression tests. They are derived from the cross-ply lamina test results using a back out formula. Unless stated otherwise, the 0° lamina strength values were derived using the following formula:

$F_{0^\circ}^{u} = F_{0^\circ/90^\circ}^{u} \cdot BF$ where BF is the backout factor.

$F_{0^\circ/90^\circ}^{u}$ =UNC0 or UNT0 strength values

$$BF = \frac{E_1\left[V_0 E_2 + \left(1 - V_0\right) E_1\right] - \left(\nu_{12} E_2\right)^2}{\left[V_0 E_1 + \left(1 - V_0\right) E_2\right]\left[V_0 E_2 + \left(1 - V_0\right) E_1\right] - \left(\nu_{12} E_2\right)^2} \qquad \text{Equation 64}$$

V_0=fraction of 0º plies in the cross-ply laminate (½ for UNT0 and 1/3 for UNC0)
E_1 = Average across of batches of modulus for LC and LT as appropriate
E_2 = Average across of batches of modulus for TC and TT as appropriate
ν_{12} = major Poisson's ratio of 0º plies from an average of all batches

This formula can also be found in CMH-17 Rev G in section 2.4.2, equation 2.4.2.1(b).

In computing these strength values, the values for each environment are computed separately. The compression values are computed using only compression data, the tension values are computed using only tension data. Both normalized and as measured computations are done using the as measured and normalized strength values from the UNC0 and UNT0 strength values.

2.5.1 0º Lamina Strength Derivation (Alternate Formula)

In some cases, the previous formula cannot be used or the manufacturer may recommend the alternate formula be used. For example, if there were no ETD tests run for transverse tension and compression, then the value for E_2 was not available. In that case, an alternative formula is needed to compute the strength values for longitudinal tension and compression. It is similar to, but not quite the same as the formula detailed above. It requires the UNC0 and UNT0 strength and modulus data in addition to the LC and LT modulus data.

The 0° lamina strength values for the LC ETD condition were derived using the formula:

$$F_{0^\circ}^{cu} = F_{0^\circ/90^\circ}^{cu} \frac{E_1^c}{E_{0^\circ/90^\circ}^c}, \quad F_{0^\circ}^{tu} = F_{0^\circ/90^\circ}^{tu} \frac{E_1^t}{E_{0^\circ/90^\circ}^t} \qquad \text{Equation 65}$$

with $F_{0^\circ}^{cu}, F_{0^\circ}^{tu}$ the derived mean lamina strength value for compression and tension respectively

$F_{0^\circ/90^\circ}^{cu}, \quad F_{0^\circ/90^\circ}^{tu}$ are the mean strength values for UNC0 and UNT0 respectively

$E_1^c, \quad E_1^t$ are the modulus values for LC and LT respectively

$E_{0^\circ/90^\circ}^c, \quad E_{0^\circ/90^\circ}^t$ are the modulus values for UNC0 and UNT0 respectively

This formula can also be found in CMH-17 Rev G in section 2.4.2, equation 2.4.2.1(d).

3. Summary Tables

The basis values for all tests are summarized in the following tables. The NCAMP recommended B-basis values meet all requirements of CMH-17 Rev G. However, not all test data meets those requirements. The summary tables provide a complete listing of all computed basis values and estimates of basis values. Data that does not meet the requirements of CMH-17 Rev G 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 and estimates computed without that modification are presented for all tests.

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/ HTS5631 12K Unitape

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	LT from UNT0	LC from UNC0	TT*	TC*	SBS*	IPS* 0.2% Offset	IPS* 5% Strain
CTD (-65 F)	B-basis	274.27	204.42	8.01	31.12	16.97	7.57**	10.59
	Mean	306.98	232.59	8.91	36.64	19.55	8.34	12.01
	CV	6.00	8.25	6.57	7.98	6.79	8.29	6.00
RTD (75 F)	B-basis	278.02	165.13	7.82	24.93	12.82	NA:A	8.99
	Mean	310.72	193.30	8.72	28.29	14.52	6.07	10.18
	CV	6.00	6.52	7.64	6.08	6.00	2.19	6.00
ETD (200 F)	B-basis					9.48		
	Mean					10.74		
	CV					6.00		
ETW (200 F)	B-basis	287.18	148.11	3.67	15.33	7.50	3.22	5.14
	Mean	319.89	176.28	4.56	17.36	8.47	3.65	5.84
	CV	6.00	7.89	8.02	6.00	6.00	6.00	6.00
ETW2 (250 F)	B-basis	289.14	112.52	3.47	12.62	6.16	2.24	NA:I
	Mean	321.85	140.28	4.36	14.27	6.98	2.64	4.48
	CV	6.00	12.96	9.05	6.00	6.00	7.90	3.24

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 3-1 : NCAMP recommended B-basis values for lamina test data

NCAMP Recommended B-basis Values for
ACG - MTM45-1/ HTS5631 12K Unitape

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	LSBS*
"Quasi-Isotropic"	CTD (-65 F)	B-basis	54.69		NA:A		103.50			
		Mean	61.17		64.25		115.96			
		CV	6.00		3.94		6.00			
	RTD (75 F)	B-basis	53.99	42.45	NA:I	NA:I	106.06	78.72	91.81	9.74
		Mean	60.47	47.44	64.63	66.64	118.52	88.02	102.47	11.22
		CV	6.00	6.00	1.99	7.13	6.00	6.00	6.14	6.74
	ETW2 (250 F)	B-basis	56.17	33.30		39.06	NA:I	52.63	81.01	5.22
		Mean	62.64	38.28		46.16	111.76	61.81	91.67	5.91
		CV	6.00	7.41		7.89	1.95	8.61	6.00	6.00
"Soft"	CTD (-65 F)	B-basis	40.61		NA:I		NA:I			
		Mean	45.99		47.97		73.34			
		CV	6.00		1.72		2.08			
	RTD (75 F)	B-basis	NA:I	NA:I	NA:I	NA:I	NA:I	NA:I	NA:I	
		Mean	42.06	38.93	43.54	51.42	66.22	58.30	109.32	
		CV	1.71	1.67	1.99	2.82	1.97	5.72	2.63	
	ETW2 (250 F)	B-basis	NA:I	24.61	NA:I	30.43	NA:I	NA:I	74.87	
		Mean	38.26	27.87	38.07	34.46	52.11	41.81	86.68	
		CV	1.28	6.00	1.86	6.00	3.26	8.77	6.99	
"Hard"	CTD (-65 F)	B-basis	82.99		NA:I		NA:I			
		Mean	94.94		98.06		184.13			
		CV	6.46		4.66		3.70			
	RTD (75 F)	B-basis	NA:I	NA:I	NA:I	NA:I	NA:I	NA:I	NA:I	
		Mean	98.29	64.11	98.30	86.68	188.29	100.88	112.19	
		CV	3.96	3.29	4.19	1.00	1.35	4.71	5.86	
	ETW2 (250 F)	B-basis	NA:I	42.95		53.72	NA:I	NA:I	74.39	
		Mean	112.67	49.04		61.40	181.51	68.66	86.37	
		CV	5.22	6.30		6.33	2.99	6.91	7.12	

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 : Recommended B-basis values for laminate test data

3.2 Lamina and Laminate Summary Tables

Material:	Advanced Composites Group - MTM45-1 HTS(12K) Unitape				**ACG - MTM45-1/ HTS 12K Unitape Lamina Properties**
Resin:	MTM45-1				
Fiber:	Tenax-E HTS40 F13 12K 800tex				
Material Specificaton:	NCAMP Material Specification NMS 451/14 Material Specification				
Process Specification:	NCAMP Process Specification NPS 81451 with baseline “MH” cure cycle				
	T_g(dry): 397.4° F	**T_g(wet):** 332.59° F	**T_g METHOD:**	DMA (SRM 18-94)	

Date of fiber manufacture	October 2005 - January 2006	**Date of testing:**	10/2008 to 2/2009
Date of resin manufacture	April 6, 2006 to April 12, 2006	**Date of data submittal:**	11/2008 to 3/2009
Date of prepreg manufacture	April 6, 2006 to April 12, 2006	**Date of analysis:**	11/2008 to 7/2009
Date of composite manufacture	2/2007 to 3/2007; 6/27/2007 and 9/26/2007 to 11/10/2007		

LAMINA MECHANICAL PROPERTY SUMMARY

Data reported: As measured followed by normalized values in parentheses, normalizing tply: 0.0055 in

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

Properties	CTD			RTD			ETD			ETW			ETW2		
Test	B-Basis value or estimate	Modified CV B-basis value or estimate	Mean	B-Basis value or estimate	Modified CV B-basis value or	Mean	B-Basis value or estimate	Modified CV B-basis value	Mean	B-Basis value or estimate	Modified CV B-basis value or estimate	Mean	B-Basis value or estimate	Modified CV B-basis value or estimate	Mean
F_1^{cu} (ksi)	202.22	201.35	229.60	167.89	167.02	195.27				146.60	145.72	173.97	111.85	110.98	138.83
from UNC0	205.32	204.42	232.59	166.03	165.13	193.30				149.01	148.11	176.28	113.40	112.52	140.28
E_1^c (Msi)			17.01			17.20						17.26			17.32
			17.24			17.02						17.50			17.50
ν_{12}^c			0.365			0.350						0.326			0.396
F_1^{tu} (ksi)	282.59	270.44	302.74	286.69	274.54	306.84				247.78	283.04	315.34	285.09	285.34	317.64
from UNT0	290.27	274.27	306.98	294.01	278.02	310.72				270.73	287.18	319.89	297.85	289.14	321.85
E_1^t (Msi)			18.80			18.76						19.38			19.90
			19.07			19.00						19.66			20.16
ν_{12}^t			0.322			0.318						0.332			0.338
F_2^{cu} (ksi)	31.14	31.12	36.64	25.99	24.93	28.29				14.72	15.33	17.36	11.92	12.62	14.27
E_2^c (Msi)			1.33			1.26						1.15			1.07
ν_{21}^c			0.025			0.025						0.020			0.022
F_2^{tu} (ksi)	8.09	8.01	8.91	7.90	7.82	8.72				3.74	3.67	4.56	3.54	3.47	4.36
E_2^t (Msi)			1.31			1.20						1.04			0.84
UNC0 (ksi)	95.55		123.01	97.59	94.65	108.65	62.51	80.55	94.81	79.44	79.24	93.64	51.22		71.73
	105.11		124.96	99.47	96.29	110.31	63.16	81.79	96.27	80.96	80.76	95.44	50.38		72.54
UNC0 (Msi)			9.12			9.57			9.12			9.29			8.95
			9.26			9.71			9.27			9.47			9.05
ν of UNC0			0.047			0.047			0.04			0.045			0.039
UNT0 (ksi)	149.83	143.49	160.45	150.54	144.20	161.16				131.00	149.76	166.72	147.36	147.22	164.18
	155.85	147.43	164.78	156.41	147.99	165.34				143.67	152.41	169.75	155.71	150.91	168.26
UNT0 (Msi)			9.97			9.85						10.25			10.28
			10.23			10.11						10.43			10.54
$F_{12}^{s5\%}$ (ksi)	11.28	10.59	12.01	9.89	8.99	10.18				5.03	5.14	5.84	3.98	3.25	4.48
$F_{12}^{s0.2\%}$ (ksi)	7.57		8.34	5.43	5.37	6.07				3.46	3.22	3.65	2.25	2.24	2.64
G_{12}^s (Msi)			0.703			0.571						0.399			0.298
SBS (ksi)	15.22	16.97	19.55	13.68	12.82	14.52	10.48	9.48	10.74	7.20	7.50	8.47	5.68	6.16	6.98

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

ACG - MTM45-1/ HTS 12K Unitape Laminate Properties Summary

Material: Advanced Composites Group - MTM45-1 HTS(12K) Unitape
Resin: MTM45-1
Fiber: Tenax-J HTS40 E13 3K 200TEX
Material Specificaton: NCAMP Material Specification NMS 451/14 Material Specification
Process Specification: NCAMP Process Specification NPS 81451 with baseline “MH” cure cycle

T_g(dry): 397.4° F **T_g(wet)** 332.59° F **T_g METHOD:** DMA (SRM 18-94)

Date of fiber manufacture	October 2005 - January 2006	**Date of testing:**	10/2008 to 2/2009
Date of resin manufacture	April 6, 2006 to April 12, 2006	**Date of data submittal:**	11/2008 to 3/2009
Date of prepreg manufacture	April 6, 2006 to April 12, 2006	**Date of analysis:**	11/2008 to 7/2009
Date of composite manufacture	2/2007 to 3/2007; 6/27/2007 and 9/26/2007 to 11/10/2007		

LAMINATE MECHANICAL PROPERTY SUMMARY

Data reported: As measured followed by normalized values in parentheses, normalizing tply: 0.0055 in

Values shown in shaded boxes do not meet 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 (Layup:)	Quasi Isotropic 25/50/25 B-basis value or estimate	Quasi Isotropic 25/50/25 Mod. CV B-basis value or estimate	Quasi Isotropic 25/50/25 Mean	"Soft" 10/80/10 B-basis value or estimate	"Soft" 10/80/10 Mod. CV B-basis value or estimate	"Soft" 10/80/10 Mean	"Hard" 50/40/10 B-basis value or estimate	"Hard" 50/40/10 Mod. CV B-basis value or estimate	"Hard" 50/40/10 Mean
OHT normalized	Strength	CTD	ksi	57.91	54.69	61.17	44.73	40.61	45.99	78.19	82.99	94.94
		RTD	ksi	55.64	53.99	60.47	39.32	35.02	42.06	90.15	81.84	98.29
		ETW	ksi	57.74	56.14	63.47						
		ETW2	ksi	60.61	56.17	62.64	36.60	31.85	38.26	100.38	93.81	112.67
OHC normalized	Strength	RTD	ksi	40.24	42.45	47.44	34.82	32.41	38.93	57.35	53.38	64.11
		ETW	ksi	34.96	36.15	41.77						
		ETW2	ksi	28.72	33.30	38.28	24.22	24.61	27.87	44.60	42.95	49.04
UNT normalized	Strength	CTD	ksi	109.42	103.50	115.96	69.01	61.33	73.34	169.89	153.32	184.13
	Modulus		Msi			7.26			4.69			11.68
	Strength	RTD	ksi	111.98	106.06	118.52	61.91	55.14	66.22	176.03	156.78	188.29
	Modulus		Msi			7.12			4.65			11.29
	Strength	ETW2	ksi	104.39	97.71	111.76	48.56	43.39	52.11	170.14	151.13	181.51
	Modulus		Msi			7.18			3.95			11.24
UNC normalized	Strength	RTD	ksi	80.31	78.72	88.02	51.32	48.54	58.30	90.24	84.00	100.88
	Modulus		Msi			6.64			4.29			10.54
	Poisson's Ratio					0.340			0.561			0.433
	Strength	ETW	ksi	65.98	64.19	74.68						
	Modulus		Msi			6.72						
	Poisson's Ratio					0.338						
	Strength	ETW2	ksi	54.20	52.63	61.81	30.59	NA	41.81	50.22	NA	68.66
	Modulus		Msi			6.42			3.88			10.51
	Poisson's Ratio					0.312			0.504			0.403
FHT normalized	Strength	CTD	ksi	48.32	NA	64.25	45.08	39.94	47.97	88.50	81.65	98.06
		RTD	ksi	60.42	53.81	64.63	40.70	36.25	43.54	89.68	81.85	98.30
		ETW2	ksi				36.42	31.70	38.07			
FHC normalized	Strength	RTD	ksi	56.70	55.48	66.64	46.00	42.81	51.42	77.54	72.17	86.68
		ETW2	ksi	39.17	39.06	46.16	31.96	30.43	34.46	55.74	53.72	61.40
LSBS as-measured	Strength	RTD	ksi	8.19	9.74	11.22						
		ETW	ksi	5.64	5.61	6.74						
		ETW2	ksi	5.19	5.22	5.91						
Pin Bearing normalized	2% Offset Strength	RTD	ksi	78.64	91.81	102.47	97.79	91.02	109.32	98.43	93.41	112.19
		ETW2	ksi	84.84	81.01	91.67	76.58	74.87	86.68	75.87	74.39	86.37
ILT as-measured	Strength	RTD	ksi			4.15						
		ETW2	ksi			3.28						
CBS as-measured	Strength	RTD	lbs			168.77						
		ETW2	lbs			133.65						
CAI normalized	Strength	RTD	ksi			35.30						

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 of 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 2.1.4for 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 Longitudinal Tension (LT) Properties

The strength values for the LT data were derived from the UNT0 data according to the alternate equation (equation) 65 provided in section 2.5.1. The CTD and RTD data could be pooled, but the ETW and ETW2 data failed the Anderson Darling k-sample test (ADK) for batch-to-batch variation. This means those datasets require the ANOVA method to compute basis values which may result in overly conservative estimates of the basis values. However, the pooled dataset did pass the normality test, and ETW and ETW2 both passed the ADK test under the modified CV transformation, so the pooled modified CV values are provided for that dataset.

There were no outliers. Statistics, estimates and basis values are given for strength data in Table 4-1 and for the modulus data in Table 4-2. The normalized data and the B-basis values and B-estimates are shown graphically in Figure 4:1.

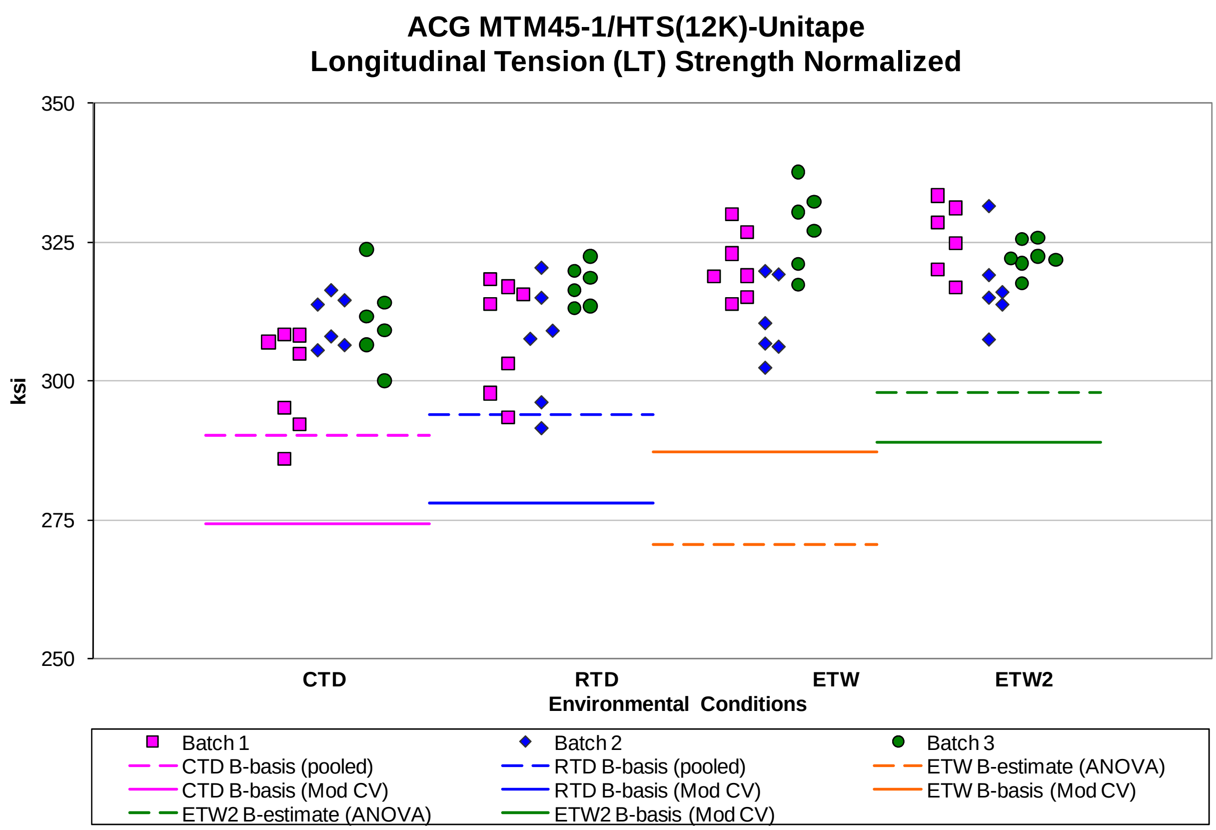

Figure 4:1 Batch plot for LT strength normalized

Longitudinal Tension (LT) Strength (ksi)								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	306.98	310.72	319.89	321.85	302.74	306.84	315.34	317.64
Stdev	8.84	9.67	9.47	6.68	9.77	12.41	11.85	7.76
CV	2.88	3.11	2.96	2.07	3.23	4.05	3.76	2.44
Mod CV	6.00	6.00	6.00	6.00	6.00	6.02	6.00	6.00
Min	285.99	291.57	302.45	307.53	284.36	278.71	294.65	299.71
Max	323.74	322.49	337.67	333.48	322.80	322.32	336.13	328.56
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19	19	19
Basis Values and/or Estimates								
B-basis Value	290.27	294.01			282.59	286.69		
B-estimates			270.73	297.85			247.78	285.09
A-estimate	278.86	282.60	235.66	280.75	268.82	272.93	199.56	261.88
Method	pooled	pooled	ANOVA	ANOVA	pooled	pooled	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates								
B-basis Value	274.27	278.02	287.18	289.14	270.44	274.54	283.04	285.34
A-estimate	252.60	256.34	265.50	267.47	249.04	253.14	261.64	263.94
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-1: Statistics, Basis Values and Estimates for LT strength from UNT0 data

Longitudinal Tension (LT) Modulus (msi)								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	19.07	19.00	19.66	20.16	18.80	18.76	19.38	19.90
Stdev	0.20	0.54	0.70	0.70	0.30	0.59	0.87	0.71
CV	1.04	2.82	3.54	3.47	1.58	3.12	4.47	3.55
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00	6.23	6.00
Min	18.70	17.39	18.81	19.29	18.15	17.71	18.37	18.63
Max	19.40	19.66	22.17	21.64	19.26	19.62	22.43	20.97
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19	19	19

Table 4-2: Statistics from LT modulus

4.2 Longitudinal Compression (LC) Properties

The strength values for the LC data were derived from the UNC0 data according to the alternate equation (equation 65) provided in section 2.5.1. The CTD and ETW2 datasets did not pass the normality test, but the pooled dataset was sufficiently close to normal for pooling across environments to be acceptable.

There were two outliers, both in batch 2 on the high side. The outlier in the ETW environment is only for the normalized data after pooling the three batches. The outlier in the ETW2 environment is for both as measured and normalized data and is an outlier before, but not after pooling the three batches. The outliers were retained for this analysis.

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

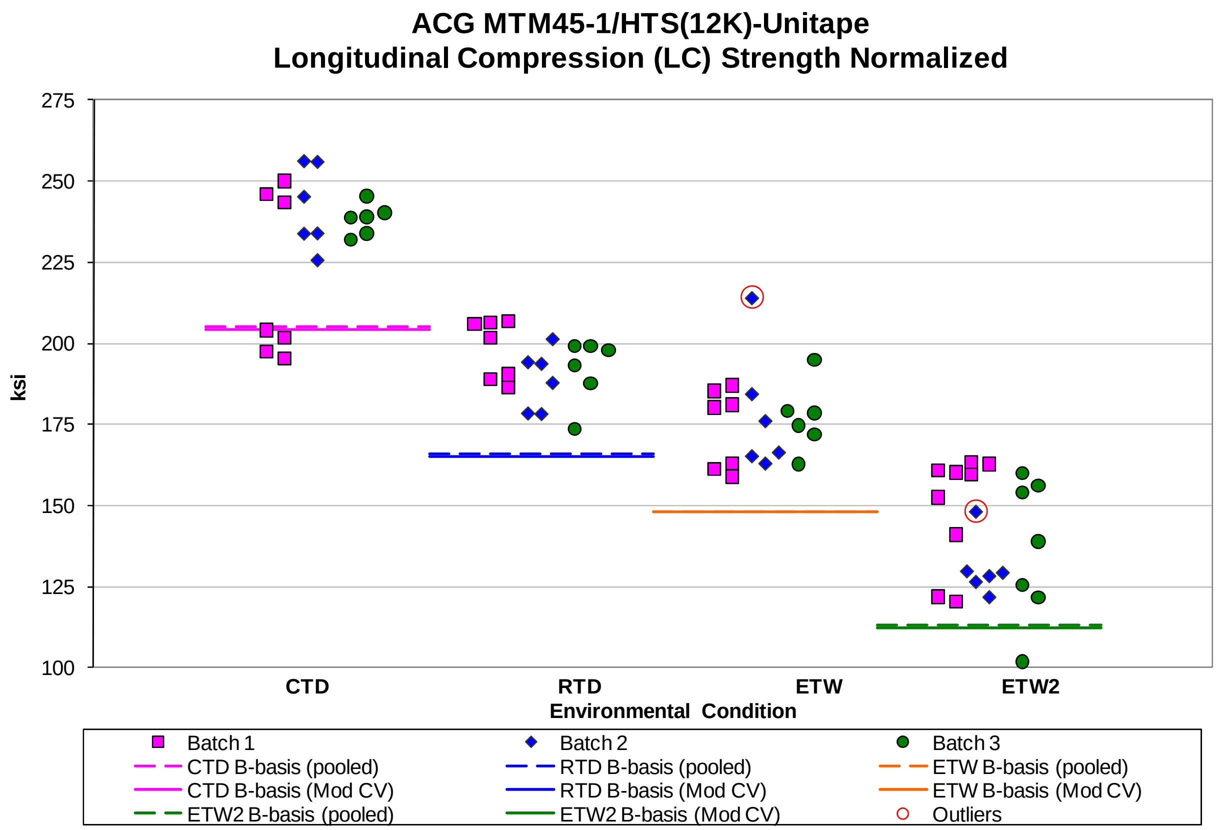

Figure 4:2 Batch plot for LC strength normalized

Longitudinal Compression (LC) Strength (ksi)								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	232.59	193.30	176.28	140.28	229.60	195.27	173.97	138.83
Stdev	19.20	9.74	13.72	18.19	19.53	10.20	13.54	17.98
CV	8.25	5.04	7.79	12.96	8.50	5.22	7.78	12.95
Mod CV	8.25	6.52	7.89	12.96	8.50	6.61	7.89	12.95
Min	195.25	173.64	158.90	101.89	189.90	176.67	155.08	103.10
Max	256.32	206.99	214.11	163.46	249.78	208.10	208.19	161.80
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	19	19	22	19	19	19	22
Basis Values and/or Estimates								
B-basis Value	205.32	166.03	149.01	113.40	202.22	167.89	146.60	111.85
A-estimate	187.27	147.99	130.96	95.30	184.11	149.78	128.48	93.67
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates								
B-basis Value	204.42	165.13	148.11	112.52	201.35	167.02	145.72	110.98
A-estimate	185.79	146.50	129.48	93.82	182.66	148.33	127.03	92.23
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-3: Statistics, Basis Values and Estimates for LC strength normalized from UNC0

Longitudinal Compression (LC) Modulus (msi)								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	17.24	17.02	17.50	17.50	17.01	17.20	17.26	17.32
Stdev	0.89	1.05	0.58	0.81	0.63	0.59	0.39	0.99
CV	5.19	6.15	3.29	4.62	3.68	3.43	2.28	5.73
Mod CV	6.59	7.08	6.00	6.31	6.00	6.00	6.00	6.87
Min	16.15	15.16	16.47	16.30	16.32	16.15	16.60	16.01
Max	19.32	19.22	18.53	19.76	18.34	18.16	17.86	19.73
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	19	19	20	19	19	19	20

Table 4-4: Statistics from LC modulus

4.3 90° Tension Properties (TT) Properties

The TT data is not normalized. Pooling across environments was acceptable. Only the CTD environment passed the normality test, but the pooled dataset sufficiently close to normal for pooling across environments to be acceptable. There were two outliers, both in batch one and both before, but not after pooling the three batches in an environment. One was in the RTD environment on the high side. One was in the ETW2 environment on the low side. The outliers were retained for this analysis.

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

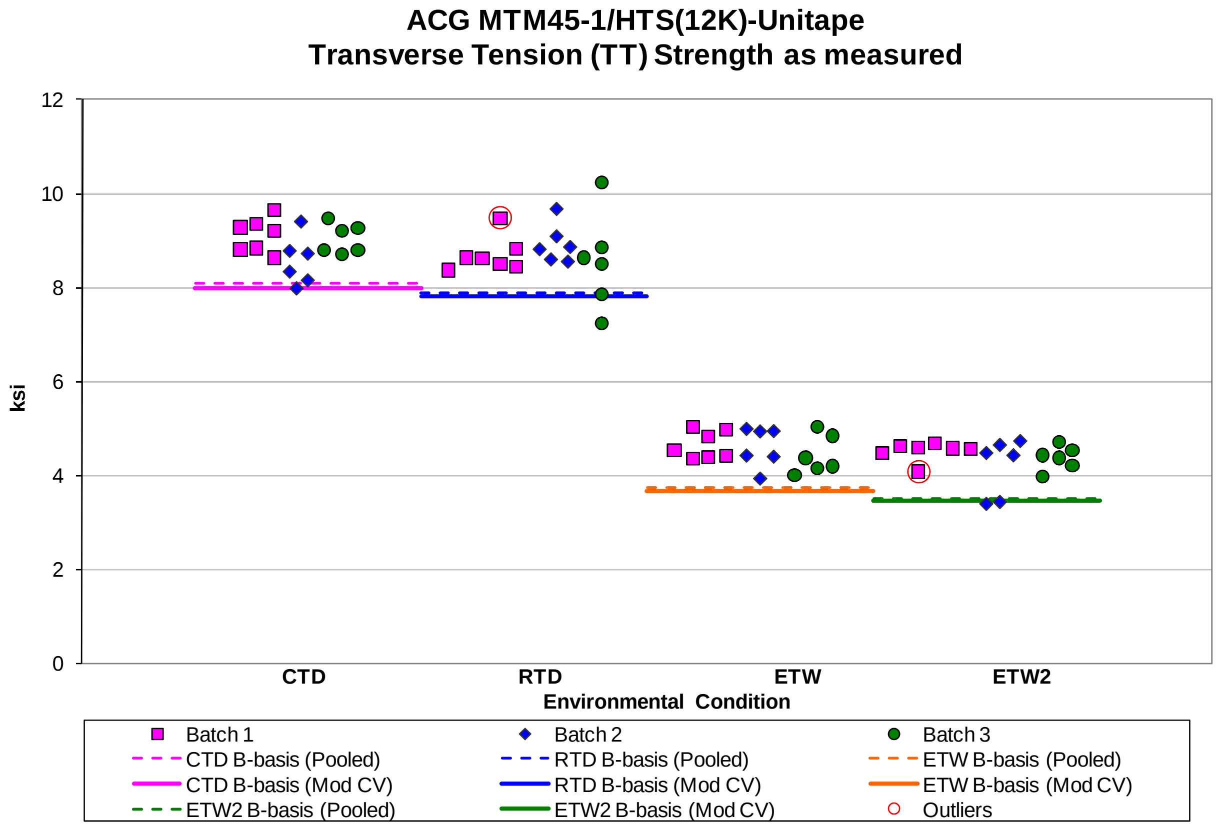

Figure 4:3: Batch Plot for TT strength as measured

Transverse Tension Strength (ksi) As Measured				
Env	CTD	RTD	ETW	ETW2
Mean	8.91	8.72	4.56	4.36
Stdev	0.46	0.63	0.37	0.39
CV	5.13	7.27	8.02	9.05
Mod CV	6.57	7.64	8.02	9.05
Min	7.97	7.24	3.92	3.38
Max	9.66	10.24	5.04	4.72
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value	8.09	7.90	3.74	3.54
A-estimate	7.54	7.36	3.20	3.00
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates				
B-basis Value	8.01	7.82	3.67	3.47
A-estimate	7.42	7.23	3.07	2.87
Method	pooled	pooled	pooled	pooled

Table 4-5: Statistics, Basis Values and Estimates for TT Strength data as measured

Transverse Tension Modulus (msi) As Measured				
Env	CTD	RTD	ETW	ETW2
Mean	1.31	1.20	1.04	0.84
Stdev	0.03	0.02	0.02	0.01
CV	1.96	2.04	2.14	1.67
Mod CV	6.00	6.00	6.00	6.00
Min	1.26	1.15	1.00	0.82
Max	1.36	1.23	1.06	0.87
No. Batches	3	3	3	3
No. Spec.	19	20	19	19

Table 4-6: Statistics from TT Modulus data as measured

4.4 90º Compression Properties (TC) Properties

The TC data is not normalized. The TC data has too much variability within and between environments to be pooled. The pooled data failed Levene's test. The ETW and ETW2 data failed the ADK test, but both environments passed the normality test, and passed the ADK test under the modified CV transformation, so the modified CV values are provided. There were no outliers.

Statistics, estimates and basis values are given for strength data in Table 4-7 and for the modulus data in Table 4-8. The data, B-estimates and B-basis values are shown graphically in Figure 4:4.

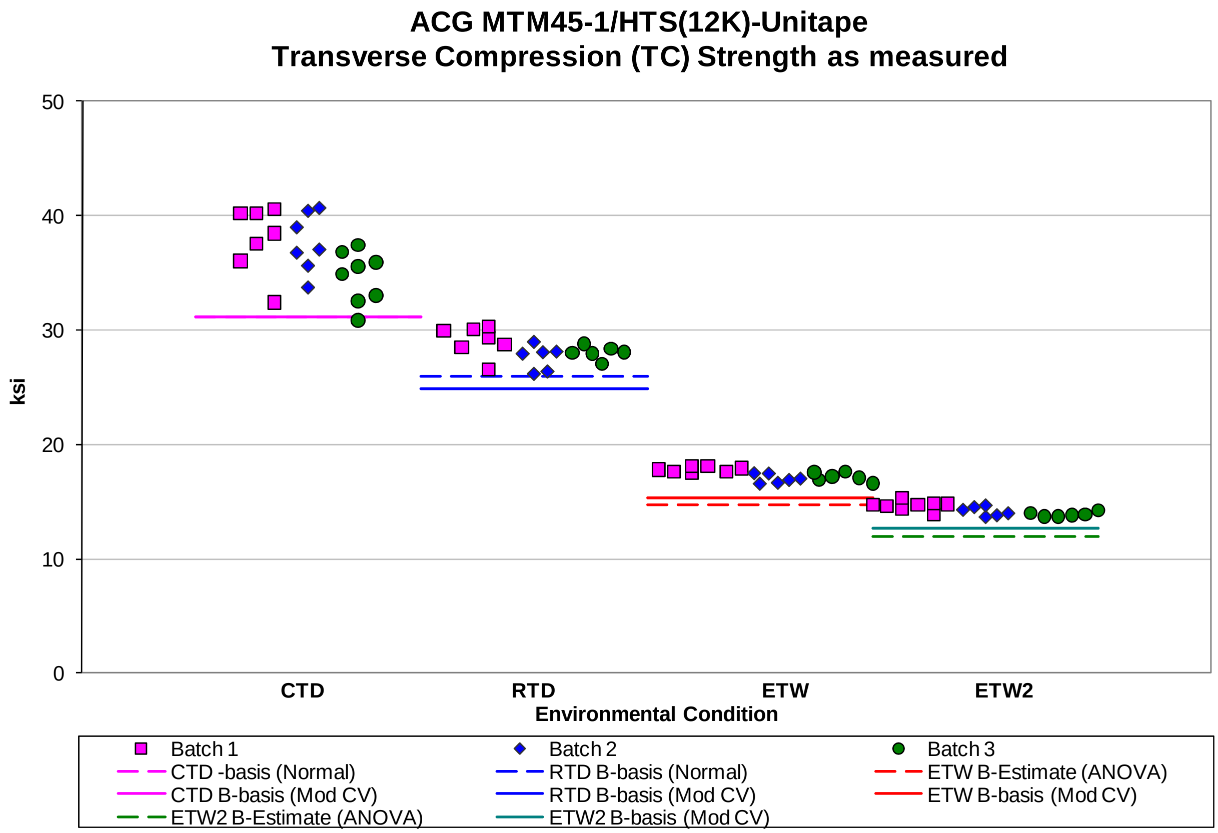

Figure 4:4: Batch Plot for TC strength as measured

Transverse Compression Strength (ksi) As Measured				
Env	CTD	RTD	ETW	ETW2
Mean	36.64	28.29	17.36	14.27
Stdev	2.92	1.18	0.50	0.48
CV	7.96	4.16	2.86	3.35
Mod CV	7.98	6.08	6.00	6.00
Min	30.85	26.19	16.56	13.65
Max	40.73	30.29	18.13	15.33
No. Batches	3	3	3	3
No. Spec.	22	19	19	20
Basis Values and/or Estimates				
B-basis value	31.14	25.99		
B-estimate			14.72	11.92
A-estimate	27.21	24.37	12.84	10.24
Method	Normal	Normal	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value	31.12	24.93	15.33	12.62
A-estimate	27.19	22.56	13.89	11.45
Method	Normal	Normal	Normal	Normal

Table 4-7: Statistics, Basis Values and Estimates for TC Strength data

Transverse Compression Modulus (msi) As Measured				
Env	CTD	RTD	ETW	ETW2
Mean	1.33	1.26	1.15	1.07
Stdev	0.06	0.06	0.04	0.06
CV	4.72	4.55	3.24	5.37
Mod CV	6.36	6.28	6.00	6.69
Min	1.22	1.17	1.11	0.98
Max	1.45	1.40	1.25	1.17
No. Batches	3	3	3	3
No. Spec.	22	19	19	20

Table 4-8: Statistics from TC Modulus data

4.5 0°/90° Unnotched Tension (UNT0) Properties

The CTD and RTD data could be pooled, but the ETW and ETW2 data failed the Anderson Darling k-sample test (ADK) for batch-to-batch variation. This means those datasets require the ANOVA method to compute basis values which may result in overly conservative estimates of the basis values. However, the pooled dataset did pass the normality test, and ETW and ETW2 both passed the ADK test under the modified CV transformation, so the pooled modified CV values are provided for that dataset.

There were no outliers. Statistics, estimates and basis values are given for strength data in Table 4-9 and for the modulus data in Table 4-10. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4:5.

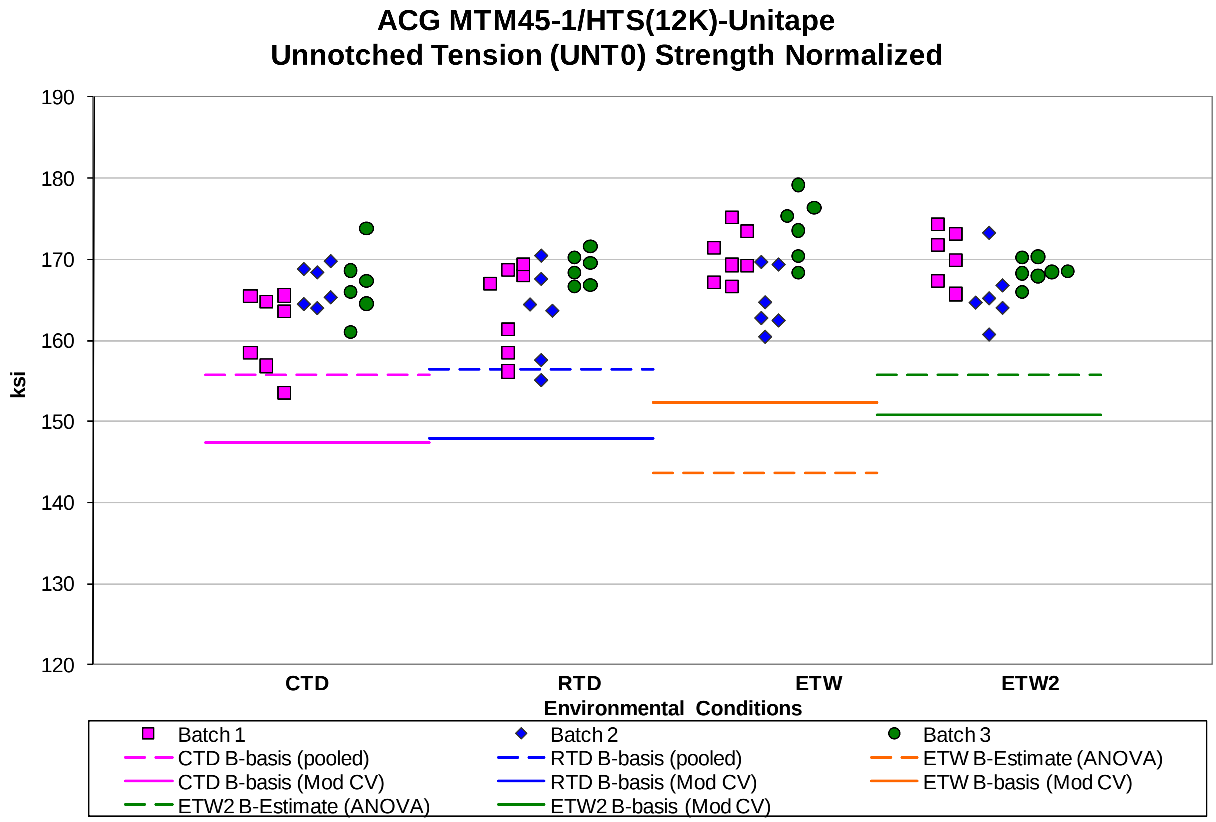

Figure 4:5: Batch Plot for UNT0 strength normalized

Unnotched Tension (UNT0) Strength (ksi)								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	164.78	165.34	169.75	168.26	160.45	161.16	166.72	164.18
Stdev	4.74	5.15	5.03	3.49	5.18	6.52	6.27	4.01
CV	2.88	3.11	2.96	2.07	3.23	4.05	3.76	2.44
Modified CV	6.00	6.00	6.00	6.00	6.00	6.02	6.00	6.00
Min	153.51	155.15	160.50	160.78	150.71	146.39	155.78	154.91
Max	173.77	171.60	179.19	174.34	171.08	169.29	177.71	169.82
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19	19	19
Basis Values and/or Estimates								
B-basis Value	155.85	156.41			149.83	150.54		
B-estimate			143.67	155.71			131.00	147.36
A-estimate	149.75	150.31	125.07	146.76	142.58	143.29	105.51	135.36
Method	pooled	pooled	ANOVA	ANOVA	pooled	pooled	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates								
B-basis Value	147.43	147.99	152.41	150.91	143.49	144.20	149.76	147.22
A-estimate	135.93	136.49	140.91	139.42	132.25	132.96	138.52	135.98
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-9: Statistics, Basis Values and Estimates for UNT0 Strength data

Unnotched Tension (UNT0) Modulus (msi)								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	10.23	10.11	10.43	10.54	9.97	9.85	10.25	10.28
Stdev	0.12	0.21	0.20	0.24	0.21	0.32	0.28	0.26
CV	1.18	2.04	1.92	2.29	2.15	3.26	2.73	2.54
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Min	10.05	9.78	10.05	10.16	9.50	9.23	9.75	9.79
Max	10.46	10.45	10.68	11.14	10.29	10.33	10.56	10.85
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19	19	19

Table 4-10: Statistics from UNT0 Modulus data

4.6 0°/90º Unnotched Compression (UNC0) Properties

Pooling across environments was not a viable method for computing basis values. Both normalized and as measured ETD condition data failed the ADK test even after applying the modified CV transformation. When pooled together, the CTD and RTD environments failed the normality test, so pooling just those two environments was not acceptable for either the normalized or as measured data. The Weibull distribution provided the best fit to the normalized CTD environment data. The as measured CTD and both the normalized and as measured ETW2 data did not adequately fit any of the tested distributions and required a non-parametric analysis.

Modified CV basis values are provided for the RTD and ETW environments. Because the modified CV method requires an assumption of normality and the CTD and ETW2 environments did not pass the normality test, no modified CV basis values are provided for those two environments. Estimates of the modified CV basis values are provided for the as measured and normalized data from the ETD environment because those datasets passed the normality test, but not the ADK test.

There were three outliers. One on the low side of batch three in the ETD environment, before but not after pooling across the three batches. It was an outlier for both the as measured and normalized data. The second was on the high side of batch two of the ETW condition. It was an outlier only after pooling the three batches and only in the normalized data. The third outlier was on the high side of batch two in the ETW2 environment. It was an outlier before, but not after pooling the three batches. It was an outlier for both the normalized and as measured data. The outliers were retained for this analysis.

Statistics, estimates and basis values are given for strength data in Table 4-11 and for the modulus data in Table 4-12. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4:6

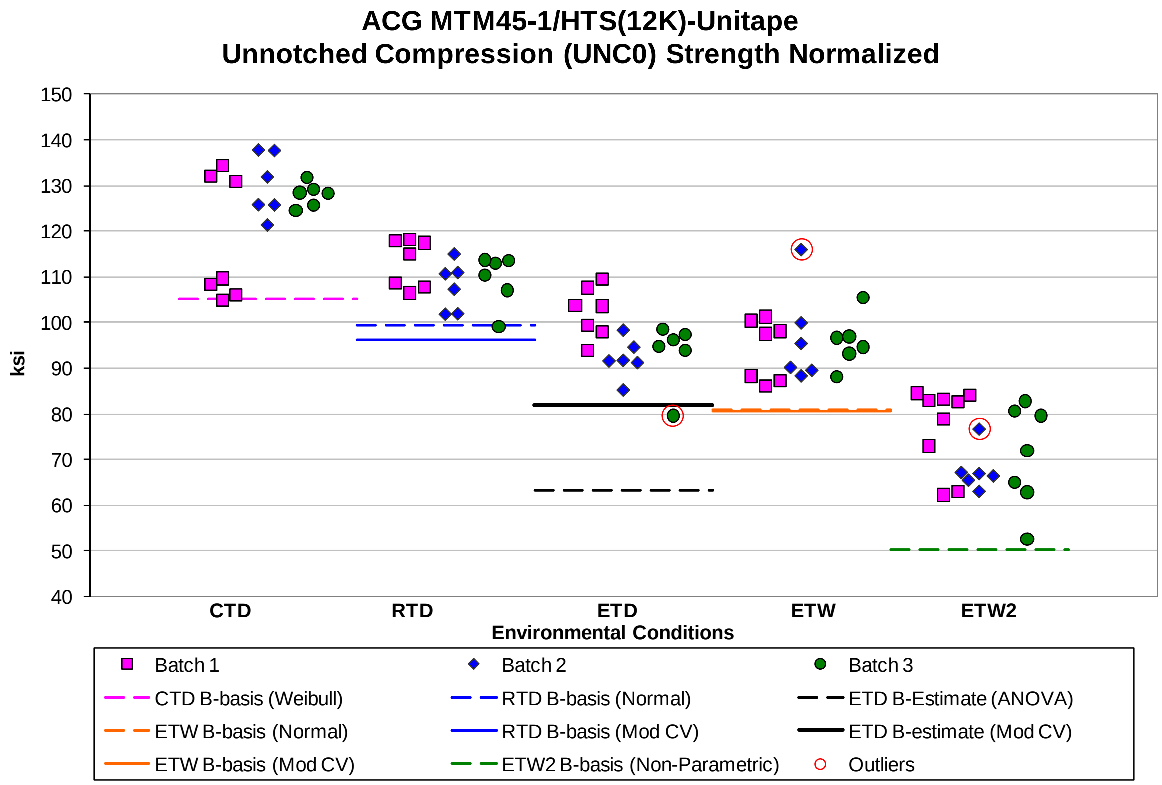

Figure 4:6: Batch Plot for UNC0 strength normalized

Unnotched Compression (UNC0) Strength (ksi)										
	Normalized					As Measured				
Env	CTD	RTD	ETD	ETW	ETW2	CTD	RTD	ETD	ETW	ETW2
Mean	124.96	110.31	96.27	95.44	72.54	123.01	108.65	94.81	93.64	71.73
Stdev	10.31	5.56	7.16	7.43	9.40	10.46	5.67	7.05	7.29	9.29
CV	8.25	5.04	7.44	7.79	12.96	8.50	5.22	7.44	7.78	12.95
Modified CV	8.25	6.52	7.72	7.89	12.96	8.50	6.61	7.72	7.89	12.95
Min	104.90	99.09	79.58	86.03	52.68	101.74	98.30	79.83	83.47	53.27
Max	137.71	118.12	109.44	115.92	84.52	133.82	115.79	106.93	112.06	83.60
No. Batches	3	3	3	3	3	3	3	3	3	3
No. Spec.	19	19	19	19	22	19	19	19	19	22
Basis Values and/or Estimates										
B-basis Value	105.11	99.47		80.96	50.38	95.55	97.59		79.44	51.22
B-estimate			63.16					62.51		
A-estimate	86.07	91.78	39.55	70.67	29.04	68.79	89.74	39.48	69.36	30.19
Method	Weibull	Normal	ANOVA	Normal	Non-Parametric	Non-Parametric	Normal	ANOVA	Normal	Non-Parametric
Modified CV Basis Values and/or Estimates										
B-basis Value	NA	96.29		80.76	NA	NA	94.65		79.24	NA
B-estimate			81.79					80.55		
A-estimate	NA	86.35	71.52	70.34	NA	NA	84.72	70.43	69.03	NA
Method	NA	Normal	Normal	Normal	NA	NA	Normal	Normal	Normal	NA

Table 4-11: Statistics, Basis Values and Estimates for UNC0 Strength data

Unnotched Compression (UNC0) Strength (msi)										
	Normalized					As Measured				
Env	CTD	RTD	ETD	ETW	ETW2	CTD	RTD	ETD	ETW	ETW2
Mean	9.26	9.71	9.27	9.47	9.05	9.12	9.57	9.12	9.29	8.95
Stdev	0.40	0.44	0.37	0.36	0.46	0.41	0.52	0.39	0.34	0.51
CV	4.27	4.57	4.03	3.82	5.14	4.49	5.39	4.22	3.70	5.67
Mod CV	6.13	6.29	6.02	6.00	6.57	6.24	6.70	6.11	6.00	6.84
Min	8.81	9.08	8.80	9.10	8.23	8.63	8.85	8.52	8.79	8.06
Max	10.22	10.51	10.17	10.26	9.88	10.01	10.58	10.00	10.05	9.78
No. Batches	3	3	3	3	3	3	3	3	3	3
No. Spec.	19	19	22	20	22	19	19	22	20	22

Table 4-12: Statistics from UNC0 Modulus data

4.7 In-Plane Shear Properties (IPS)

In-Plane Shear data is not normalized. Pooling across environments was not a viable method for computing basis values for IPS. The pooled dataset failed the normality test for both the 0.2% offset strength and strength at 5% strain. After applying the modified CV transform, both datasets failed Levene's test.

The CTD 0.2% offset strength data did not adequately fit any of the tested distributions and required a non-parametric analysis. The RTD 0.2% offset strength data and the ETW strength at 5% strain data failed the Anderson Darling k-sample test (ADK) for batch-to-batch variation so an ANOVA analysis is required. In order for B-basis values computed using the ANOVA method, data from five batches is required. Since this dataset has only three batches, the basis values computed using ANOVA are considered estimates. Using the ANOVA method to compute basis values with fewer than five batches may result in overly conservative estimates of the basis values.

The ETW strength at 5% strain passed the ADK test after the modified CV transform, so modified CV basis values are provided. In the ETW2 environment, there were only five specimens from a single batch that had measurements recorded for the strength at 5% strain. Estimates computed using the single point method (normal distribution) and the single batch method (normal distribution) are provided. The CTD and RTD data for 0.2% offset strength failed the normality test, so modified CV values are not provided.

There were three outliers. One was in the strength at 5% strain data. It was on the low side of batch two in the CTD environment. It was an outlier only after pooling the three batches. The other two outliers were in the 2% offset strength data. One was on the high side of batch two in the CTD environment and one was on the low side of batch three in the RTD environment. Both were outliers before, but not after, pooling the three batches. The outliers were retained for this analysis.

Statistics, estimates and basis values are given for strength data in Table 4-13 and the modulus data in Table 4-14. The data, B-basis values and B-estimates are shown graphically in Figure 4:7 and Figure 4:8.

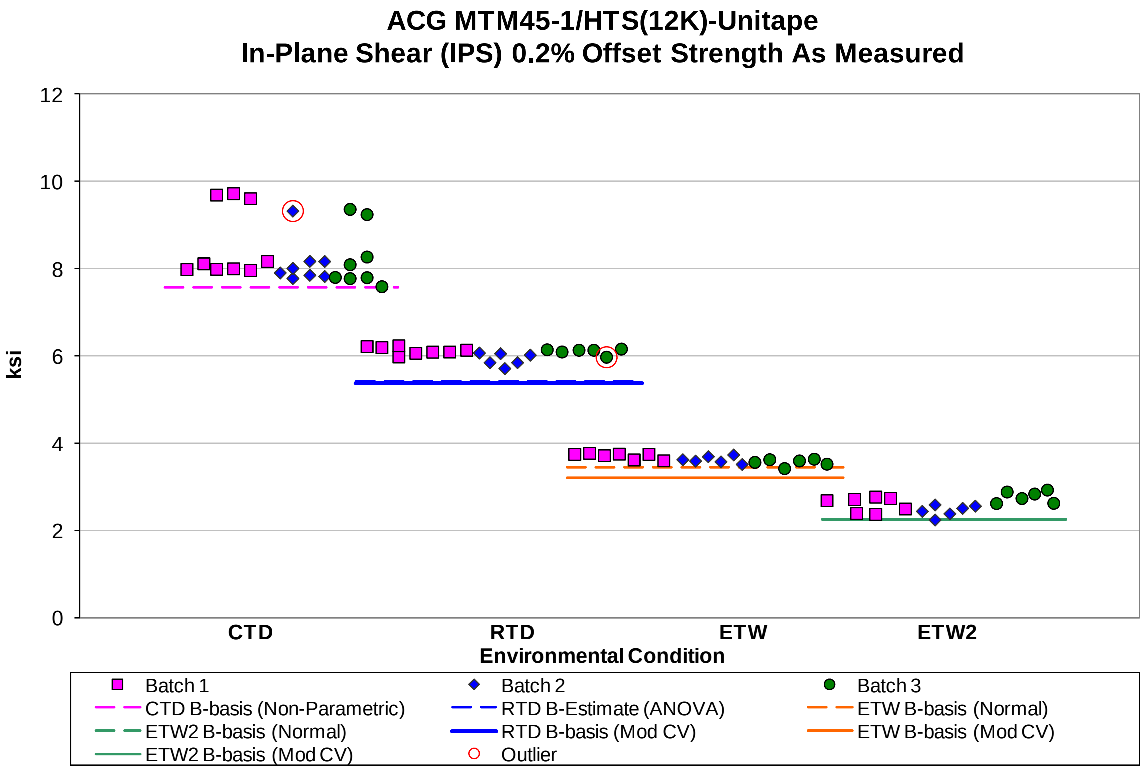

Figure 4:7: Batch plot for IPS 0.2% Offset strength

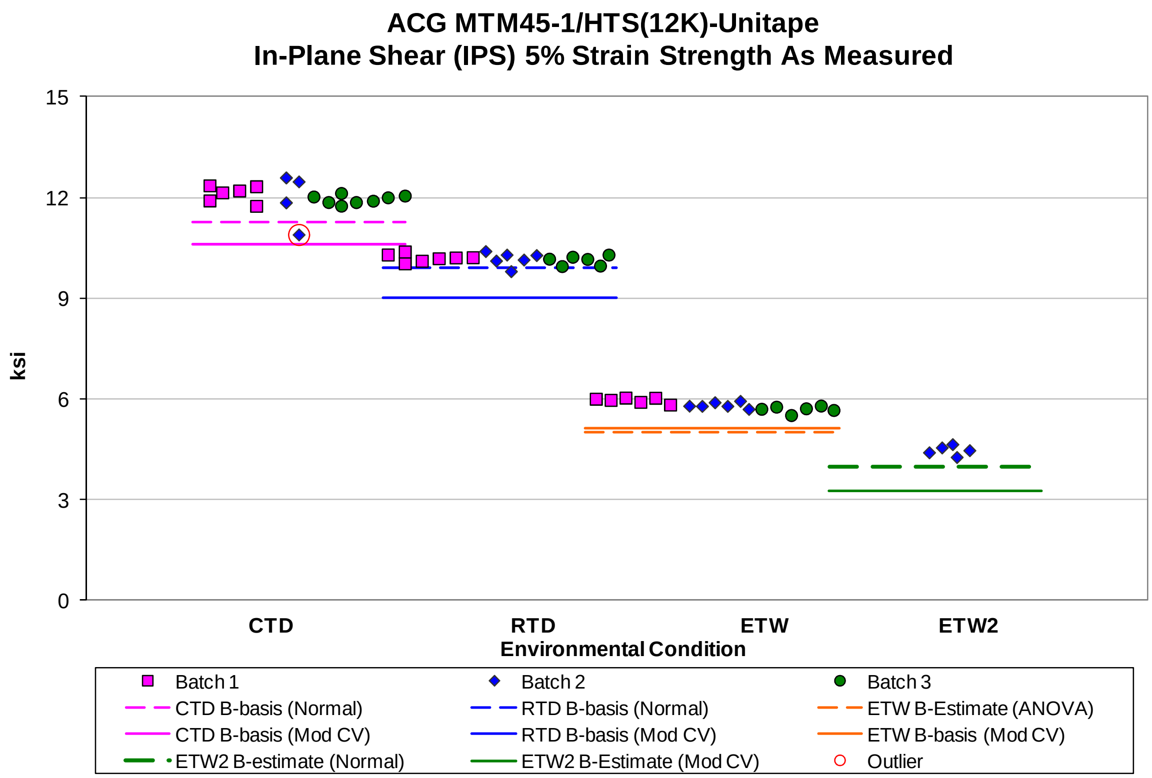

Figure 4:8: Batch plot for IPS strength at 5% strain

In-Plane Shear Properties (IPS)								
	0.2% Offset Strength (ksi)				Strength at 5% Strain (ksi)			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	8.34	6.07	3.65	2.64	12.01	10.18	5.84	4.48
Stdev	0.69	0.13	0.10	0.21	0.37	0.15	0.14	0.15
CV	8.29	2.19	2.61	7.81	3.08	1.49	2.41	3.24
Mod CV	8.29	6.00	6.00	7.90	6.00	6.00	6.00	8.00
Min	7.60	5.73	3.43	2.25	10.90	9.81	5.53	4.28
Max	9.74	6.25	3.78	3.08	12.60	10.41	6.05	4.66
No. Batches	3	3	3	3	3	3	3	1
No. Spec.	25	20	19	21	18	19	18	5
Basis Values and/or Estimates								
B-basis Value	7.57		3.46	2.25	11.28	9.89		
B-estimate		5.43					5.03	3.98
A-estimate	5.75	4.97	3.33	1.97	10.77	9.68	4.46	3.65
Method	Non-Parametric	ANOVA	Normal	Normal	Normal	Normal	ANOVA	Normal
Modified CV Basis Values and/or Estimates								
B-basis Value	NA	NA	3.22	2.24	10.59	8.99	5.14	
B-estimate								3.25
A-estimate	NA	NA	2.92	1.96	9.58	8.15	4.66	2.41
Method	NA	NA	Normal	Normal	Normal	Normal	Normal	Single Batch

Table 4-13: Statistics, Basis Values and Estimates for IPS Strength data

In-Plane Shear Properties (IPS) - Modulus (msi)				
Env	CTD	RTD	ETW	ETW2
Mean	0.70	0.57	0.40	0.30
Stdev	0.09	0.02	0.01	0.03
CV	12.38	3.12	2.60	10.07
Mod CV	12.38	6.00	6.00	10.07
Min	0.62	0.53	0.38	0.25
Max	0.89	0.59	0.42	0.35
No. Batches	3	3	3	3
No. Spec.	25	20	19	21

Table 4-14: Statistics for IPS modulus

4.8 Short Beam Strength (SBS)

Pooling across environments was not a viable method for computing basis values for SBS. The pooled dataset failed Levene's test. The CTD, ETW and ETW2 environments failed the Anderson Darling k-sample test (ADK) for batch-to-batch variation which means that those datasets required the ANOVA method to compute basis values. In order for B-basis values computed using the ANOVA method, data from five batches is required. Since this dataset has only three batches, the basis values computed using ANOVA are considered estimates. Using the ANOVA method to compute basis values with fewer than five batches may result in overly conservative estimates of the basis values. However, all three datasets did pass the ADK test after the modified CV transform, so modified CV basis values are provided. There were no outliers.

Statistics, estimates and basis values are given for SBS data in Table 4-15. The data, B-basis values and B-estimates are shown graphically in Figure 4:9.

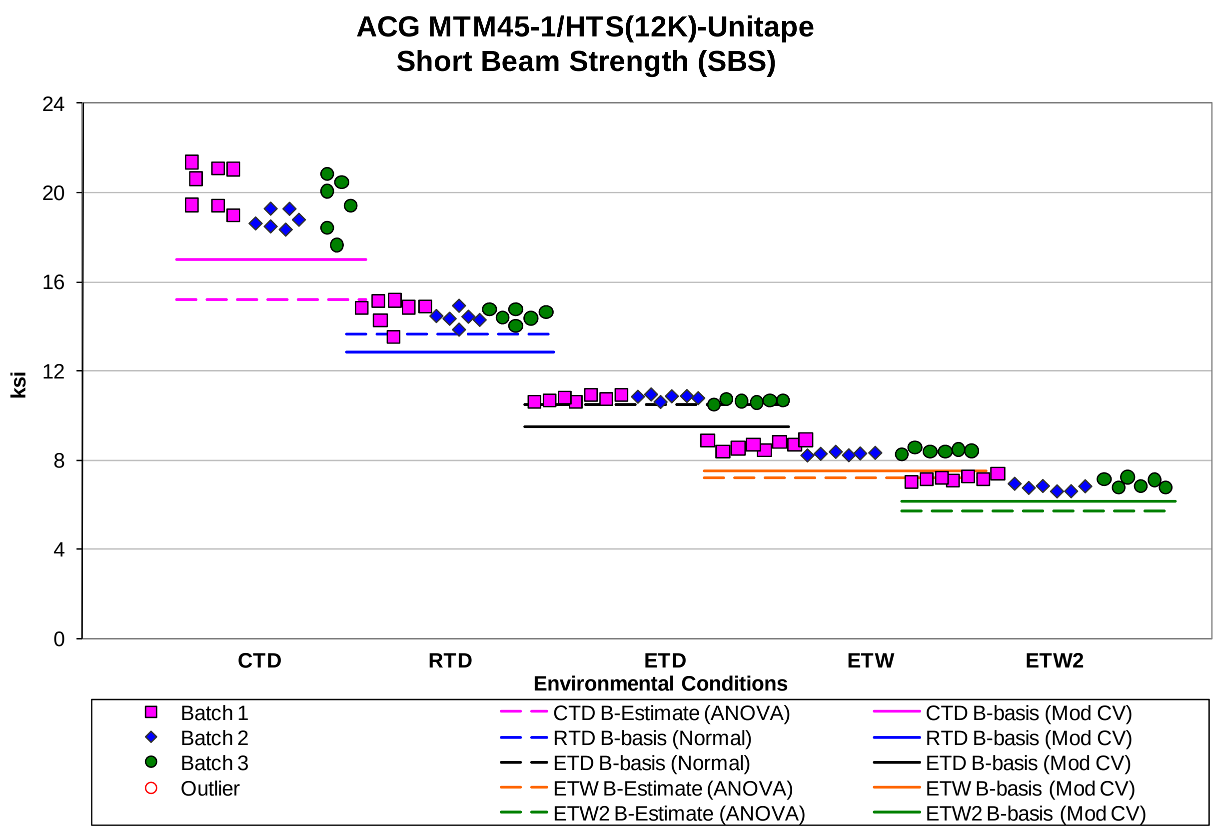

Figure 4:9: Batch plot for SBS as measured

Short Beam (SBS) Strength (ksi) as measured					
Env	CTD	RTD	ETD	ETW	ETW2
Mean	19.55	14.52	10.74	8.47	6.98
Stdev	1.09	0.43	0.13	0.22	0.24
CV	5.57	2.99	1.24	2.62	3.37
Mod CV	6.79	6.00	6.00	6.00	6.00
Min	17.64	13.51	10.49	8.20	6.58
Max	21.38	15.17	10.94	8.91	7.39
No. Batches	3	3	3	3	3
No. Spec.	19	19	19	20	19
Basis Values and/or Estimates					
B-basis Value		13.68	10.48		
B-estimate	15.22			7.20	5.68
A-estimate	12.13	13.07	10.29	6.28	4.76
Method	ANOVA	Normal	Normal	ANOVA	ANOVA
Modified CV Basis Values and/or Estimates					
B-basis Value	16.97	12.82	9.48	7.50	6.16
A-estimate	15.13	11.62	8.59	6.80	5.58
Method	Normal	Normal	Normal	Normal	Normal

Table 4-15: Statistics, Basis Values and Estimates for SBS data

5. Laminate Test Results, Statistics, Basis Values and Graph

Many of the laminate tests were performed with one batch only. In those cases, there was insufficient data to produce basis values meeting the requirements of CMH-17 Rev G, so only estimates are provided. When possible, estimates were prepared in the following ways and multiple estimates are provided.

1. Using the ASAP program to pool across the available environments. The modified CV values from this program are provided.
2. The Lamina Variability method detailed in section 2.4. For properties that use the CV of the LC CTD, LC ETW2 and TT ETW datasets, modified CV values are not available due to the large CV (over 8%) of the those datasets.

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

5.1.1 Quasi Isotropic Open Hole Tension (OHT1)

The OHT1 RTD data (both normalized and as measured) does not pass the ADK test but passes it after the transform for the modified CV method, so pooling was acceptable for the modified CV basis values. There was one outlier. It was on the low side of batch two in the CTD environment. It was an outlier after pooling only and was retained for this analysis. Statistics, estimates and basis values are given for OHT1 strength data in Table 5-1. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:1.

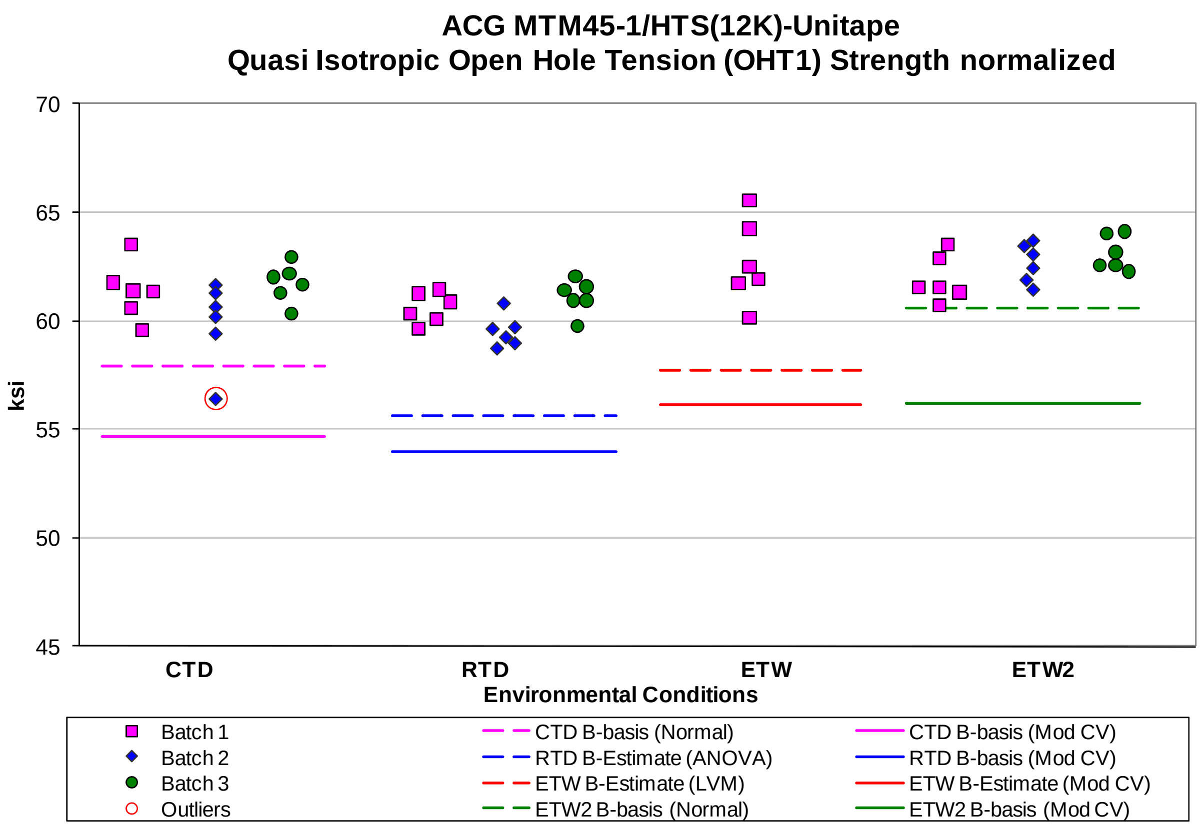

Figure 5:1: Batch plot for OHT1 strength normalized

Open Hole Tension (OHT1) Strength (ksi)								
	Normalized				As Measured			
Env	CTD	RTD	ETW	ETW2	CTD	RTD	ETW	ETW2
Mean	61.17	60.47	63.47	62.64	60.27	59.56	62.28	61.77
Stdev	1.67	0.98	2.74	1.05	2.00	1.34	2.63	1.38
CV	2.73	1.62	4.32	1.67	3.31	2.26	4.22	2.24
Modified CV	6.00	6.00	6.16	6.00	6.00	6.00	6.11	6.00
Min	56.42	58.73	60.14	60.72	55.42	56.60	59.41	59.52
Max	64.05	62.04	68.23	64.19	64.15	61.43	67.18	63.85
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	19	19	7	19	19	19	7	19
Basis Values and/or Estimates								
B-basis Value	57.91			60.61	56.38			59.07
B-estimate		55.64	57.74			52.35	56.78	
A-estimate	55.60	52.20	NA	59.16	53.61	47.20	NA	57.16
Method	Normal	ANOVA	LVM	Normal	Normal	ANOVA	LVM	Normal
Modified CV Basis Values and/or Estimates								
B-basis Value	54.69	53.99		56.17	53.90	53.19		55.40
B-estimate			56.14				55.07	
A-estimate	50.37	49.67	51.93	51.85	49.64	48.94	50.92	51.14
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 5-1: Statistics, Basis Values and Estimates for OHT1 Strength data

5.1.2 "Soft" Open Hole Tension (OHT2)

The OHT2 CTD data (as measured only) failed the ADK test, so it required an ANOVA analysis. In order for B-basis values to be computed using the ANOVA method, data from five batches is required. Since this dataset has only three batches, the basis values computed using ANOVA are considered estimates. However, it passed the ADK test after the transform for the modified CV method, so modified CV basis values are provided. There were no outliers.

Statistics, estimates and basis values are given for OHT2 strength data in Table 5-2. The normalized data, estimated B-basis values and B-estimates are shown graphically in Figure 5:2.

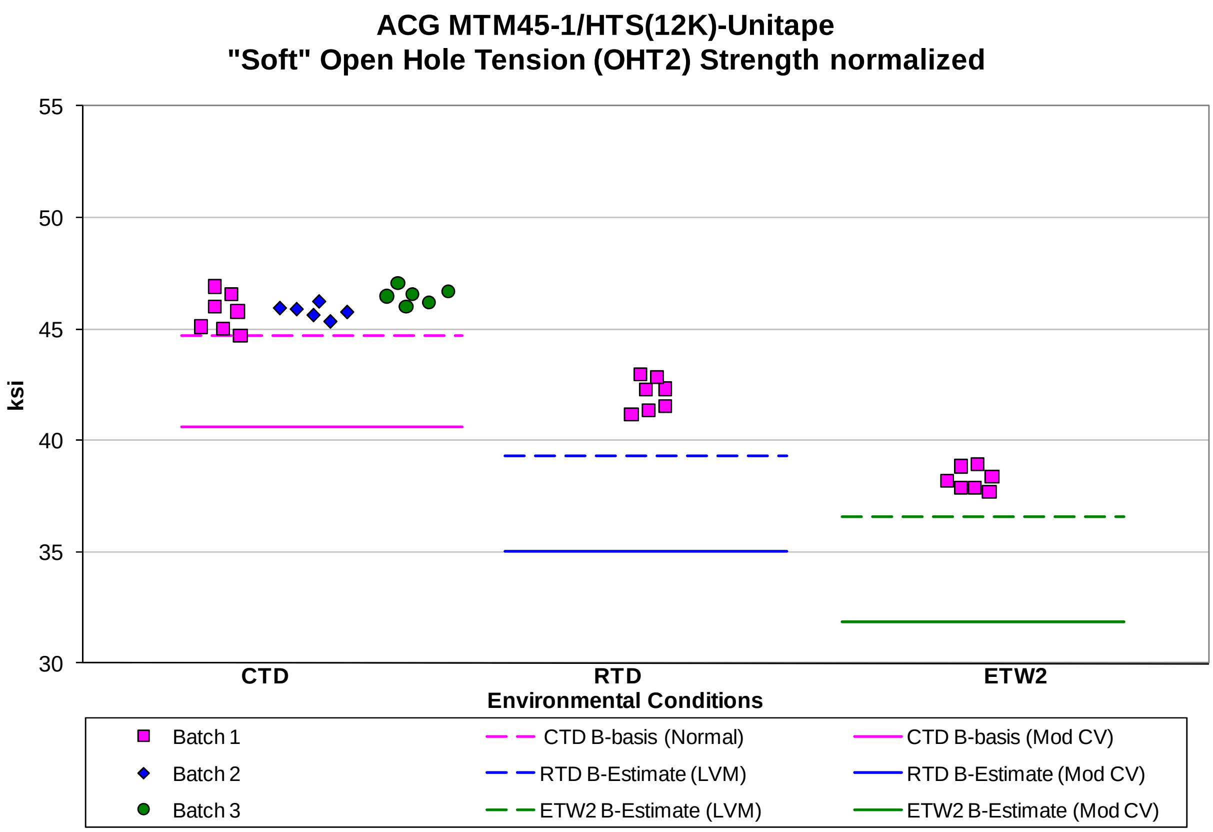

Figure 5:2: Batch plot for OHT2 strength normalized

Open Hole Tension (OHT2) Strength						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	45.99	42.06	38.26	45.09	41.50	37.64
Stdev	0.65	0.72	0.49	1.05	0.70	0.60
CV	1.41	1.71	1.28	2.34	1.69	1.60
Modified CV	6.00	8.00	8.00	6.00	8.00	8.00
Min	44.70	41.15	37.67	43.30	40.72	36.92
Max	47.08	42.96	38.93	46.41	42.49	38.58
No. Batches	3	1	1	3	1	1
No. Spec.	19	7	7	19	7	7
Basis Values and/or Estimates						
B-basis Value	44.73					
B-estimate		39.32	36.60	39.10	37.99	35.71
A-estimate	43.83	NA	NA	34.82	NA	NA
Method	Normal	LVM	LVM	ANOVA	LVM	LVM
Modified CV Basis Values and/or Estimates						
B-basis Value	40.61			39.82		
B-estimate		35.02	31.85		34.55	31.34
A-estimate	36.80	NA	NA	36.08	NA	NA
Method	Normal	LVM	LVM	Normal	LVM	LVM

Table 5-2: Statistics, Basis Values and Estimates for OHT2 Strength data

5.1.3 "Hard" Open Hole Tension (OHT3)

The OHT3 CTD data (both as measured and normalized) failed the ADK test, so they required an ANOVA analysis. In order for B-basis values to be computed using the ANOVA method, data from five batches is required. Since this dataset has only three batches, the basis values computed using ANOVA are considered estimates. However, it passed the ADK test after the transform for the modified CV method, so modified CV basis values are provided. Modified CV basis values are provided for the normalized data, but the as measured data did not pass the normality test so modified CV basis values are not provided for that dataset.

There was one outlier. It was on the high side of batch one in the ETW2 condition. It was an outlier before pooling only and it was retained for this analysis. Statistics, estimates and basis values are given for OHT3 strength data in Table 5-3. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:3.

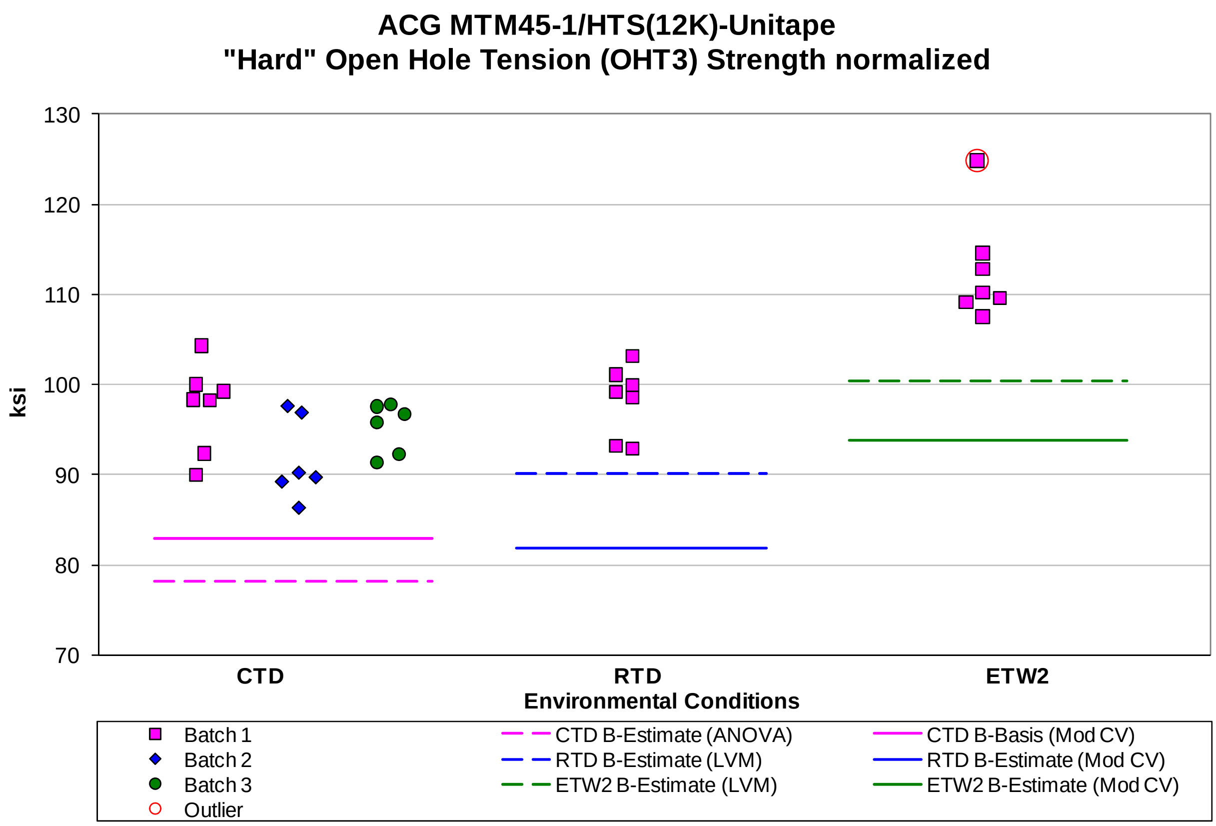

Figure 5:3: Batch plot for OHT3 strength normalized

Open Hole Tension (OHT3) Strength						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	94.94	98.29	112.67	94.25	97.15	111.21
Stdev	4.67	3.89	5.88	4.85	3.70	5.81
CV	4.92	3.96	5.22	5.14	3.81	5.22
Modified CV	6.46	8.00	8.00	6.57	8.00	8.00
Min	86.31	92.86	107.53	84.52	91.63	106.44
Max	104.31	103.13	124.88	102.68	101.78	123.36
No. Batches	3	1	1	3	1	1
No. Spec.	19	7	7	19	7	7
Basis Values and/or Estimates						
B-estimate	78.19	90.15	100.38	77.30	88.93	99.05
A-estimate	66.26	NA	NA	65.23	NA	NA
Method	ANOVA	LVM	LVM	ANOVA	LVM	LVM
Modified CV Basis Values and/or Estimates						
B-basis Value	82.99			NA		
B-estimate		81.84	93.81		80.89	92.59
A-estimate	74.51	NA	NA	NA	NA	NA
Method	Normal	LVM	LVM	NA	LVM	LVM

Table 5-3: Statistics, Basis Values and Estimates for OHT3 Strength data

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

5.2.1 Quasi Isotropic Open Hole Compression (OHC1)

The OHC1 RTD data (normalized only) and ETW2 data (both as measured and normalized) failed the ADK test, so they required an ANOVA analysis. In order for B-basis values to be computed using the ANOVA method, data from five batches is required. Since this dataset has only three batches, the basis values computed using ANOVA are considered estimates. However, both datasets passed the ADK test after the transform for the modified CV method. The as measured ETW2 data does not pass the normality test, so modified CV basis values are not provided for that dataset, but they are provided for the normalized RTD dataset.

Pooling was appropriate for the normalized data when computing modified CV basis values. There were no outliers. Statistics, estimates and basis values are given for OHC1 strength data in Table 5-4. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:4.

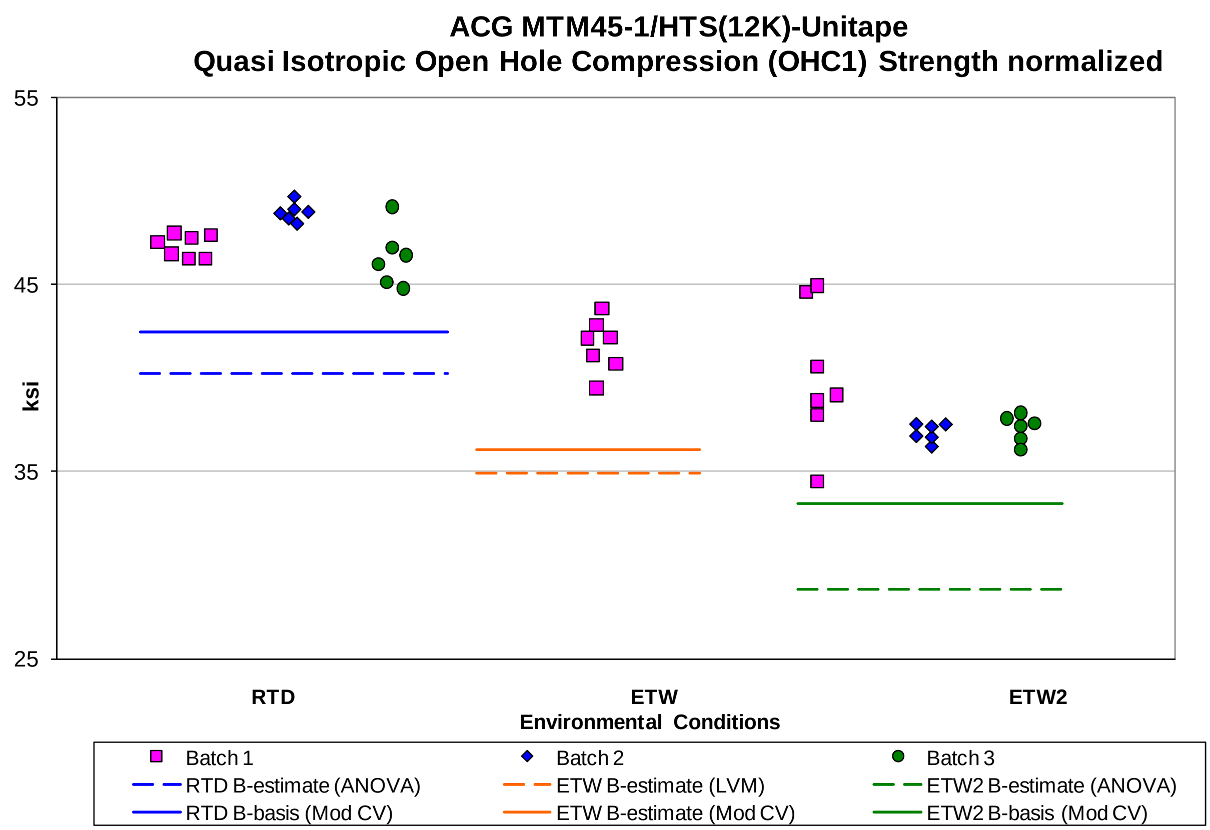

Figure 5:4: Batch plot for OHC1 strength normalized

Open Hole Compression (OHC1) Strength						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	47.44	41.77	38.28	46.51	41.20	37.40
Stdev	1.38	1.41	2.61	0.96	1.27	2.84
CV	2.90	3.39	6.81	2.06	3.09	7.58
Modified CV	6.00	6.00	7.41	6.00	8.00	7.79
Min	44.81	39.47	34.49	44.94	39.30	33.11
Max	49.67	43.74	44.94	48.80	42.78	44.11
No. Batches	3	1	3	3	1	3
No. Spec.	19	7	19	19	7	19
Basis Values and/or Estimates						
B-basis Value				44.64		
B-estimate	40.24	34.96	28.72		34.49	25.87
A-estimate	35.10	NA	21.90	43.32	NA	17.65
Method	ANOVA	LVM	ANOVA	Normal	LVM	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	42.45		33.30	41.07		NA
B-estimate		36.15			34.30	
A-estimate	39.07	32.87	29.92	37.21	NA	NA
Method	pooled	pooled	pooled	Normal	LVM	NA

Table 5-4: Statistics, Basis Values and Estimates for OHC1 Strength data

5.2.2 "Soft" Open Hole Compression (OHC2)

The OHC2 ETW2 data (both as measured and normalized) failed the ADK test, so they required an ANOVA analysis. In order for B-basis values to be computed using the ANOVA method, data from five batches is required. Since this dataset has only three batches, the basis values computed using ANOVA are considered estimates. However, this dataset passed the ADK test after the transform for the modified CV method, so modified CV basis values are provided.

There was one outlier. It was on the high side of batch one in the as measured ETW2 data. It was an outlier only before pooling the three batches. The outlier was retained for this analysis. Statistics, estimates and basis values are given for OHC2 strength data in Table 5-5. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:5.

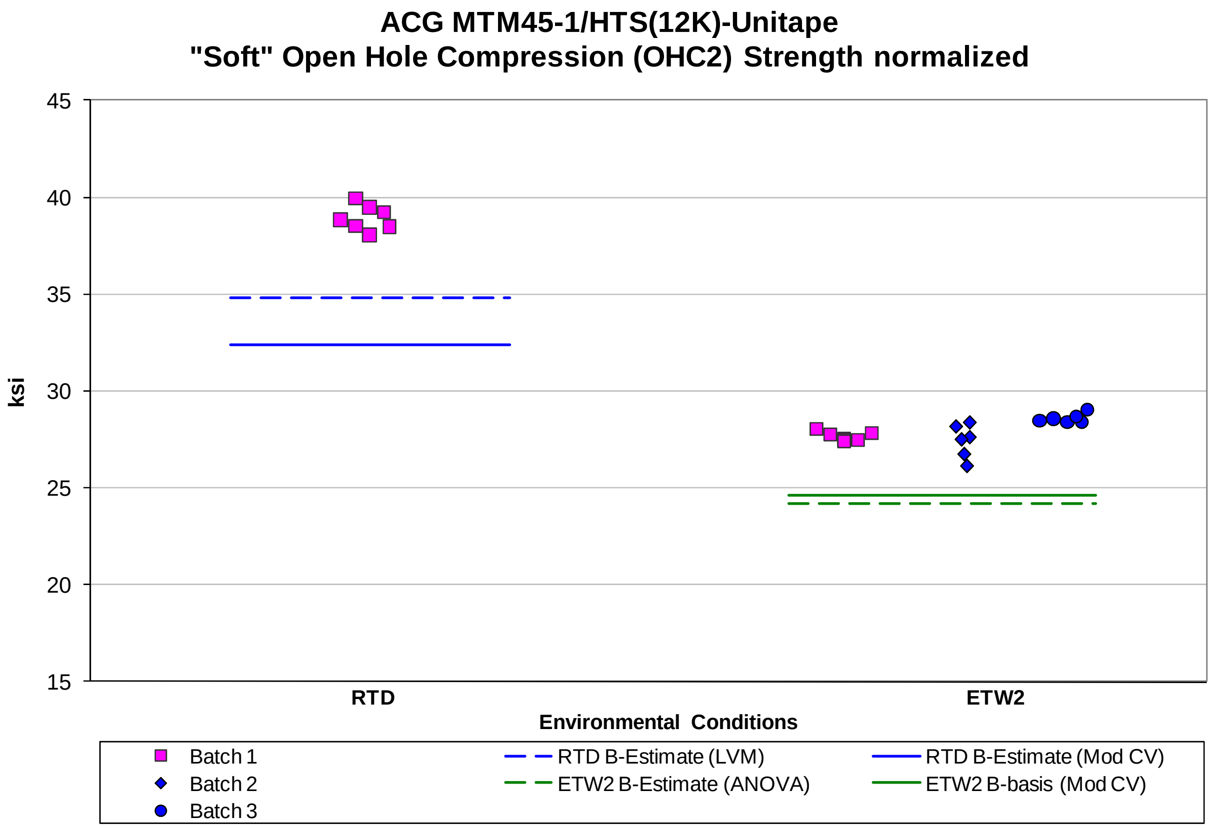

Figure 5:5: Batch plot for OHC2 strength normalized

Open Hole Compression Strength (OHC2)				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	38.93	27.87	38.49	27.56
Stdev	0.65	0.70	0.82	0.68
CV	1.67	2.52	2.13	2.47
Modified CV	8.00	6.00	8.00	6.00
Min	38.05	26.16	37.13	26.28
Max	39.93	29.03	39.64	28.65
No. Batches	1	3	1	3
No. Spec.	7	19	7	19
Basis Values and/or Estimates				
B-estimate	34.82	24.22	34.29	23.18
A-estimate	NA	21.62	NA	20.05
Method	LVM	ANOVA	LVM	ANOVA
Modified CV Basis Values and/or Estimates				
B-basis Value		24.61		24.33
B-estimate	32.41		32.05	
A-estimate	NA	22.30	NA	22.05
Method	LVM	Normal	LVM	Normal

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

5.2.3 "Hard" Open Hole Compression (OHC3)

There were no test failures or outliers. Statistics, estimates and basis values are given for OHC3 strength data in Table 5-6. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:6.

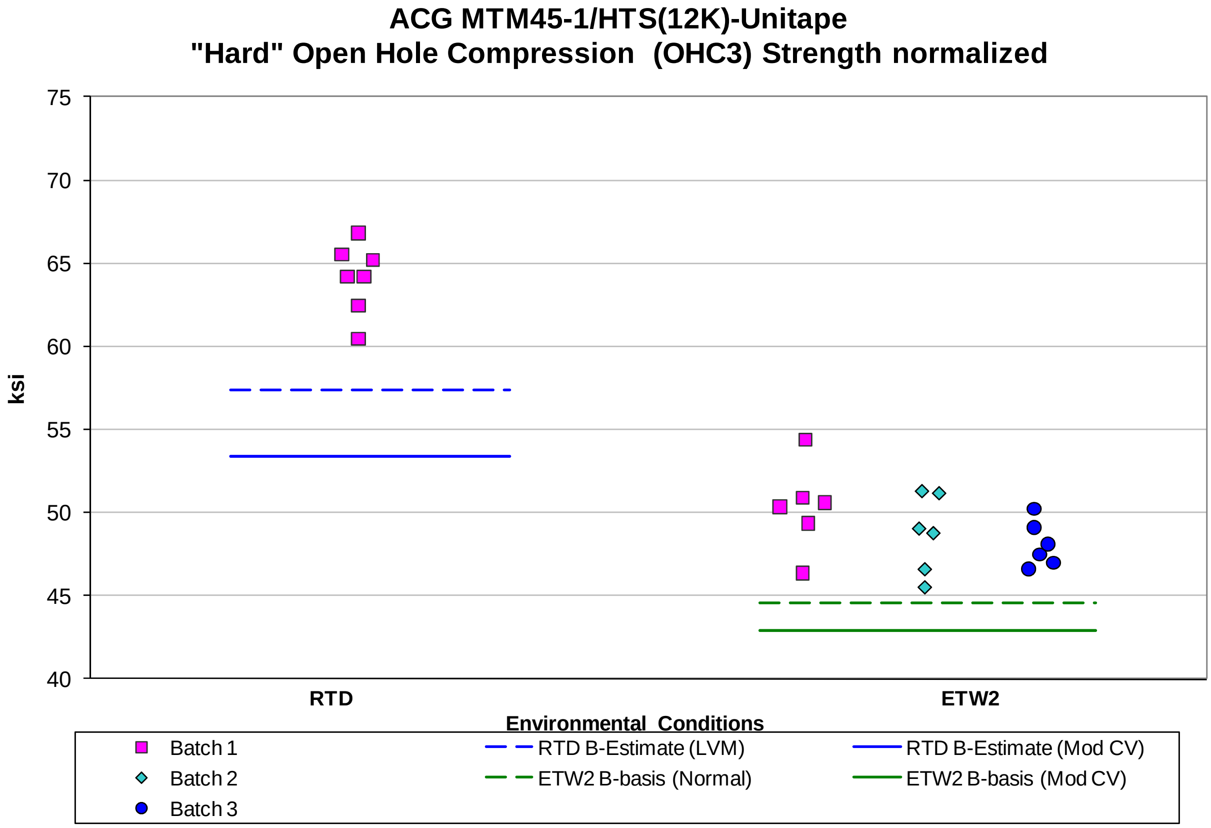

Figure 5:6: Batch plot for OHC3 strength normalized

Open Hole Compression Strength (OHC3)				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	64.11	49.04	62.68	48.45
Stdev	2.11	2.25	2.09	2.09
CV	3.29	4.59	3.34	4.32
Modified CV	8.00	6.30	8.00	6.16
Min	60.43	45.53	59.08	44.53
Max	66.80	54.40	65.09	53.38
No. Batches	1	3	1	3
No. Spec.	7	18	7	18
Basis Values and/or Estimates				
B-basis Value		44.60		44.32
B-estimate	57.35		55.83	
A-estimate	NA	41.45	NA	41.39
Method	LVM	Normal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		42.95		42.56
B-estimate	53.38		52.19	
A-estimate	NA	38.63	NA	38.39
Method	LVM	Normal	LVM	Normal

Table 5-6: Statistics, Basis Values and Estimates for OHC3 Strength data

5.3 Unnotched Tension (UNT1, UNT2, UNT3) Properties

5.3.1 Quasi Isotropic Unnotched Tension (UNT1) Properties

The UNT1 data had no outliers or test failures. Pooling was appropriate and included the ETW2 data. The pooled basis value estimates are provided as they were more conservative than the LVM basis value estimates for the ETW2 data. Statistics, basis values and estimates are given for the UNT1 strength data in Table 5-7. Modulus statistics are given in Table 5-8. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:7.

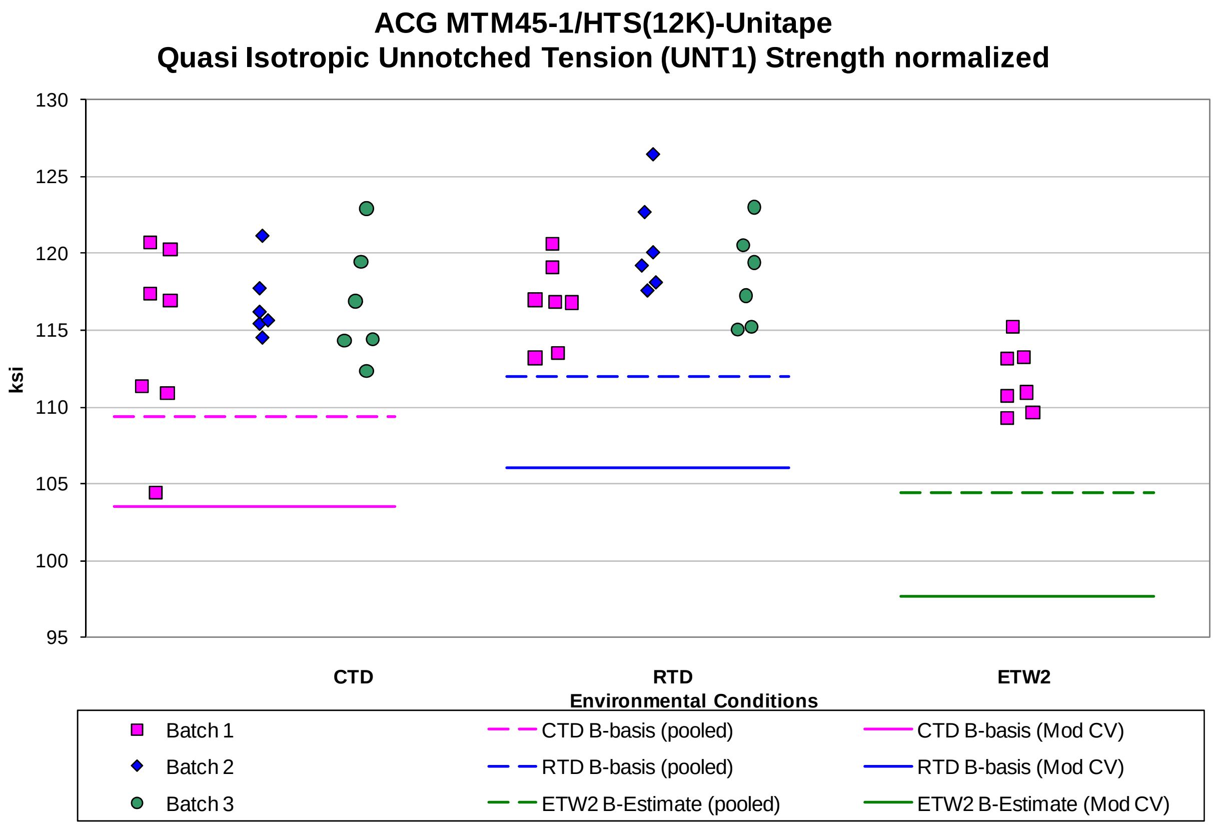

Figure 5:7: Batch plot for UNT1 strength normalized

Unnotched Tension Properties (UNT1) Strength						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	115.96	118.52	111.76	113.38	115.54	109.88
Stdev	4.32	3.33	2.18	4.25	2.79	2.05
CV	3.72	2.81	1.95	3.75	2.42	1.87
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	104.46	113.21	109.29	104.14	110.71	106.60
Max	122.91	126.46	115.25	121.70	120.65	112.89
No. Batches	3	3	1	3	3	1
No. Spec.	19	19	7	19	19	7
Basis Values and/or Estimates						
B-basis Value	109.42	111.98		107.29	109.44	
B-estimate			104.39			103.01
A-estimate	104.99	107.55	100.09	103.15	105.31	98.99
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	103.50	106.06		101.21	103.36	
B-estimate			97.71			96.15
A-estimate	95.05	97.61	89.51	92.95	95.11	88.14
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 5-7: Statistics, Basis Values and Estimates for UNT1 Strength data

Unnotched Tension Properties (UNT1) Modulus						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	7.26	7.12	7.18	7.10	6.94	7.06
Stdev	0.16	0.15	0.14	0.20	0.18	0.14
CV	2.17	2.18	1.96	2.76	2.63	2.04
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	7.06	6.90	6.98	6.82	6.64	6.89
Max	7.60	7.43	7.42	7.46	7.27	7.33
No. Batches	3	3	1	3	3	1
No. Spec.	19	19	7	19	19	7

Table 5-8: Statistics from UNT1 Modulus Data

5.3.2 "Soft" Unnotched Tension Properties (UNT2)

There were no outliers. Statistics and estimated basis values are given for UNT2 normalized strength data in Table 5-9. Modulus statistics are given in Table 5-10. The normalized data and B-estimates are shown graphically in Figure 5:8.

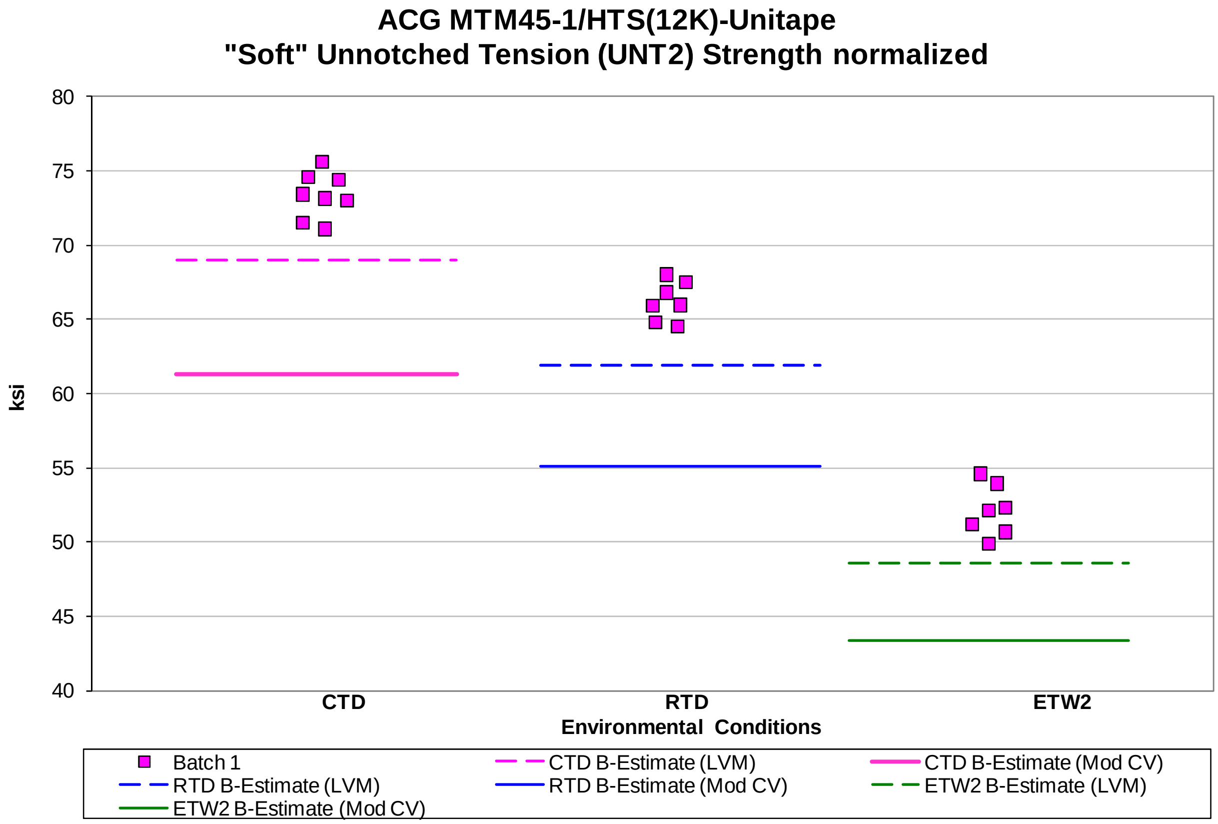

Figure 5:8: Batch plot for UNT2 strength normalized

Unnotched Tension Properties (UNT2) Strength						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	73.34	66.22	52.11	72.58	65.24	51.33
Stdev	1.53	1.30	1.70	1.47	1.47	1.70
CV	2.08	1.97	3.26	2.02	2.26	3.31
Modified CV	8.00	8.00	8.00	8.00	8.00	8.00
Min	71.07	64.55	49.92	70.18	62.48	49.08
Max	75.60	68.00	54.61	74.29	66.65	53.87
No. Batches	1	1	1	1	1	1
No. Spec.	8	7	7	8	7	7
Lamina Variability Method B-estimates						
B-estimate	69.01	61.91	48.56	67.78	59.72	47.78
Modified CV Lamina Variability Method B-estimates						
B-estimate	61.33	55.14	43.39	60.69	54.32	42.74

Table 5-9: Statistics, Basis Values and Estimates for UNT2 Strength data

Unnotched Tension Properties (UNT2) Modulus						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	4.69	4.65	3.95	4.64	4.59	3.89
Stdev	0.10	0.13	0.09	0.09	0.14	0.08
CV	2.16	2.71	2.23	1.84	2.95	2.17
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	4.58	4.49	3.85	4.55	4.46	3.77
Max	4.88	4.83	4.12	4.78	4.78	4.04
No. Batches	1	1	1	1	1	1
No. Spec.	8	6	7	8	6	7

Table 5-10: Statistics from UNT2 Modulus Data

5.3.3 "Hard" Unnotched Tension Properties (UNT3)

There were no outliers. Statistics and B-estimates are given for UNT3 strength data in Table 5-11. Modulus statistics are given in Table 5-12. The normalized data and the B-estimates are shown graphically in Figure 5:9.

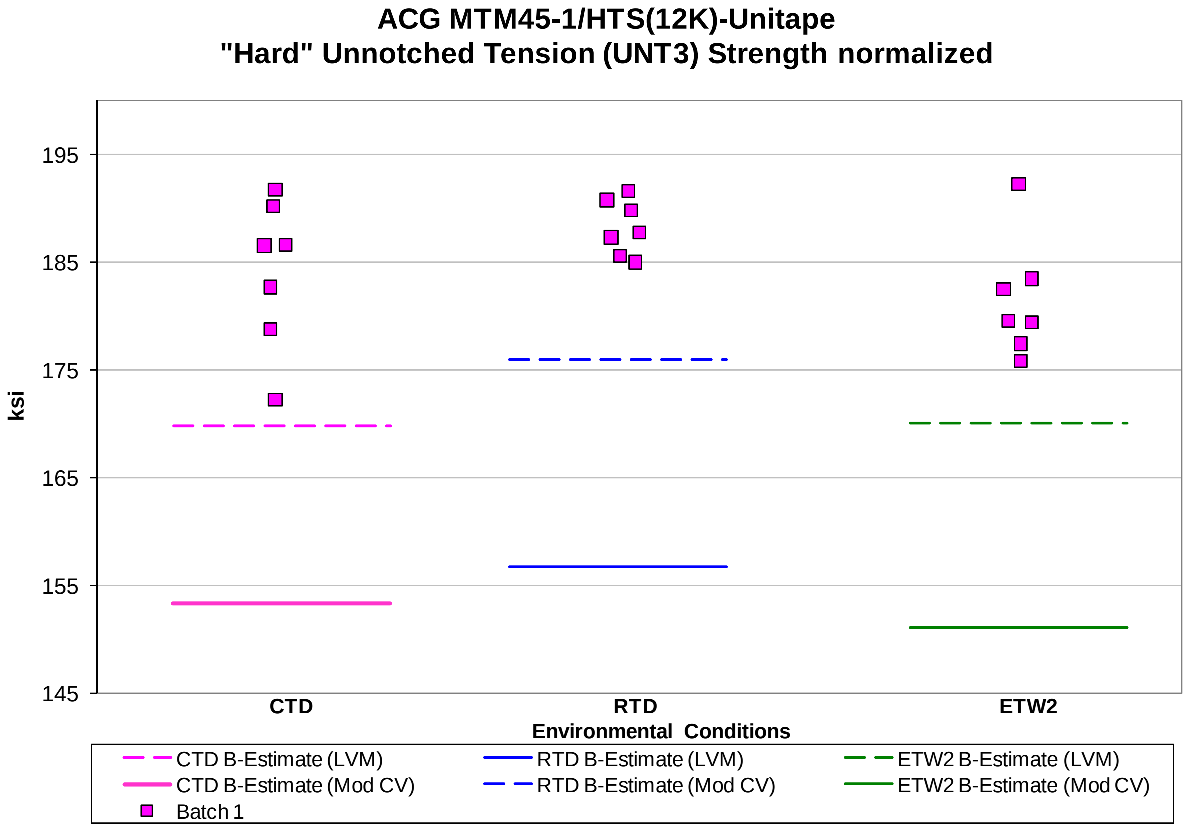

Figure 5:9: Batch plot for UNT3 strength normalized

Unnotched Tension Properties (UNT3) Strength						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	184.13	188.29	181.51	182.25	186.43	179.79
Stdev	6.81	2.54	5.43	7.00	2.93	6.53
CV	3.70	1.35	2.99	3.84	1.57	3.63
Modified CV	8.00	8.00	8.00	8.00	8.00	8.00
Min	172.29	185.02	175.82	169.02	182.36	172.81
Max	191.77	191.60	192.27	188.06	190.13	192.01
No. Batches	1	1	1	1	1	1
No. Spec.	7	7	7	7	7	7
Lamina Variability Method B-estimates						
B-estimate	169.89	176.03	170.14	167.60	170.65	166.13
Modified CV Lamina Variability Method B-estimates						
B-estimate	153.32	156.78	151.13	151.75	155.23	149.70

Table 5-11: Statistics, Basis Values and Estimates for UNT3 Strength data

Unnotched Tension Properties (UNT3) Modulus						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	11.68	11.29	11.24	11.56	11.18	11.13
Stdev	0.22	0.19	0.35	0.20	0.22	0.29
CV	1.92	1.64	3.08	1.74	1.95	2.62
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	11.45	11.01	10.58	11.24	10.93	10.57
Max	12.00	11.59	11.66	11.78	11.59	11.53
No. Batches	1	1	1	1	1	1
No. Spec.	7	7	7	7	7	7

Table 5-12: Statistics for UNT3 Modulus data

5.4 Unnotched Compression (UNC1, UNC2, UNC3) Properties

5.4.1 Quasi Isotropic Unnotched Compression (UNC1) Properties

Pooling was appropriate for the UNC1 data. There were no outliers. Statistics, estimates and basis values are given for UNC1 strength data in Table 5-13. Modulus data is given in Table 5-14. The normalized data, B-estimates and B-basis values are shown graphically in Figure 5:10.

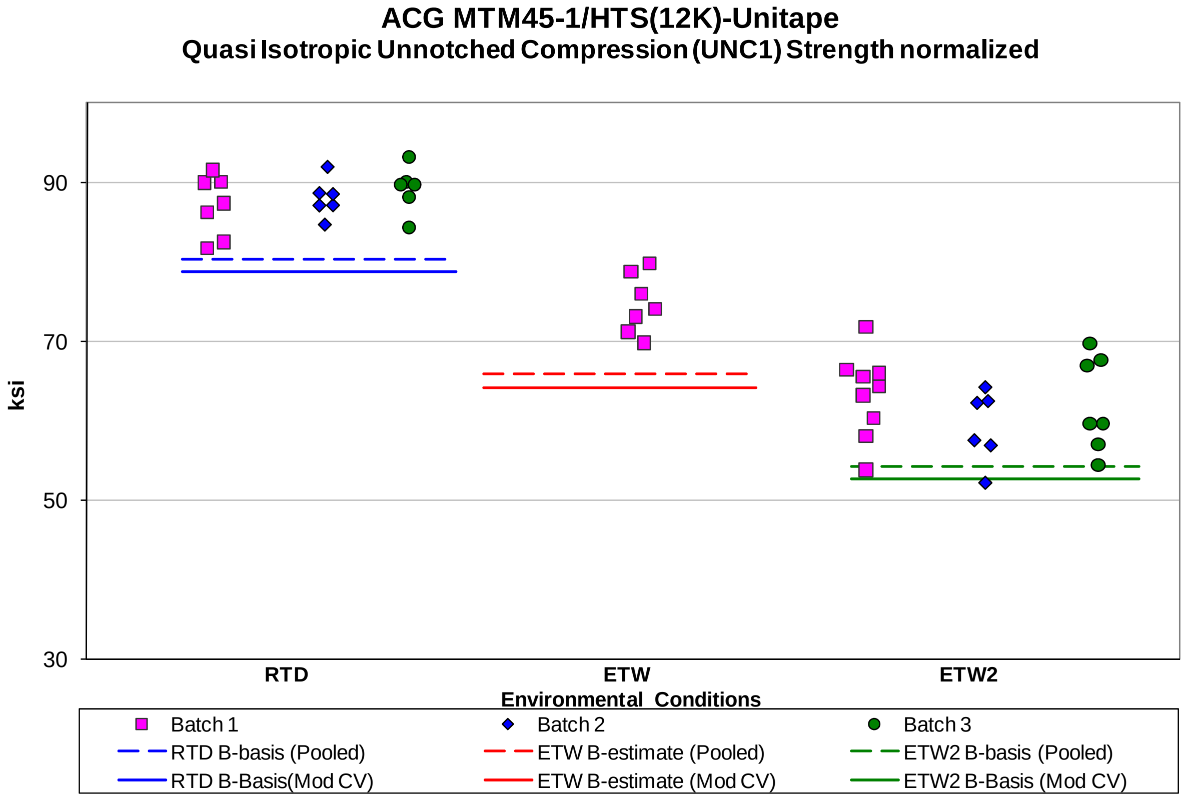

Figure 5:10: Batch plot for UNC1 strength normalized

Unnotched Compression Properties (UNC1) Strength						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	88.02	74.68	61.81	86.60	74.13	60.97
Stdev	3.10	3.71	5.32	3.28	3.54	5.54
CV	3.52	4.96	8.61	3.79	4.77	9.09
Modified CV	6.00	6.48	8.61	6.00	6.38	9.09
Min	81.72	69.84	52.11	80.75	69.20	50.24
Max	93.16	79.79	71.78	92.64	79.00	71.83
No. Batches	3	1	3	3	1	3
No. Spec.	19	7	22	19	7	22
Basis Values and/or Estimates						
B-basis Value	80.31		54.20	78.61		53.08
B-estimate		65.98			65.11	
A-estimate	75.10	60.92	48.96	73.20	59.86	47.66
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	78.72		52.63	77.19		51.69
B-estimate		64.19			63.52	
A-estimate	72.43	58.07	46.31	70.83	57.34	45.30
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 5-13: Statistics, Basis Values and Estimates for UNC1 Strength data

Unnotched Compression Properties (UNC1) Modulus						
	Normalized			As Measured		
Env	RTD	ETW	ETW2	RTD	ETW	ETW2
Mean	6.64	6.72	6.42	6.54	6.67	6.33
Stdev	0.15	0.15	0.22	0.17	0.13	0.24
CV	2.22	2.28	3.37	2.65	1.95	3.82
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	6.35	6.41	6.02	6.15	6.40	5.88
Max	6.91	6.84	6.80	6.87	6.77	6.77
No. Batches	3	1	3	3	1	3
No. Spec.	19	7	20	19	7	20

Table 5-14: Statistics from UNC1 Modulus data

5.4.2 "Soft" Unnotched Compression Properties (UNC2)

There were no outliers. Statistics and B-estimates are given for UNC2 normalized strength data in Table 5-15. Modulus statistics are given in Table 5-16. The normalized data and the B-estimates are shown graphically in Figure 5:11.

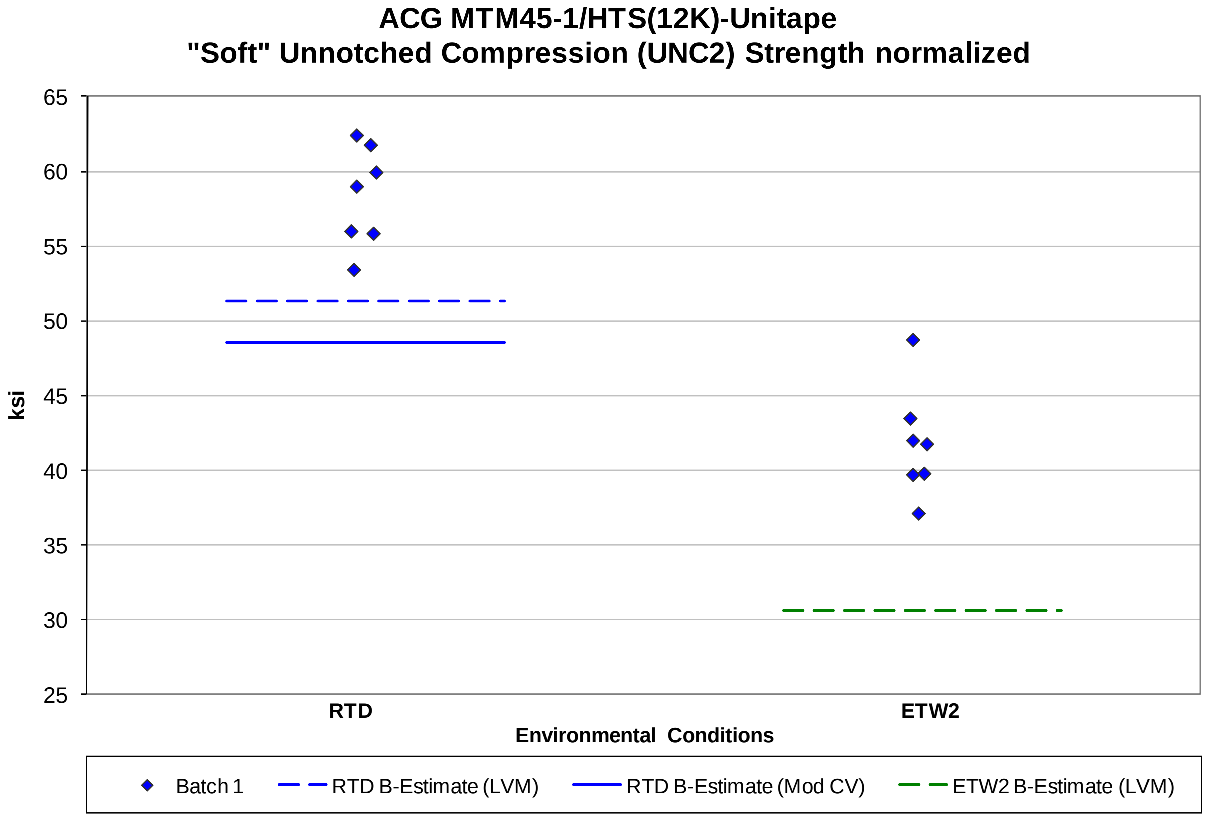

Figure 5:11: Batch plot for UNC2 strength normalized

Unnotched Compression Properties (UNC2) Strength				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	58.30	41.81	58.51	41.67
Stdev	3.34	3.67	3.02	3.67
CV	5.72	8.77	5.16	8.80
Modified CV	8.00	8.77	8.00	8.80
Min	53.40	37.15	55.15	36.98
Max	62.36	48.73	62.00	48.49
No. Batches	1	1	1	1
No. Spec.	7	7	7	7
Lamina Variability Method B-estimates				
B-estimate	51.32	30.59	52.12	30.50
Modified CV LVM B-estimates				
B-estimate	48.54	NA	48.72	NA

Table 5-15: Statistics, Basis Values and Estimates for UNC2 Strength data

Unnotched Compression Properties (UNC2) Modulus				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	4.29	3.88	4.30	3.86
Stdev	0.08	0.07	0.11	0.07
CV	1.87	1.93	2.59	1.91
Mod CV	6.00	6.00	6.00	6.00
Min	4.12	3.80	4.12	3.78
Max	4.38	4.02	4.45	4.00
No. Batches	1	1	1	1
No. Spec.	7	7	7	7

Table 5-16: Statistics from UNC2 Modulus data

5.4.3 "Hard" Unnotched Compression Properties (UNC3)

There were no outliers. Statistics and B-estimates are given for UNC3 normalized strength data in Table 5-17. Modulus statistics are given in Table 5-18. The normalized data and the B-estimates are shown graphically in Figure 5:12.

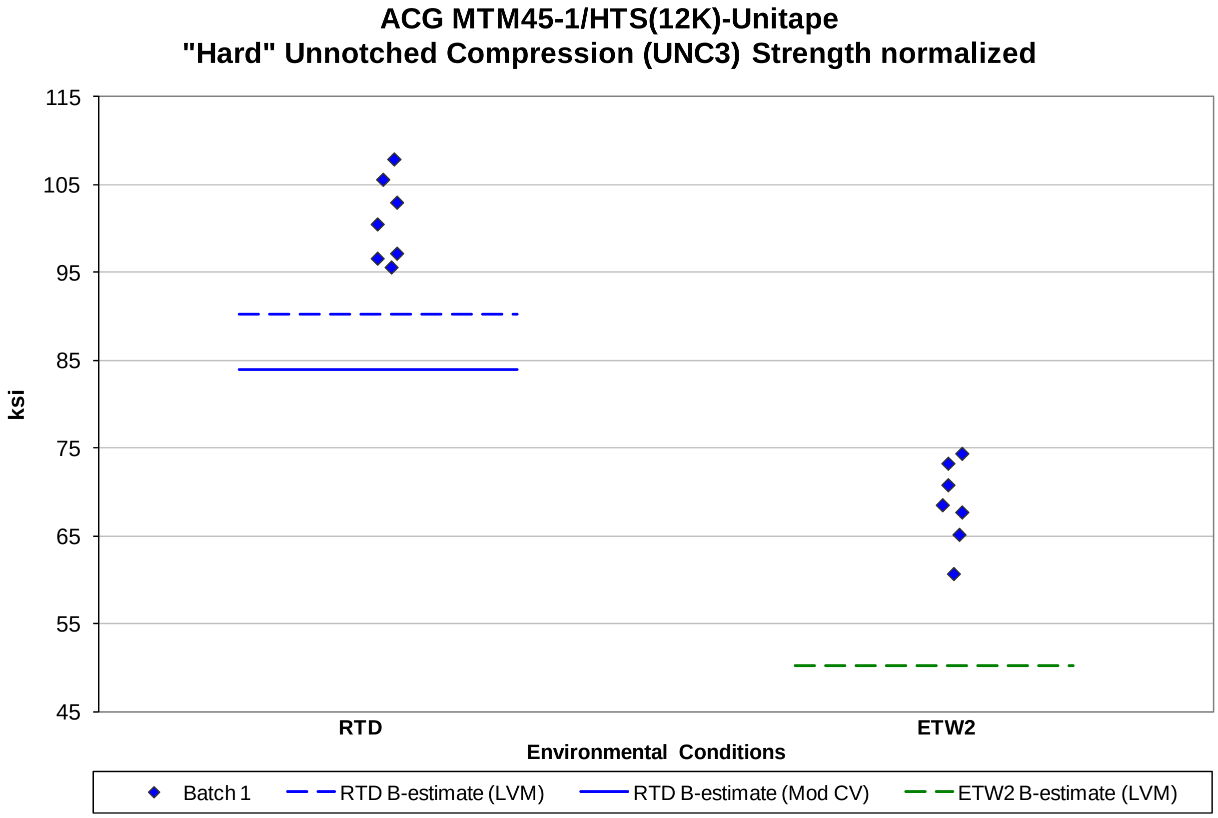

Figure 5:12: Batch plot for UNC3 strength normalized

Unnotched Compression Properties (UNC3) Strength				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	100.88	68.66	98.05	66.71
Stdev	4.75	4.74	2.81	4.86
CV	4.71	6.91	2.87	7.29
Modified CV	8.00	8.00	8.00	8.00
Min	95.58	60.71	95.23	60.45
Max	107.87	74.38	102.80	73.58
No. Batches	1	1	1	1
No. Spec.	7	7	7	7
Lamina Variability Method B-estimates				
B-estimate	90.24	50.22	87.33	48.82
Modified CV LVM B-estimates				
B-estimate	84.00	NA	81.64	NA

Table 5-17: Statistics, Basis Values and Estimates for UNC3 Strength data

Unnotched Compression Properties (UNC3) Modulus				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	10.54	10.51	10.25	10.20
Stdev	0.49	0.79	0.28	0.55
CV	4.69	7.56	2.73	5.43
Mod CV	6.34	7.78	6.00	6.71
Min	9.97	9.33	9.89	9.29
Max	11.15	11.86	10.63	11.14
No. Batches	1	1	1	1
No. Spec.	7	7	7	7

Table 5-18: Statistics from UNC3 Modulus Data

5.5 Laminate Short Beam Strength Properties (LSBS)

The LSBS data is not normalized. The RTD and ETW2 data failed the ADK test, so they required an ANOVA analysis. In order for B-basis values to be computed using the ANOVA method, data from five batches is required. Since these datasets have only three batches, the basis values computed using ANOVA are considered estimates. However, both datasets passed the ADK test after the transform for the modified CV method, so modified CV basis values are provided, but pooling across environments was not appropriate because the transformed data did not pass Levene's test. There were two outliers, one in the RTD data and one in the ETW2 data. Both outliers were on the low side of the batch three data. Both were outliers only before pooling the three batches. Both outliers were retained for this analysis.

Statistics, estimates and basis values are given for LSBS strength data in Table 5-19. The data, B-basis values and B-estimates are shown graphically in Figure 5:13.

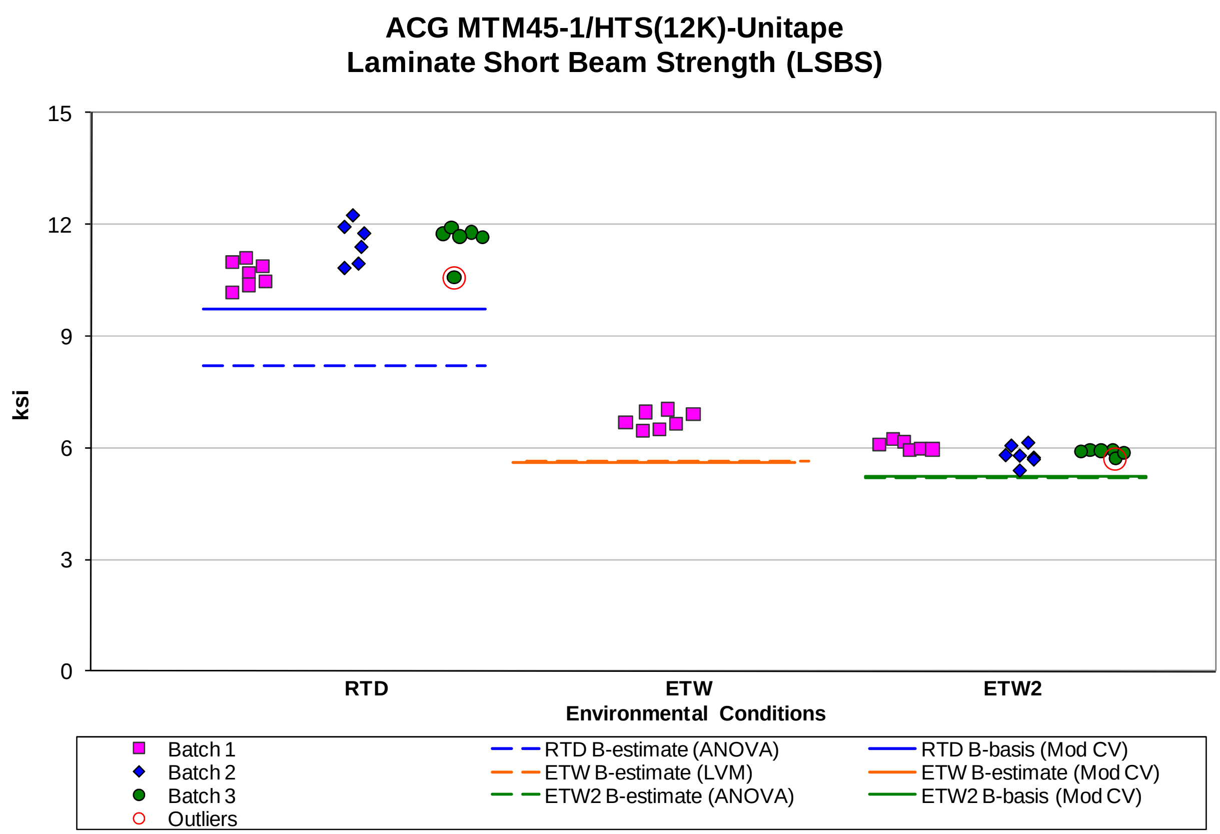

Figure 5:13: Batch plot for LSBS strength as measured

Laminate Short Beam Strength (LSBS) as measured			
Env	RTD	ETW	ETW2
Mean	11.22	6.74	5.91
Stdev	0.61	0.23	0.20
CV	5.48	3.37	3.30
Mod CV	6.74	8.00	6.00
Min	10.18	6.45	5.41
Max	12.24	7.03	6.24
No. Batches	3	1	3
No. Spec.	19	7	19
Basis Values and/or Estimates			
B-estimate	8.19	5.64	5.19
A-estimate	6.04	NA	4.67
Method	ANOVA	LVM	ANOVA
Modified CV Basis Values and/or Estimates			
B-basis Value	9.74		5.22
B-estimate		5.61	
A-estimate	8.70	NA	4.73
Method	Normal	LVM	Normal

Table 5-19: Statistics, Basis Values and Estimates for LSBS Strength data

5.6 Filled Hole Tension (FHT1, FHT2, FHT3) Properties

5.6.1 Quasi Isotropic Filled Hole Tension (FHT1) Properties

The FHT1 CTD data failed the ADK test, so it required an ANOVA analysis. In order for B-basis values to be computed using the ANOVA method, data from five batches is required. Since this dataset has only three batches, the basis values computed using ANOVA are considered estimates. The dataset passed the ADK test after the transform for the modified CV method, but failed the normality test. The lack of normality means that modified CV basis values are not appropriate. There was one outlier. It was in the normalized CTD data on the high side of batch two. It was an outlier only before pooling the three batches. The outlier was retained for this analysis.

Statistics, basis values and estimates are given for FHT1 normalized strength data in Table 5-20. The normalized data and B-estimates are shown graphically in Figure 5:14.

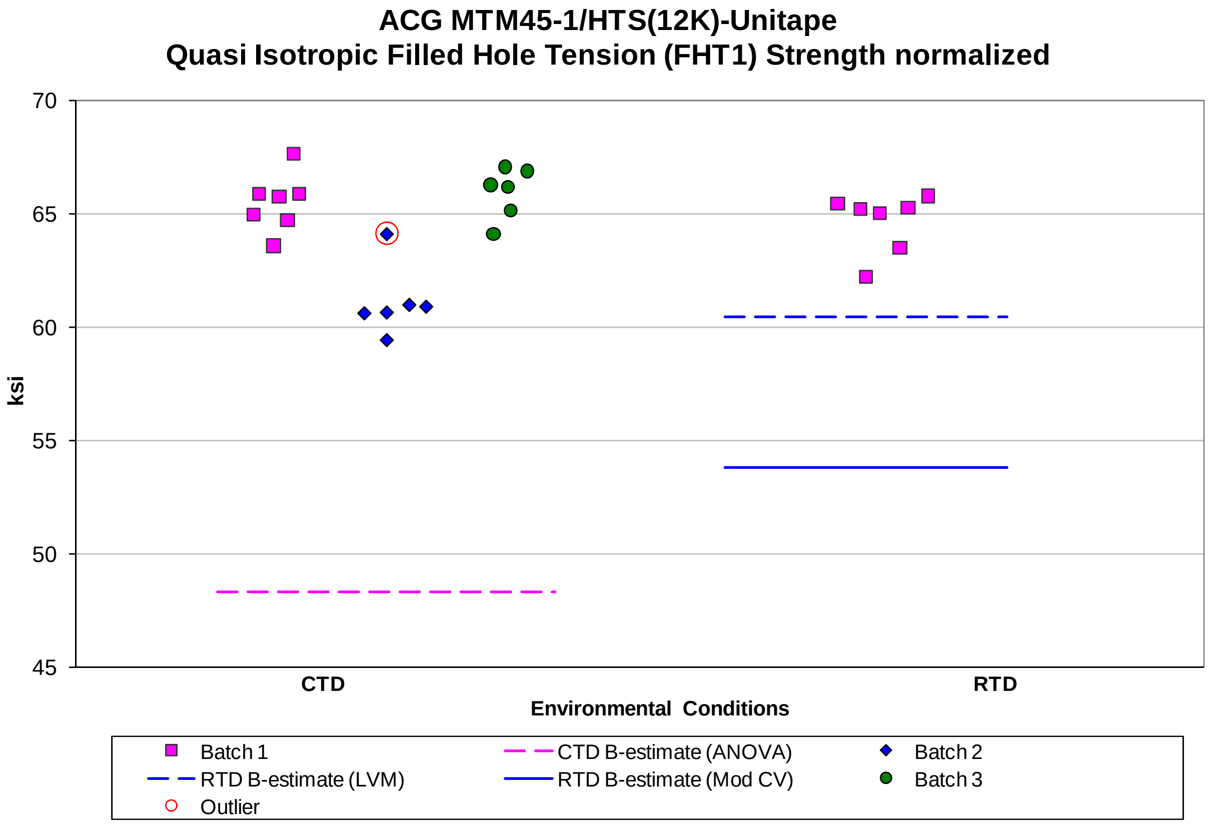

Figure 5:14: Batch plot for FHT1 strength normalized

Filled-Hole Tension Properties (FHT1) Strength				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	64.25	64.63	63.51	64.44
Stdev	2.53	1.28	2.86	1.37
CV	3.94	1.99	4.50	2.13
Modified CV	6.00	8.00	6.25	8.00
Min	59.42	62.24	58.08	61.74
Max	67.65	65.78	67.05	65.72
No. Batches	3	1	3	1
No. Spec.	19	7	19	7
Basis Values and/or Estimates				
B-estimate	48.32	60.42	45.03	58.98
A-estimate	36.94	NA	31.83	NA
Method	ANOVA	LVM	ANOVA	LVM
Modified CV Basis Values and/or Estimates				
B-estimate	NA	53.81	NA	53.65
A-estimate	NA	NA	NA	NA
Method	NA	LVM	NA	LVM

Table 5-20: Statistics, Basis Values and Estimates for FHT1 Strength data

5.6.2 "Soft" Filled Hole Tension (FHT2)

There were no outliers. Statistics and B-estimates are given for FHT2 strength data in Table 5-21. The normalized data and B-estimates are shown graphically in Figure 5:15.

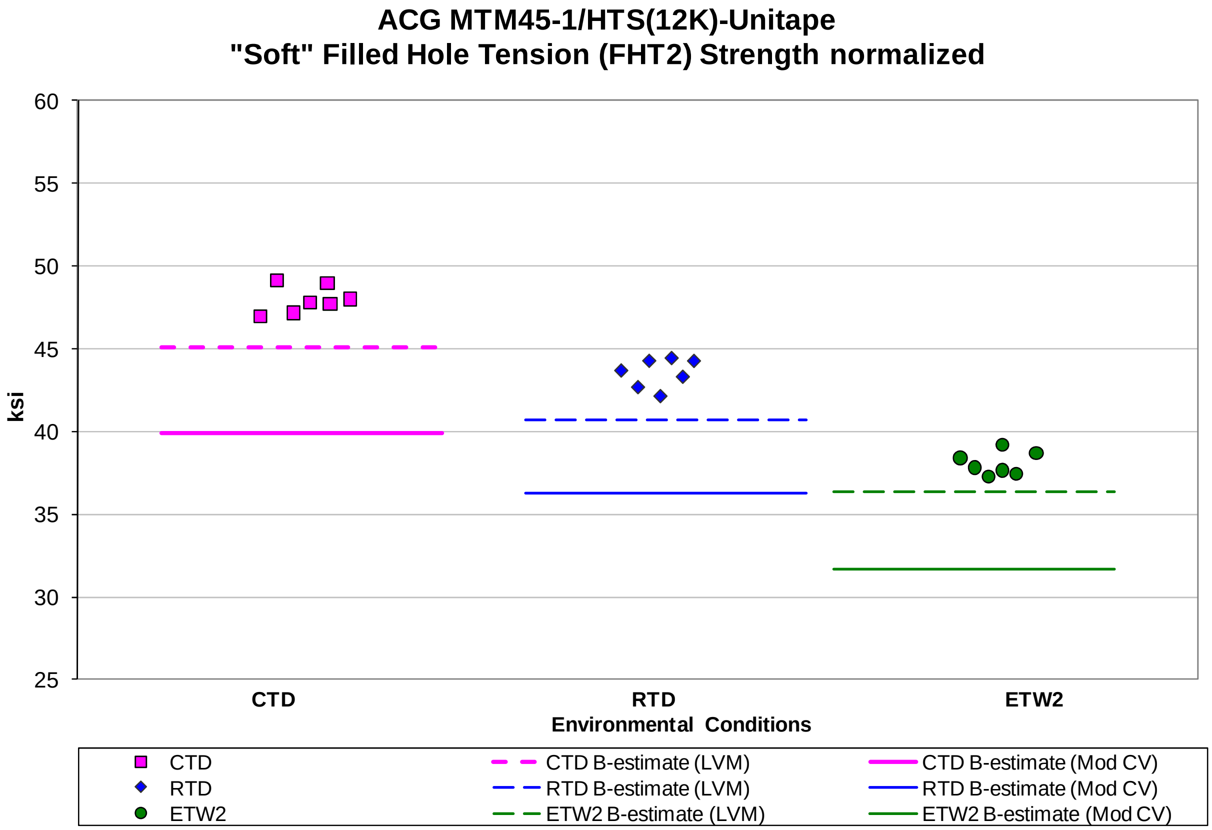

Figure 5:15: Batch plot for FHT2 strength normalized

Filled-Hole Tension Properties (FHT2) Strength						
	Normalized			As Measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	47.97	43.54	38.07	47.30	42.91	37.51
Stdev	0.82	0.87	0.71	0.85	0.80	0.65
CV	1.72	1.99	1.86	1.80	1.88	1.72
Modified CV	8.00	8.00	8.00	8.00	8.00	8.00
Min	46.95	42.16	37.29	46.16	41.57	36.93
Max	49.14	44.42	39.20	48.34	43.87	38.47
No. Batches	1	1	1	1	1	1
No. Spec.	7	7	7	7	7	7
Lamina Variability Method (LVM) Estimates of Basis Values						
B-estimate	45.08	40.70	36.42	44.11	39.27	35.59
Modified CV LVM Estimates of Basis Values						
B-estimate	39.94	36.25	31.70	39.39	35.73	31.23

Table 5-21: Statistics, Basis Values and Estimates for FHT2 Strength data

5.6.3 "Hard" Filled Hole Tension (FHT3)

There were no outliers. Statistics and B-estimates are given for FHT3 strength data in Table 5-22. The normalized data and B-estimates are shown graphically in Figure 5:16.

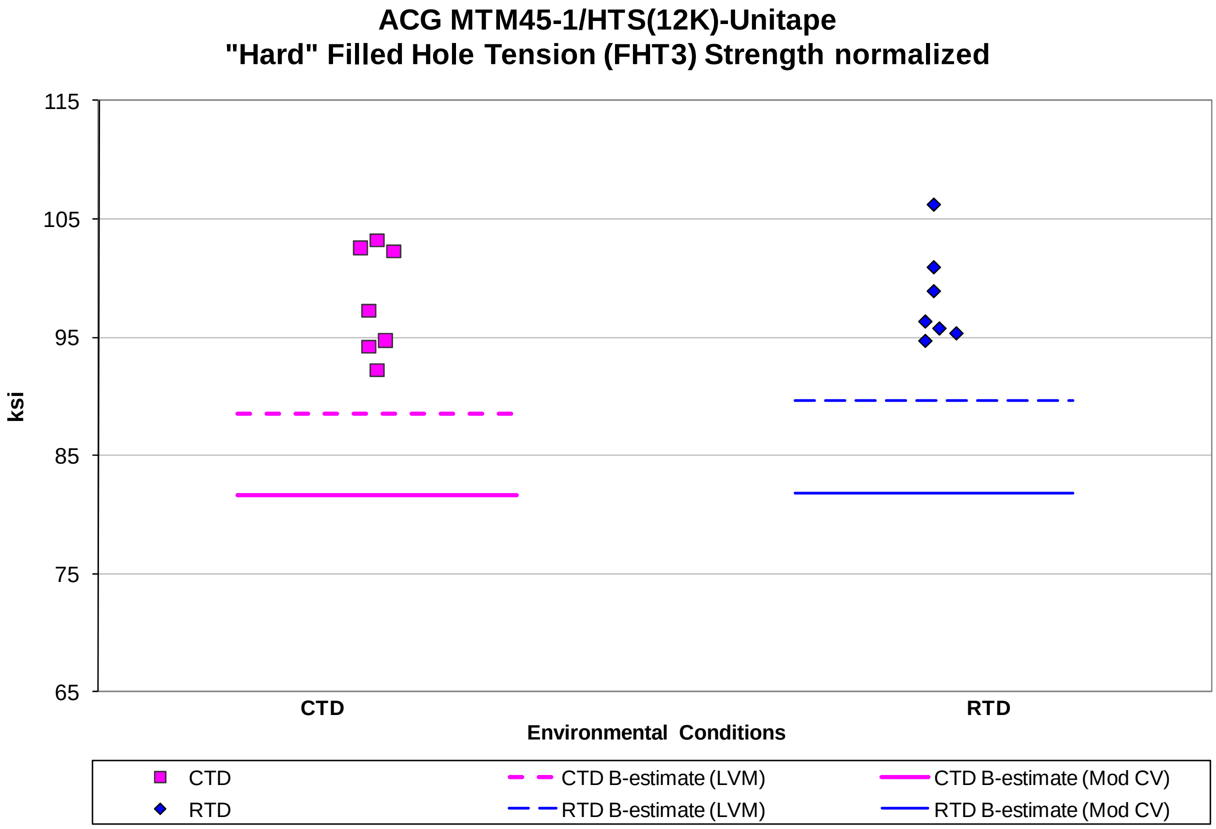

Figure 5:16: Batch plot for FHT3 strength normalized

Filled-Hole Tension Properties (FHT3) Strength				
	Normalized		As Measured	
Env	CTD	RTD	CTD	RTD
Mean	98.06	98.30	97.01	97.35
Stdev	4.57	4.12	4.63	4.23
CV	4.66	4.19	4.77	4.35
Modified CV	8.00	8.00	8.00	8.00
Min	92.22	94.69	91.08	92.88
Max	103.20	106.21	102.23	105.22
No. Batches	1	1	1	1
No. Spec.	7	7	7	7
Lamina Variability Method Estimated B-Basis				
B-estimate	88.50	89.68	87.33	88.50
Modified CV LVM Estimates of Basis Values				
B-estimate	81.65	81.85	80.77	81.06

Table 5-22: Statistics, Basis Values and Estimates for FHT3 Strength data

5.7 Filled Hole Compression (FHC1, FHC2, FHC3) Properties

5.7.1 Quasi Isotropic Filled Hole Compression (FHC1)

There were no test failures or outliers. Statistics, estimates and basis values are given for FHC1 strength data in Table 5-23. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:17.

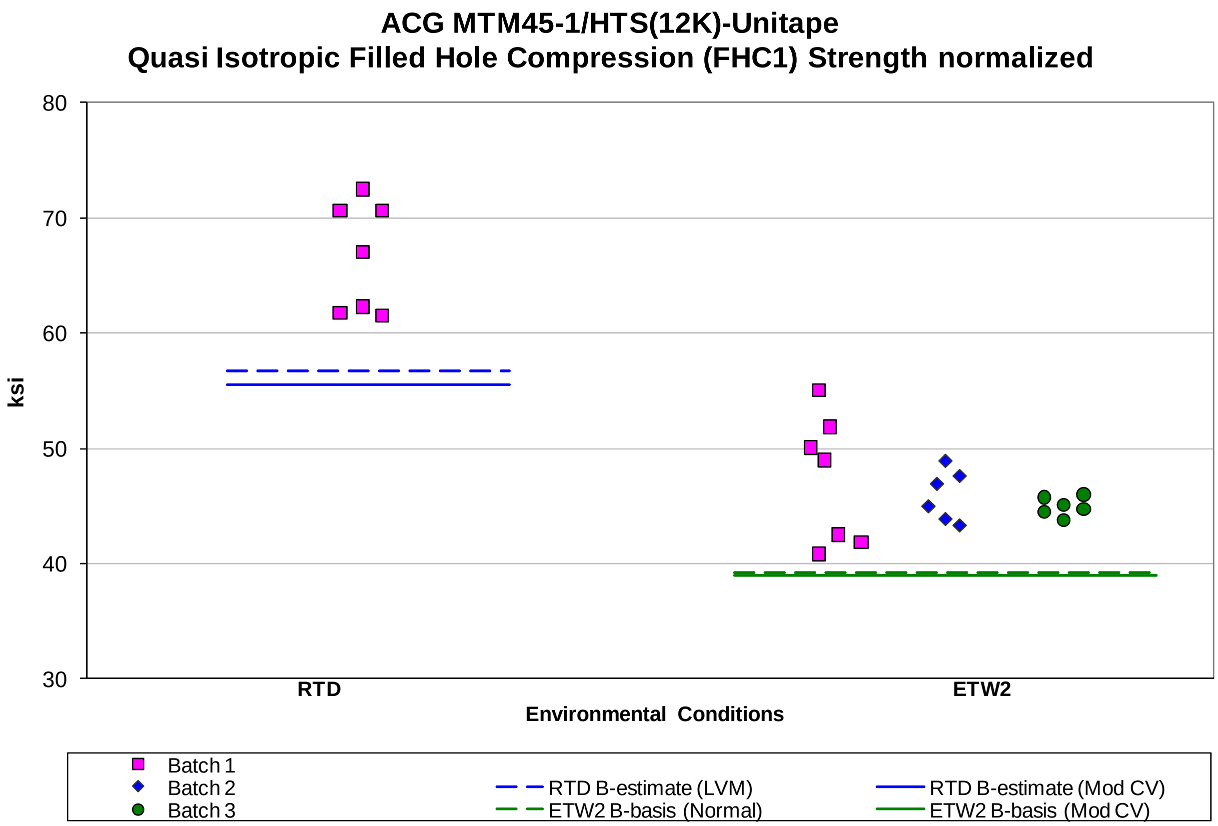

Figure 5:17: Batch plot for FHC1 strength normalized

Filled-Hole Compression Properties (FHC1) Strength				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	66.64	46.16	65.30	45.32
Stdev	4.75	3.59	5.03	3.50
CV	7.13	7.78	7.71	7.72
Modified CV	8.00	7.89	8.00	7.86
Min	61.50	40.85	59.84	39.92
Max	72.48	55.07	71.29	54.05
No. Batches	1	3	1	3
No. Spec.	7	19	7	19
Basis Values and/or Estimates				
B-basis Value		39.17		38.50
B-estimate	56.70		54.77	
A-estimate	NA	34.20	NA	33.66
Method	LVM	Normal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		39.06		38.38
B-estimate	55.48		54.37	
A-estimate	NA	34.03	NA	33.45
Method	LVM	Normal	LVM	Normal

Table 5-23: Statistics, Basis Values and Estimates for FHC1 Strength data

5.7.2 "Soft" Filled Hole Compression (FHC2)

There were no test failures or outliers. Statistics, estimates and basis values are given for FHC2 strength data in Table 5-24. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:18.

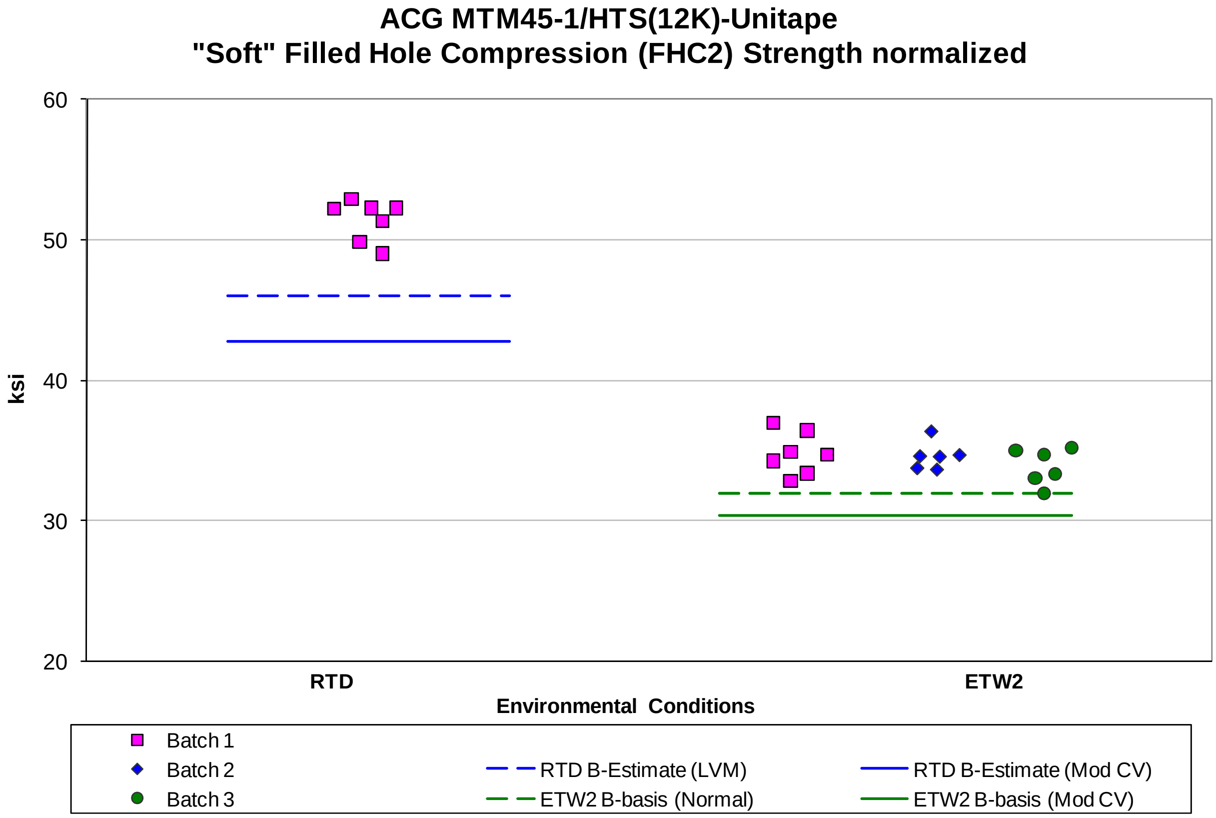

Figure 5:18: Batch plot for FHC2 strength normalized

Filled-Hole Compression Properties (FHC2) Strength				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	51.42	34.46	50.41	33.86
Stdev	1.45	1.28	1.44	1.31
CV	2.82	3.72	2.86	3.86
Modified CV	8.00	6.00	8.00	6.00
Min	49.02	31.99	47.96	31.90
Max	52.91	36.96	51.70	36.06
No. Batches	1	3	1	3
No. Spec.	7	19	7	19
Basis Values and/or Estimates				
B-basis Value		31.96		31.32
B-estimate	46.00		44.90	
A-estimate	NA	30.19	NA	29.51
Method	LVM	Normal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		30.43		29.90
B-estimate	42.81		41.97	
A-estimate	NA	27.57	NA	27.10
Method	LVM	Normal	LVM	Normal

Table 5-24: Statistics, Basis Values and Estimates for FHC2 Strength data

5.7.3 "Hard" Filled Hole Compression (FHC3)

There were no test failures or outliers. Statistics, estimates and basis values are given for FHC3 strength data in Table 5-25. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:19.

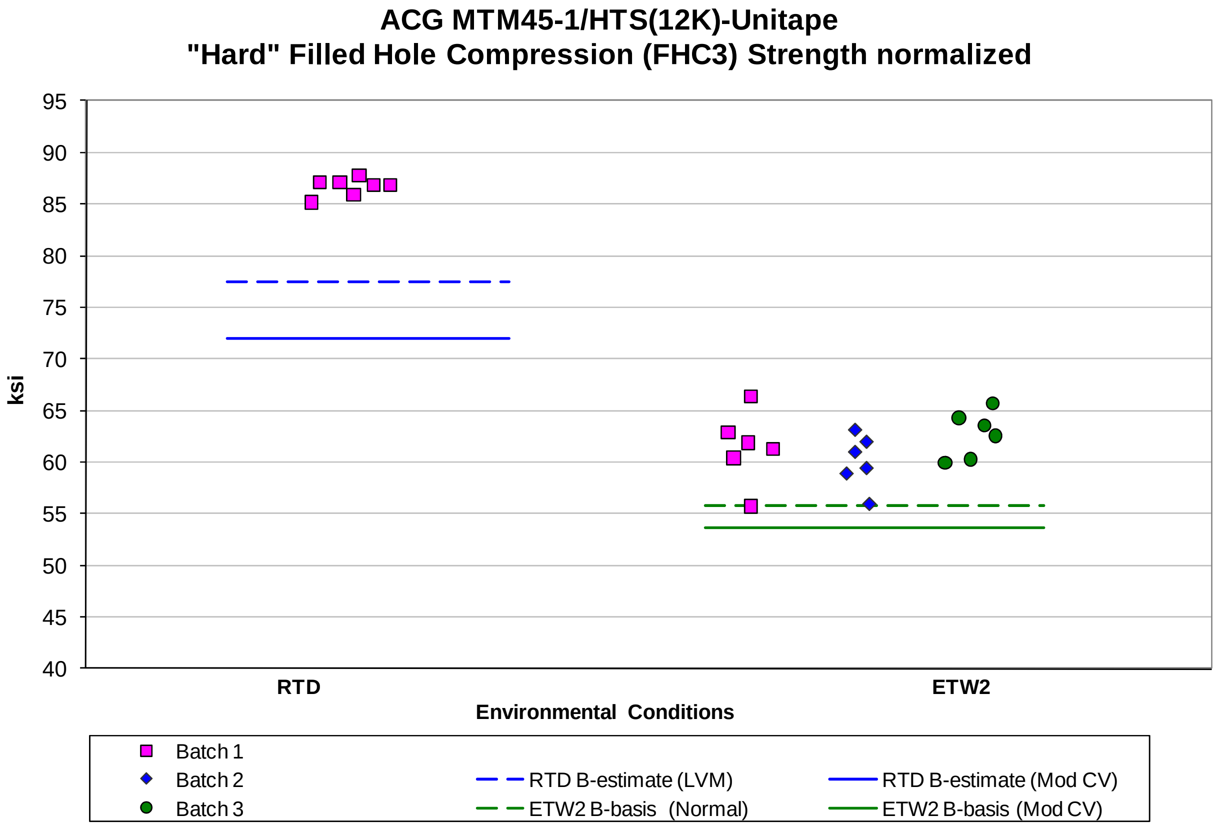

Figure 5:19: Batch plot for FHC3 strength normalized

Filled-Hole Compression Properties (FHC3) Strength				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	86.68	61.40	85.21	60.80
Stdev	0.87	2.87	0.96	3.44
CV	1.00	4.67	1.12	5.66
Modified CV	8.00	6.33	8.00	6.83
Min	85.17	55.74	83.81	54.19
Max	87.79	66.39	86.69	66.37
No. Batches	1	3	1	3
No. Spec.	7	18	7	18
Basis Values and/or Estimates				
B-basis Value		55.74		54.01
B-estimate	77.54		75.91	
A-estimate	NA	51.73	NA	49.20
Method	LVM	Normal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		53.72		52.60
B-estimate	72.17		70.95	
A-estimate	NA	48.29	NA	46.80
Method	LVM	Normal	LVM	Normal

Table 5-25: Statistics, Basis Values and Estimates for FHC3 Strength data

5.8 Pin Bearing (PB1, PB2, PB3) Properties

5.8.1 Quasi Isotropic Pin Bearing (PB1)

The PB1 RTD 2% strength data, both normalized and as measured, failed the ADK test, so they required an ANOVA analysis. In order for B-basis values to be computed using the ANOVA method, data from five batches is required. Since these datasets have only three batches, the basis values computed using ANOVA are considered estimates. However, both datasets passed the ADK test after the transform for the modified CV method, so modified CV basis values are provided. Pooling the two environments was appropriate for computing the modified CV basis values. There were no outliers.

Statistics, estimates and basis values are given for the 2% offset strength data in Table 5-26. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:20.

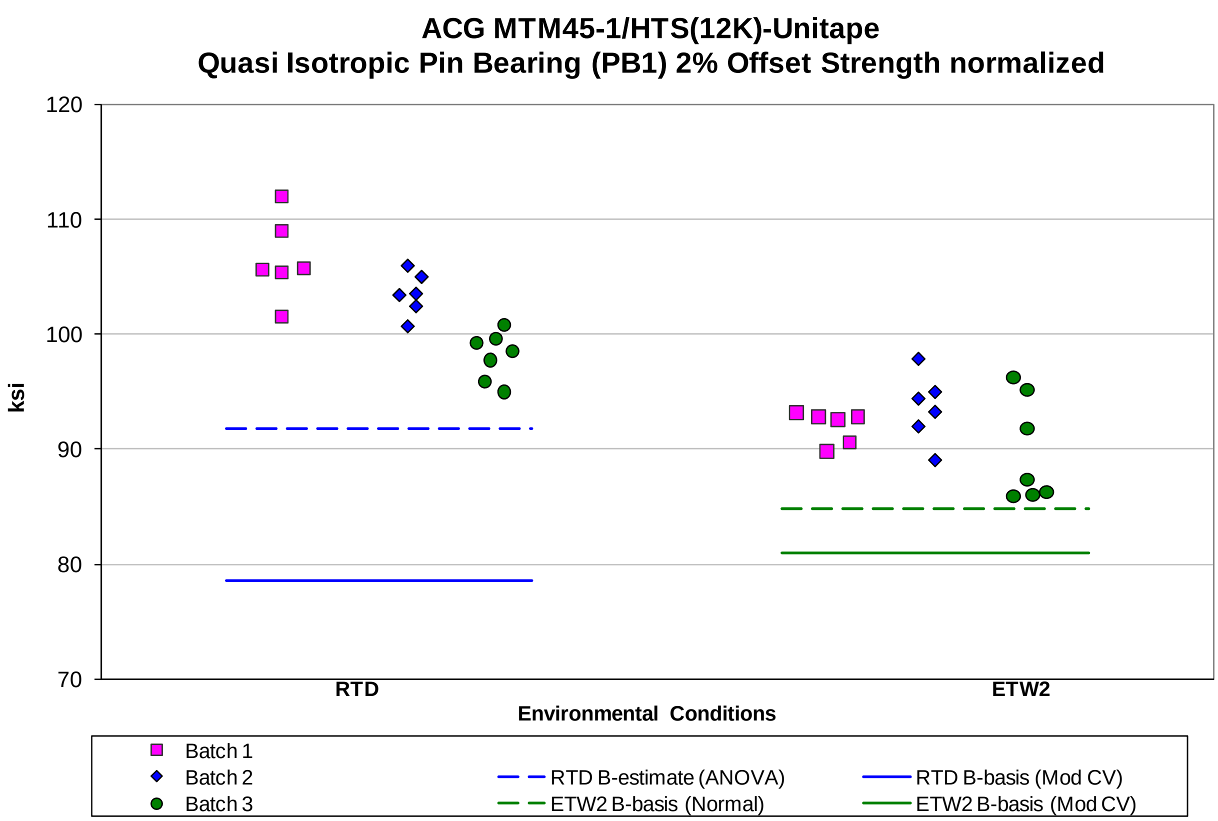

Figure 5:20: Batch plot for PB1 strength normalized

Pin Bearing (PB1) 2% Offset Strength				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	102.47	91.67	100.54	90.10
Stdev	4.38	3.51	4.48	3.58
CV	4.27	3.83	4.46	3.98
Modified CV	6.14	6.00	6.23	6.00
Min	94.97	85.88	93.70	84.02
Max	112.00	97.81	111.54	95.96
No. Batches	3	3	3	3
No. Spec.	19	19	19	19
Basis Values and/or Estimates				
B-basis Value		84.84		83.11
B-estimate	78.64		76.64	
A-estimate	61.63	79.98	59.58	78.15
Method	ANOVA	Normal	ANOVA	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value	91.81	81.01	89.99	79.55
A-estimate	84.53	73.74	82.78	72.34
Method	pooled	pooled	pooled	pooled

Table 5-26: Statistics, Basis Values and Estimates for PB1 2% Offset Strength data

5.8.2 "Soft" Pin Bearing (PB2)

The PB2 ETW2 data had one outlier. It was an outlier in both the normalized and as measured data. It was on the high side of batch three. It was an outlier only after pooling the three batches. The outlier was retained for this analysis.

Statistics, estimates and basis values are given for the 2% offset strength data in Table 5-27. The normalized data, B-basis values and B-estimates are shown graphically in Figure 5:21.

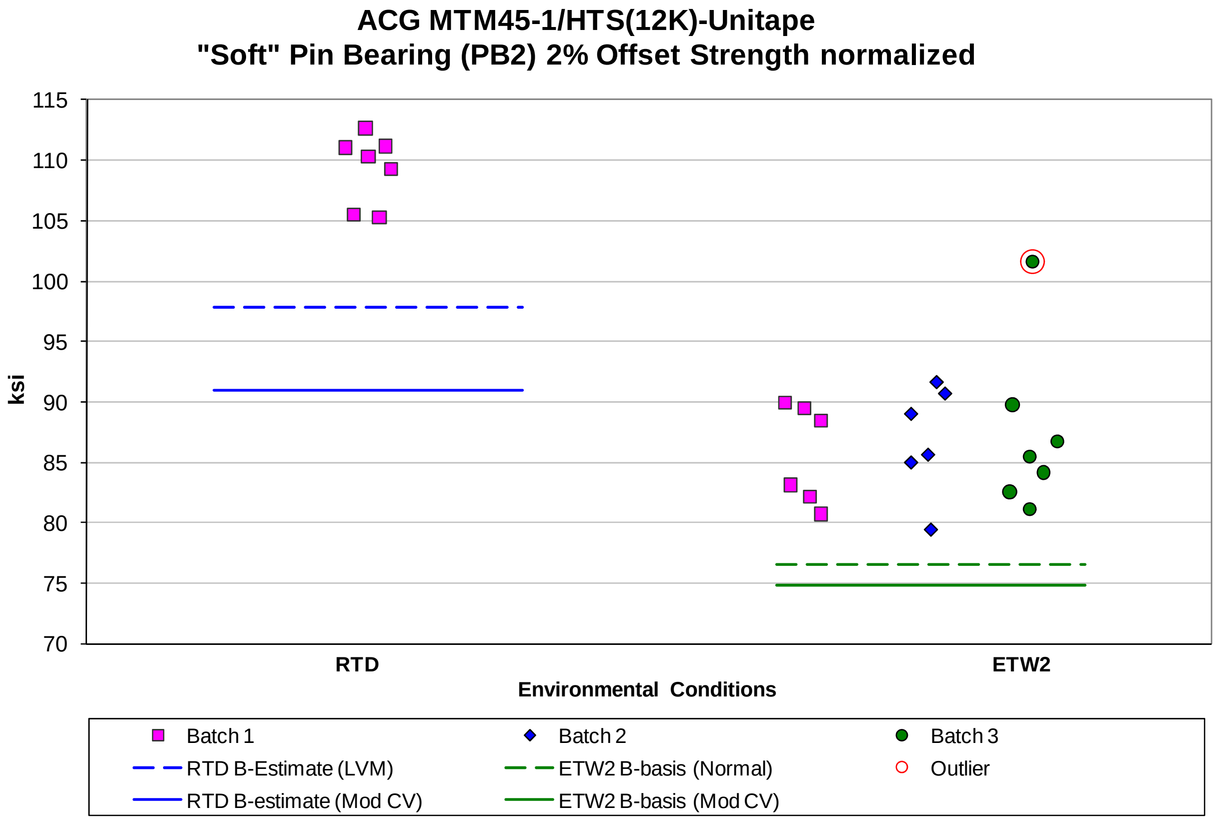

Figure 5:21: Batch plot for PB2 strength normalized

Pin Bearing (PB2) 2% Offset Strength				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	109.32	86.68	107.47	85.59
Stdev	2.88	5.18	3.00	5.20
CV	2.63	5.98	2.79	6.08
Modified CV	8.00	6.99	8.00	7.04
Min	105.26	79.40	102.30	77.82
Max	112.65	101.62	111.07	100.66
No. Batches	1	3	1	3
No. Spec.	7	19	7	19
Basis Values and/or Estimates				
B-basis Value		76.58		75.46
B-estimate	97.79		95.73	
A-estimate	NA	69.41	NA	68.26
Method	LVM	Normal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		74.87		73.85
B-estimate	91.02		89.49	
A-estimate	NA	66.50	NA	65.53
Method	LVM	Normal	LVM	Normal

Table 5-27: Statistics, Basis Values and Estimates for PB2 2% Offset Strength data

5.8.3 "Hard" Pin Bearing (PB3)

There were no test failures or outliers. Statistics, estimates and basis values and estimates are given for the 2% offset strength data in Table 5-28. The normalized data, B-basis values and B-estimates for the strength data are shown graphically in Figure 5:22.

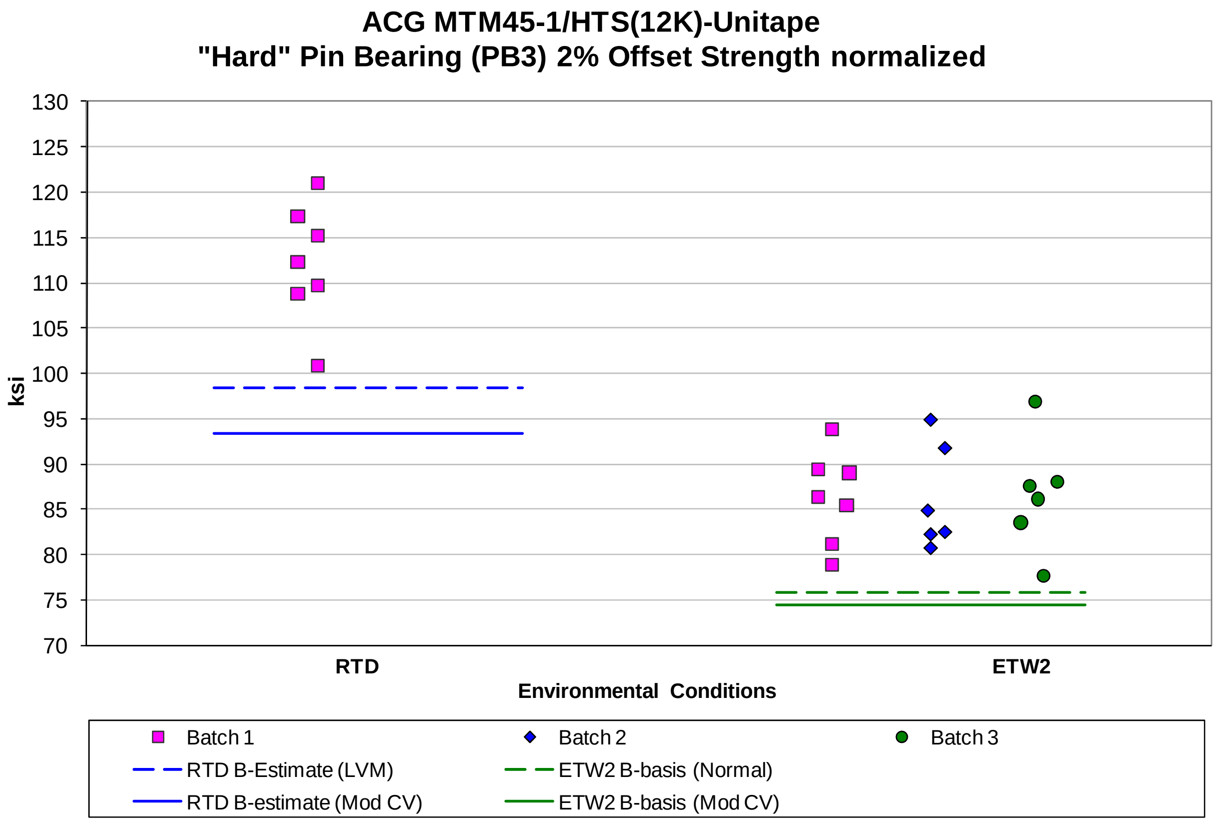

Figure 5:22: Batch plot for PB3 strength normalized

Pin Bearing (PB3) 2% Offset Strength				
	Normalized		As Measured	
Env	RTD	ETW2	RTD	ETW2
Mean	112.19	86.37	110.62	85.46
Stdev	6.57	5.39	6.64	5.34
CV	5.86	6.24	6.01	6.24
Modified CV	8.00	7.12	8.00	7.12
Min	100.89	77.70	99.31	76.74
Max	120.99	96.91	119.79	95.77
No. Batches	1	3	1	3
No. Spec.	7	19	7	19
Basis Values and/or Estimates				
B-basis Value		75.87		75.06
B-estimate	98.43		96.72	
A-estimate	NA	68.41	NA	67.68
Method	LVM	Normal	LVM	Normal
Modified CV Basis Values and/or Estimates				
B-basis Value		74.39		73.60
B-estimate	93.41		92.11	
A-estimate	NA	65.89	NA	65.19
Method	LVM	Normal	LVM	Normal

Table 5-28: Statistics, Basis Values and Estimates for PB3 2% Offset Strength data

5.9 Compression After Impact (CAI) Properties

Basis values are not computed for this property. Test results only are presented here. It was tested at only one environmental condition (RTD). Statistics are given for the Compression After Impact (CAI) strength data in Table 5-29. The normalized data are shown graphically in Figure 5:23.

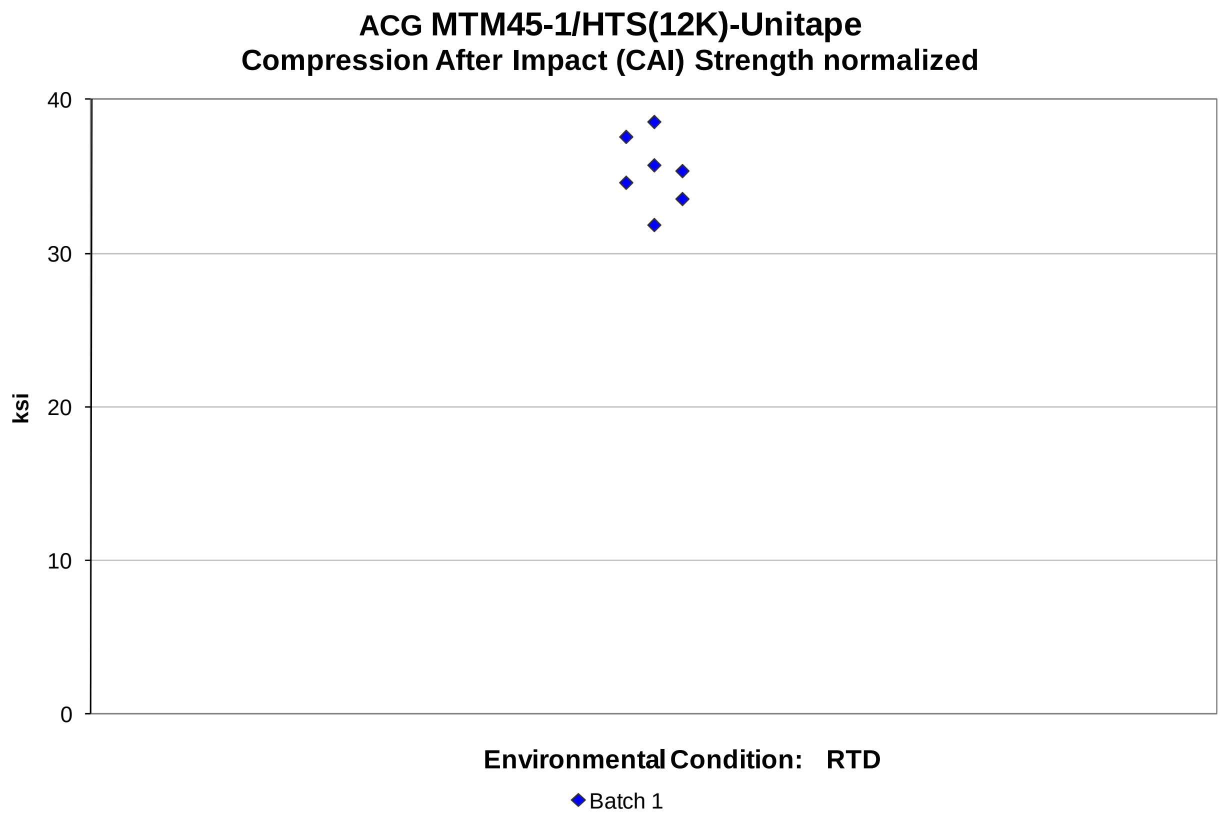

Figure 5:23: Plot of CAI strength data normalized

Compression After Impact Strength (ksi)		
RTD Env.	Normalized	As measured
Mean	35.30	34.79
Stdev	2.28	2.34
CV	6.47	6.74
Modified CV	7.24	7.37
Min	31.84	31.37
Max	38.53	38.12
No. Batches	1	1
No. Spec.	7	7

Table 5-29: Statistics for CAI data

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

The ILT and CBS data is not normalized. Basis values are not computed for the Interlaminar tension or curved beam strength data. Test results only are presented here. ILT tests were performed at both RTD and ETW2 environmental conditions. Statistics are given for the Interlaminar Tension (ILT) and Curved Beam strength (CBS) data in Table 5-30. The normalized data are shown graphically in Figure 5:24.

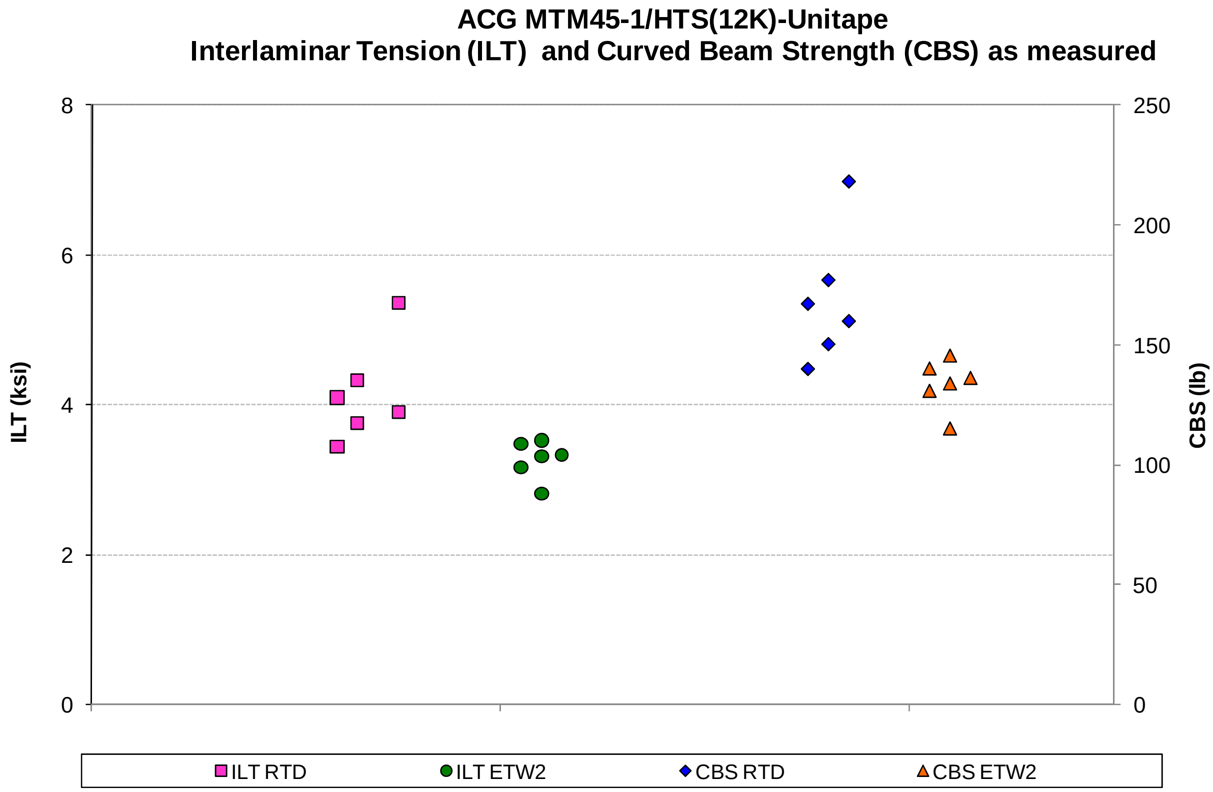

Figure 5:24: Plot of ILT and CBS data

Property	ILT (ksi)		CBS (lb)	
Env	RTD	ETW2	RTD	ETW2
Mean	4.15	3.28	168.77	133.65
Stdev	0.67	0.26	27.28	10.50
CV	16.10	7.86	16.16	7.86
Mod CV	16.10	7.93	16.16	7.93
Min	3.44	2.82	140.13	114.99
Max	5.37	3.53	217.91	145.67
No. Batches	1	1	1	1
No. Spec.	6	6	6	6

Table 5-30: Statistics for ILT and CBS data

6. Outliers

Outliers were identified according to the standards documented in section 2.1.4, 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.

All outliers identified were investigated to determine if a cause could be found. Outliers with causes were removed from the dataset and the remaining specimens were analyzed for this report. Information about specimens that were removed from the dataset along with the cause for removal is documented in the material property data report, NCAMP Test Report CAM-RP-2009-010 Rev B.

Outliers for which no causes could be identified 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
TT	RTD	1	ABMUA212A	NA	9.47	High	Yes	No
TT	ETW2	1	ABMUA21ED	NA	4.08	Low	Yes	No
UNC0	ETD	3	ABMRC21AC	79.58	79.83	Low	Yes	No
UNC0	ETW	2	ABMRB11DN	115.92	Not an Outlier	High	No	Yes
LC				214.11				
UNC0	ETW2	2	ABMRB21HD	76.69	74.87	High	Yes	No
LC				148.31	144.92			
IPS - 0.2% Offset	CTD	2	ABMNB218B	NA	9.34	High	Yes	No
IPS - 0.2% Offset	RTD	3	ABMNA115A	NA	5.99	Low	Yes	No
IPS - 5% Strain	CTD	2	ABMNB216B	NA	10.90	Low	No	Yes
OHT1	CTD	2	ABMDB218B	56.42	Not an Outlier	Low	No	Yes
OHT3	ETW2	1	ABMFA11AD	123.36	124.88	High	Yes	NA
OHC2	ETW2	1	ABMHA216D	Not an Outlier	27.83	High	Yes	No
LSBS	RTD	3	ABMqC1W2A	NA	10.57	Low	Yes	No
LSBS	ETW2	3	ABMqC2W6D	NA	5.71	Low	Yes	No
FHT1	CTD	2	ABM4B214B	64.12	Not an Outlier	High	Yes	No
PB2	ETW2	3	ABM2C111D	101.62	100.66	High	No	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.
3. Scholz, F.W. and Stephens, M.A., "K-Sample Anderson-Darling Tests of Fit," *Journal of the American Statistical Association*, Vol. 82, 1987, pp. 918-924.
4. Lehmann, E.L., *Testing Statistical Hypotheses*, John Wiley & Sons, 1959, pp. 274-275.
5. Levene, H., "Robust Tests for Equality of Variances," in *Contributions to Probability and Statistics*, ed. I. Olkin, Palo, Alto, CA: Stanford University Press, 1960.
6. Lawless, J.F., *Statistical Models and Methods for Lifetime Data*, John Wiley & Sons, 1982, pp. 150, 452-460.
7. *Metallic Materials and Elements for Aerospace Vehicle Structures*, MIL-HDBK-5E, Naval Publications and Forms Center, Philadelphia, Pennsylvania, 1 June 1987, pp. 9-166,9-167.
8. Hanson, D.L. and Koopmans, L.H., "Tolerance Limits for the Class of Distribution with Increasing Hazard Rates," *Annals of Math. Stat.*, Vol 35, 1964, pp. 1561-1570.
9. Vangel, M.G., "One-Sided Nonparametric Tolerance Limits," *Communications in Statistics: Simulation and Computation*, Vol. 23, 1994, p. 1137.
10. Vangel, M.G., "New Methods for One-Sided Tolerance Limits for a One-Way Balanced Random Effects ANOVA Model," *Technometrics*, Vol 34, 1992, pp. 176-185.
11. Odeh, R.E. and Owen, D.B., *Tables of Normal Tolerance Limits, Sampling Plans and Screening*, Marcel Dekker, 1980.
12. Tomblin, John and Seneviratne, Waruna, *Laminate Statistical Allowable Generation for Fiber-Reinforced Composites Material: Lamina Variability Method,* U.S. Department of Transportation, Federal Aviation Administration, May 2006.
13. CMH-17 Rev G, Volume 1, 2012. SAE International, 400 Commonwealth Drive, Warrendale, PA 15096