Solvay Cytec Cycom 5320-1 T650 Unitape Gr 145 Qualification Statistical Analysis Report

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1. Introduction

This report contains statistical analysis of the Solvay Cytec Cycom 5320-1 T650 Unitape Gr 145 RC 33% material property data published in NCAMP Test Report CAM-RP-2013-002 Rev A. The lamina and laminate material property data have been generated with NCAMP oversight in accordance with NSP 100 NCAMP Standard Operating Procedures; the test panels and test specimens have been inspected by NCAMP Authorized Inspection Representatives (AIR) and the testing has been witnessed by NCAMP Authorized Engineering Representatives (AER).

B-Basis values, A-estimates, and B-estimates were calculated using a variety of techniques that are detailed in section two. The qualification material was procured to NCAMP Material Specification NMS 532/5 Initial Release dated July 6, 2010. The qualification test panels were cured in accordance with NCAMP Process Specification NPS85321 Rev A dated September 23, 2010 Baseline "C" Cure Cycle. The NCAMP Test Plan NTP5325Q1 was used for this qualification program. The panels were fabricated at Gulfstream Aerospace Corporation, 500 Gulfstream Rd., Savannah Ga. 31408. 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 and the specific requirement(s) the data fails to meet is identified. The method used to compute the basis value is noted for each basis value provided. When appropriate, in addition to the traditional computational methods, values computed using the modified coefficient of variation method is also provided.

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

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

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

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

Part fabricators that wish to utilize the material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17 Vol. 1 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 Vol. 1 are adequate for the given program.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 532/5. NMS 532/5 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 532/5*. NMS 532/5 is a free, publicly available, non-proprietary aerospace industry material specification.

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1.1 Symbols and Abbreviations

Test Property	Abbreviation
Longitudinal Compression	LC
Longitudinal Tension	LT
Transverse Compression	TC
Transverse Tension	TT
In-Plane Shear	IPS
Short Beam Strength	SBS
Laminate Short Beam Strength	SBS1
Unnotched Tension	UNT
Unnotched Compression	UNC
Filled Hole Tension	FHT
Filled Hole Compression	FHC
Open Hole Tension	OHT
Open Hole Compression	OHC
Single Shear Bearing	SSB
Interlaminar Tension	ILT
Curved Beam Strength	CBS
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 Tension Strength	F_1^{tu}
Longitudinal Tension Modulus	E_1^{t}
Longitudinal Tension Poisson's Ratio	ν_{12}^{t}
Transverse Compression Strength	F_2^{cu}
Transverse Compression Modulus	E_2^{c}
Transverse Tension Strength	F_2^{tu}
Transverse Tension Modulus	E_2^{t}
In-Plane Shear Peak Strength before 5% Strain	F_{12}^{smax}
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	Temperature
Cold Temperature Dry	CTD	−65°F
Room Temperature Dry	RTD	70°F
Elevated Temperature Dry	ETD1	180°F
Elevated Temperature Wet	ETW1	180°F
Elevated Temperature Dry	ETD2	250°F
Elevated Temperature Wet	ETW2	250°F

Table 1-3: Environmental Conditions Abbreviations

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

1 refers to a 25/50/25 layup. This is also referred to as "Quasi-Isotropic"
2 refers to a 10/80/10 layup. This is also referred to as “Soft”
3 refers to a 50/40/10 layup. This is also referred to as “Hard”

EX: OHT1 is an Open-Hole Tension test with a 25/50/25 layup

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2013-002 Rev A.

1.2 Pooling Across Environments

When pooling across environments was allowable, the pooled standard deviation method was used. The CMH17-Stats 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: $\text{basis value} = \bar{X} - kS$ 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 of 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 CMH-17 Rev G requirements for a single point analysis, estimates are created by a variety of methods depending on which is most appropriate for the dataset available. Specific procedures used are presented in the individual sections where the data is presented.

2.1 CMH STATS and 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.: $$S = \sqrt{\tfrac{1}{n-1} \sum_{i=1}^{n} \left(X_i - \bar{X} \right)^2}$$ **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, S_i indicates the standard deviation of i^{th} sample, 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.

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

2.1.3 Basis Value Computations

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

Basis Values:

$$A-basis = \bar{X} - K_a S$$
$$B-basis = \bar{X} - K_b S \qquad \textbf{Equation 6}$$

2.1.3.1 K-factor computations

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

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

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

Where

r = the number of environments being pooled together

n_j= number of data values for environment j

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

$$f = N - r$$

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

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

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

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

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

2.1.4 Modified Coefficient of Variation

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

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

This is converted to percent by multiplying by 100%.

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

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

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

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

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

2.1.4.1 Transformation of data based on Modified CV

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

To accomplish this requires a transformation in two steps:

Step 1: Apply the modified CV rules to each batch and compute the modified standard deviation $S_i^* = CV^* \cdot \bar{X}_i$ for each batch. Transform the individual data values (X_{ij}) 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

All outliers are identified in text and graphics. If an outlier is removed from the dataset, it will be specified and the reason why will be documented in the text. Outliers are identified using the Maximum Normed Residual Test for Outliers as specified in section 8.3.3 of CMH-17 Rev G.

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

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

where t is the $1-\frac{.05}{2n}$ quartile of a t distribution with n−2 degrees of freedom, n being the total number of data values.

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

2.1.6 The k-Sample Anderson Darling Test for Batch Equivalency

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

The k-sample Anderson-Darling test statistic is:

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

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 $1-\alpha$ level is computed:

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

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.

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

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

$$z_{(i)} = \frac{x_{(i)} - \bar{x}}{s}, \quad \text{for i = 1,\ldots,n}$$ **Equation 29**

where $x_{(i)}$ is the smallest sample observation, $\bar{x}$ 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

$$OSL = \frac{1}{1 + e^{-0.48 + 0.78\ln(AD^*) + 4.58 AD^*}}, \quad AD^* = \left(1 + \frac{4}{n} - \frac{25}{n^2}\right) AD$$ **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:

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

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 STAT-17

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

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

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

2.2.1 Distribution Tests

In addition to testing for normality using the Anderson-Darling test (see 2.1.7); 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) when the sample size is less than 16 and a slightly different formula than ASAP to compute approximate k-values for the normal distribution when the sample size is 16 or larger.

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

Table 2-1: K factors for normal distribution

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

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

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

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

and the observed significance level is

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

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

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

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

$$SSE = SST - SSB \quad \text{Equation 54}$$

Next, the mean sums of squares are computed:

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

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

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

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

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

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

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

$$T = \frac{k_0 - \frac{k_1}{\sqrt{n'}} + (k_1 - k_0)\sqrt{\frac{u}{u + n' - 1}}}{1 - \frac{1}{\sqrt{n'}}}$$ **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 batchs are available and no valid B-basis value could be computed using any other method. The estimate is made using the mean of the data and setting the coefficient of variation to 8 percent if it was less than that. A modified standard deviation (S_{adj}) was computed by multiplying the mean by 0.08 and computing the A and B-basis values using this inflated value for the standard deviation.

Estimated B-Basis = $\bar{X} - k_b S_{adj} = \bar{X} - k_b \cdot 0.08 \cdot \bar{X}$ **Equation 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_1 is the coefficient of variation of the laminate (small dataset)

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

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

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

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

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

$$BF = \frac{E_1\left[V_0E_2 + (1-V_0)E_1\right] - (\nu_{12}E_2)^2}{\left[V_0E_1 + (1-V_0)E_2\right]\left[V_0E_2 + (1-V_0)E_1\right] - (\nu_{12}E_2)^2} \qquad \textbf{Equation 64}$$

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 section 2.4.2, equation 2.4.2.1(b) of CMH-17 Rev G.

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. For example, if there were no ETD tests run for transverse tension and compression, the value for E_2 would not be available for that condition. In that case, this alternative formula is used 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.

$$F^{cu}_{0^\circ} = F^{cu}_{0^\circ/90^\circ}\frac{E^c_1}{E^c_{0^\circ/90^\circ}}, \quad F^{tu}_{0^\circ} = F^{tu}_{0^\circ/90^\circ}\frac{E^t_1}{E^t_{0^\circ/90^\circ}} \qquad \textbf{Equation 65}$$

with

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

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

E^c_1, E^t_1 are the modulus values for LC and LT respectively

$E^c_{0^\circ/90^\circ}$, $E^t_{0^\circ/90^\circ}$ are the modulus values for UNC0 and UNT0 respectively

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

3. Summary of Results

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. Basis values of 90% or more of the mean value imply that the CV is unusually low and may not be conservative.Caution is recommended with B-Basis values calculated from STAT17 when the B-basis value is 90% or more of the average value. 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 Cytec Cycom 5320-1 T650 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	LC from UNC0**	TT	TC	Short Beam Strength*	In-Plane Shear*			UNC0
							0.2% Offset	5% Strain	Peak before 5% Strain	
CTD (-65º F)	B-basis	257.049	224.897	NA:A	45.422	16.680	10.224		15.232	87.518
	Mean	293.615	251.251	10.975	51.397	18.126	11.269		17.198	97.657
	CV	6.479	7.742	13.251	6.100	6.468	6.000		6.000	7.742
RTD (70º F)	B-basis	262.527	210.744	8.549	37.002***	14.180	7.075	11.958		81.753
	Mean	299.093	237.098	10.096	39.751	15.639	8.121	13.501		91.892
	CV	6.645	6.786	8.045	3.931	6.000	6.000	6.000		6.786
ETW2 (250º F)	B-basis	238.173	152.783	NA:A	17.150	6.271	2.675	4.545		57.136
	Mean	274.431	179.138	4.730	19.364	7.722	3.060	5.139		67.275
	CV	8.535	6.790	12.327	6.000	6.000	6.725	6.000		6.790

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
** Derived from cross-ply using back-out factor
*** 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 Cytec Cycom 5320-1 T650 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	SSB 2% Offset	SSB Initial Peak	SSB Ultimate	SBS1*
25/50/25	CTD (-65º F)	B-basis	NA:A		50.344		82.306					
		Mean	47.105		56.416		92.513					
		CV	5.534		6.000		6.000					
	RTD (70º F)	B-basis	NA:A	46.119	51.890	73.794	87.415	82.369	123.999	122.477	137.050	10.649
		Mean	49.601	50.894	57.962	81.560	97.622	96.628	136.627	135.155	151.576	13.710
		CV	5.909	6.000	6.143	6.299	6.000	7.822	6.000	6.022	6.341	6.205
	ETW2 (250º F)	B-basis	47.505	34.424	53.976	47.991	93.145	60.866	89.937	88.800	99.314	NA:A
		Mean	53.675	39.199	60.048	55.757	103.351	68.635	102.565	101.299	113.840	7.356
		CV	6.032	6.000	6.000	6.644	6.000	6.000	6.000	6.041	6.000	5.199
10/80/10	CTD (-65º F)	B-basis	39.018		46.363		64.693					
		Mean	44.056		51.295		71.302					
		CV	6.000		6.000		6.000					
	RTD (70º F)	B-basis	NA	40.343	44.626	56.352	61.023	63.044	122.062		146.052	
		Mean	42.535	44.484	49.558	61.954	67.633	72.330	134.738		161.861	
		CV	6.000	6.000	6.000	6.000	6.000	6.737	6.000		6.359	
	ETW2 (250º F)	B-basis	31.209	28.248	34.966	35.660	43.520	38.760	88.406		104.558	
		Mean	35.238	32.389	39.898	41.262	50.130	43.957	101.082		120.367	
		CV	6.000	6.000	6.000	6.000	6.000	6.204	6.000		6.046	
50/40/10	CTD (-65º F)	B-basis	56.773		NA:A		127.579					
		Mean	65.202		70.552		144.363					
		CV	7.372		5.417		6.344					
	RTD (70º F)	B-basis	62.169	59.676	68.396	85.188	136.561	117.435	124.107	116.805	131.620	
		Mean	70.597	66.016	77.031	94.140	153.345	129.217	137.336	129.575	145.805	
		CV	6.510	6.000	6.188	6.000	6.547	6.000	6.084	6.000	6.000	
	ETW2 (250º F)	B-basis	78.192	46.394	74.401	62.210	148.115	74.689	89.422	87.460	106.279	
		Mean	86.585	52.759	83.001	71.163	164.899	86.522	102.704	100.496	120.521	
		CV	6.000	6.000	6.000	6.133	6.000	6.000	6.315	6.049	6.000	

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

Table 3-2: NCAMP Recommended B-basis values for laminate test data

3.2 Lamina and Laminate Summary Tables

Prepreg Material:	Cytec 5320-1 T650 Unitape Gr 145 RC 33%	**Lamina Properties Summary Cytec 5320-1 T650 Unitape Gr 145 RC 33%**
Material Specification:	NMS 532/5	
Process Specification:	NPS 85321 Baseline Cure Cycle C	

Fiber: T650 Unitape **Resin:** Cycom 5320-1

Tg(dry): 389.13 °F **Tg(wet):** 321.79 °F **Tg METHOD:** ASTM D7028

Date of fiber manufacture	Apr-May 2010	**Date of testing**	Mar-Oct 2012
Date of resin manufacture	Aug 2010	**Date of data submittal**	Feb 2013
Date of prepreg manufacture	Aug- Spet 2010	**Date of analysis**	Feb 2013
Date of composite manufacture	Sept-Dec 2011		

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY

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

Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only

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

	CTD			RTD			ETW2		
	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean
F_1^{tu} (ksi)	267.069 (266.648)	258.751 (257.049)	292.317 (293.615)	273.756 (272.126)	265.438 (262.527)	299.004 (299.093)	231.005 (233.031)	NA (238.173)	272.069 (274.431)
E_1^t (Msi)			20.128 (20.214)			20.077 (20.082)			19.892 (20.084)
ν_{12}^t			0.325			0.326			0.337
F_2^{tu} (ksi)	6.882	NA	10.975	8.549	NA	10.096	1.829	NA	4.730
E_2^t (Msi)			1.485			1.331			0.840
F_1^{cu} (ksi) from UNC0*	214.981 (228.837)	225.029 (224.897)	251.646 (251.251)	218.929 (214.683)	211.258 (210.744)	237.875 (237.098)	158.181 (156.723)	150.511 (152.783)	177.128 (179.138)
E_1^c (Msi)			17.308 (17.256)			18.356 (18.301)			18.216 (18.252)
F_2^{cu} (ksi)	47.295	45.422	51.397	37.002	NA	39.751	18.289	17.150	19.364
E_2^c (Msi)			1.531			1.427			1.094
F_{12}^{smax} (ksi)	15.217	15.232	17.198	NA	NA	NA	NA	NA	NA
$F_{12}^{s5\%}$ (ksi)	NA	NA	NA	12.793	11.958	13.501	4.755	4.545	5.139
$F_{12}^{s0.2\%}$ (ksi)	10.411	10.224	11.269	7.758	7.075	8.121	2.748	2.675	3.060
G_{12}^s (Msi)			0.838			0.718			0.325
SBS (ksi)	13.531	16.680	18.126	14.531	14.180	15.639	7.262	6.271	7.722
UNC0 (ksi)	84.024 (89.014)	88.051 (87.518)	98.354 (97.657)	85.213 (83.249)	82.207 (81.753)	92.510 (91.892)	60.184 (58.632)	57.178 (57.136)	67.481 (67.275)
UNC0 (Msi)			6.765 (6.707)			7.139 (7.093)			6.940 (6.855)

*** Derived from cross-ply using back-out factor**

Table 3-3: Summary of Test Results for Lamina Data CTD RTD and ETW2 Conditions

Prepreg Material:	Cytec 5320-1 T650 Unitape Gr 145 RC 33%	**Lamina Properties Summary Cytec 5320-1 T650 Unitape Gr 145 RC 33%**
Material Specification:	NMS 532/5	
Process Specification:	NPS 85321 Baseline Cure Cycle C	

Fiber: T650 Unitape **Resin:** Cycom 5320-1

Tg(dry): 389.13 °F **Tg(wet):** 321.79 °F **Tg METHOD:** ASTM D7028

Date of fiber manufacture	Apr-May 2010	**Date of testing**	Mar-Oct 2012
Date of resin manufacture	Aug 2010	**Date of data submittal**	Feb 2013
Date of prepreg manufacture	Aug- Spet 2010	**Date of analysis**	Feb 2013
Date of composite manufacture	Sept-Dec 2011		

LAMINA MECHANICAL PROPERTY B-ESTIMATE SUMMARY

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

These values do not meet CMH17 Rev G requirements due to insufficient data. They are estimates only.

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

	ETD1			ETW1			ETD2		
	B-Estimate	Modified CV B-Estimate	Mean	B-Estimate	Modified CV B-Estimate	Mean	B-Estimate	Modified CV B-Estimate	Mean
F_1^{tu} (ksi)				216.578 (210.303)	216.910 (231.948)	276.017 (272.989)			
E_1^t (Msi)						20.263 (20.030)			
ν_{12}^t						0.334			
F_2^{tu} (ksi)				4.858	NA	8.432			
E_2^t (Msi)						1.213			
F_1^{cu} (ksi) from UNC0*	207.225 (204.874)	198.934 (200.636)	227.566 (228.986)	175.745 (172.265)	166.877 (167.746)	197.413 (197.980)	196.557 (193.133)	187.690 (188.614)	218.226 (218.848)
E_1^c (Msi)			18.407 (18.454)			18.550 (18.534)			18.220 (18.271)
F_2^{cu} (ksi)	27.439	24.267	31.141	23.329	19.661	25.231	23.449	20.454	26.248
E_2^c (Msi)			1.301			1.292			1.244
$F_{12}^{s5\%}$ (ksi)				7.777	6.197	8.165			
$F_{12}^{s0.2\%}$ (ksi)				4.921	4.014	5.151			
G_{12}^s (Msi)						0.547			
SBS (ksi)	10.801	10.057	11.730	9.455	8.577	10.250	9.270	8.026	9.665
UNC0 (ksi)	78.547 (77.225)	75.298 (75.615)	86.381 (86.522)	67.682 (65.654)	64.207 (63.938)	76.027 (75.570)	75.023 (73.766)	71.548 (72.050)	83.368 (83.682)
UNC0 (Msi)			6.987 (6.973)			7.144 (7.074)			6.961 (6.987)

**** Derived from cross-ply using back-out factor***

Table 3-4: Summary of Test Results for Lamina Data ETD1 ETW1 and ETD2 Conditions

Prepreg Material:	Cytec 5320-1 T650 Unitape Gr 145 RC 33%
Material Specification:	NMS 532/5
Process Specification:	NPS 85321 Baseline Cure Cycle C

Laminate Properties Summary Cytec 5320-1 T650 Unitape Gr 145 RC 33%

Fiber: T650 Unitape **Resin:** Cycom 5320-1
Tg(dry): 389.13 °F **Tg(wet):** 321.79 °F **Tg METHOD:** ASTM D7028

Date of fiber manufacture:	Apr-May 2010	**Date of testing:**	Mar-Oct 2012
Date of resin manufacture:	Aug 2010	**Date of data submittal:**	Feb 2013
Date of prepreg manufacture:	Aug- Sept 2010	**Date of analysis:**	Feb 2013
Date of composite manufacture:	Sept-Dec 2011		

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported as normalized used a normalizing t_{ply} of 0.0055 in

Values shown in shaded boxes do not meet CMH17 Rev G requirements and are estimates only
These values may not be used for certification unless specifically allowed by the certifying agency

Test	Property	Test Condition	Unit	Quasi Isotropic 25/50/25 B-value	Quasi Isotropic 25/50/25 Mod. CV B-value	Quasi Isotropic 25/50/25 Mean	"Soft" 10/80/10 B-value	"Soft" 10/80/10 Mod. CV B-value	"Soft" 10/80/10 Mean	"Hard" 50/40/10 B-value	"Hard" 50/40/10 Mod. CV B-value	"Hard" 50/40/10 Mean
OHT (normalized)	Strength	CTD	ksi	31.667	41.031	47.105	40.796	39.018	44.056	58.777	56.773	65.202
		RTD	ksi	30.489	43.027	49.601	40.615	NA	42.535	64.172	62.169	70.597
		ETW1	ksi	46.068	41.177	52.842	---	---	---	---	---	---
		ETW2	ksi	49.519	47.505	53.675	34.369	31.209	35.238	80.188	78.192	86.585
OHC (normalized)	Strength	RTD	ksi	49.015	46.119	50.894	37.204	40.343	44.484	63.396	59.676	66.016
		ETW1	ksi	42.491	39.193	44.630	---	---	---	---	---	---
		ETW2	ksi	37.320	34.424	39.199	30.427	28.248	32.389	50.128	46.394	52.759
UNT (normalized)	Strength	CTD	ksi	86.791	82.306	92.513	56.195	64.693	71.302	108.512	127.579	144.363
	Modulus		Msi	---	---	7.709	---	---	5.124	---	---	11.805
	Strength	RTD	ksi	86.272	87.415	97.622	64.025	61.023	67.633	140.549	136.561	153.345
	Modulus		Msi	---	---	7.580	---	---	4.917	---	---	11.698
	Strength	ETW1	ksi	92.690	93.507	105.189	---	---	---	---	---	---
	Modulus		Msi	---	---	7.209	---	---	---	---	---	---
	Strength	ETW2	ksi	97.286	93.145	103.351	44.748	43.520	50.130	152.103	148.115	164.899
	Modulus		Msi	---	---	6.963	---	---	4.173	---	---	11.574
UNC (normalized)	Strength	RTD	ksi	82.700	82.369	96.628	64.787	63.044	72.330	121.507	117.435	129.217
	Modulus		Msi	---	---	7.189	---	---	4.743	---	---	10.913
	Strength	ETW1	ksi	74.061	65.630	81.676	---	---	---	---	---	---
	Modulus		Msi	---	---	7.172	---	---	---	---	---	---
	Strength	ETW2	ksi	64.487	60.866	68.635	40.266	38.760	43.957	82.674	74.689	86.522
	Modulus		Msi	---	---	6.752	---	---	3.932	---	---	10.463
FHT (normalized)	Strength	CTD	ksi	43.142	50.344	56.416	42.020	46.363	51.295	48.170	61.533	70.552
		RTD	ksi	42.540	51.890	57.962	46.772	44.626	49.558	58.077	68.396	77.031
		ETW1	ksi	54.389	53.652	60.602	---	---	---	---	---	---
		ETW2	ksi	57.976	53.976	60.048	38.622	34.966	39.898	77.787	74.401	83.001
FHC (normalized)	Strength	RTD	ksi	75.985	73.794	81.560	58.682	56.352	61.954	89.010	85.188	94.140
		ETW1	ksi	60.805	58.310	67.154	---	---	---	---	---	---
		ETW2	ksi	50.182	47.991	55.757	37.991	35.660	41.262	66.032	62.210	71.163
Single Shear Bearing (normalized)	2% Offset Strength	RTD	ksi	129.556	123.999	136.627	128.270	122.062	134.738	128.037	124.107	137.336
		ETW1	ksi	105.283	98.954	113.335	---	---	---	---	---	---
		ETW2	ksi	95.495	89.937	102.565	87.269	88.406	101.082	93.368	89.422	102.704
	Initial PeakStrength	RTD	ksi	124.363	122.477	135.155	---	---	---	121.901	116.805	129.575
		ETW1	ksi	105.842	100.414	114.633	---	---	---	---	---	---
		ETW2	ksi	81.955	88.800	101.299	---	---	---	92.662	87.460	100.496
	Ultimate Strength	RTD	ksi	141.659	137.050	151.576	150.466	146.052	161.861	136.833	131.620	145.805
		ETW1	ksi	119.041	113.792	130.335	---	---	---	---	---	---
		ETW2	ksi	103.923	99.314	113.840	108.972	104.558	120.367	111.513	106.279	120.521
SBS1 (as-measured)	Strength	RTD	ksi	10.649	NA	13.710	---	---	---	---	---	---
		ETW2	ksi	4.875	6.431	7.356	---	---	---	---	---	---
ILT (as-measured)	Strength	CTD	ksi	---	---	6.831	---	---	---	---	---	---
		RTD	ksi	---	---	7.399	---	---	---	---	---	---
		ETW2	ksi	---	---	4.719	---	---	---	---	---	---
CBS (as-measured)	Strength	CTD	lb	---	---	238.501	---	---	---	---	---	---
		RTD	lb	---	---	251.215	---	---	---	---	---	---
		ETW2	lb	---	---	153.369	---	---	---	---	---	---
CAI (Normalized)	Strength	RTD	ksi	---	---	24.280	---	---	---	---	---	---

Table 3-5: Summary of Test Results for Laminate Data

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

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

All individual specimen results are graphed for each test by batch and environmental condition with a line indicating the recommended basis values for each environmental condition. The data is jittered (moved slightly to the left or right) in order for all specimen values to be clearly visible. The strength values are always graphed on the vertical axis with the scale adjusted to include all data values and their corresponding basis values. The vertical axis may not include zero. The horizontal axis values will vary depending on the data and how much overlapping there was of the data within and between batches. When there was little variation, the batches were graphed from left to right. 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 are required. Since this qualification dataset has only three batches, the basis values computed using ANOVA are considered estimates only. However, the basis values resulting from the ANOVA method using only three batches may be overly conservative. The ADK test is performed again after a transformation of the data according to the assumptions of the modified CV method (see section 2.1.4 for details). If the dataset still passes the ADK test at this point, modified CV basis values are provided. If the dataset does not pass the ADK test after the transformation, estimates may be computed using the modified CV method per the guidelines in CMH-17 Vol 1 Chapter 8 section 8.3.10.

4.1 Longitudinal Tension (LT)

The LT data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. The ETW2 data did not fit any of the tested distributions, so the non-parametric method was used to compute basis values.

The pooled datasets, both normalized and as measured, did not fit the normal distribution, so pooling all four conditions was not acceptable. However, the CTD and RTD data could be pooled for both normalized and as-measured datasets. When the data was transformed to meet the assumptions of the modified CV method, all four conditions could be pooled for the normalized dataset but not for the as-measured dataset. There were no outliers.

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

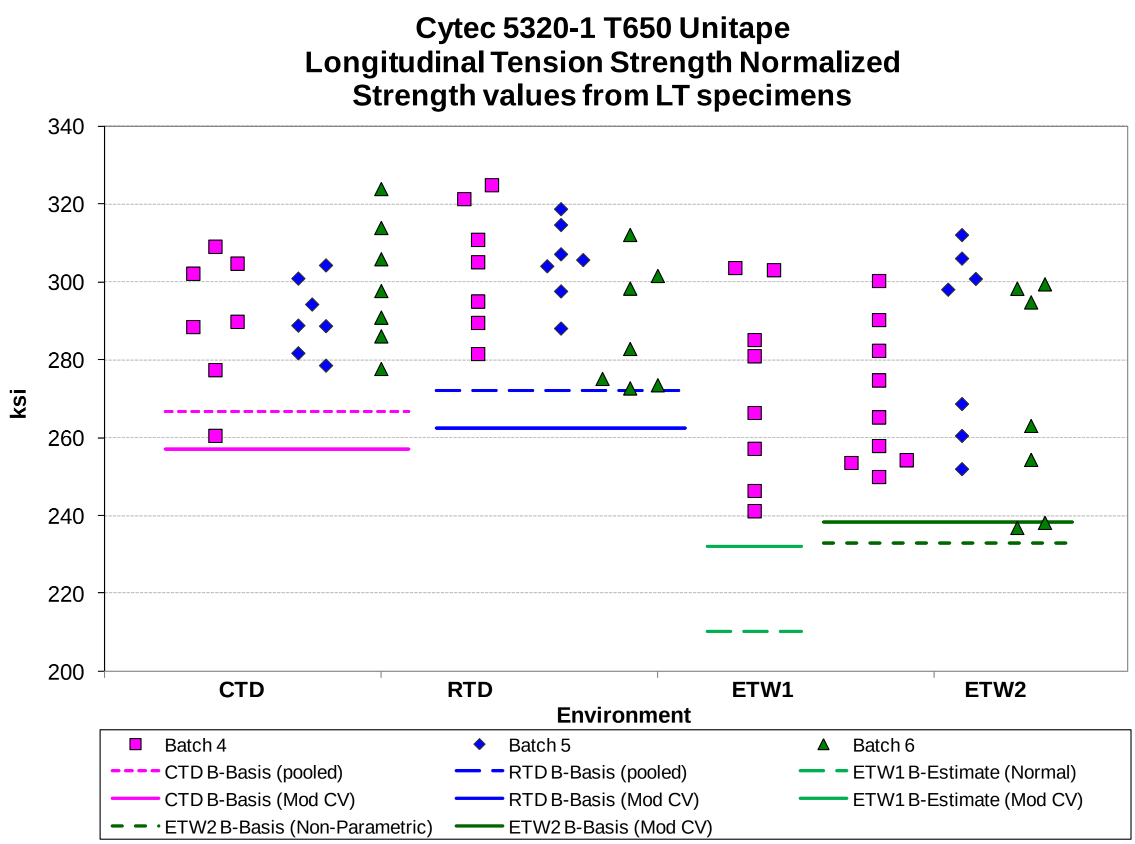

Figure 4-1 Batch plot for LT strength normalized

Longitudinal Tension Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	293.615	299.093	272.989	274.431	292.317	299.004	276.017	272.069
Stdev	14.557	15.822	24.118	23.422	12.623	15.681	22.869	22.429
CV	4.958	5.290	8.835	8.535	4.318	5.244	8.285	8.244
Mod CV	6.479	6.645	8.835	8.535	6.159	6.622	8.285	8.244
Min	260.542	272.717	241.145	236.839	266.291	269.754	248.616	234.704
Max	323.949	324.928	303.649	312.116	311.839	320.612	305.972	304.278
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	8	23	21	21	8	23
Basis Values and Estimates								
B-basis Value	266.648	272.126		233.031	267.069	273.756		231.005
B-estimate			210.303				216.578	
A-estimate	248.115	253.593	166.426	169.429	249.716	256.404	174.975	171.273
Method	pooled	pooled	Normal	Non-Parametric	pooled	pooled	Normal	Non-Parametric
Modified CV Basis Values and Estimates								
B-basis Value	257.049	262.527		238.173	258.751	265.438		NA
B-Estimate			231.948				216.910	
A-Estimate	232.484	237.962	207.926	213.554	235.682	242.369	176.350	NA
Method	pooled	pooled	pooled	pooled	pooled	pooled	Normal	NA

Table 4-1: Statistics and Basis values for LT strength

Longitudinal Tension Modulus Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	20.214	20.082	20.030	20.084	20.128	20.077	20.263	19.892
Stdev	0.440	0.441	0.614	0.413	0.326	0.264	0.464	0.284
CV	2.175	2.195	3.065	2.056	1.619	1.313	2.291	1.428
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Min	19.248	18.685	18.806	19.202	19.469	19.536	19.670	19.354
Max	20.884	20.860	20.693	20.703	20.620	20.695	20.891	20.546
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	20	7	22	21	20	7	22

Table 4-2: Statistics from LT Modulus data

4.2 Transverse Tension (TT)

Transverse Tension data is not normalized for unidirectional tape. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. The CTD and ETW2 datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

Modified CV basis values are not provided due to failures of normality (CTD and ETW1) and/or having a CV larger than 8% (CTD, RTD and ETW2).

There was one outlier. The smallest value in the ETW1 dataset (which had data from batch 4 only) was an outlier. It was retained for this analysis.

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

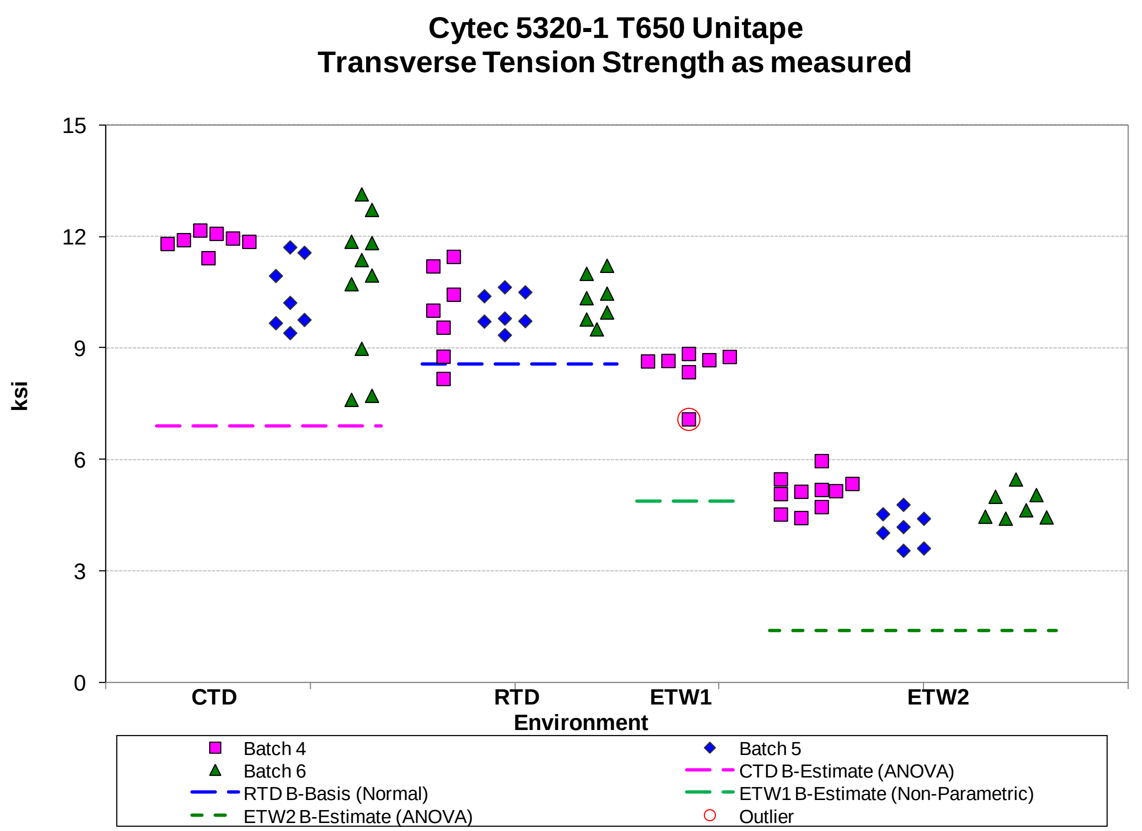

Figure 4-2: Batch Plot for TT strength as-measured

Transverse Tension Strength Basis Values and Statistics				
As-measured				
Env	CTD	RTD	ETW1	ETW2
Mean	10.975	10.096	8.432	4.730
Stdev	1.454	0.812	0.614	0.583
CV	13.251	8.045	7.278	12.327
Mod CV	13.251	8.045	8.000	12.327
Min	7.610	8.171	7.083	3.546
Max	13.142	11.459	8.844	5.960
No. Batches	3	3	1	3
No. Spec.	24	21	7	24
Basis Values and Estimates				
B-basis Value		8.549		
B-estimate	6.882		4.858	1.829
A-estimate	3.953	7.446	3.058	0.000
Method	ANOVA	Normal	Non-Parametric	ANOVA

Table 4-3: Statistics and Basis Values for TT Strength data as-measured

Transverse Tension Modulus Statistics				
As-measured				
Env	CTD	RTD	ETW1	ETW2
Mean	1.485	1.331	1.213	0.840
Stdev	0.048	0.025	0.022	0.020
CV	3.218	1.859	1.796	2.367
Mod CV	6.000	6.000	6.000	6.000
Min	1.415	1.291	1.178	0.804
Max	1.577	1.403	1.241	0.874
No. Batches	3	3	1	3
No. Spec.	21	21	7	24

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

4.3 Longitudinal Compression (LC)

The strength values for 0^o properties are computed using equation 65 specified in section 2.5. The ETD1, ETW1, and ETD2 datasets lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for those condition. The normalized data could be pooled across all environmental conditions, but the as-measured data failed Levene's test when all six conditions were included. Conditions RTD through ETW2 could be pooled, but the single point method was used to compute basis values and estimates for the CTD as-measured data. After transforming the data to meet the assumptions of the modified CV method, pooling was acceptable to compute the modified CV basis values and estimates for all conditions for both normalized and as-measured datasets.

There was one outliers. The lowest value in batch six of the ETW2 condition was an outlier for batch six, but not for the ETW2 condition. It was an outlier for both the normalized and as measured datasets. It was retained for this analysis.

Statistics and B-estimates are given for strength data in Table 4-5 and for the modulus data in Table 4-6. The data and the B-estimates are shown graphically in Figure 4-3.

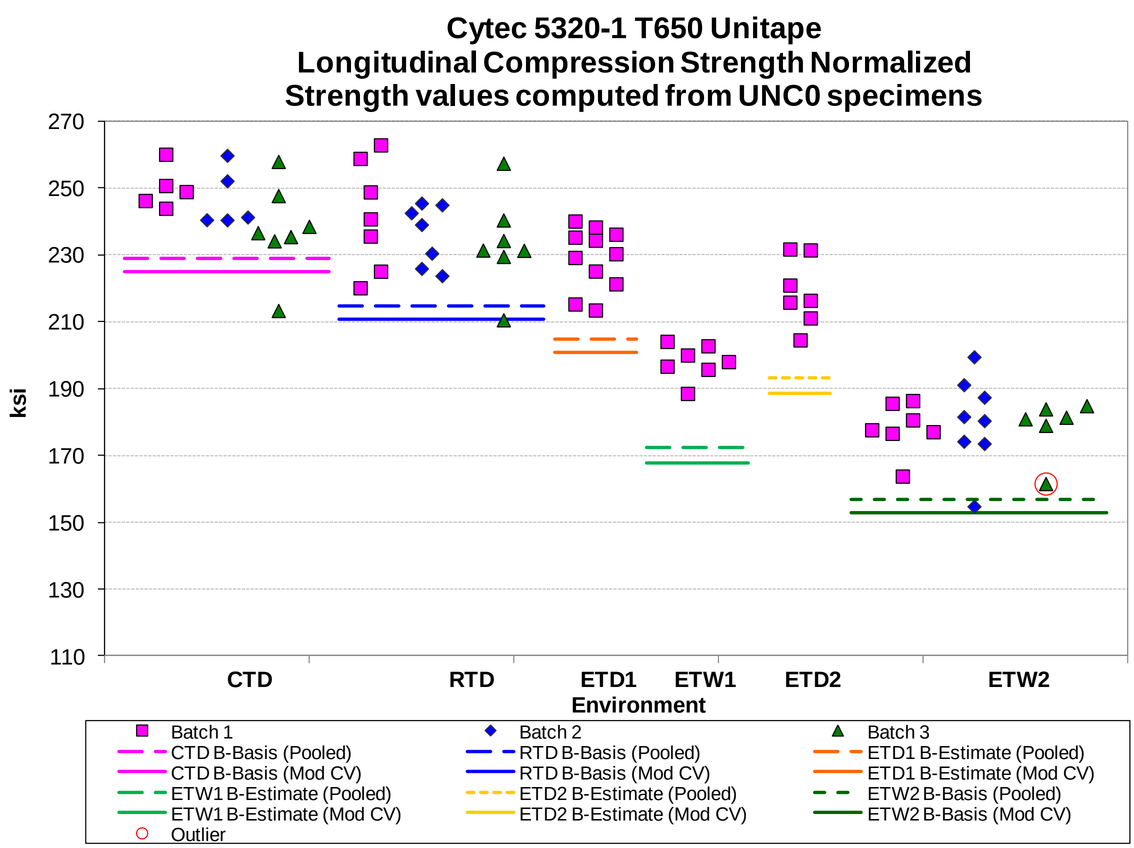

Figure 4-3 Batch plot for LC strength normalized

Longitudinal Compression Strength Basis Values and Statistics												
	Normalized						As-measured					
Env	CTD	RTD	ETD1	ETW1	ETD2	ETW2	CTD	RTD	ETD1	ETW1	ETD2	ETW2
Mean	251.251	237.098	228.986	197.980	218.848	179.138	251.646	237.875	227.566	197.413	218.226	177.128
Stdev	18.801	13.213	9.129	5.175	10.075	9.997	19.247	13.905	8.670	5.586	9.815	10.212
CV	7.483	5.573	3.987	2.614	4.603	5.581	7.648	5.846	3.810	2.829	4.497	5.765
Mod CV	7.742	6.786	6.000	6.000	6.302	6.790	7.824	6.923	6.000	6.000	6.249	6.883
Min	213.343	210.551	213.475	188.526	204.535	154.774	215.026	211.431	212.865	188.241	205.677	152.404
Max	290.927	262.869	240.085	204.096	231.723	199.475	291.186	270.243	237.392	203.712	231.659	197.853
No. Batches	3	3	1	1	1	3	3	3	1	1	1	3
No. Spec.	21	21	11	7	7	21	21	21	11	7	7	21
Basis Values and Estimates												
B-basis Value	228.837	214.683				156.723	214.981	218.929				158.181
B-estimate			204.874	172.265	193.133				207.225	175.745	196.557	
A-estimate	213.883	199.730	190.127	157.647	178.515	141.769	188.841	206.146	194.648	163.300	184.113	145.399
Method	pooled	pooled	pooled	pooled	pooled	pooled	Normal	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Value Estimates												
B-basis Value	224.897	210.744				152.783	225.029	211.258				150.511
B-estimate			200.636	167.746	188.614				198.934	166.877	187.690	
A-estimate	207.315	193.162	183.297	150.559	171.427	135.201	207.272	193.501	181.423	149.519	170.332	132.754
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-5: Statistics and Basis Values for LC strength derived from UNC0

Longitudinal Compression Modulus Statistics												
	Normalized						As-measured					
Env	CTD	RTD	ETD1	ETW1	ETD2	ETW2	CTD	RTD	ETD1	ETW1	ETD2	ETW2
Mean	17.256	18.301	18.454	18.534	18.271	18.252	17.308	18.356	18.407	18.550	18.220	18.216
Stdev	1.737	0.243	0.124	0.423	0.112	0.454	1.808	0.300	0.130	0.480	0.083	0.522
CV	10.064	1.328	0.671	2.284	0.611	2.488	10.447	1.633	0.707	2.585	0.457	2.863
Mod CV	10.064	6.000	6.000	6.000	6.000	6.000	10.447	6.000	6.000	6.000	6.000	6.000
Min	15.232	17.791	18.304	17.895	18.119	17.198	15.000	17.868	18.247	18.094	18.058	17.093
Max	21.898	18.741	18.646	19.312	18.409	19.068	22.407	19.023	18.615	19.573	18.303	19.083
No. Batches	3	3	1	1	1	3	3	3	1	1	1	3
No. Spec.	21	21	7	7	7	21	21	21	7	7	7	21

Table 4-6: Statistics from LC modulus

4.4 Transverse Compression (TC)

Transverse Compression data is not normalized. The CTD and RTD conditions failed the normality test, but the Weibull distribution fit both datasets sufficiently well to use that method to compute basis values. Both the CTD and RTD datasets failed the normality test even after outliers were removed. After transforming the data to match the assumptions of the modified CV method the CTD dataset passed the normality test but the RTD dataset did not. Modified CV basis values and estimates are provided for the CTD dataset but not the RTD dataset for that reason.

There were three statistical outliers, one in batch five of the CTD dataset and one each in batches four and five of the RTD dataset. All three outliers were outliers only for their respective batches, not for their respective conditions. All three were outliers for being too low. All three outliers were retained for this analysis.

Statistics, basis values and estimates 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.

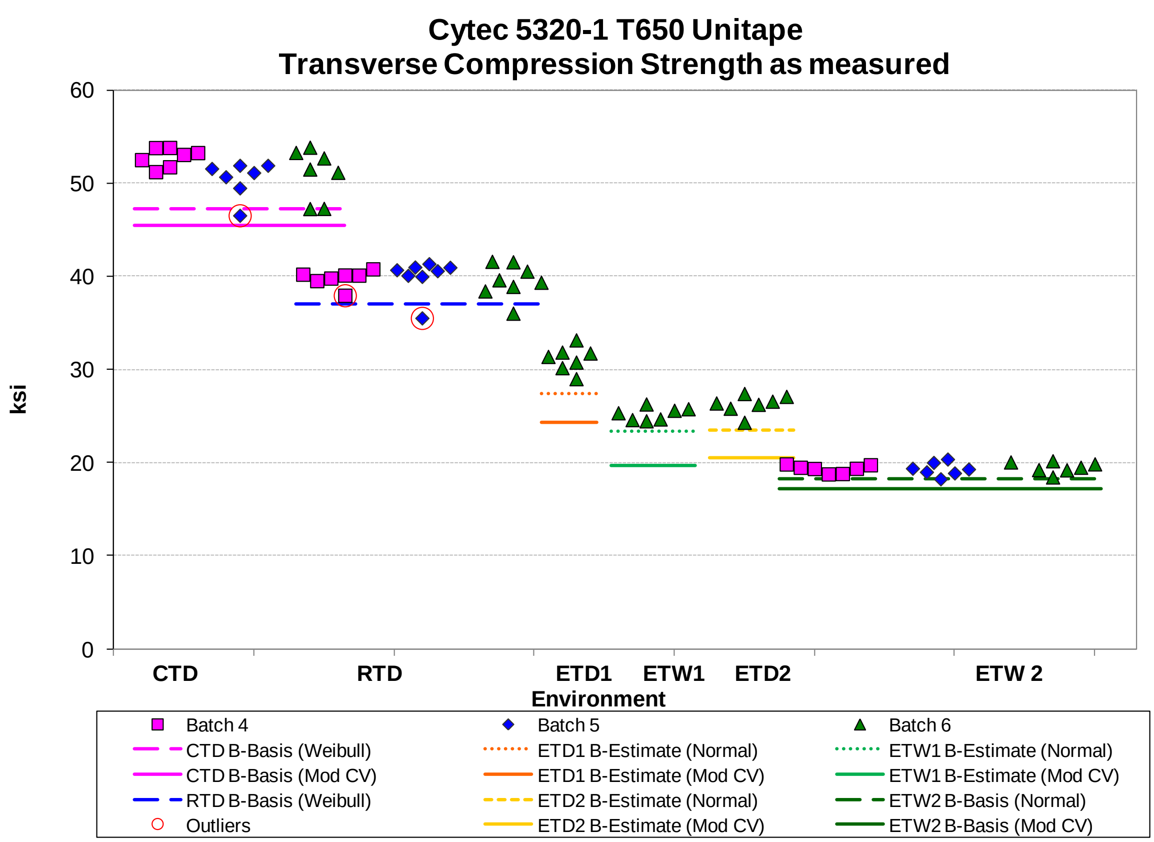

Figure 4-4: Batch Plot for TC strength as-measured

Transverse Compression Strength Basis Values and Statistics						
As-measured						
Env	CTD	RTD	ETD1	ETW1	ETD2	ETW2
Mean	51.397	39.751	31.141	25.231	26.248	19.364
Stdev	2.159	1.563	1.333	0.685	1.008	0.564
CV	4.200	3.931	4.282	2.715	3.841	2.913
Mod CV	6.100	6.000	8.000	8.000	8.000	6.000
Min	46.520	35.507	28.982	24.457	24.300	18.232
Max	53.834	41.579	33.144	26.262	27.387	20.350
No. Batches	3	3	1	1	1	3
No. Spec.	21	23	7	7	7	21
Basis Values and Estimates						
B-basis Value	47.295	37.002				18.289
B-estimate			27.439	23.329	23.449	
A-estimate	42.895	33.985	24.834	21.991	21.480	17.523
Method	Weibull	Weibull	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis Value	45.422	NA				17.150
B-estimate			24.267	19.661	20.454	
A-estimate	41.166	NA	19.560	15.848	16.487	15.573
Method	Normal	NA	Normal	Normal	Normal	Normal

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

Transverse Compression Modulus Statistics						
	As-measured					
Env	CTD	RTD	ETD1	ETW1	ETD2	ETW2
Mean	1.531	1.427	1.301	1.292	1.244	1.094
Stdev	0.029	0.067	0.026	0.040	0.018	0.061
CV	1.875	4.673	1.977	3.097	1.435	5.618
Mod CV	6.000	6.336	6.000	6.000	6.000	6.809
Min	1.485	1.353	1.274	1.249	1.221	0.999
Max	1.583	1.646	1.353	1.373	1.276	1.194
No. Batches	3	3	1	1	1	3
No. Spec.	21	21	7	7	7	21

Table 4-8: Statistics from TC Modulus data

4.5 In-Plane Shear (IPS)

In Plane Shear data is not normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

The CTD condition had no data available for strength at 5% strain due to strain gauge failures prior to 5% being reached. Values are given for the peak shear strength prior to 5% strain. This dataset and the RTD dataset for 5% strain failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When these CTD and RTD datasets were transformed according to the assumptions of the modified CV method, both passed the ADK test, so the modified CV basis values are provided.

Pooling was not appropriate for all conditions for the 0.2% offset strength data after the modified CV transform due to a failure of Levene's test. However, CTD & RTD condition could be pooled for Mod CV basis values computations. The 0.2% offset strength dataset for the RTD condition failed all distribution tests, so the non-parametric method was used for that dataset. After transforming the data to meet the assumptions of the modified CV method, the RTD dataset passed the normality test so modified CV basis values are provided. However, pooling was not appropriate after the modified CV transformation because the pooled dataset for the strength at 0.2% offset strength property failed Levene's test.

There was one outlier. The highest value in batch five of the RTD dataset for 0.2% offset strength was an outlier for that batch but not for the RTD condition.

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

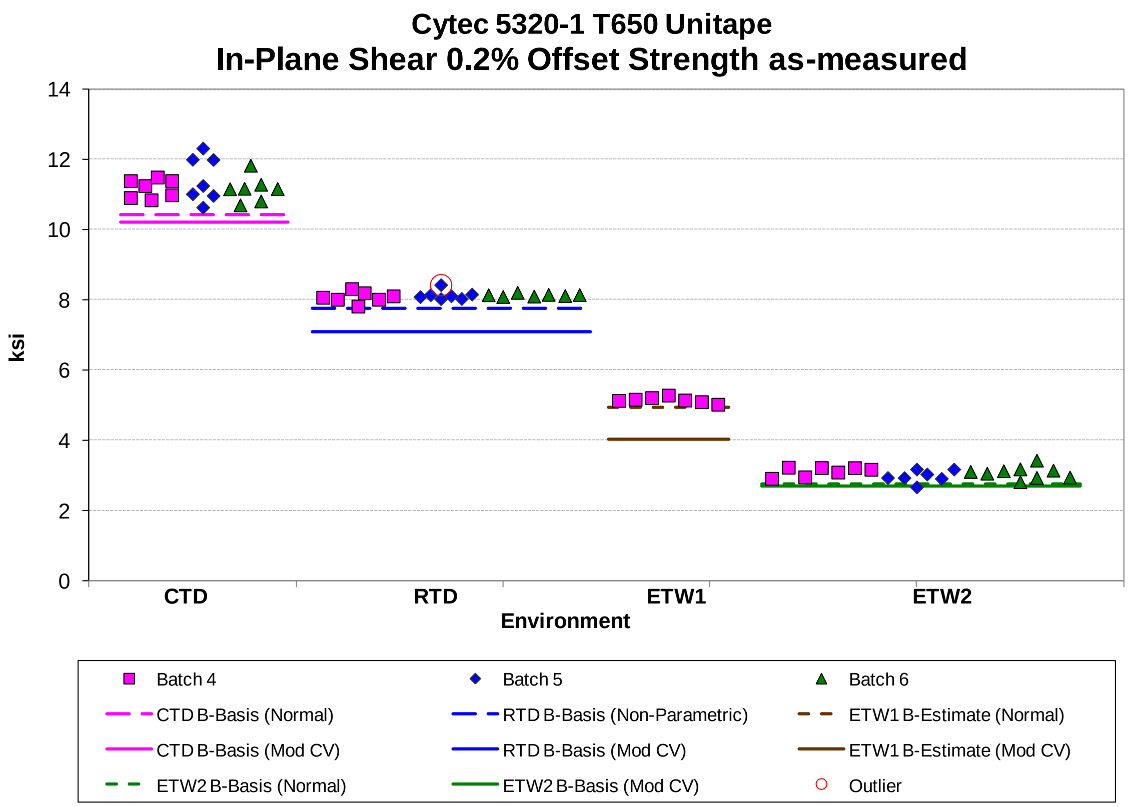

Figure 4-5: Batch plot for IPS for 0.2% offset strength as-measured

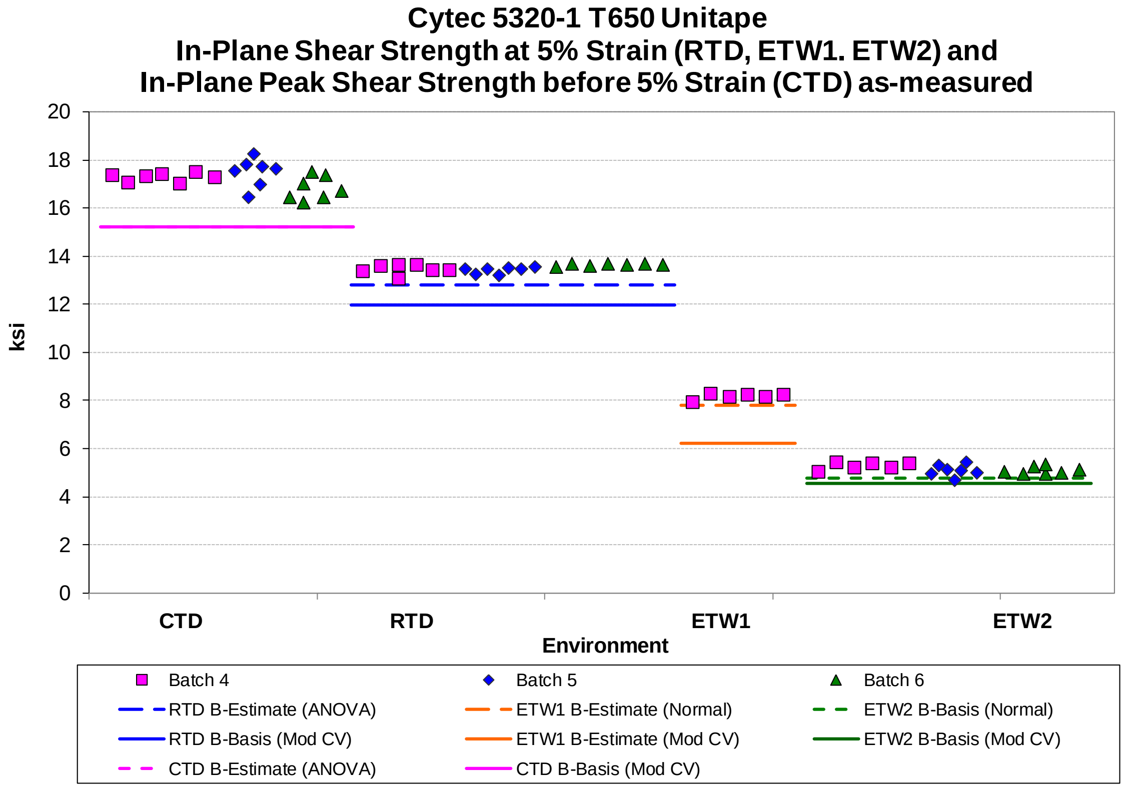

Figure 4-6: Batch plot for IPS for strength at 5% strain and peak strength before 5% strain as-measured

In-Plane Shear Strength Basis Values and Statistics As-Measured								
	Peak before 5% Strain	Strength at 5% Strain			0.2% Offset Strength			
Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	17.198	13.501	8.165	5.139	11.269	8.121	5.151	3.060
Stdev	0.517	0.173	0.128	0.199	0.451	0.119	0.083	0.167
CV	3.004	1.278	1.568	3.874	3.999	1.468	1.608	5.451
Mod CV	6.000	6.000	8.000	6.000	6.000	6.000	8.000	6.725
Min	16.245	13.055	7.935	4.695	10.639	7.820	5.023	2.668
Max	18.252	13.697	8.297	5.438	12.321	8.430	5.283	3.430
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	6	20	21	21	7	23
Basis Values and Estimates								
B-basis Value				4.755	10.411	7.758		2.748
B-estimate	15.217	12.793	7.777				4.921	
A-estimate	13.803	12.287	7.502	4.482	9.799	7.088	4.759	2.525
Method	ANOVA	ANOVA	Normal	Normal	Normal	Non-Parametric	Normal	Normal
Modified Basis Values and Estimates								
B-basis Value	15.232	11.958		4.545	10.224	7.075		2.675
B-estimate			6.197				4.014	
A-estimate	13.831	10.858	4.851	4.123	9.506	6.357	3.235	2.400
Method	Normal	Normal	Normal	Normal	pooled	pooled	Normal	Normal

Table 4-9: Statistics and Basis Values for IPS Strength data

In Plane Shear Modulus Statistics				
As-measured				
Env	CTD	RTD	ETW1	ETW2
Mean	0.838	0.718	0.547	0.325
Stdev	0.021	0.015	0.010	0.021
CV	2.505	2.152	1.914	6.547
Mod CV	6.000	6.000	6.000	7.274
Min	0.791	0.702	0.532	0.275
Max	0.865	0.756	0.564	0.373
No. Batches	3	3	1	3
No. Spec.	21	21	7	23

Table 4-10: Statistics from IPS Modulus data

4.6 "25/50/25" Unnotched Tension 1 (UNT1)

The UNT1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition.

There were no test failures for the as measured datasets so pooling across environmental conditions was acceptable. The normalized RTD dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the normalized RTD dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided. The normalized dataset passed both normality and Levene's tests after modified CV transformation was applied to all environments, so pooling was acceptable for the normalized data when computing the modified CV basis values.

There were no outliers. Statistics, basis values and estimates are given for UNT1 strength data in Table 4-11and for the modulus data in Table 4-12. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-7.

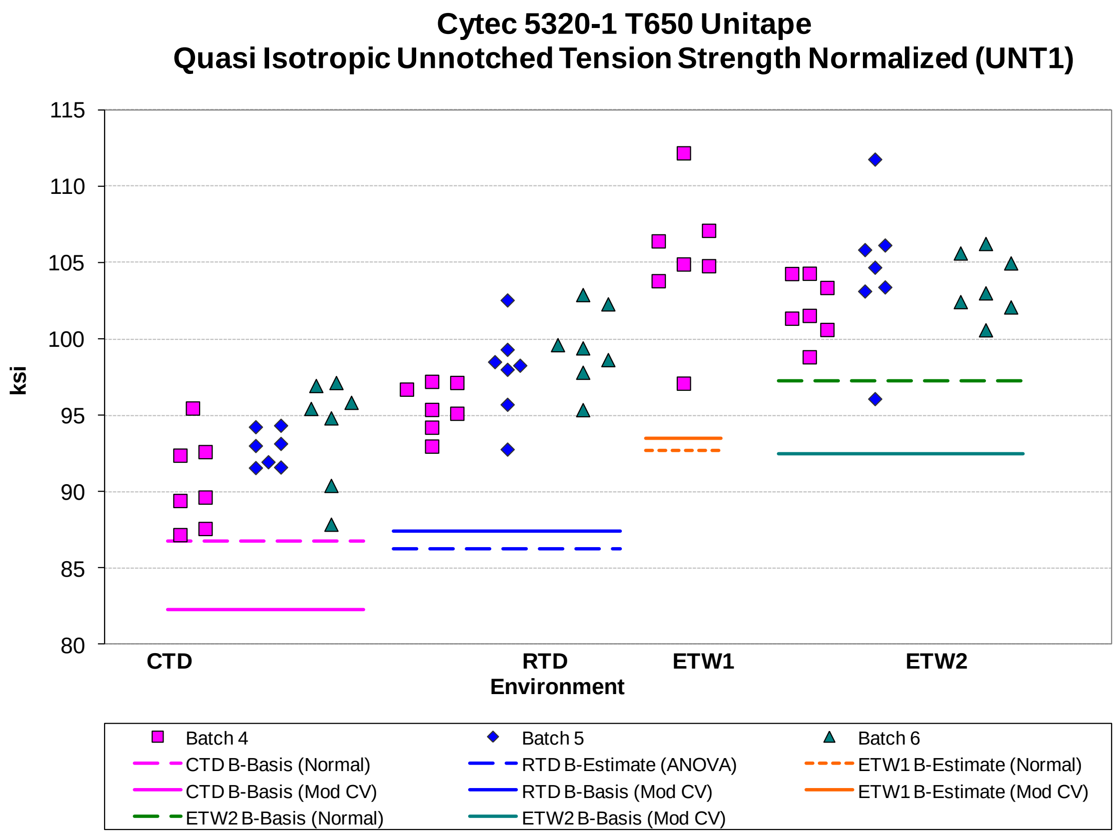

Figure 4-7: Batch Plot for UNT1 strength normalized

Unnotched Tension (UNT1) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	92.513	97.622	105.189	103.351	92.199	97.737	105.614	102.659
Stdev	3.004	2.864	4.501	3.184	3.150	2.671	4.775	3.180
CV	3.247	2.934	4.279	3.081	3.417	2.733	4.521	3.097
Modified CV	6.000	6.000	6.140	6.000	6.000	6.000	6.260	6.000
Min	87.187	92.787	97.105	96.092	87.194	92.616	97.548	94.640
Max	97.145	102.902	112.181	111.772	96.632	103.154	113.558	110.454
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	7	21	21	21	7	21
Basis Values and Estimates								
B-basis Value	86.791			97.286	86.675	92.213		97.135
B-estimate		86.272	92.690				99.291	
A-estimate	82.712	78.172	83.897	92.962	82.957	88.495	95.668	93.417
Method	Normal	ANOVA	Normal	Normal	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis Value	82.306	87.415		93.145	81.994	87.532		92.454
B-estimate			93.507				93.934	
A-estimate	75.437	80.546	86.813	86.276	75.127	80.664	87.241	85.586
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-11: Statistics and Basis Values for UNT1 Strength data

Unnotched Tension (UNT1) Modulus Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	7.709	7.580	7.209	6.963	7.683	7.590	7.238	6.916
Stdev	0.105	0.140	0.248	0.229	0.105	0.158	0.261	0.215
CV	1.368	1.849	3.445	3.287	1.371	2.076	3.600	3.108
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Min	7.416	7.366	6.921	6.696	7.441	7.343	6.942	6.615
Max	7.874	7.939	7.534	7.483	7.887	7.977	7.627	7.458
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	7	21	21	21	7	21

Table 4-12: Statistics from UNT1 Modulus data

4.7 "10/80/10" Unnotched Tension 2 (UNT2)

The UNT2 data is normalized. The CTD and ETW2 datasets, both normalized and as-measured, all failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the datasets were transformed according to the assumptions of the modified CV method, they passed the ADK test, so modified CV basis values are provided for all datasets. The datasets for all three conditions, both normalized and as-measured, could be pooled to compute the modified CV basis values.

There was one outlier. The highest value in batch five of the as-measured ETW2 dataset was an outlier for batch 5 only. It was not an outlier for the ETW2 condition nor was it an outlier for the normalized dataset. The outlier was retained for this analysis.

Statistics, basis values and estimates are given for UNT2 strength data in Table 4-13 and for the modulus data in Table 4-14. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-8.

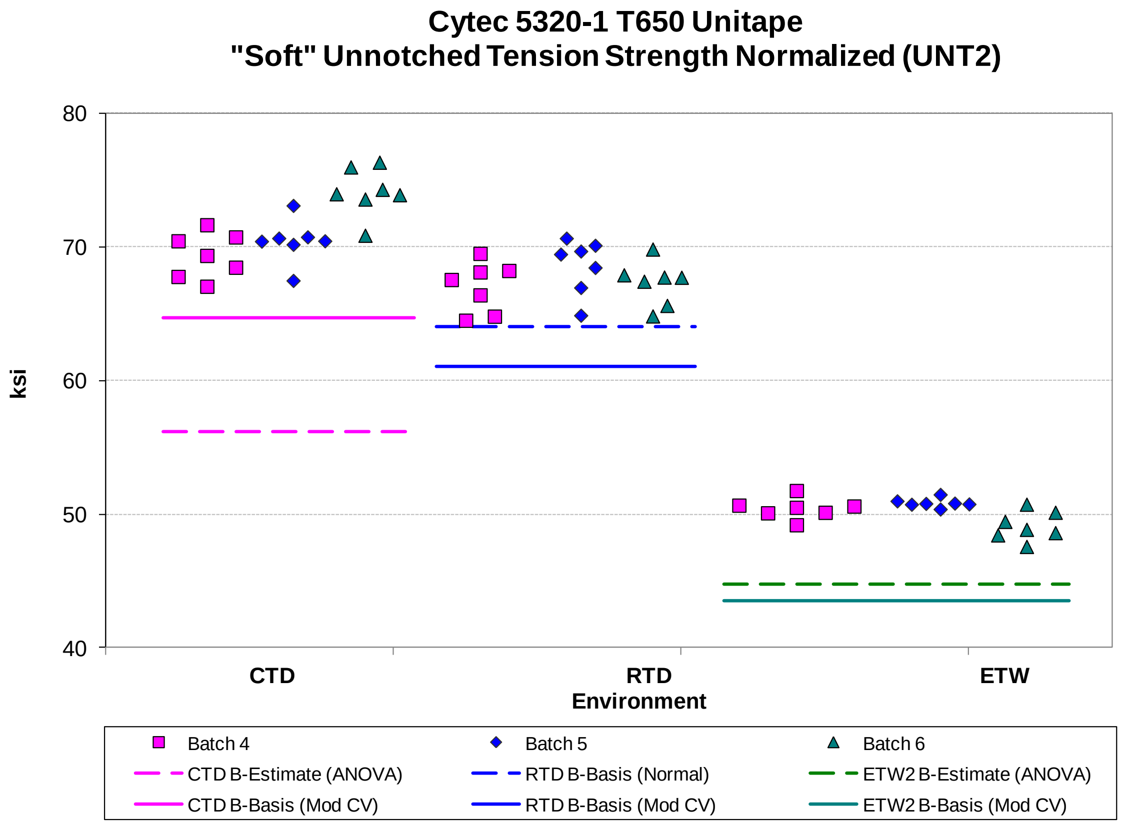

Figure 4-8: Batch Plot for UNT2 strength normalized

Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	71.302	67.633	50.130	70.795	67.581	49.782
Stdev	2.646	1.894	1.062	2.277	1.949	1.223
CV	3.711	2.800	2.119	3.217	2.884	2.456
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	67.044	64.502	47.580	66.653	63.838	47.045
Max	76.326	70.643	51.761	75.468	70.976	52.084
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value		64.025			63.868	
B-estimate	56.195		44.748	59.448		43.102
A-estimate	45.411	61.452	40.906	51.348	61.221	38.334
Method	ANOVA	Normal	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	64.693	61.023	43.520	64.217	61.002	43.204
A-estimate	60.231	56.561	39.058	59.776	56.561	38.763
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-13: Statistics and Basis Values for UNT2 Strength data

Unnotched Tension (UNT2) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW
Mean	5.124	4.917	4.173	5.089	4.914	4.144
Stdev	0.073	0.100	0.096	0.091	0.111	0.105
CV	1.417	2.024	2.298	1.791	2.253	2.527
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	4.973	4.770	4.012	4.897	4.723	3.991
Max	5.252	5.196	4.401	5.232	5.201	4.340
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21

Table 4-14: Statistics from UNT2 Modulus data

4.8 "50/40/10" Unnotched Tension 3 (UNT3)

The UNT3 data is normalized. The normalized RTD and ETW2 datasets could be pooled. The CTD datasets, both normalized and as-measured, and the as-measured ETW2 dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When these datasets were transformed according to the assumptions of the modified CV method, they passed the ADK test, so modified CV basis values are provided for all datasets. The datasets for all three conditions, both normalized and as-measured, could be pooled to compute the modified CV basis values.

There were no outliers. Statistics and basis values are given for UNT3 strength data in Table 4-15 and for the modulus data in Table 4-16. The normalized data and the B-basis values are shown graphically in Figure 4-9.

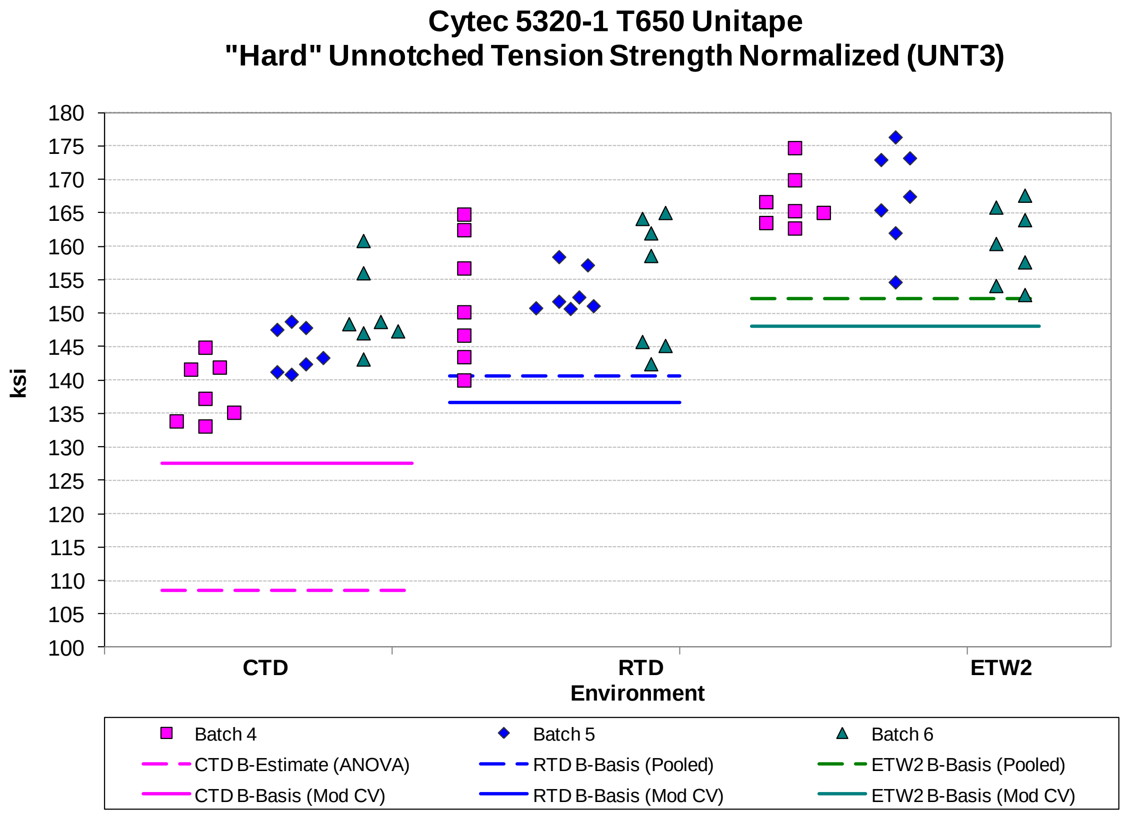

Figure 4-9: Batch Plot for UNT3 strength normalized

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	144.363	153.345	164.899	143.639	152.653	163.352
Stdev	6.768	7.810	6.570	5.800	7.271	7.251
CV	4.688	5.093	3.984	4.038	4.763	4.439
Modified CV	6.344	6.547	6.000	6.019	6.382	6.220
Min	133.118	140.003	152.789	133.604	140.268	148.996
Max	160.869	165.067	176.367	157.692	164.324	174.740
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value		140.549	152.103		138.802	
B-estimate	108.512			119.124		131.324
A-estimate	82.920	131.748	143.302	101.627	128.927	108.464
Method	ANOVA	pooled	pooled	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	127.579	136.561	148.115	127.145	136.159	146.858
A-estimate	116.248	125.231	136.785	116.011	125.024	135.724
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-15: Statistics and Basis Values for UNT3 Strength data

Unnotched Tension (UNT3) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	11.805	11.698	11.574	11.750	11.641	11.489
Stdev	0.152	0.203	0.197	0.200	0.206	0.204
CV	1.289	1.733	1.702	1.700	1.771	1.773
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	11.440	11.417	11.083	11.381	11.398	11.181
Max	12.054	12.342	11.849	12.212	12.266	11.859
No. Batches	3	3	3	3	3	3
No. Spec.	21	22	23	21	22	23

Table 4-16: Statistics from UNT3 Modulus data

4.9 "33/0/67" Unnotched Compression 0 (UNC0)

The UNC0 data is normalized. The ETD1, ETW1 and ETD2 datasets lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for those condition. The as-measured dataset failed Levene's test, so pooling across environments was not acceptable, but pooling was acceptable for conditions RTD through ETW2. There were no other diagnostic test failures. Pooling was acceptable for the normalized dataset. After the modified CV transform was applied to the data, pooling across all environmental conditions was acceptable to compute the as-measured modified CV basis values.

There was one outlier. The lowest value in batch six of the ETW2 condition was an outlier for batch six, but not for the ETW2 condition. It was an outlier for batch six for both the normalized and as-measured datasets. It was retained for this analysis.

Statistics and estimates of basis values are given for UNC0 strength data in Table 4-17 and for the modulus data in Table 4-18. The normalized data and the B-estimates are shown graphically in Figure 4-10.

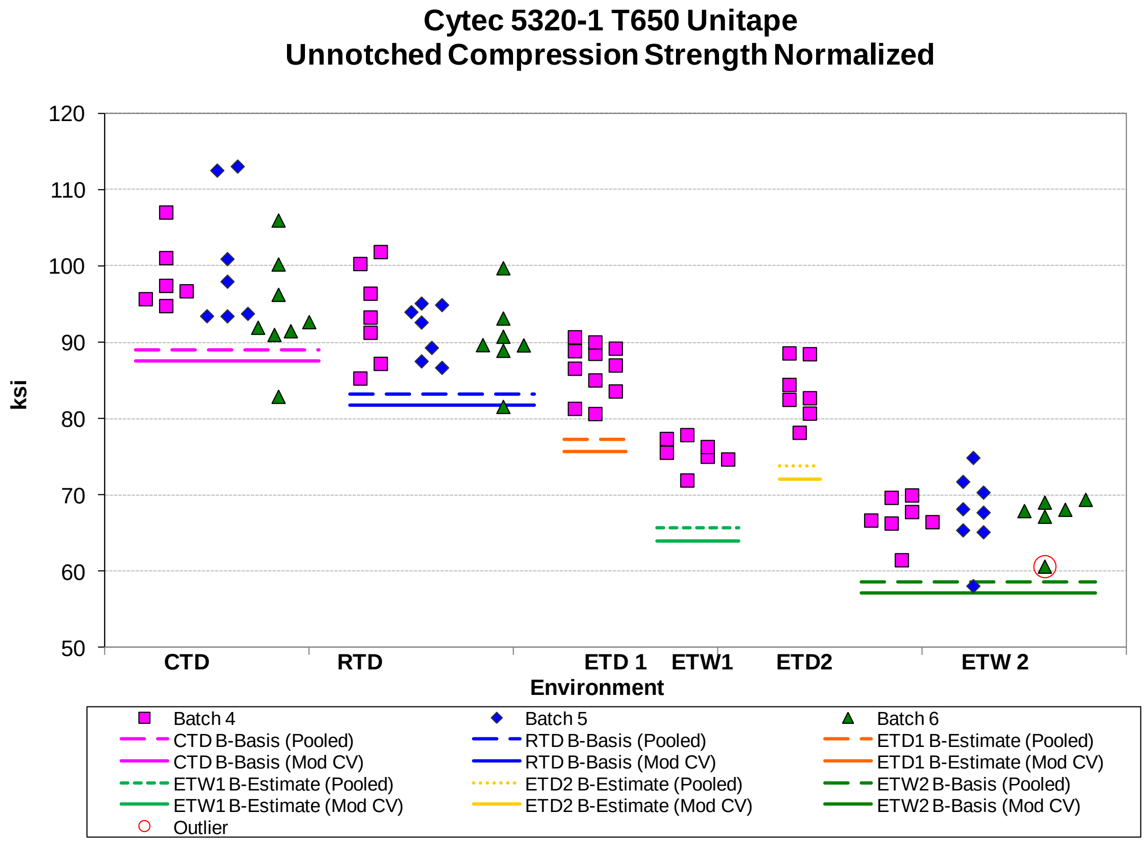

Figure 4-10: Batch Plot for UNC0 strength normalized

Unnotched Compression (UNC0) Strength Basis Values and Statistics												
	Normalized						As-measured					
Env	CTD	RTD	ETD1	ETW1	ETD2	ETW2	CTD	RTD	ETD1	ETW1	ETD2	ETW2
Mean	97.657	91.892	86.522	75.570	83.682	67.275	98.354	92.510	86.381	76.027	83.368	67.481
Stdev	7.308	5.121	3.449	1.975	3.852	3.754	7.523	5.408	3.291	2.151	3.749	3.891
CV	7.483	5.573	3.987	2.614	4.603	5.581	7.648	5.846	3.810	2.829	4.497	5.765
Modified CV	7.742	6.786	6.000	6.000	6.302	6.790	7.824	6.923	6.000	6.000	6.249	6.883
Min	82.923	81.603	80.661	71.961	78.209	58.125	84.042	82.226	80.801	72.495	78.574	58.062
Max	113.079	101.879	90.716	77.904	88.605	74.912	113.808	105.098	90.111	78.453	88.500	75.377
No. Batches	3	3	1	1	1	3	3	3	1	1	1	3
No. Spec.	21	21	11	7	7	21	21	21	11	7	7	21
Basis Values and Estimates												
B-basis Value	89.014	83.249				58.632	84.024	85.213				60.184
B-estimate			77.225	65.654	73.766				78.547	67.682	75.023	
A-estimate	83.248	77.482	71.538	60.018	68.129	52.865	73.807	80.290	73.703	62.889	70.230	55.261
Method	pooled	pooled	pooled	pooled	pooled	pooled	Normal	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates												
B-basis Value	87.518	81.753				57.136	88.051	82.207				57.178
B-estimate			75.615	63.938	72.050				75.298	64.207	71.548	
A-estimate	80.754	74.988	68.945	57.326	65.437	50.371	81.178	75.334	68.520	57.488	64.829	50.305
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-17: Statistics and Basis Values for UNC0 Strength data

Unnotched Compression (UNC0) Modulus Statistics												
	Normalized						As-measured					
Env	CTD	RTD	ETD1	ETW1	ETD2	ETW2	CTD	RTD	ETD1	ETW1	ETD2	ETW2
Mean	6.707	7.093	6.973	7.074	6.987	6.855	6.765	7.139	6.987	7.144	6.961	6.940
Stdev	0.397	0.192	0.125	0.262	0.141	0.247	0.421	0.151	0.192	0.219	0.133	0.282
CV	5.914	2.706	1.789	3.701	2.022	3.610	6.228	2.112	2.751	3.068	1.913	4.069
Mod CV	6.957	6.000	6.000	6.000	6.000	6.000	7.114	6.000	6.000	6.000	6.000	6.035
Min	5.989	6.744	6.856	6.742	6.687	6.442	5.968	6.843	6.782	6.909	6.668	6.529
Max	7.284	7.562	7.186	7.467	7.104	7.468	7.304	7.502	7.299	7.478	7.054	7.525
No. Batches	3	3	1	1	1	3	3	3	1	1	1	3
No. Spec.	21	21	7	7	7	21	21	21	7	7	7	21

Table 4-18: Statistics from UNC0 Modulus data

4.10 "25/50/25" Unnotched Compression 1 (UNC1)

The UNC1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. Pooling was not acceptable for either the normalized or the as-measured data due to the failure of Levene's test for equality of variance. However, the as-measured dataset passed Levene's test after the modified CV transformation of the data, so pooling was used to compute the as-measured modified CV basis values. The normal distribution single-point method was used to compute basis values and estimates for all other basis values computations.

There were no statistical outliers. Statistics, basis values and estimates are given for UNC1 strength data in Table 4-19 and for the modulus data in Table 4-20. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-11.

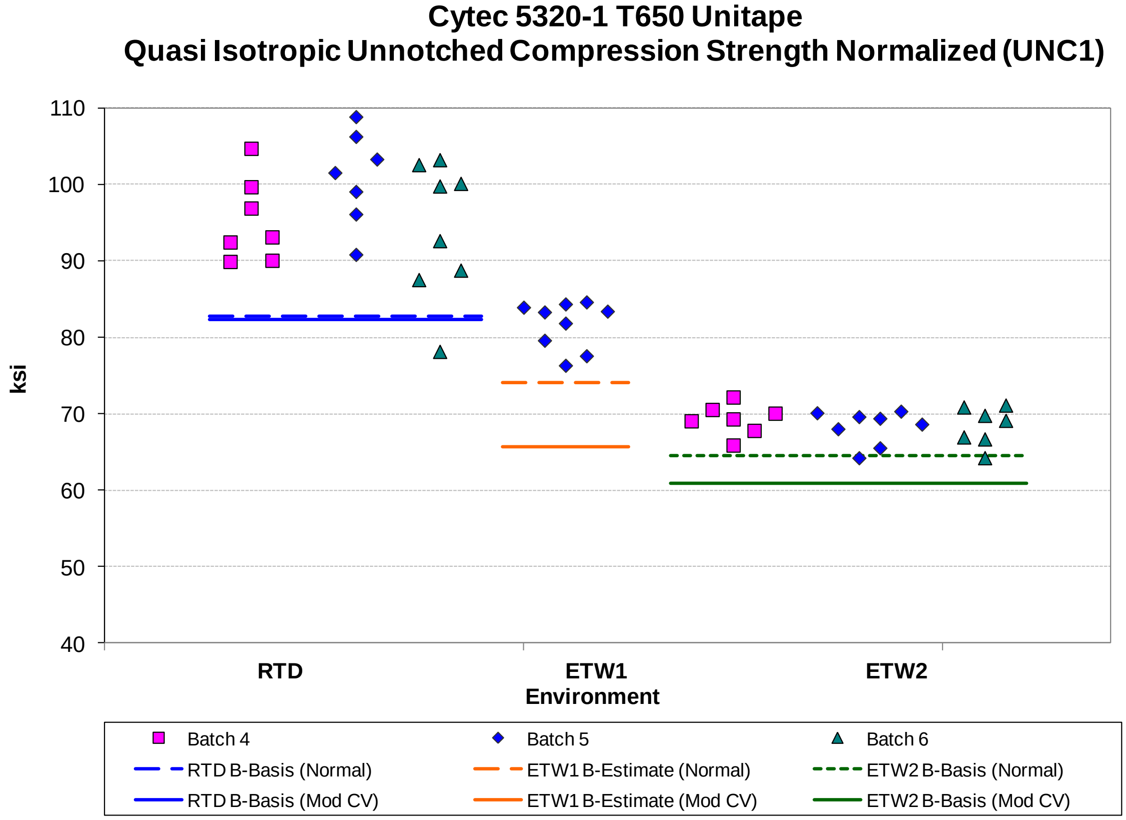

Figure 4-11: Batch plot for UNC1 strength normalized

Unnotched Compression (UNC1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	RTD	ETW1	ETW2	RTD	ETW1	ETW2
Mean	96.628	81.676	68.635	97.952	81.965	68.666
Stdev	7.386	3.087	2.199	6.296	2.705	2.248
CV	7.643	3.779	3.204	6.428	3.301	3.274
Modified CV	7.822	8.000	6.000	7.214	8.000	6.000
Min	78.165	76.344	64.255	84.338	76.963	63.768
Max	108.860	84.627	72.195	109.295	84.828	72.456
No. Batches	3	1	3	3	1	3
No. Spec.	22	9	22	22	9	22
Basis Values and Estimates						
B-basis Value	82.700		64.487	86.078		64.425
B-estimate		74.061			75.291	
A-estimate	72.751	68.741	61.524	77.596	70.628	61.397
Method	Normal	Normal	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis Value	82.369		60.866	88.116		58.830
B-estimate		65.630			71.101	
A-estimate	72.190	54.586	55.319	81.385	64.532	52.098
Method	Normal	Normal	Normal	pooled	pooled	pooled

Table 4-19: Statistics and Basis Values for UNC1 Strength data

Unnotched Compression (UNC1) Modulus Statistics						
	Normalized			As-measured		
Env	RTD	ETW1	ETW2	RTD	ETW1	ETW2
Mean	7.189	7.172	6.752	7.301	7.171	6.764
Stdev	0.143	0.112	0.182	0.223	0.097	0.193
CV	1.991	1.564	2.693	3.051	1.347	2.858
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	6.980	7.044	6.353	6.870	7.072	6.304
Max	7.418	7.386	7.088	7.753	7.371	7.114
No. Batches	3	1	3	3	1	3
No. Spec.	21	7	21	21	7	21

Table 4-20: Statistics from UNC1 Modulus data

4.11 "10/80/10" Unnotched Compression 2 (UNC2)

The UNC2 data is normalized. Pooling was not acceptable for either the normalized or the as-measured data due to the failure of Levene's test for equality of variance. The normal distribution method was used to compute basis values and estimates for the normalized data in both conditions and the as-measured ETW2 dataset. The as-measured RTD dataset did not fit the normal, lognormal or Weibull distributions so the non-parametric method was used to compute basis values. Mod CV basis values could not be computed for the as-measured RTD dataset due to its non-normality .

There was one outlier. The lowest value in batch six of the ETW2 dataset was an outlier for batch six, but not for the ETW2 condition. It was an outlier in both the normalized and as-measured datasets. The outlier was retained for this analysis.

Statistics and basis values are given for UNC2 strength data in Table 4-21 and for the modulus data in Table 4-22. The normalized data and the B-basis values are shown graphically in Figure 4-12.

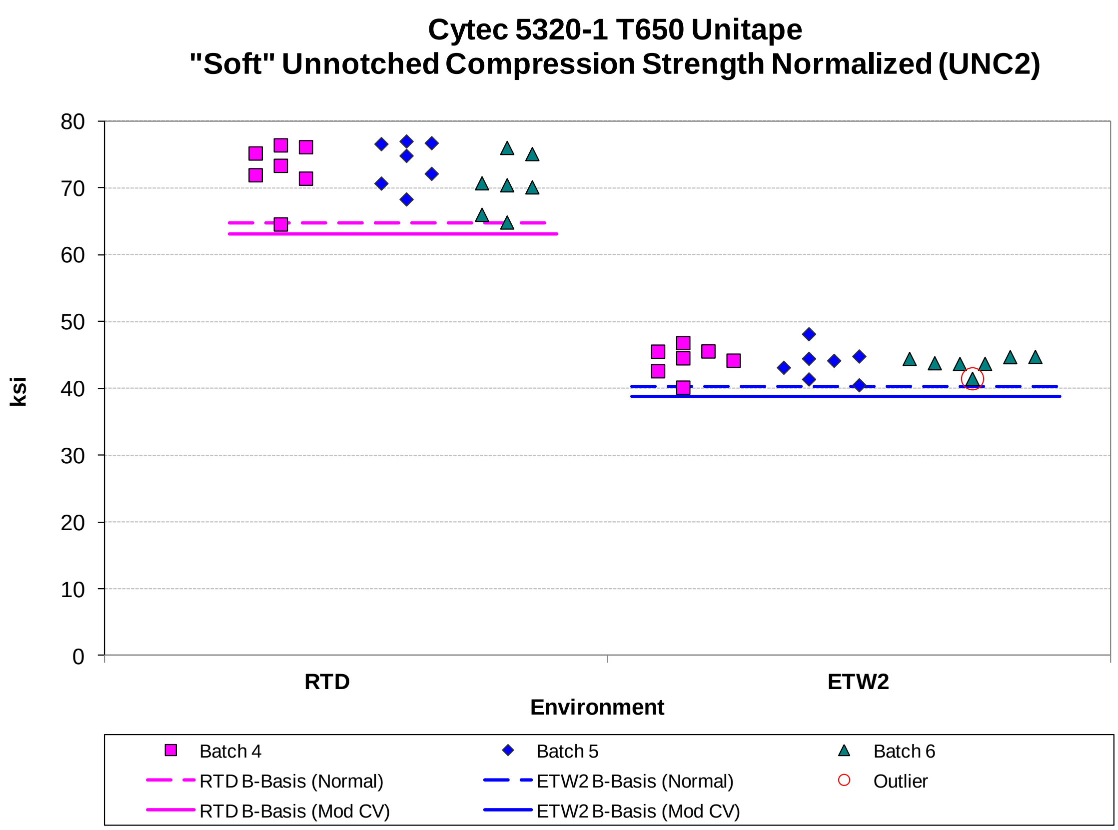

Figure 4-12: Batch plot for UNC2 strength normalized

Unnotched Compression (UNC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	72.330	43.957	73.618	43.965
Stdev	3.960	1.937	3.344	2.051
CV	5.475	4.408	4.543	4.665
Modified CV	6.737	6.204	6.271	6.332
Min	64.583	40.233	68.731	40.288
Max	77.006	48.163	78.152	47.853
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	64.787	40.266	67.728	40.058
A-estimate	59.409	37.635	58.077	37.273
Method	Normal	Normal	Non-Parametric	Normal
Modified CV Basis Values and Estimates				
B-basis Value	63.044	38.760	NA	38.660
A-estimate	56.429	35.059	NA	34.881
Method	Normal	Normal	NA	Normal

Table 4-21: Statistics and Basis Values for UNC2 Strength data

Unnotched Compression (UNC2) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	4.743	3.932	4.842	3.927
Stdev	0.122	0.136	0.214	0.127
CV	2.581	3.470	4.427	3.236
Modified CV	6.000	6.000	6.214	6.000
Min	4.567	3.725	4.514	3.677
Max	4.953	4.222	5.239	4.175
No. Batches	3	3	3	3
No. Spec.	21	20	21	20

Table 4-22: Statistics from UNC2 Modulus data

4.12 "50/40/10" Unnotched Compression 3 (UNC3)

The UNC3 data is normalized. Pooling was not acceptable for either the normalized or the as-measured data due to the failure of Levene's test for equality of variance. The normal distribution method was used to compute basis values and estimates for both conditions. After transforming the data to match the assumptions of the modified CV method, the datasets passed Levene's test and pooling was used to compute the modified CV basis values.

There were no statistical outliers. Statistics, basis values and estimates are given for UNC3 strength data in Table 4-23 and for the modulus data in Table 4-24. The normalized data and the B-basis values are shown graphically in Figure 4-13.

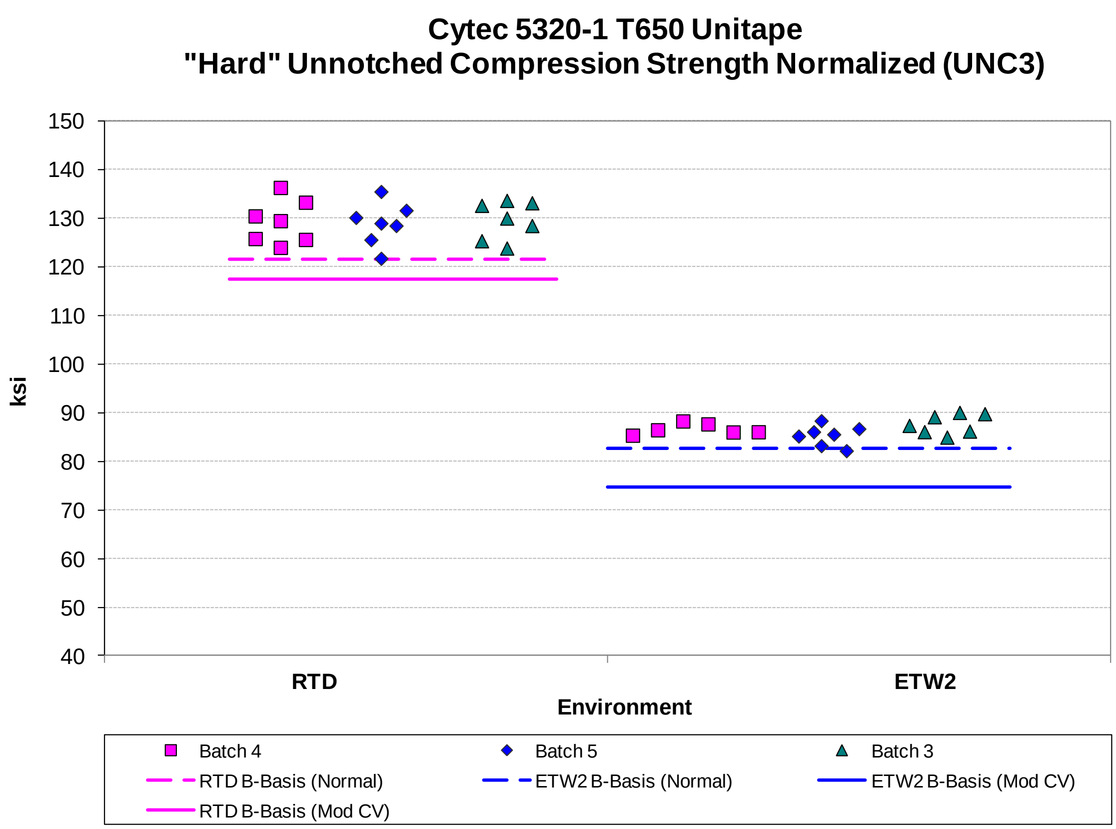

Figure 4-13: Batch plot for UNC3 strength normalized

Unnotched Compression (UNC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	129.217	86.522	130.454	86.791
Stdev	4.047	1.998	4.480	1.969
CV	3.132	2.309	3.434	2.269
Modified CV	6.000	6.000	6.000	6.000
Min	121.715	82.166	123.856	82.456
Max	136.286	90.033	142.082	90.281
No. Batches	3	3	3	3
No. Spec.	21	20	21	20
Basis Values and Estimates				
B-basis Value	121.507	82.674	121.919	82.999
A-estimate	116.010	79.936	115.834	80.300
Method	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates				
B-basis Value	117.435	74.689	118.582	74.868
A-estimate	109.327	66.593	110.412	66.711
Method	pooled	pooled	pooled	pooled

Table 4-23: Statistics and Basis Values for UNC3 Strength data

Unnotched Compression (UNC3) Modulus Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	10.913	10.463	11.041	10.509
Stdev	0.273	0.254	0.264	0.222
CV	2.500	2.423	2.390	2.116
Modified CV	6.000	6.000	6.000	6.000
Min	10.215	9.948	10.493	10.140
Max	11.344	10.994	11.573	10.937
No. Batches	3	3	3	3
No. Spec.	21	21	21	21

Table 4-24: Statistics from UNC3 Modulus data

4.13 Lamina Short-Beam Strength (SBS)

The Short Beam Strength data is not normalized. The ETD1, ETW1 and ETD2 conditions have insufficient data to meet CMH17 requirements so only estimates are provided for those conditions.

The CTD dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the CTD dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided.

Pooling the RTD through ETW2 conditions was not acceptable due to a failure of Levene's test for equality of variation. However, the pooled dataset passed Levene's test after applying the Mod CV transform to all conditions, so pooling was used to compute the modified CV basis values.
There were no outliers.

Statistics and basis values are given for SBS data in Table 4-25. The data and the B-basis values are shown graphically in Figure 4-14.

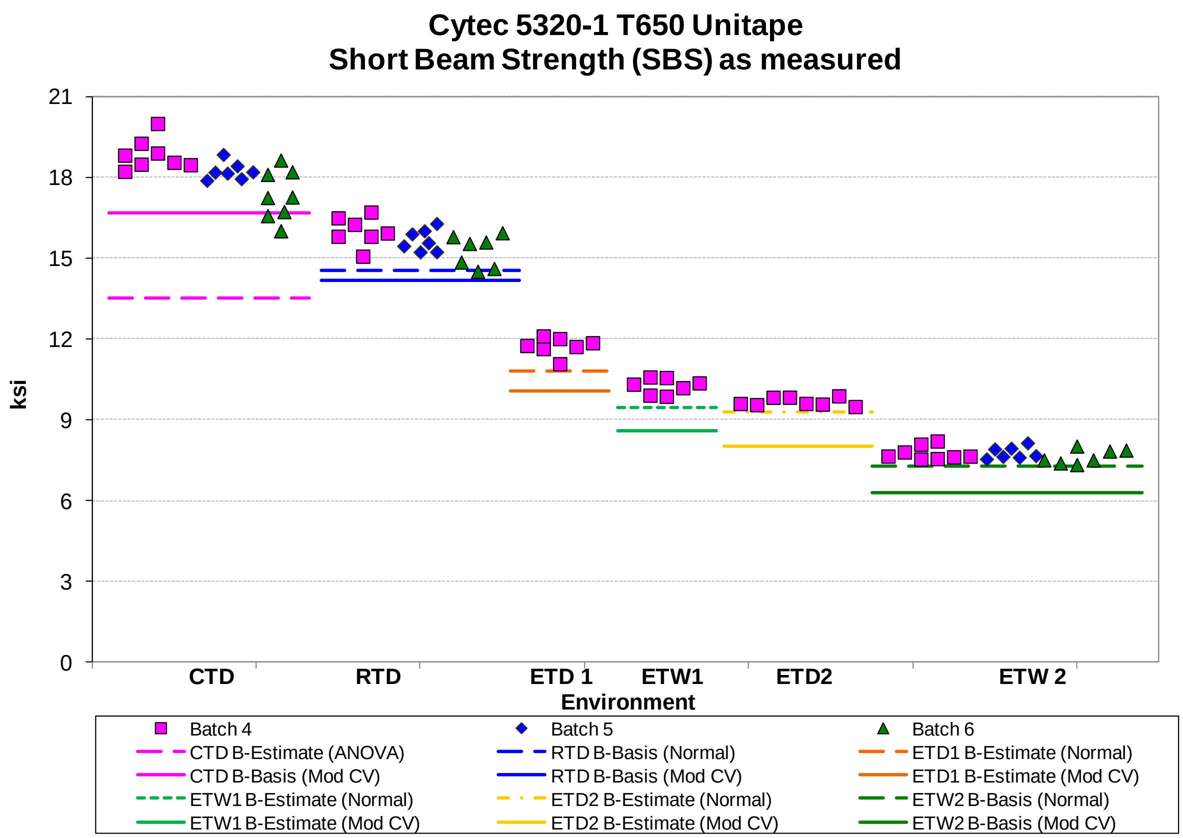

Figure 4-14: Batch plot for SBS as-measured

Short Beam Strength (SBS) Basis Values and Statistics As-measured						
Env	CTD	RTD	ETD1	ETW1	ETD2	ETW2
Mean	18.126	15.639	11.730	10.250	9.665	7.722
Stdev	0.895	0.582	0.335	0.286	0.152	0.244
CV	4.936	3.720	2.853	2.794	1.574	3.159
Mod CV	6.468	6.000	6.000	6.000	6.000	6.000
Min	16.003	14.502	11.071	9.862	9.481	7.327
Max	19.986	16.698	12.103	10.578	9.878	8.202
No. Batches	3	3	1	1	1	3
No. Spec.	23	21	7	7	8	22
Basis Values and Estimates						
B-basis Value		14.531				7.262
B-estimate	13.531		10.801	9.455	9.270	
A-estimate	10.250	13.740	10.147	8.895	8.993	6.934
Method	ANOVA	Normal	Normal	Normal	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis Value	16.680	14.180				6.271
B-estimate			10.057	8.577	8.026	
A-estimate	15.705	13.208	9.106	7.626	7.072	5.297
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-25: Statistics and Basis Values for SBS data

4.14 Laminate Short-Beam Strength (SBS1)

The Laminate Short Beam Strength data is not normalized. The RTD condition fails all distribution tests while passing the ADK test. This means that the non-parametric method must be used to compute basis values. The RTD condition fails normality even after the data has been transformed to match the assumptions of the modified CV method. Modified CV basis values are not provided due to this failure of the normality test.

ETW2 conditions fails both the ADK test and the normality test, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the ETW2 dataset was transformed according to the assumptions of the modified CV method, it failed the ADK test, but passed the normality test. Modified CV basis values are provided but considered estimates due to the failure of the ADK test.

There were two statistical outliers, both in the RTD dataset. The lowest value in batch five was an outlier for both batch five and for the RTD dataset. The lowest value in batch six was an outlier only for batch six, not for the RTD dataset. Both outliers were retained for this analysis.

Statistics, estimates and basis values are given for SBS1 strength data in Table 4-26. The data and the B-basis values are shown graphically in Figure 4-15.

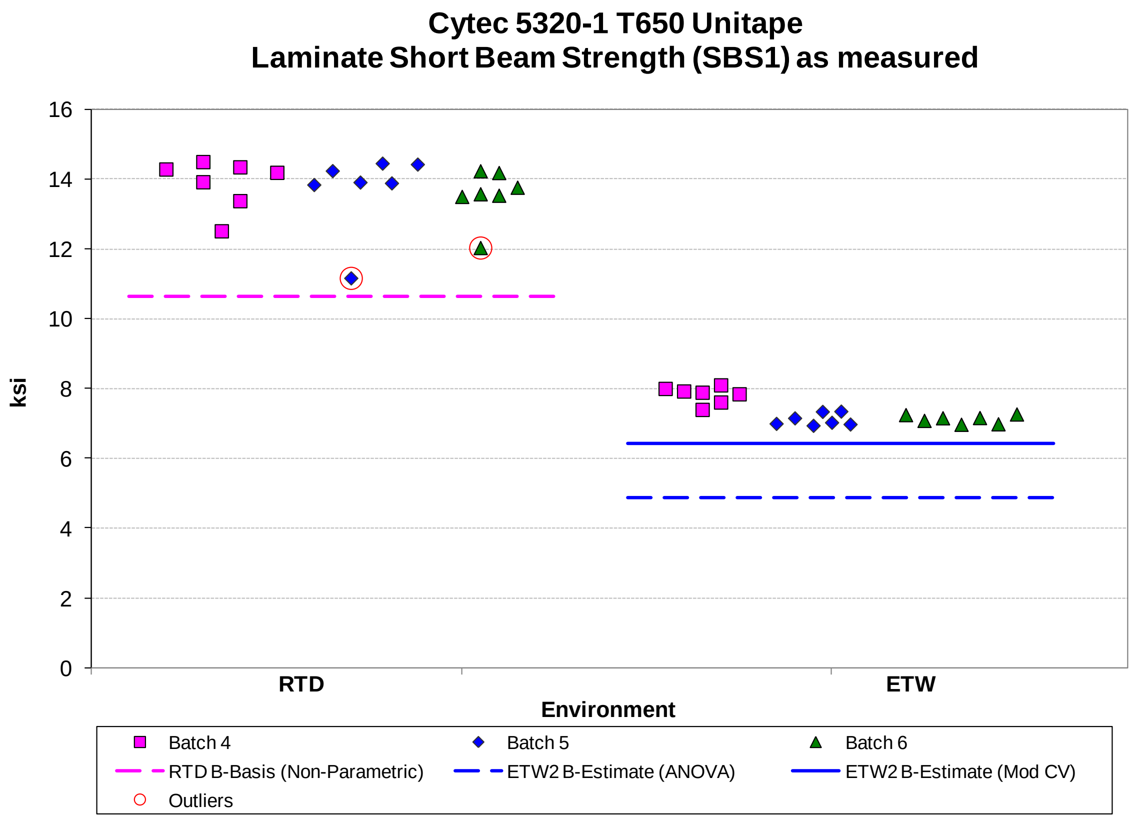

Figure 4-15: Batch plot for SBS1 strength as-measured

Laminate Short Beam Strength (SBS1) Basis Values and Statistics		
As-measured		
Env	RTD	ETW2
Mean	13.710	7.356
Stdev	0.851	0.382
CV	6.205	5.199
Modified CV	7.102	6.599
Min	11.168	6.943
Max	14.499	8.102
No. Batches	3	3
No. Spec.	21	21
Basis Values and Estimates		
B-basis Value	10.649	
B-estimate		4.875
A-estimate	7.931	3.104
Method	Non-Parametric	ANOVA
Modified CV Estimates of Basis Values		
B-estimate	NA	6.431
A-estimate	NA	5.772
Method	NA	Normal

Table 4-26: Statistics and Basis Values for SBS1 Strength data

4.15 “25/50/25” Open-Hole Tension 1 (OHT1)

The OHT1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. The CTD and RTD datasets, both normalized and as-measured, all failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the datasets were transformed according to the assumptions of the modified CV method, only the as-measured CTD dataset passed the ADK test, so the modified CV basis values are provided that dataset. The normalized CTD dataset and the RTD datasets (both normalized and as-measured) have B-estimates given computed using the modified CV method. The modified CV basis values for those datasets are considered estimates due to the failure of the ADK test even after the modified CV transformation. Pooling was not acceptable due to the failure of the ADK test for the RTD condition.

There were two outliers. The highest value in batch six of the ETW2 dataset was an outlier for batch six, but not for the ETW2 condition. It was an outlier for both the normalized and as-measured datasets. It was retained for this analysis. The lowest value in the ETW1 dataset was an outlier. Since the ETW1 dataset has only one batch, it is an outlier for both the batch and the condition. It was an outlier for the as-measured dataset only.

Statistics, basis values and estimates are given for OHT1 strength data in Table 4-27. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-16.

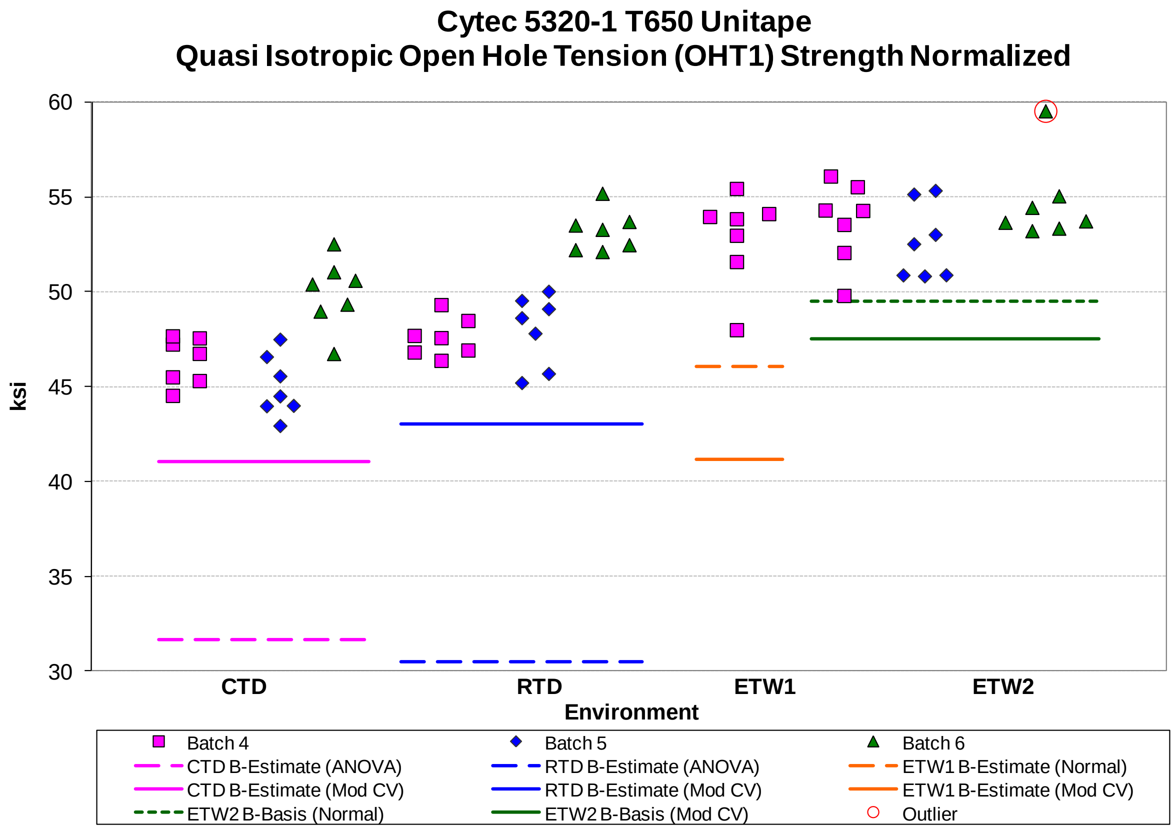

Figure 4-16: Batch Plot for OHT1 strength normalized

Open Hole Tension (OHT1) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	47.105	49.601	52.842	53.675	47.046	49.605	52.375	53.427
Stdev	2.607	2.931	2.440	2.181	2.353	2.760	2.390	2.038
CV	5.534	5.909	4.617	4.064	5.001	5.563	4.563	3.814
Modified CV	6.767	6.955	8.000	6.032	6.500	6.782	8.000	6.000
Min	42.940	45.207	47.992	49.798	43.509	46.052	47.409	49.405
Max	52.517	55.184	55.437	59.532	52.269	54.842	54.620	58.775
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	7	21	21	21	7	21
Basis Values and Estimates								
B-basis Value				49.519				49.545
B-estimate	31.667	30.489	46.068		33.710	31.939	45.739	
A-estimate	20.646	16.844	41.303	46.556	24.189	19.326	41.071	46.777
Method	ANOVA	ANOVA	Normal	Normal	ANOVA	ANOVA	Normal	Normal
Modified CV Basis Values and Estimates								
B-basis Value				47.505	41.219			47.318
B-estimate	41.031	43.027	41.177			43.195	40.813	
A-estimate	36.704	38.345	33.191	43.110	37.067	38.628	32.898	42.967
Method	Normal	Normal	Normal	Normal	Normal	Normal	Normal	Normal

Table 4-27: Statistics and Basis Values for OHT1 Strength data

4.16 "10/80/10" Open-Hole Tension 2 (OHT2)

The OHT2 data is normalized. The normalized and as-measured CTD datasets and the normalized RTD dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the datasets were transformed according to the assumptions of the modified CV method, they passed the ADK test, so modified CV basis values are provided for those datasets with the exception of the normalized RTD dataset which failed the normality test.

The as-measured RTD and ETW2 datasets could be pooled. The as-measured datasets for all three conditions could be pooled to compute the modified CV basis values. Pooling was not acceptable for the normalized modified CV basis values due to non-normality of the pooled dataset.

There were no outliers. Statistics, basis values and estimates are given for OHT2 strength data in Table 4-28. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-17.

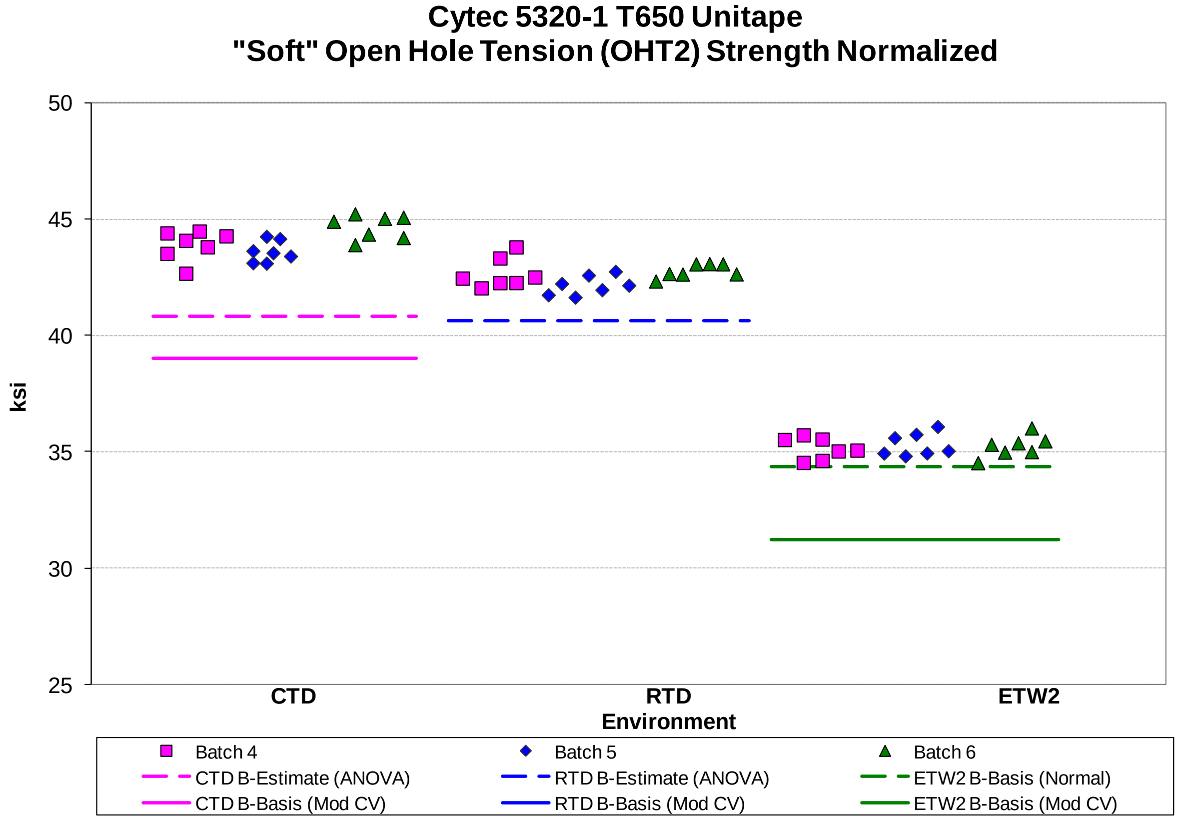

Figure 4-17: Batch Plot for OHT2 strength normalized

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	44.056	42.535	35.238	43.732	42.191	34.909
Stdev	0.689	0.530	0.456	0.587	0.499	0.481
CV	1.564	1.245	1.294	1.343	1.183	1.379
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	42.671	41.642	34.532	42.856	41.612	34.139
Max	45.222	43.801	36.087	44.851	43.439	35.727
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21
Basis Values and Estimates						
B-basis Value			34.369		41.321	34.039
B-estimate	40.796	40.615		40.891		
A-estimate	38.470	39.245	33.750	38.863	40.724	33.442
Method	ANOVA	ANOVA	Normal	ANOVA	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	39.018	NA	31.209	39.534	37.992	30.710
A-estimate	35.430	NA	28.339	36.699	35.158	27.876
Method	Normal	NA	Normal	pooled	pooled	pooled

Table 4-28: Statistics and Basis Values for OHT2 Strength data

4.17 "50/40/10" Open-Hole Tension 3 (OHT3)

The OHT3 data is normalized. There were no test failures or outliers. Pooling across environments was acceptable. Statistics, basis values and estimates are given for OHT3 strength data in Table 4-29. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-18.

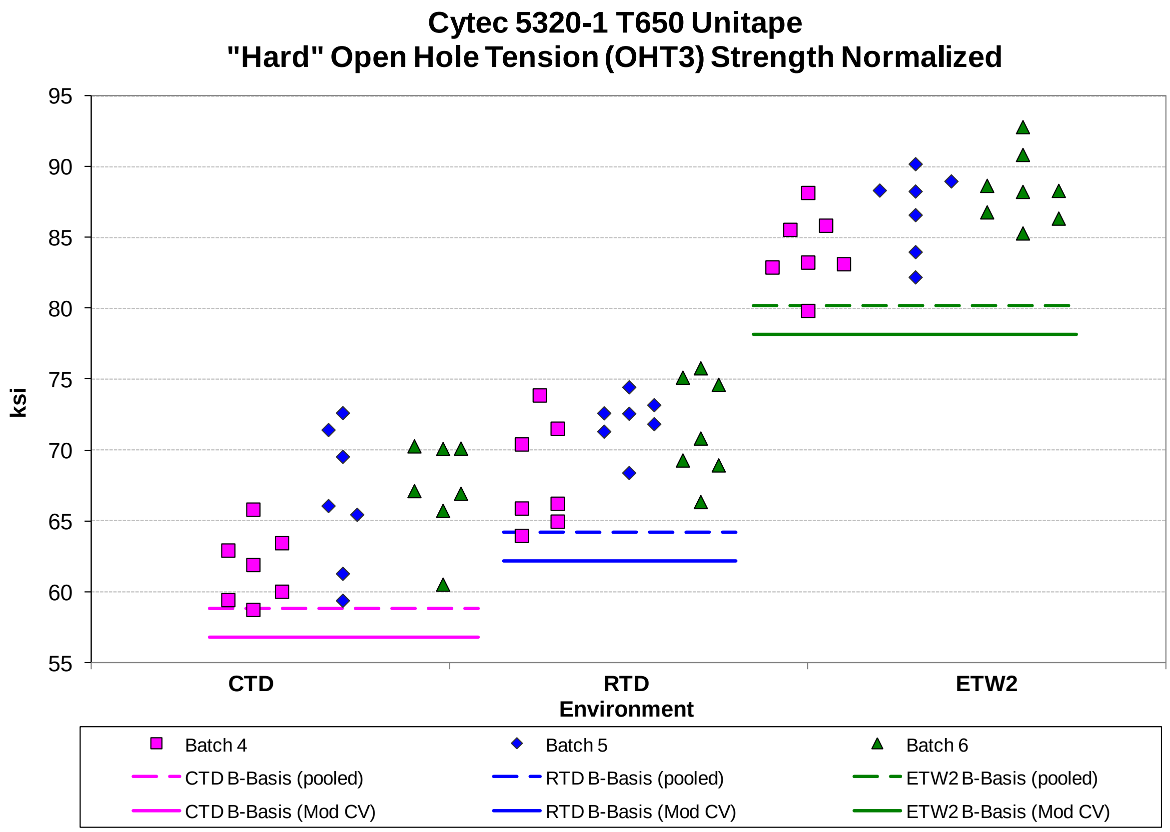

Figure 4-18: Batch Plot for OHT3 strength normalized

Open Hole Tension (OHT3) Strength (ksi) Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	65.202	70.597	86.585	64.585	69.906	85.508
Stdev	4.398	3.543	3.128	4.228	3.376	3.062
CV	6.744	5.019	3.612	6.546	4.829	3.581
Modified CV	7.372	6.510	6.000	7.273	6.415	6.000
Min	58.756	63.981	79.852	58.183	64.017	79.014
Max	72.639	75.804	92.821	71.802	74.997	91.001
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	22	21	21	22
Basis Value Estimates						
B-basis Value	58.777	64.172	80.188	58.397	63.718	79.346
A-estimate	54.442	59.838	75.848	54.222	59.543	75.166
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	56.773	62.169	78.192	56.318	61.639	77.276
A-estimate	51.087	56.483	72.500	50.741	56.061	71.692
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-29: Statistics and Basis Values for OHT3 Strength data

4.18 "25/50/25" Filled-Hole Tension 1 (FHT1)

The FHT1 data is normalized. The normalized and as-measured CTD and RTD datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the datasets were transformed according to the assumptions of the modified CV method, they all passed the ADK test, so modified CV basis values are provided for those datasets. When all conditions were transformed for the Mod CV method, the datasets, both normalized and as-measured, could be pooled across the conditions to compute the modified CV basis values.

There was one outlier. The lowest value in batch five of the RTD condition was an outlier for batch five, but not for the RTD condition. It was an outlier only for the normalized dataset, not for the as-measured dataset. It was retained for this analysis.

Statistics, estimates and basis values are given for FHT1 strength data in Table 4-30. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-19 .

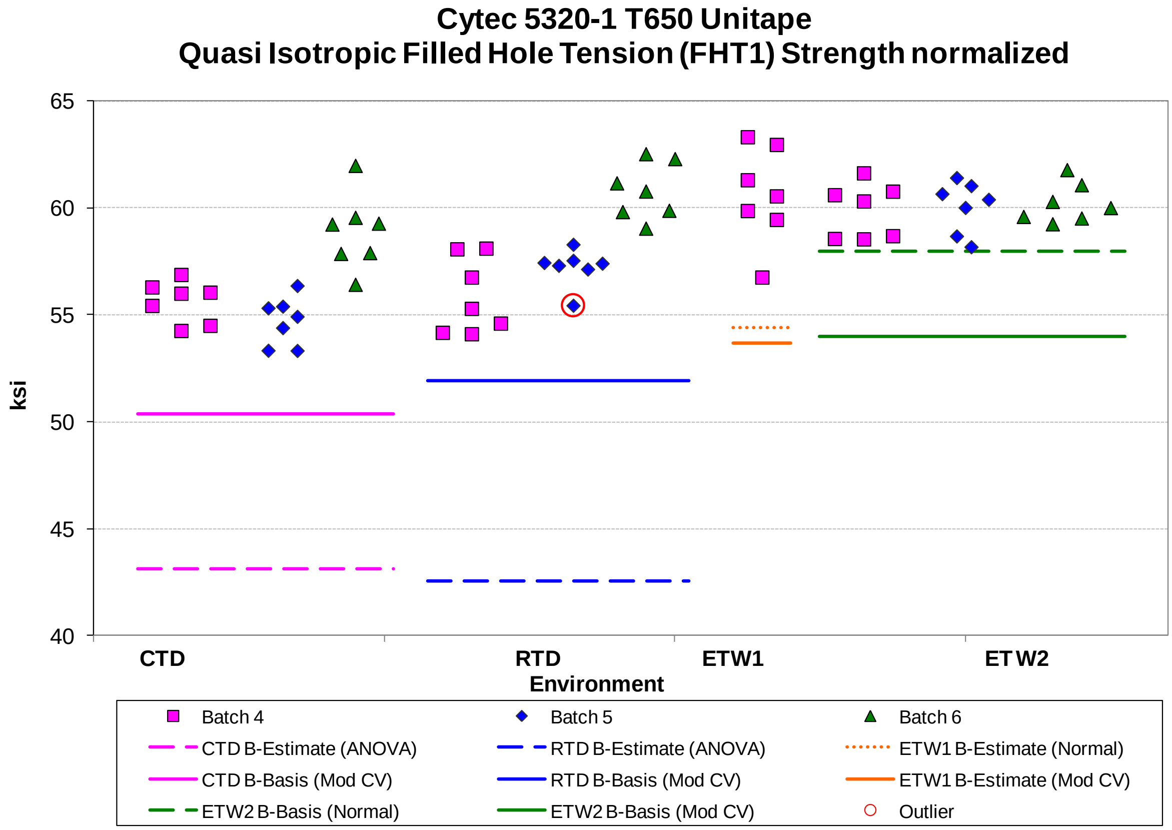

Figure 4-19: Batch plot for FHT1 strength normalized

Filled-Hole Tension (FHT1) Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETW1	ETW2	CTD	RTD	ETW1	ETW2
Mean	56.416	57.962	60.602	60.048	56.125	57.744	60.648	59.695
Stdev	2.220	2.484	2.238	1.087	2.376	2.345	2.010	1.209
CV	3.936	4.286	3.692	1.811	4.234	4.062	3.314	2.026
Modified CV	6.000	6.143	6.000	6.000	6.117	6.031	6.000	6.000
Min	53.328	54.109	56.759	58.177	52.580	53.895	56.942	57.298
Max	61.980	62.525	63.316	61.781	61.089	62.265	63.030	61.652
No. Batches	3	3	1	3	3	3	1	3
No. Spec.	21	21	7	21	21	21	7	21
Basis Values and Estimates								
B-basis Value				57.976				57.391
B-estimate	43.142	42.540	54.389		41.868	42.837	55.067	
A-estimate	33.666	31.530	50.018	56.499	31.689	32.195	51.141	55.748
Method	ANOVA	ANOVA	Normal	Normal	ANOVA	ANOVA	Normal	Normal
Modified CV Basis Values and Estimates								
B-basis Value	50.344	51.890		53.976	50.080	51.699		53.650
B-estimate			53.652				53.730	
A-estimate	46.257	47.804	49.670	49.889	46.012	47.631	49.765	49.582
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-30: Statistics and Basis Values for FHT1 Strength data

4.19 “10/80/10” Filled-Hole Tension 2 (FHT2)

The FHT2 data is normalized. The normalized and as-measured CTD datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across all environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. The RTD and ETW2 datasets could not be pooled together (normalized and as-measured) due to a failure of Levene's test for equality of variance.

When the datasets were transformed according to the assumptions of the modified CV method, they all passed the ADK test, so modified CV basis values are provided for those datasets. All three conditions could be pooled to compute the modified CV basis values.

There were no outliers. Statistics and basis values are given for FHT2 strength data in Table 4-31. The normalized data and the B-basis values are shown graphically in Figure 4-20.

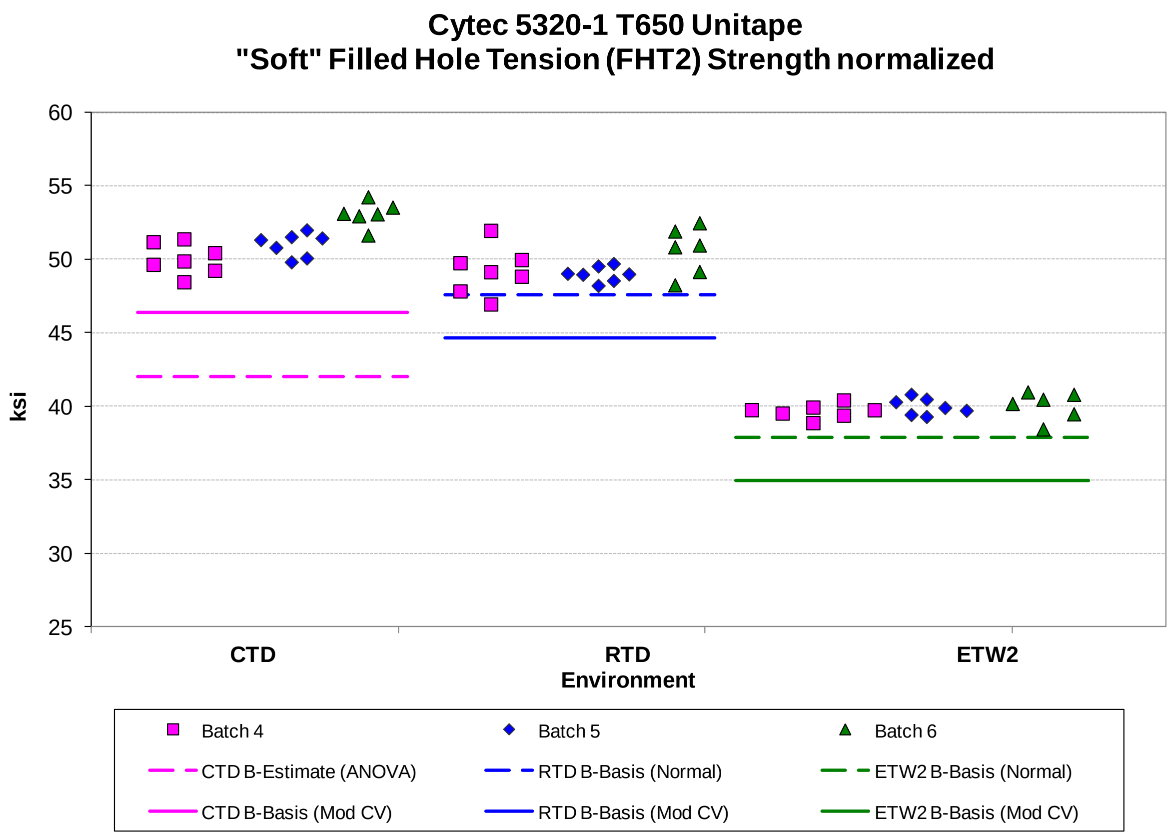

Figure 4-20: Batch plot for FHT2 strength normalized

Filled-Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	51.295	49.558	39.898	51.297	49.549	39.805
Stdev	1.545	1.447	0.663	1.527	1.425	0.700
CV	3.011	2.919	1.661	2.977	2.875	1.759
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	48.468	46.954	38.453	48.387	46.531	38.135
Max	54.251	52.481	40.970	53.727	52.400	41.201
No. Batches	3	3	3	3	3	3
No. Spec.	20	20	20	20	20	20
Basis Values and Estimates						
B-basis Value		46.772	38.622		46.805	38.457
B-estimate	42.020			42.464		
A-estimate	35.399	44.790	37.713	36.159	44.853	37.497
Method	ANOVA	Normal	Normal	ANOVA	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis Value	46.363	44.626	34.966	46.368	44.620	34.876
A-estimate	43.046	41.309	31.649	43.053	41.305	31.561
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-31: Statistics and Basis Values for FHT2 Strength data

4.20 "50/40/10" Filled-Hole Tension 3 (FHT3)

The FHT3 data is normalized. The CTD and RTD datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across all environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate When the datasets were transformed according to the assumptions of the modified CV method, the normalized RTD and both the CTD and RTD as-measured datasets passed the ADK test, so modified CV basis values are provided for those datasets. The normalized RTD and ETW2 conditions and all three conditions for the as-measured datasets could be pooled to compute the modified CV basis values.

The normalized CTD dataset did not pass the ADK test after the modified CV transformation of the data so the modified CV basis values for the normalized CTD dataset are considered estimates.

There was one outlier. The highest value in batch six of the as-measured ETW2 condition was an outlier for batch six only, not the ETW2 condition. It was an outlier only for the as-measured dataset, not for the normalized dataset. It was retained for this analysis.

Statistics, estimates and basis values are given for FHT3 strength data in Table 4-32. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-21.

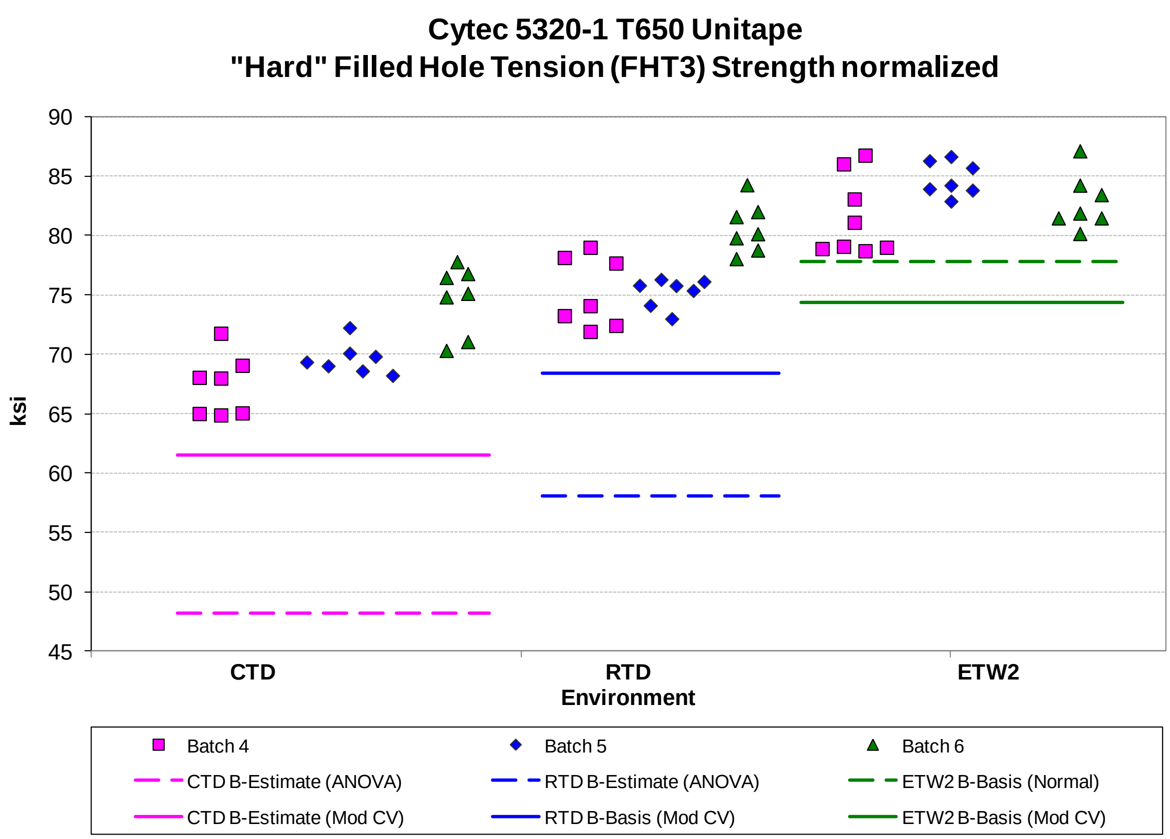

Figure 4-21: Batch plot for FHT3 strength normalized

Filled-Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	70.552	77.031	83.001	70.159	76.861	82.528
Stdev	3.821	3.371	2.765	3.558	3.033	2.702
CV	5.417	4.376	3.331	5.071	3.946	3.274
Modified CV	6.708	6.188	6.000	6.536	6.000	6.000
Min	64.889	71.921	78.716	64.801	72.547	78.292
Max	77.795	84.274	87.128	76.406	83.552	87.230
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	22	21	21	22
Basis Values and Estimates						
B-basis Value			77.787			77.432
B-estimate	48.170	58.077		50.612	60.657	
A-estimate	32.191	44.547	74.063	36.658	49.090	73.792
Method	ANOVA	ANOVA	Normal	ANOVA	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value		68.396	74.401	61.997	68.700	74.401
B-estimate	61.533					
A-estimate	55.109	62.468	68.465	56.491	63.194	68.889
Method	Normal	pooled	pooled	pooled	pooled	pooled

Table 4-32: Statistics and Basis Values for FHT3 Strength data

4.21 "25/50/25" Open-Hole Compression 1 (OHC1)

The OHC1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. There were no test failures or outliers. Pooling across environments was acceptable.

Statistics, estimates and basis values are given for OHC1 strength data in Table 4-33. The normalized data and the B-basis values are shown graphically in Figure 4-22.

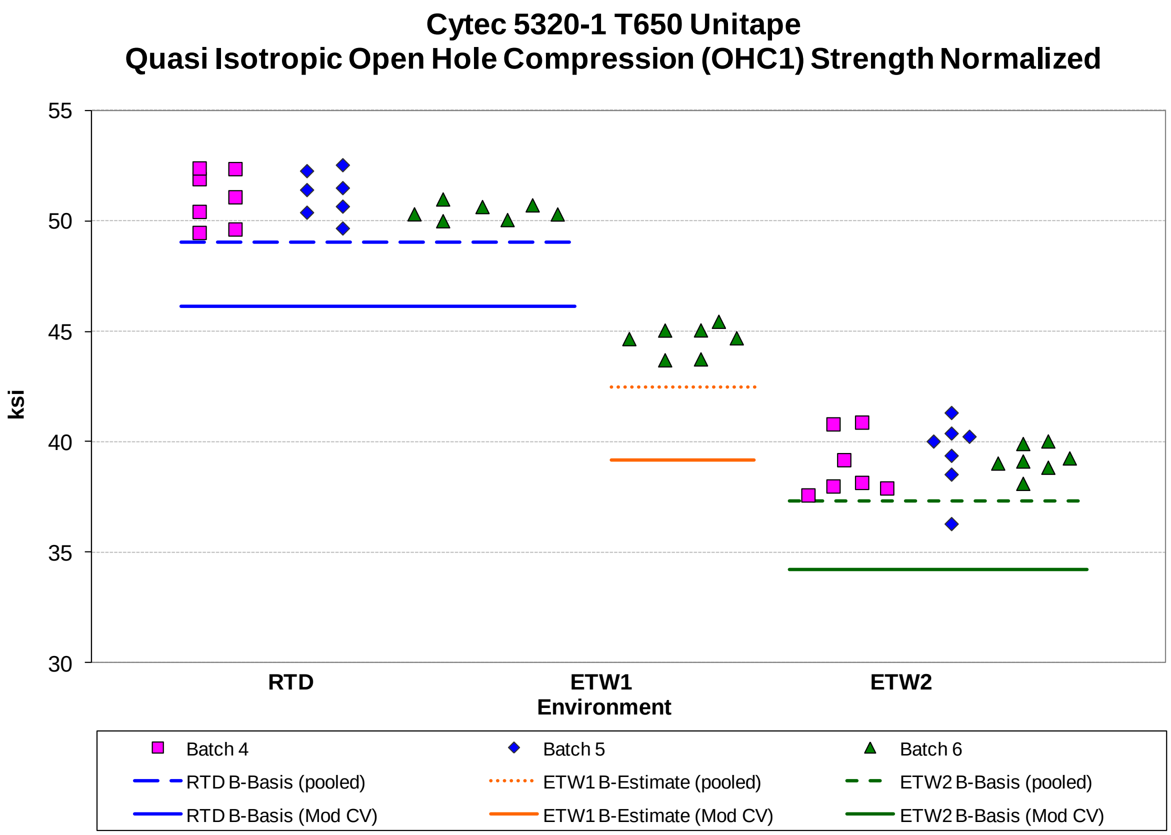

Figure 4-22: Batch plot for OHC1 strength normalized

Open Hole Compression (OHC1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	RTD	ETW1	ETW2	RTD	ETW1	ETW2
Mean	50.894	44.630	39.199	50.684	44.446	39.002
Stdev	0.964	0.667	1.253	0.937	0.630	1.166
CV	1.894	1.495	3.196	1.850	1.418	2.989
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	49.474	43.711	36.300	49.213	43.468	36.542
Max	52.538	45.454	41.327	52.207	45.159	41.000
No. Batches	3	1	3	3	1	3
No. Spec.	21	7	21	21	7	21
Basis Values and Estimates						
B-basis Value	49.015		37.320	48.906		37.224
B-estimate		42.491			42.421	
A-estimate	47.732	41.247	36.037	47.691	41.244	36.009
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	46.119		34.424	45.930		34.248
B-estimate		39.193			39.032	
A-estimate	42.856	36.030	31.161	42.681	35.883	31.000
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-33: Statistics and Basis Values for OHC1 Strength data

4.22 "10/80/10" Open-Hole Compression 2 (OHC2)

The OHC2 data is normalized. The RTD and ETW2 datasets, both normalized and as-measured, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the datasets were transformed according to the assumptions of the modified CV method, they all passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable to compute the modified CV basis values.

There were no outliers. Statistics, estimates and basis values are given for OHC2 strength data in Table 4-34. The normalized data and the B-basis values are shown graphically in Figure 4-23.

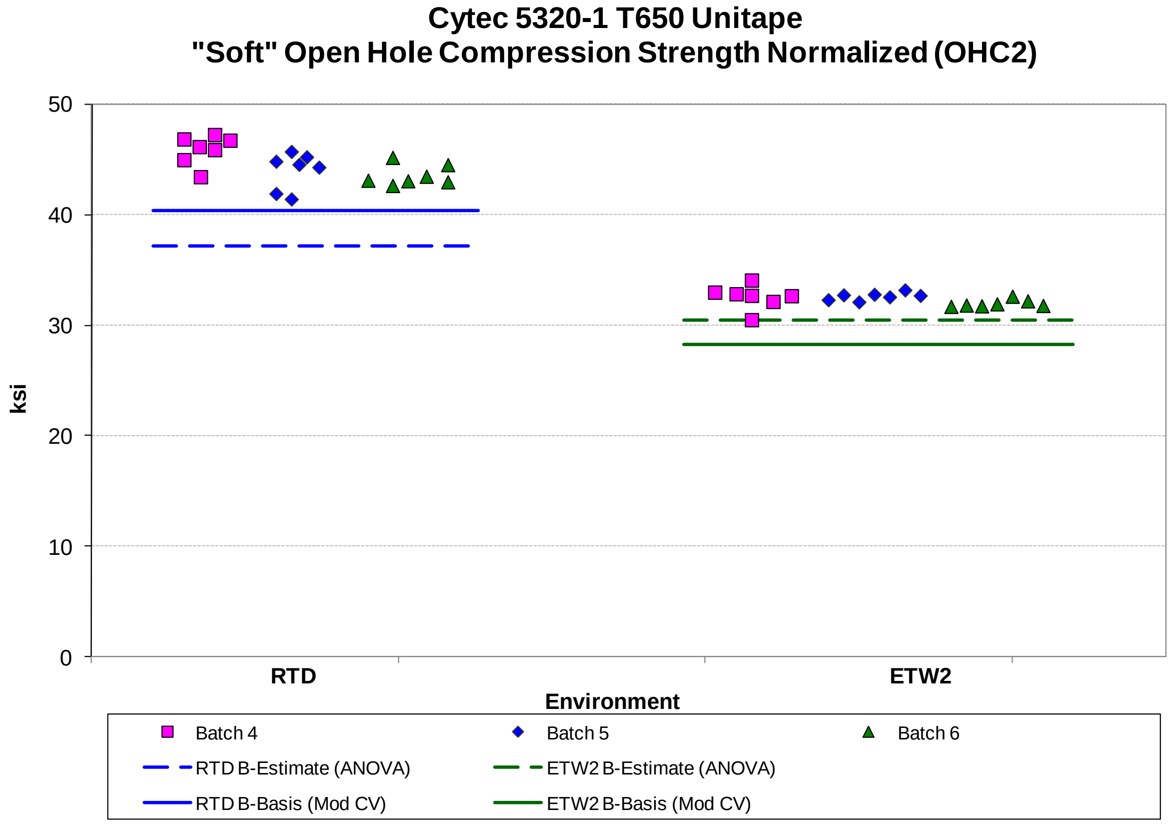

Figure 4-23: Batch plot for OHC2 strength normalized

Open-Hole Compression (OHC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	44.484	32.389	44.400	32.252
Stdev	1.638	0.715	1.648	0.648
CV	3.682	2.208	3.711	2.011
Modified CV	6.000	6.000	6.000	6.000
Min	41.415	30.500	41.462	30.908
Max	47.243	34.082	47.214	33.833
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-Estimate	37.204	30.427	36.880	29.981
A-estimate	32.008	29.026	31.512	28.361
Method	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	40.343	28.248	40.270	28.122
A-estimate	37.497	25.402	37.432	25.284
Method	pooled	pooled	pooled	pooled

Table 4-34: Statistics and Basis Values for OHC2 Strength data

4.23 "50/40/10" Open-Hole Compression 3 (OHC3)

The OHC3 data is normalized. There were no test failures or outliers. Pooling across environments was acceptable. Statistics, estimates and basis values are given for OHC3 strength data in Table 4-35. The normalized data and the B-basis values are shown graphically in Figure 4-24.

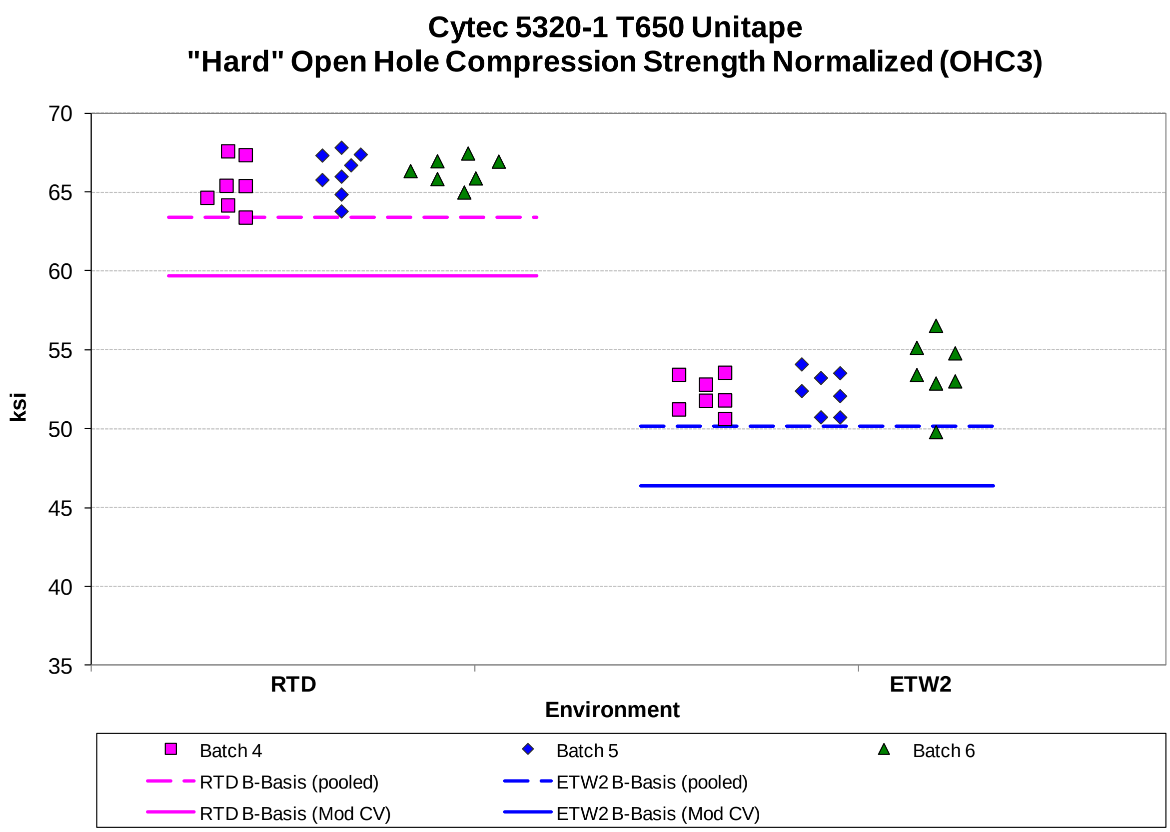

Figure 4-24: Batch plot for OHC3 strength normalized

Open-Hole Compression (OHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	66.016	52.759	65.929	52.603
Stdev	1.308	1.652	1.350	1.460
CV	1.982	3.131	2.047	2.776
Modified CV	6.000	6.000	6.000	6.000
Min	63.411	49.810	63.450	49.202
Max	67.837	56.555	68.737	55.537
No. Batches	3	3	3	3
No. Spec.	22	21	22	21
Basis Values and Estimates				
B-basis Value	63.396	50.128	63.452	50.115
A-estimate	61.587	48.322	61.743	48.408
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	59.676	46.394	59.602	46.250
A-estimate	55.301	42.024	55.235	41.889
Method	pooled	pooled	pooled	pooled

Table 4-35: Statistics and Basis Values for OHC3 Strength data

4.24 "25/50/25" Filled-Hole Compression 1 (FHC1)

The FHC1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. There were no test failures for the normalized datasets. The as-measured RTD dataset failed the normality test, but the pooled dataset passed normality, so pooling across environments was acceptable for both the normalized and the as-measured datasets.

There was one outlier. The lowest value in batch six of the RTD condition was an outlier for the RTD condition but not for batch six. It was an outlier for both the normalized and the as-measured datasets. It was retained for this analysis.

Statistics, estimates and basis values are given for FHC1 strength data in Table 4-36. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-25.

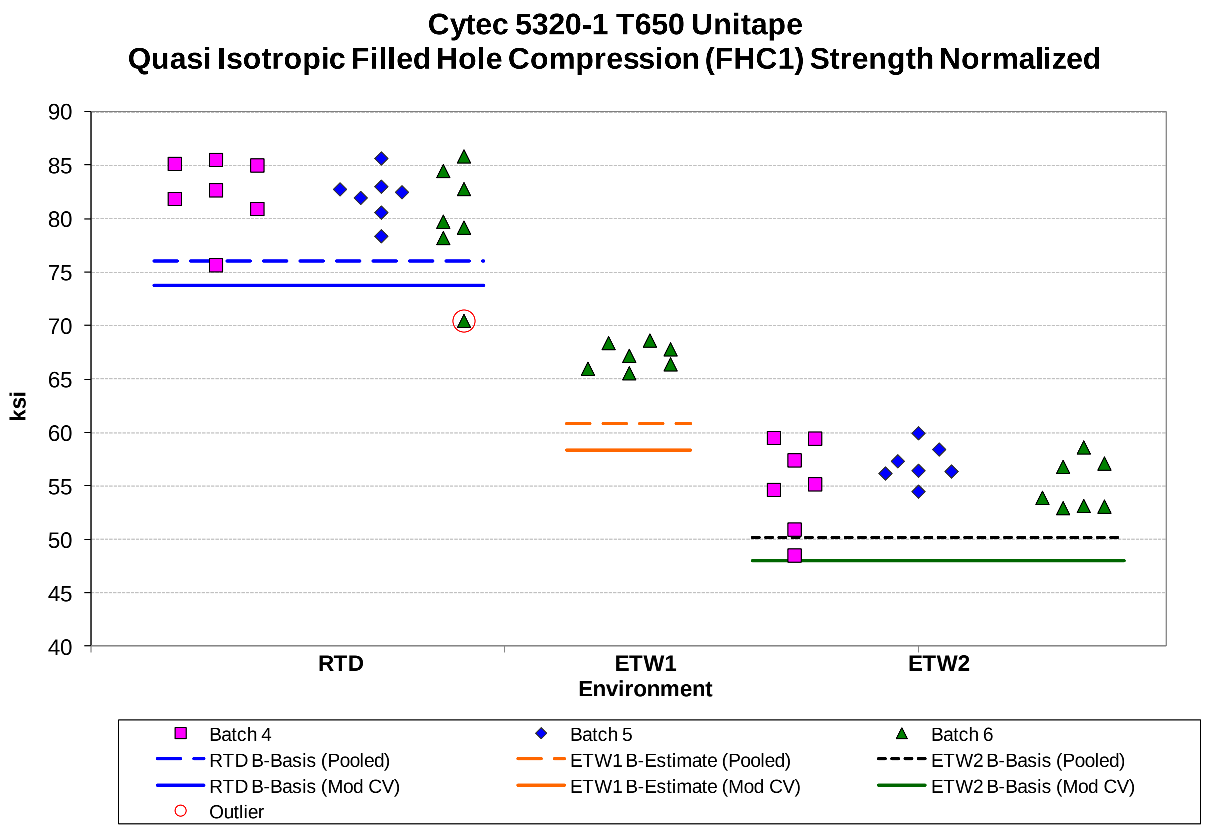

Figure 4-25: Batch plot for FHC1 strength normalized

Filled-Hole Compression (FHC1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	RTD	ETW1	ETW2	RTD	ETW1	ETW2
Mean	81.560	67.154	55.757	81.291	66.868	55.575
Stdev	3.751	1.195	2.948	3.719	1.097	3.003
CV	4.599	1.779	5.287	4.576	1.641	5.403
Modified CV	6.299	6.000	6.644	6.288	6.000	6.702
Min	70.470	65.580	48.536	69.941	65.505	48.453
Max	85.868	68.646	59.972	85.246	68.265	59.830
No. Batches	3	1	3	3	1	3
No. Spec.	21	7	21	21	7	21
Basis Values and Estimates						
B-basis Value	75.985		50.182	75.713		49.997
B-estimate		60.805			60.515	
A-estimate	72.175	57.112	46.372	71.901	56.819	46.185
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	73.794		47.991	73.539		47.823
B-estimate		58.310			58.039	
A-estimate	68.487	53.166	42.685	68.242	52.904	42.526
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-36: Statistics and Basis Values for FHC1 Strength data

4.25 “10/80/10” Filled-Hole Compression 2 (FHC2)

The FHC2 data is normalized. There were no test failures for the normalized datasets so pooling the two environmental conditions was acceptable. The as-measured RTD dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the as-measured RTD dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for the as-measured data when computing the modified CV basis values.

There was one outlier. The highest value in batch six of the ETW2 condition was an outlier for batch six but not for the ETW2 condition. It was an outlier only for the as-measured dataset, not for the normalized dataset. It was retained for this analysis.

Statistics, estimates and basis values are given for FHC2 strength data in Table 4-37. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-26.

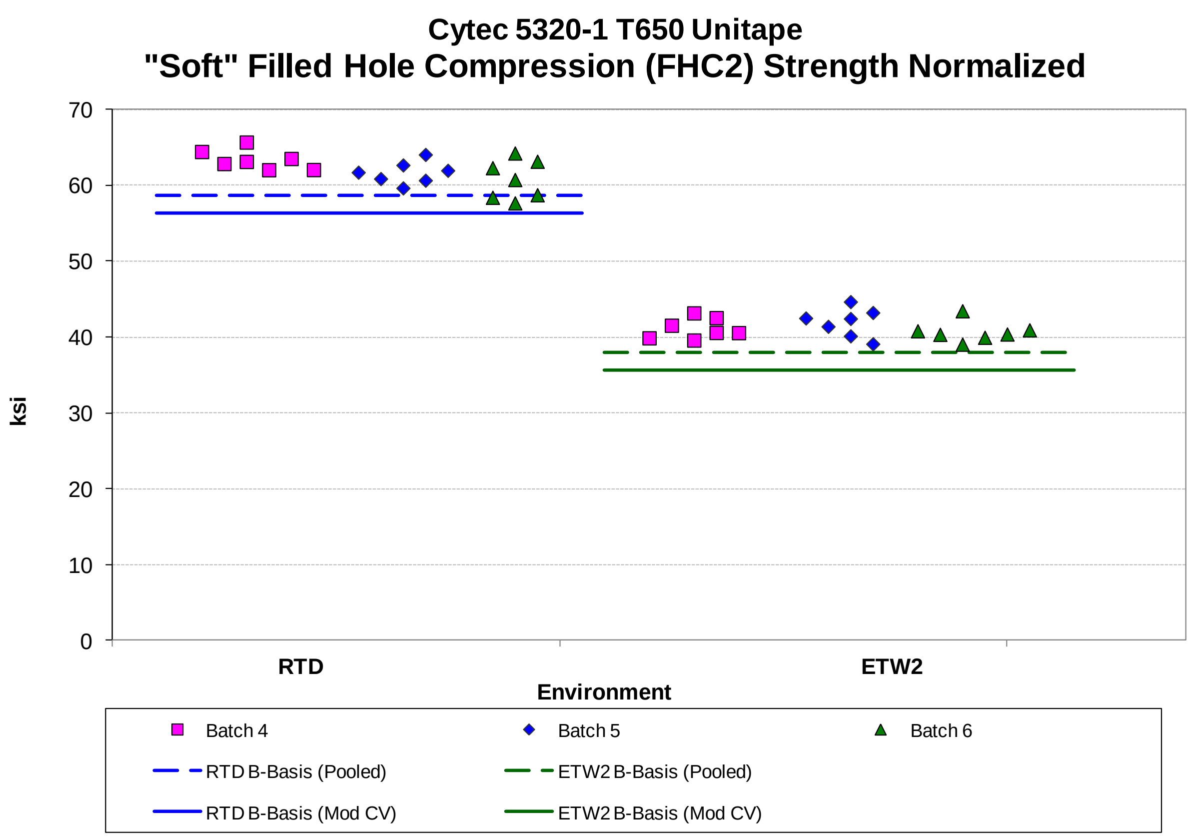

Figure 4-26: Batch plot for FHC2 strength normalized

Filled-Hole Compression (FHC2) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	61.954	41.262	61.727	41.030
Stdev	2.092	1.558	2.070	1.527
CV	3.376	3.777	3.354	3.723
Modified CV	6.000	6.000	6.000	6.000
Min	57.690	39.055	57.455	38.669
Max	65.707	44.671	65.454	44.146
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	58.682	37.991		38.120
B-estimate			52.938	
A-estimate	56.434	35.742	46.664	36.046
Method	pooled	pooled	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	56.352	35.660	56.150	35.452
A-estimate	52.502	31.810	52.316	31.619
Method	pooled	pooled	pooled	pooled

Table 4-37: Statistics and Basis Values for FHC2 Strength data

4.26 "50/40/10" Filled-Hole Compression 3 (FHC3)

The FHC3 data is normalized. There were no test failures for the normalized datasets so pooling the two environmental conditions was acceptable. The as-measured ETW2 dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the as-measured ETW2 dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided. Pooling was acceptable for the as-measured data when computing the modified CV basis values.

There were no outliers. Statistics, estimates and basis values are given for FHC3 strength data in Table 4-38. The normalized data and the B-basis values are shown graphically in Figure 4-27.

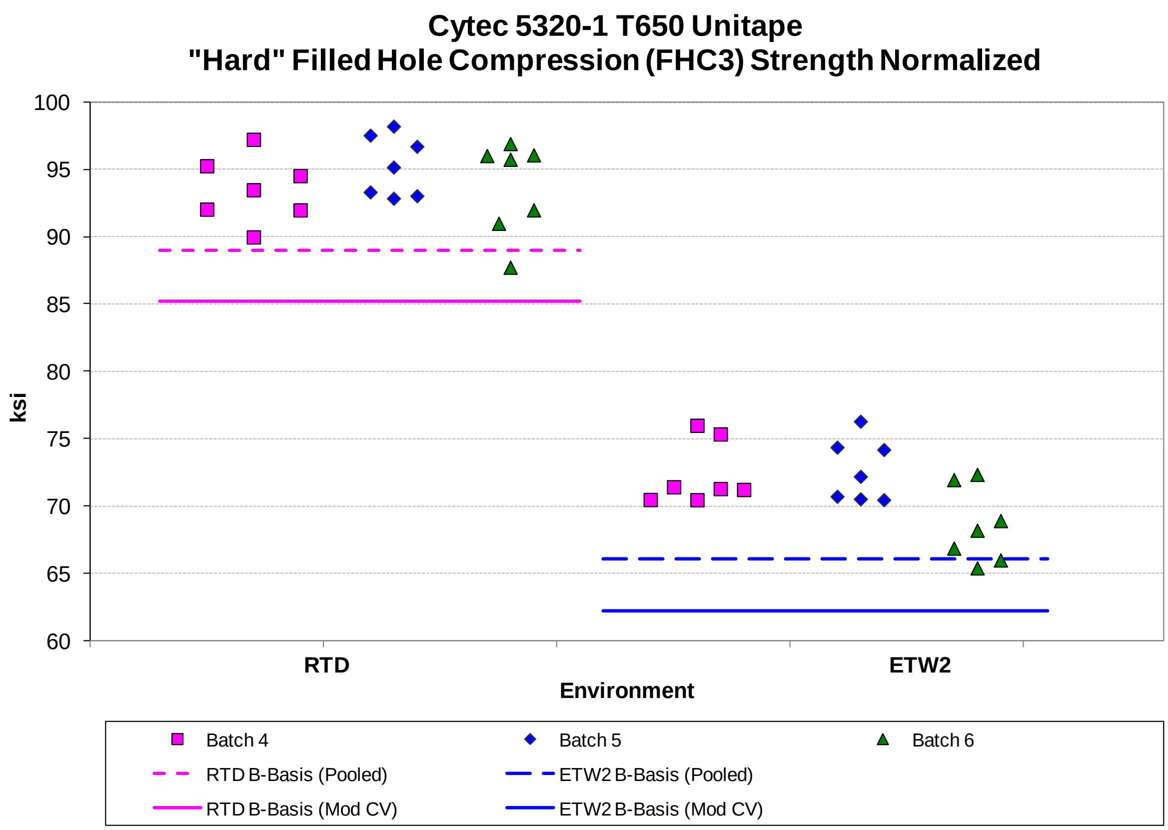

Figure 4-27: Batch plot for FHC3 strength normalized

Filled-Hole Compression (FHC3) Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	94.140	71.163	93.816	70.894
Stdev	2.742	3.036	2.705	3.412
CV	2.912	4.266	2.883	4.813
Modified CV	6.000	6.133	6.000	6.406
Min	87.732	65.385	86.804	64.694
Max	98.210	76.286	97.715	76.410
No. Batches	3	3	3	3
No. Spec.	21	21	21	21
Basis Values and Estimates				
B-basis Value	89.010	66.032	88.663	
B-estimate				54.517
A-estimate	85.484	62.506	84.990	42.827
Method	pooled	pooled	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	85.188	62.210	84.745	61.823
A-estimate	79.035	56.057	78.510	55.588
Method	pooled	pooled	pooled	pooled

Table 4-38: Statistics and Basis Values for FHC3 Strength data

4.27 "25/50/25" Single-Shear Bearing 1 (SSB1)

The SSB1 data is normalized. The ETW1 dataset lacked sufficient specimens to meet CMH-17 guidelines, so only estimates are provided for that condition. The ETW2 datasets, both normalized and as-measured, for initial peak strength failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the ETW2 datasets were transformed according to the assumptions of the modified CV method, both normalized and as measured passed the ADK test, so the modified CV basis values are provided.

There were no other diagnostic test failures and no statistical outliers.

Statistics, estimates and basis values are given for the 2% offset strength data in Table 4-39, for the initial peak strength in Table 4-40, and for ultimate strength in Table 4-41. The normalized data and the B-basis values are shown graphically in for the 2% offset strength data in Figure 4-28, for the initial peak strength in Figure 4-29, and for ultimate strength in Figure 4-30 .

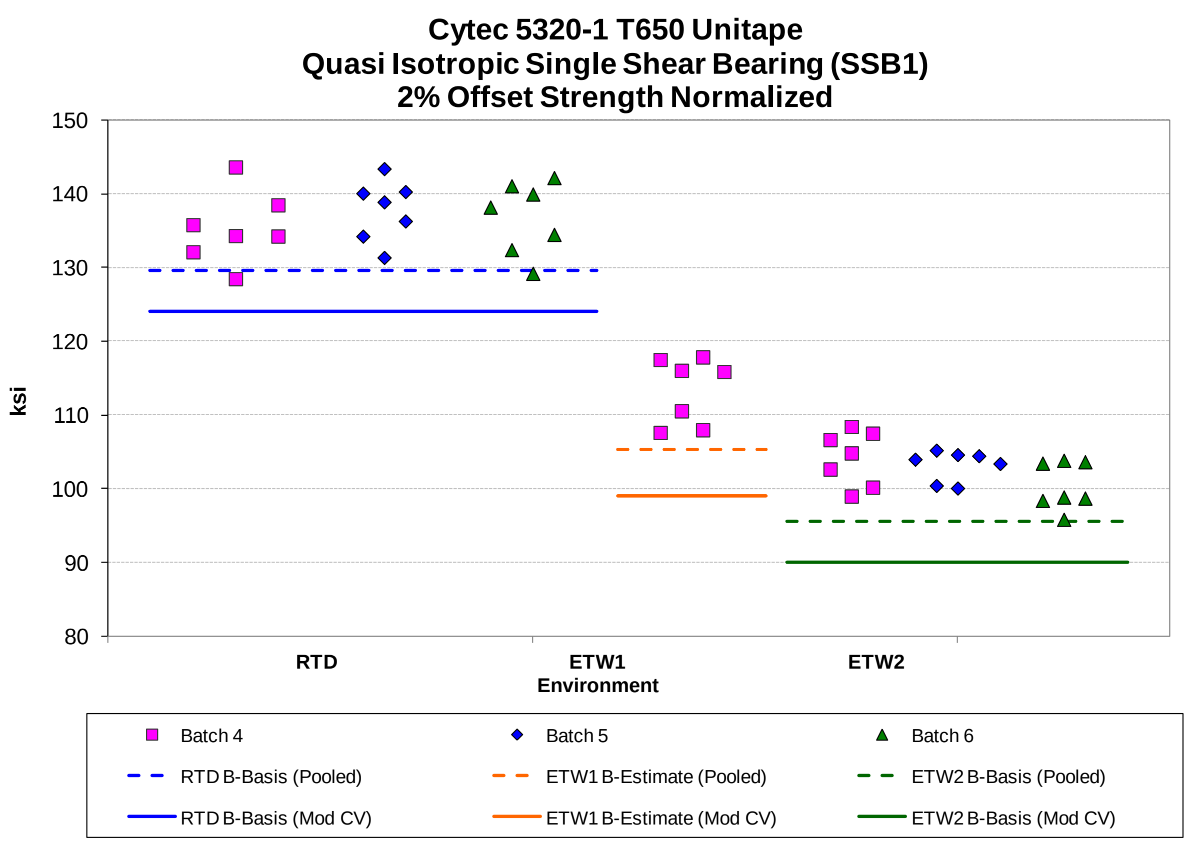

Figure 4-28: Batch plot for SSB1 2% offset strength normalized

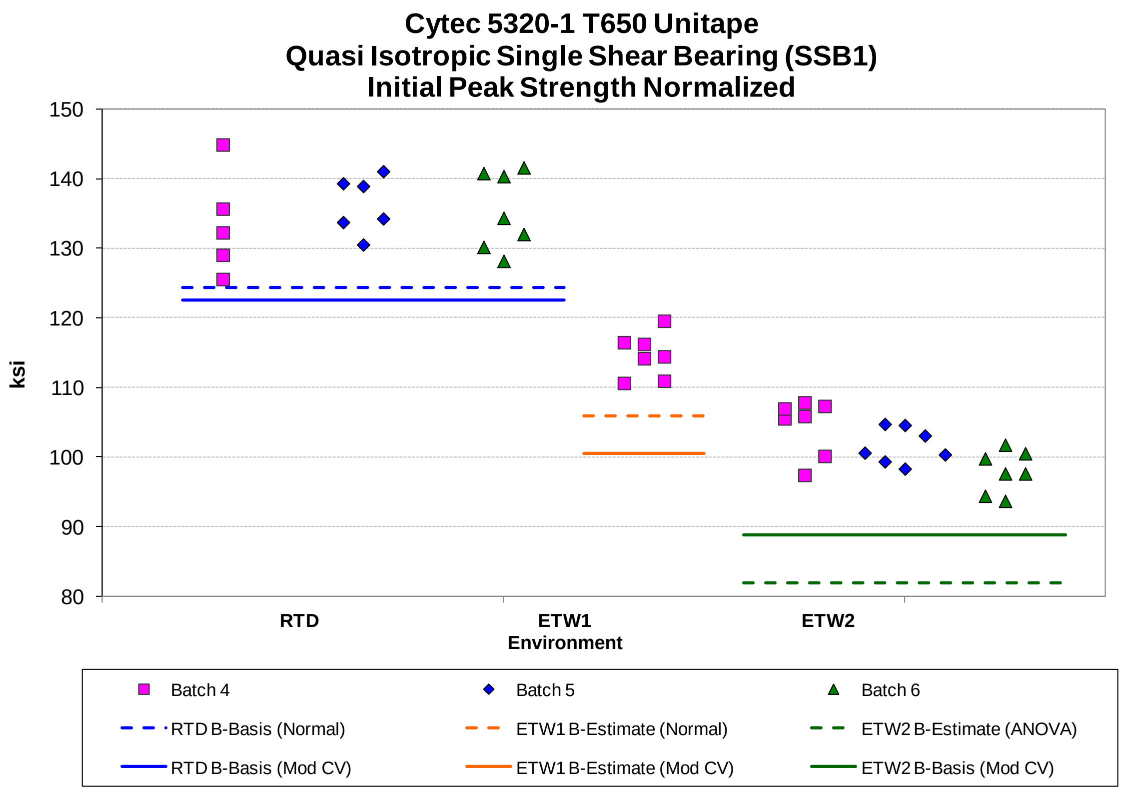

Figure 4-29: Batch plot for SSB1 initial peak strength normalized

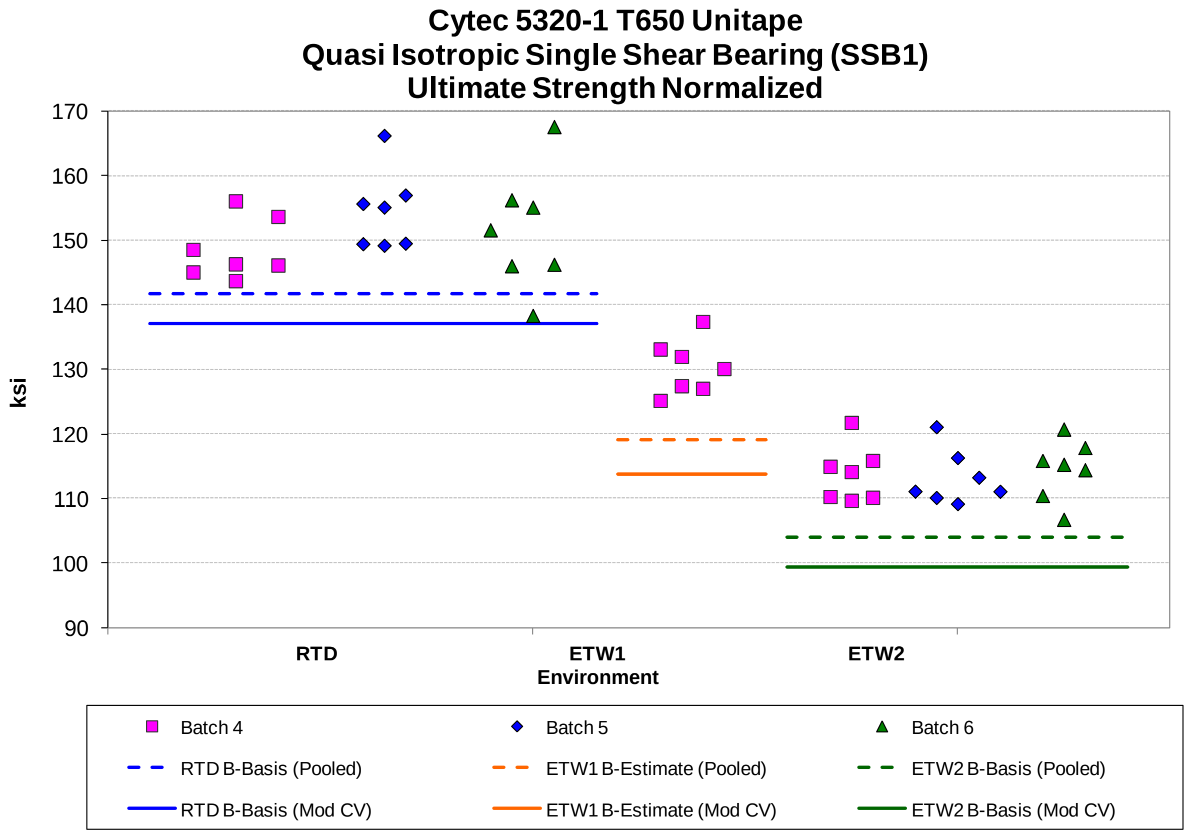

Figure 4-30: Batch plot for SSB1 ultimate strength normalized

Single Shear Bearing (SSB1) 2% Offset Strength Basis Values and						
	Normalized			As-measured		
Env	RTD	ETW1	ETW2	RTD	ETW1	ETW2
Mean	136.627	113.335	102.565	139.642	114.664	102.719
Stdev	4.488	4.487	3.332	3.555	4.501	3.625
CV	3.285	3.959	3.249	2.546	3.926	3.529
Modified CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	128.464	107.615	95.820	133.145	108.992	94.993
Max	143.628	117.850	108.411	148.320	119.757	108.931
No. Batches	3	1	3	3	1	3
No. Spec.	21	7	21	21	7	21
Basis Values and Estimates						
B-basis Value	129.556		95.495	133.106		96.184
B-estimate		105.283			107.221	
A-estimate	124.725	100.600	90.664	128.641	102.892	91.719
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	123.999		89.937	126.832		89.910
B-estimate		98.954			100.077	
A-estimate	115.370	90.590	81.309	118.080	91.592	81.158
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-39: Statistics and Basis Values for SSB1 2% Offset Strength data

Single Shear Bearing (SSB1) Initial Peak Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	RTD	ETW1	ETW2	RTD	ETW2	RTD
Mean	135.155	114.633	101.299	138.099	115.963	101.461
Stdev	5.466	3.166	4.135	4.824	2.462	4.642
CV	4.044	2.762	4.082	3.493	2.123	4.575
Modified CV	6.022	6.000	6.041	6.000	6.000	6.287
Min	125.560	110.624	93.673	130.606	113.079	93.585
Max	144.899	119.555	107.830	149.632	119.851	110.949
No. Batches	3	1	3	3	1	3
No. Spec.	18	7	21	18	7	21
Basis Values and Estimates						
B-basis Value	124.363			128.575		
B-estimate		105.842	81.955		109.128	78.736
A-estimate	116.716	99.657	68.147	121.827	104.319	62.515
Method	Normal	Normal	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	122.477		88.800	125.095		88.640
B-estimate		100.414			101.378	
A-estimate	113.948	92.117	80.232	116.346	92.867	79.852
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-40: Statistics and Basis Values for SSB1 Initial Peak Strength data

Single Shear Bearing (SSB1) Ultimate Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	RTD	ETW1	ETW2	RTD	ETW1	ETW2
Mean	151.576	130.335	113.840	154.903	131.854	114.010
Stdev	7.098	4.207	4.202	6.028	3.868	4.479
CV	4.683	3.228	3.692	3.892	2.934	3.929
Modified CV	6.341	6.000	6.000	6.000	6.000	6.000
Min	138.343	125.191	106.765	145.247	128.078	107.451
Max	167.597	137.403	121.781	168.234	139.116	122.547
No. Batches	3	1	3	3	1	3
No. Spec.	21	7	21	21	7	21
Basis Values and Estimates						
B-basis Value	141.659		103.923	145.868		104.975
B-estimate		119.041			121.564	
A-estimate	134.883	112.473	97.147	139.694	115.579	98.801
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	137.050		99.314	140.630		99.737
B-estimate		113.792			115.600	
A-estimate	127.124	104.170	89.388	130.878	106.145	89.985
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-41: Statistics and Basis Values for SSB1 Ultimate Strength data

4.28 "10/80/10" Single-Shear Bearing 2 (SSB2)

The SSB2 data is normalized. The ETW2 datasets, both normalized and as-measured, for ultimate strength failed the normality test, but the pooled dataset was acceptable so pooling was used to compute basis values for ultimate strength.

The ETW2 datasets, both normalized and as-measured, for 2% offset strength failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate. When the ETW2 datasets were transformed according to the assumptions of the modified CV method, both normalized and as measured passed the ADK test. The as-measured RTD 2% offset strength dataset did not pass normality. The Weibull distribution was used to compute basis values for that dataset. The pooled dataset passed the normality test so pooling was used to compute the modified CV basis values.

There were three outliers. The lowest value in batch four of the RTD dataset for ultimate strength was an outlier for batch four (as-measured and normalized datasets) and the RTD condition (normalized dataset). The highest value in batch four of the ETW2 dataset for ultimate strength was an outlier for ETW2 condition, but not for the batch four. It was an outlier for both as-measured and normalized datasets. The lowest value in batch five of the 2% offset strength RTD dataset was an outlier for the RTD condition but not for batch five. It was an outlier only for the as-measured dataset. All three outliers were retained for this analysis.

Statistics, estimates and basis values are given for the strength data in Table 4-42. The normalized data and the B-basis values are shown graphically in for the 2% offset strength data in Figure 4-31 and for ultimate strength in Figure 4-32.

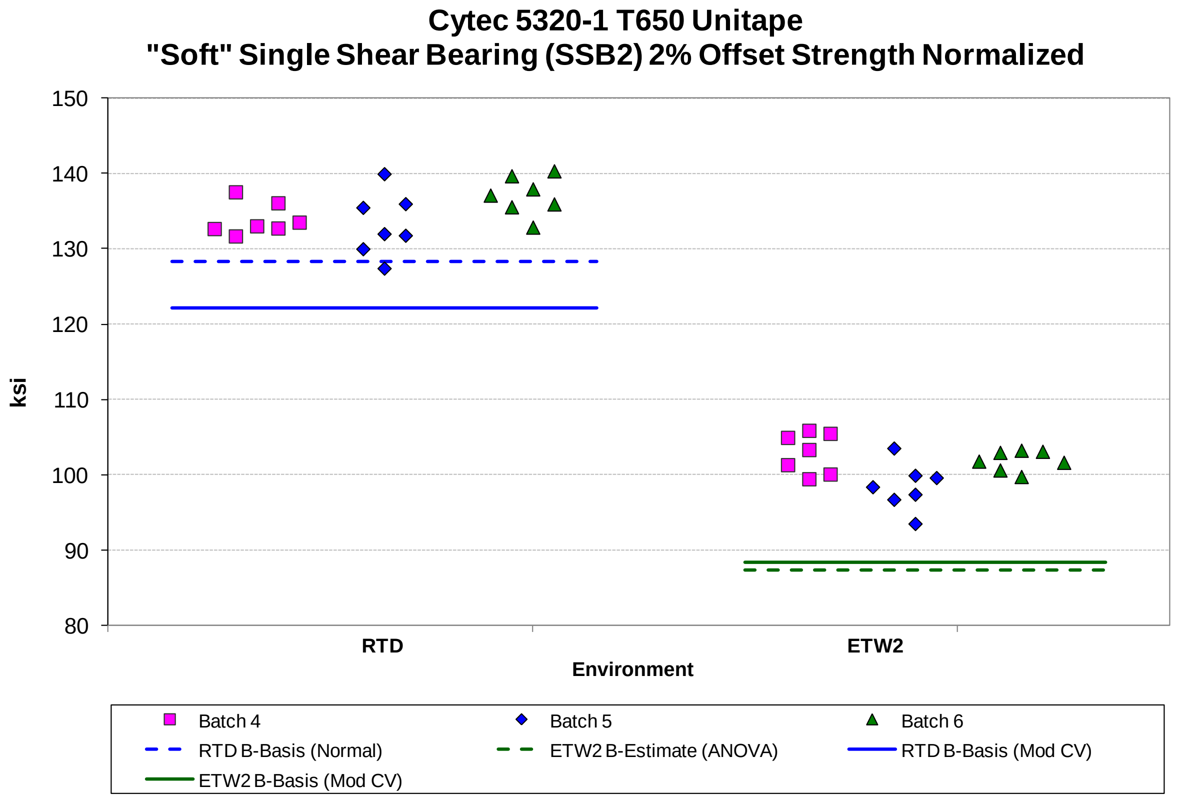

Figure 4-31: Batch plot for SSB2 2% offset strength normalized

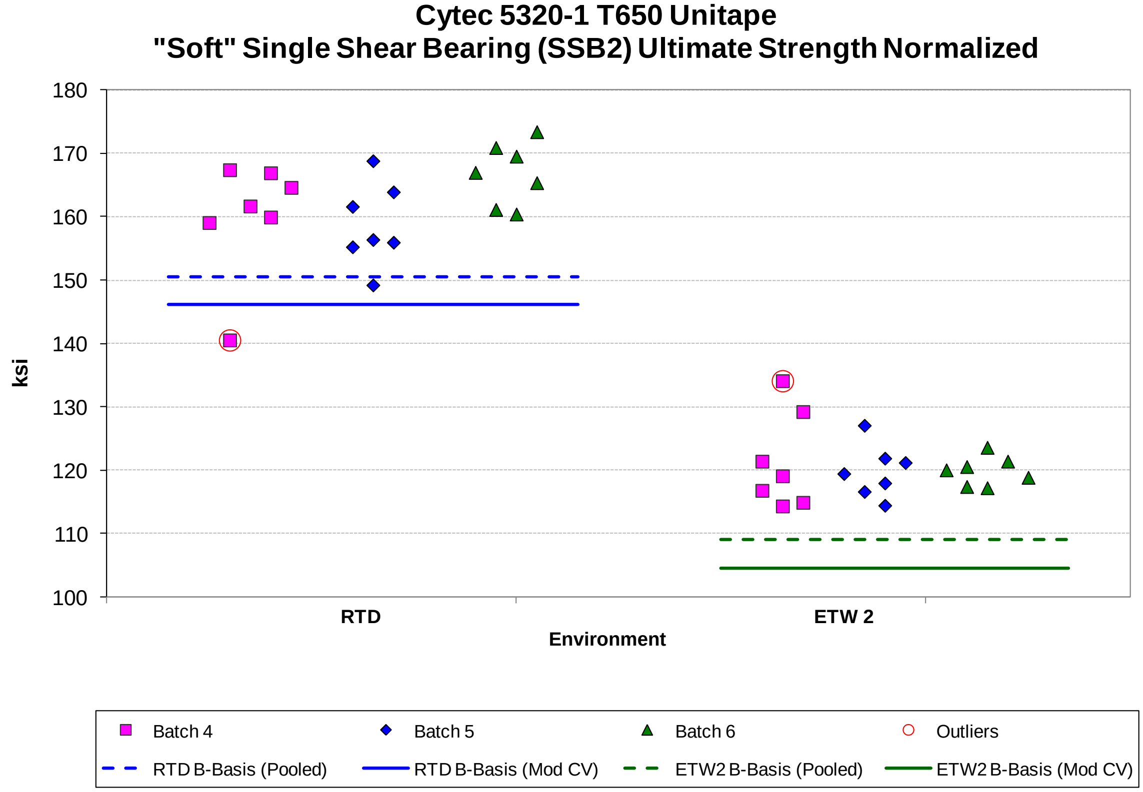

Figure 4-32: Batch plot for SSB2 ultimate strength normalized

Single Shear Bearing (SSB2) Strength Basis Values and Statistics								
	Normalized				As-measured			
	2% Offset		Ultimate		2% Offset		Ultimate	
Env	RTD	ETW2	RTD	ETW2	RTD	ETW2	RTD	ETW2
Mean	134.738	101.082	161.861	120.367	135.741	100.954	163.020	120.198
Stdev	3.395	3.065	7.635	4.924	4.266	3.510	7.335	4.906
CV	2.520	3.032	4.717	4.091	3.143	3.476	4.500	4.081
Modified CV	6.000	6.000	6.359	6.046	6.000	6.000	6.250	6.041
Min	127.426	93.513	140.545	114.344	123.515	93.443	145.460	114.038
Max	140.341	105.886	173.405	134.110	141.457	106.759	172.698	135.217
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	21	21	21	21	21	21
Basis Values and Estimates								
B-basis Value	128.270		150.466	108.972	127.558		151.952	109.130
B-estimate		87.269				83.235		
A-estimate	123.659	77.410	142.634	101.140	118.587	70.587	144.345	101.523
Method	Normal	ANOVA	pooled	pooled	Weibull	ANOVA	pooled	pooled
Modified CV Basis Values and Estimates								
B-basis Value	122.062	88.406	146.052	104.558	123.011	88.224	147.328	104.506
A-estimate	113.351	79.695	135.187	93.693	114.262	79.475	136.544	93.722
Method	pooled	pooled	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-42: Statistics and Basis Values for SSB2 Strength data

4.29 "50/40/10" Single-Shear Bearing 3 (SSB3)

The SSB3 data is normalized. The as-measured 2% offset strength, both RTD and ETW2 conditions, failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17 Rev G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the as-measured 2% offset strength datasets were transformed according to the assumptions of the modified CV method, both RTD and ETW2 passed the ADK test, so the modified CV basis values are provided. The as-measured data failed normality when the two conditions were pooled, so the single point method was used to compute the modified CV basis values for the 2% offset strength as-measured data.

There were no diagnostic test failures for the normalized 2% offset strength data, the initial peak strength data or the ultimate strength data, so pooling was used to compute basis values and modified CV basis values.

There were no statistical outliers. Statistics, estimates and basis values are given for the 2% offset strength data in Table 4-43, for the initial peak strength in Table 4-44, and for ultimate strength in Table 4-45. The normalized data and the B-basis values are shown graphically in for the 2% offset strength data in Figure 4-33, for the initial peak strength in Figure 4-34, and for ultimate strength in Figure 4-35.

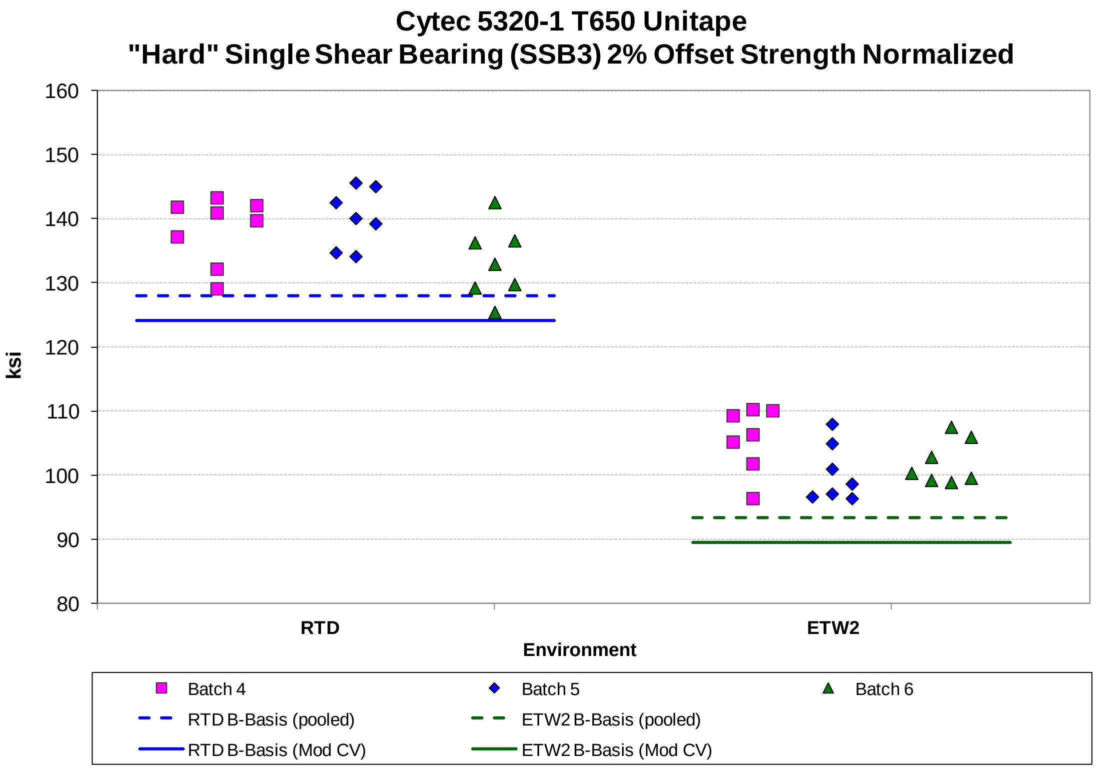

Figure 4-33: Batch plot for SSB3 2% offset strength normalized

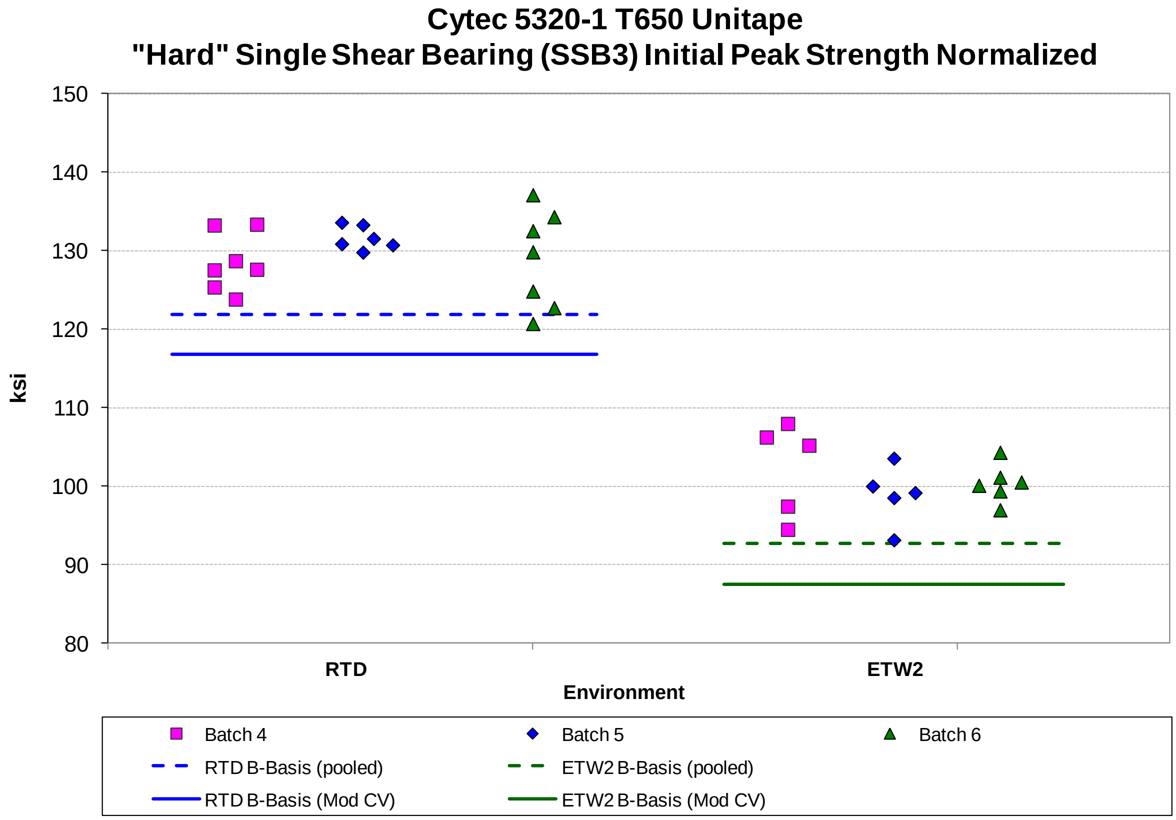

Figure 4-34: Batch plot for SSB3 Initial Peak Strength normalized

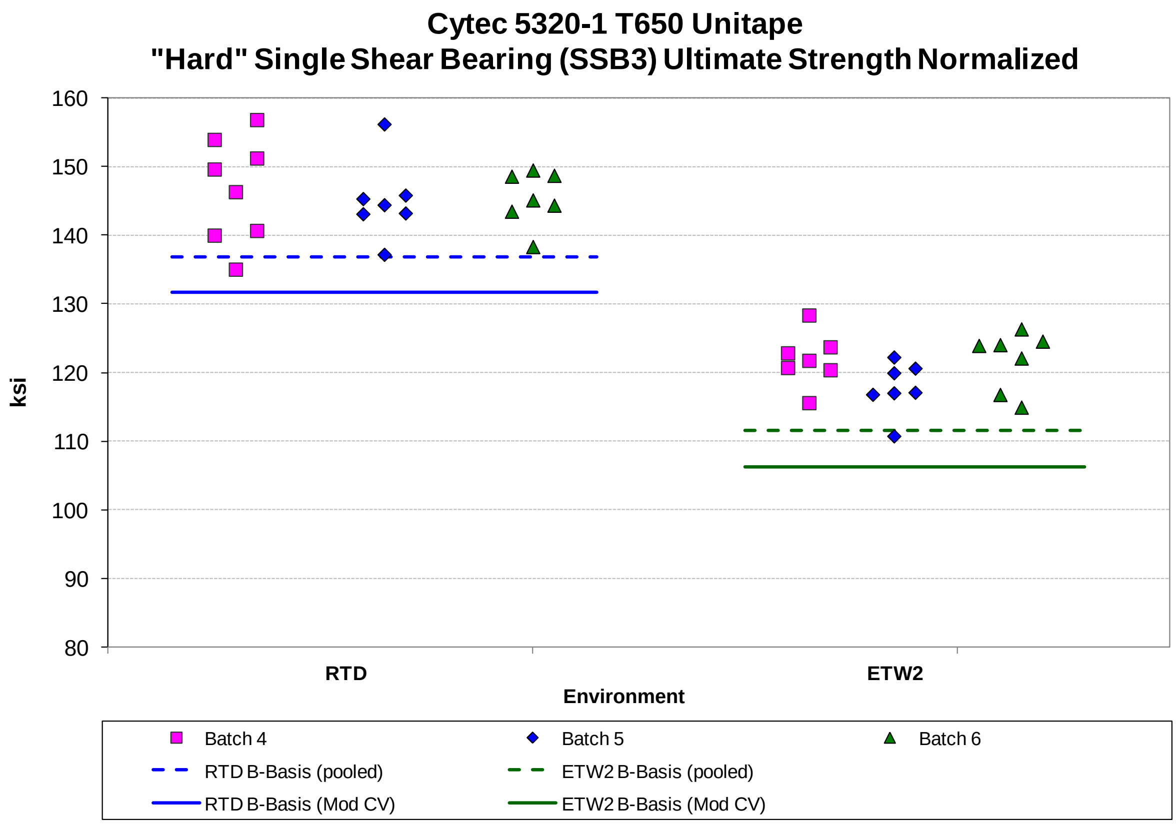

Figure 4-35: Batch plot for SSB3 Ultimate Strength normalized

Single Shear Bearing (SSB3) 2% Offset Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	137.336	102.704	138.310	102.392
Stdev	5.724	4.755	5.652	4.934
CV	4.168	4.630	4.086	4.819
Modified CV	6.084	6.315	6.043	6.409
Min	125.465	96.390	127.473	95.641
Max	145.648	110.285	147.111	110.704
No. Batches	3	3	3	3
No. Spec.	22	21	22	21
Basis Values and Estimates				
B-basis Value	128.037	93.368		
B-estimate			113.790	84.017
A-estimate	121.619	86.958	96.281	70.905
Method	pooled	pooled	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	124.107	89.422	122.541	89.886
A-estimate	114.977	80.305	111.284	80.978
Method	pooled	pooled	Normal	Normal

Table 4-43: Statistics and Basis Values for SSB3 2% Offset Strength data

Single Shear Bearing (SSB3) Initial Peak Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	129.575	100.496	130.664	100.224
Stdev	4.356	4.119	4.047	4.354
CV	3.362	4.099	3.097	4.344
Modified CV	6.000	6.049	6.000	6.172
Min	120.707	93.138	122.640	93.350
Max	137.112	107.963	137.351	108.489
No. Batches	3	3	3	3
No. Spec.	20	16	20	16
Basis Values and Estimates				
B-basis Value	121.901	92.662	123.112	92.516
A-estimate	116.614	87.411	117.910	87.350
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	116.805	87.460	117.748	87.040
A-estimate	108.008	78.723	108.851	78.204
Method	pooled	pooled	pooled	pooled

Table 4-44: Statistics and Basis Values for SSB3 Initial Peak Strength data

Single Shear Bearing (SSB3) Ultimate Strength Basis Values and Statistics				
	Normalized		As-measured	
Env	RTD	ETW2	RTD	ETW2
Mean	145.805	120.521	146.834	120.150
Stdev	5.773	4.251	5.540	4.424
CV	3.959	3.527	3.773	3.682
Modified CV	6.000	6.000	6.000	6.000
Min	135.066	110.766	137.313	109.603
Max	156.862	128.379	157.196	128.867
No. Batches	3	3	3	3
No. Spec.	22	21	22	21
Basis Values and Estimates				
B-basis Value	136.833	111.513	137.970	111.250
A-estimate	130.642	105.329	131.852	105.141
Method	pooled	pooled	pooled	pooled
Modified CV Basis Values and Estimates				
B-basis Value	131.620	106.279	132.605	105.864
A-estimate	121.830	96.502	122.785	96.057
Method	pooled	pooled	pooled	pooled

Table 4-45: Statistics and Basis Values for SSB3 Ultimate Strength data

4.30 Compression After Impact 1 (CAI1)

CAI1 data is normalized. There were no statistical outliers. Basis values are not computed for these properties. However the summary statistics are presented in Table 4-46 and the data are displayed graphically in Figure 4-36.

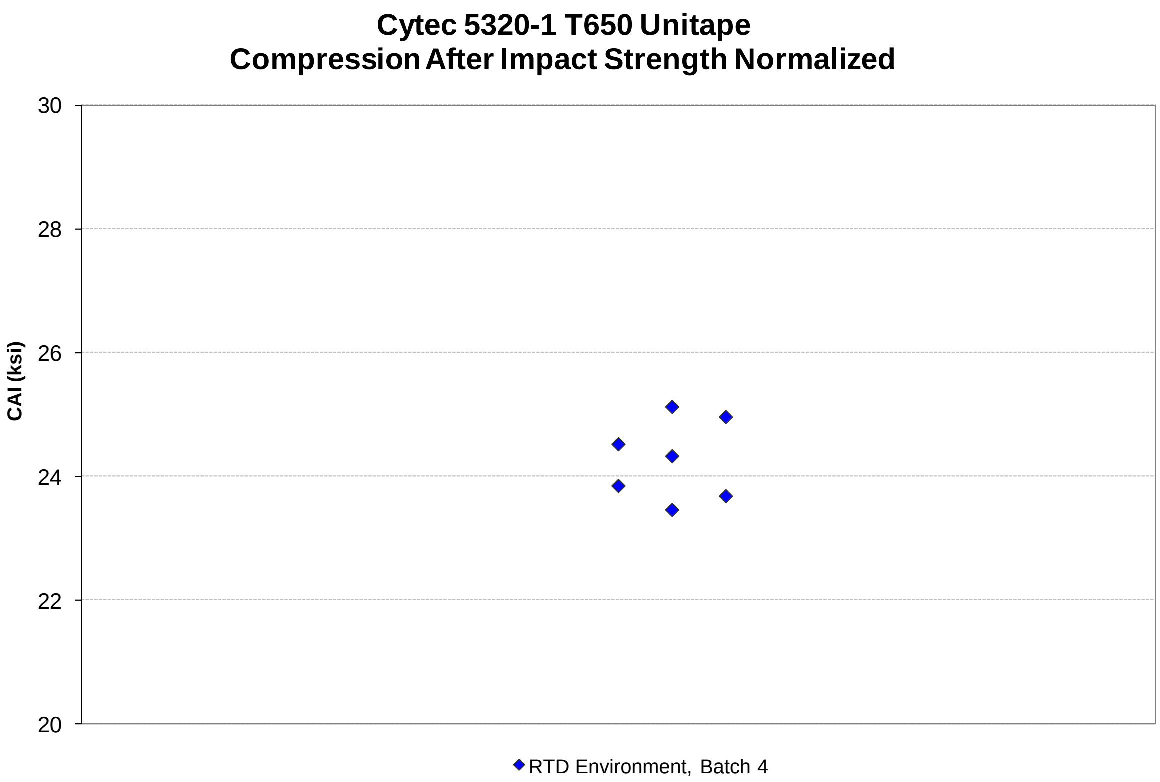

Figure 4-36: Plot for Compression After Impact strength normalized

Compression After Impact Strength (ksi)		
	Normalized	As-measured
Env	RTD	RTD
Mean	24.280	24.270
Stdev	0.639	0.576
CV	2.633	2.374
Modified CV	6.000	6.000
Min	23.466	23.549
Max	25.129	25.044
No. Batches	1	1
No. Spec.	7	7

Table 4-46: Statistics for Compression After Impact Strength data

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

The ILT and CBS data is not normalized. There were no statistical outliers. Basis values are not computed for these properties. However the summary statistics are presented in Table 4-47 and the data are displayed graphically in Figure 4-37.

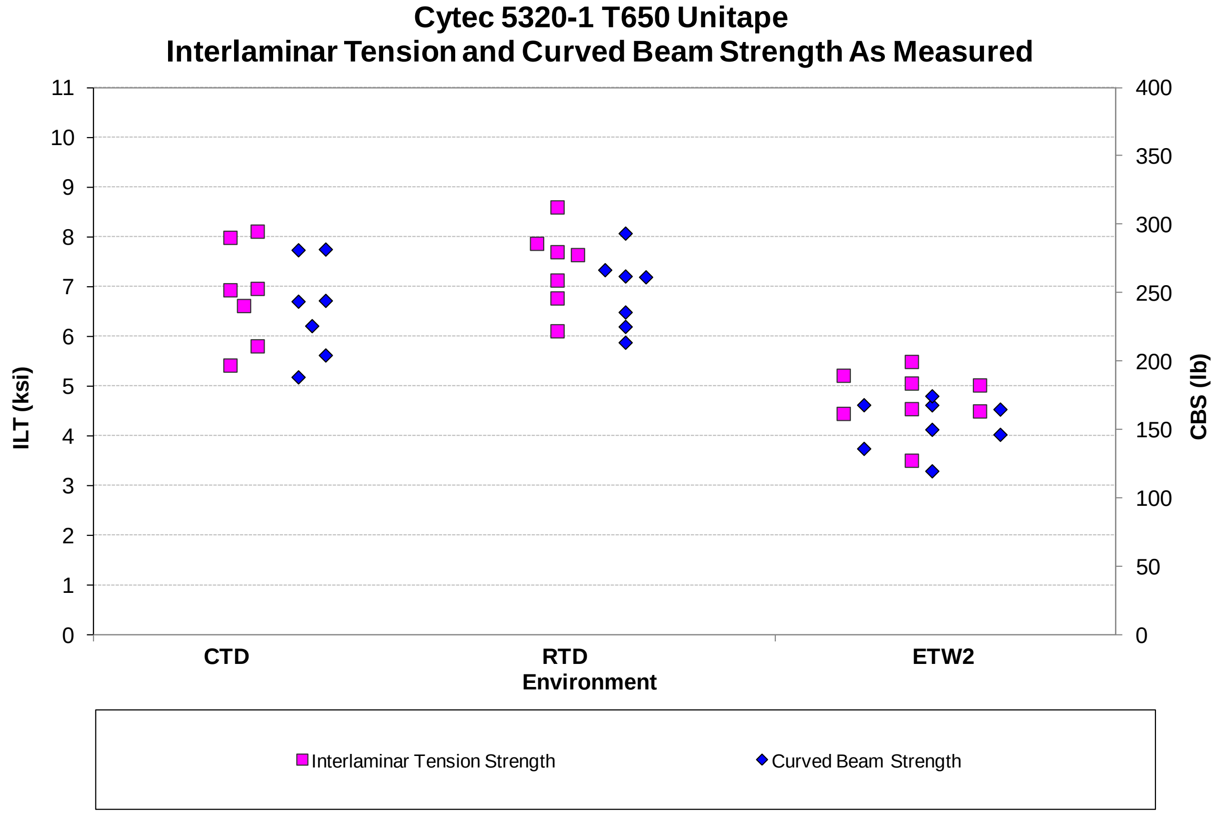

Figure 4-37: Plot for ILT and CBS as-measured

Property	Interlaminar Strength (ksi)			Curved Beam Strength (lb)		
Env	CTD	RTD	ETW2	CTD	RTD	ETW2
Mean	6.831	7.399	4.719	238.501	251.215	153.369
Stdev	1.008	0.811	0.618	35.617	27.612	18.895
CV	14.761	10.959	13.101	14.934	10.991	12.320
Mod CV	14.761	10.959	13.101	14.934	10.991	12.320
Min	5.416	6.106	3.502	188.327	213.670	119.620
Max	8.110	8.597	5.489	281.814	293.481	174.475
No. Batches	1	1	1	1	1	1
No. Spec.	7	7	8	7	7	8

Table 4-47: Statistics for ILT and CBS Strength data

5. Outliers

Outliers were identified according to the standards documented in section 2.1.5, which are in accordance with the guidelines developed in section 8.3.3 of CMH-17 Rev G. 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-2013-002 Rev A.

Outliers for which no causes could be identified are listed in Table 5-1. 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
IPS 0.2% Offset Strength	RTD	5	CUGNE211A	NA	8.430	High	Yes	No
OHT1	ETW1	4	CUGDD119D	Not an Outlier	47.409	Low	Yes	NA
OHT1	ETW2	6	CUGDF11CF	59.532	58.775	High	Yes	No
FHT3	ETW2	6	CUG6F21DF	Not an Outlier	87.168	High	Yes	No
FHC1	RTD	6	CUG7F211A	70.470	69.941	Low	No	Yes
FHC2	ETW2	6	CUG8F217F	Not an Outlier	43.138	High	Yes	No
UNT2	ETW2	5	CUGBE21BF	Not an Outlier	51.426	High	Yes	No
UNC0	ETW2	6	CUGRF21GF	60.681	60.211	Low	Yes	No
LC from UNC0				161.579	158.045			
UNC2	ETW2	6	CUGXF21BF	41.494	41.064	Low	Yes	No
SBS1	RTD	5	CUGqE271A	NA	11.168	Low	Yes	Yes
SBS1	RTD	6	CUGqF171A	NA	12.037	Low	Yes	No
TC	CTD	5	CUGZE118B	NA	46.520	Low	Yes	No
TC	RTD	4	CUGZD211A	NA	37.936	Low	Yes	No
TC	RTD	5	CUGZE211A	NA	35.507	Low	Yes	No
TT	ETW1	4	CUGUD11FD	NA	7.083	Low	Yes	NA
SSB2 - Ultimate Strength	RTD	4	CUG2D111A	140.545	145.460	Low	Yes	Yes - Norm, No - as meas
SSB2 - Ultimate Strength	ETW2	4	CUG2D11AF	134.110	135.217	High	No	Yes
SSB2 - 2% Offset Strength	RTD	5	CUG2E111A	Not an Outlier	123.515	Low	No	Yes
FHT1	RTD	5	CUG4E211A	55.441	Not an Outlier	Low	Yes	No

Table 5-1: List of Outliers

6. References

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