Cytec Cycom 5250-5 T650 3K70PW Fabric 36% RC Qualification Statistical Analysis Report

FAA Special Project Number SP4613WI-Q

Report Release Date: July 20, 2012

NCAMP Test Report Number: NCP-RP-2010-071 N/C

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

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

Test Panel Fabrication Facility:
Northrop Grumman Corporation
700 N. Douglas St., Building 902
El Segundo, CA 90245

Prepared by: ______________________
Elizabeth Clarkson, Ph.D

Reviewed by: ____________ ____________
Evelyn Lian **Michelle Man**

Approved by: ______________
Yeow Ng

REVISIONS:

Rev	By	Date	Pages Revised or Added
N/C	Elizabeth Clarkson	07/20/2012	Document Initial Release

Table of Contents

List of Figures

List of Tables

1. Introduction

This report contains statistical analysis of the Cytec 5250-5 T650 3K70PW fabric material property data published in NCAMP Test Report CAM-RP-2010-082 Rev B. The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP4613WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

B-Basis values, 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 226/3 Rev – Initial Release dated July 17, 2007. The qualification test panels were cured in accordance with NCAMP Process Specification NPS 81226 Revision C dated July 23, 2008 with baseline "C" cure cycle has been created. The panels were fabricated at Northrop Grumman, 700 N. Douglas St., bldg 902, El Segundo, CA 90245. The NCAMP Test Plan NTP 2263Q1 was used for this qualification program. The testing was performed at the National Institute for Aviation Research (NIAR) in Wichita, Kansas.

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

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

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

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

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

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

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 226/3. NMS 226/3 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 226/3. NMS 226/3* is a free, publicly available, non-proprietary aerospace industry material specification.

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

1.1 Symbols and Abbreviations

Test Property	Abbreviation
Warp Compression	WC
Warp Tension	WT
Fill Compression	FC
Fill Tension	FT
In-Plane Shear	IPS
Short Beam Strength	SBS
Unnotched Tension	UNT
Unnotched Compression	UNC
Laminate Short Beam Strength	SBS1
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
Warp Compression Strength	F_1^{cu}
Warp Compression Modulus	E_1^{c}
Warp Compression Poisson's Ratio	ν_{12}^{c}
Warp Tension Strength	F_1^{tu}
Warp Tension Modulus	E_1^{t}
Warp Tension Poisson's Ratio	ν_{12}^{t}
Fill Compression Strength	F_2^{cu}
Fill Compression Modulus	E_2^{c}
Fill Compression Poisson's Ratio	ν_{21}^{c}
Fill Tension Strength	F_2^{tu}
Fill Tension Modulus	E_2^{t}
In-Plane Shear Strength at 5% strain	$F_{12}^{s5\%}$
In-Plane Shear Strength at 0.2% offset	$F_{12}^{s0.2\%}$
In-Plane Shear Peak Strength before 5% strain	$F_{12}^{s\,max}$
In-Plane Shear Modulus	G_{12}^{s}

Table 1-2: Test Property Symbols

Environmental Condition	Test Temp.	Abbreviation
Cold Temperature Dry	−65°F	CTD
Room Temperature Dry	70°F	RTD
Elevated Temperature Dry	350°F	ETD
Elevated Temperature Wet	350°F	ETW

Table 1-3: Environmental Conditions Abbreviations

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

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

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

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2010-082 Rev B.

1.2 Pooling Across Environments

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

When pooling across environments was not advisable because the data was not eligible for pooling and engineering judgment indicated there was no justification for overriding the result, then B-Basis values were computed for each environmental condition separately using Stat-17 version 5.

1.3 Basis Value Computational Process

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

1.4 Modified Coefficient of Variation (CV) Method

A common problem with new material qualifications is that the initial specimens produced and tested do not contain all of the variability that will be encountered when the material is being produced in larger amounts over a lengthy period of time. This can result in setting basis values that are unrealistically high. The variability as-measured in the qualification program is often lower than the actual material variability because of several reasons. The materials used in the qualification programs are usually manufactured within a short period of time, typically 2-3 weeks only, which is not representative of the production material. Some raw ingredients that are used to manufacture the multi-batch qualification materials may actually be from the same production batches or manufactured within a short period of time so the qualification materials, although regarded as multiple batches, may not truly be multiple batches so they are not representative of the actual production material variability.

The modified Coefficient of Variation (CV) used in this report is in accordance with section 8.4.4 of CMH-17 Rev G. It is a method of adjusting the original basis values downward in anticipation of the expected additional variation. Composite materials are expected to have a CV of at least 6%. The modified coefficient of variation (CV) method increases the measured coefficient of variation when it is below 8% prior to computing basis values. A higher CV will result in lower or more conservative basis values and lower specification limits. The use of the modified CV method is intended for a temporary period of time when there is minimal data available. When a sufficient number of production batches (approximately 8 to 15) have been produced and tested, the as-measured CV may be used so that the basis values and specification limits may be adjusted higher.

The material allowables in this report are calculated using both the as-measured CV and modified CV, so users have the choice of using either one. When the measured CV is greater than 8%, the modified CV method does not change the basis value. NCAMP recommended values make use 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 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 and n_i refers to the number of specimens in the i^{th} sample.

2.1.2.2 Pooled Coefficient of Variation

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

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

2.1.3 Basis Value Computations

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

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

2.1.3.1 K-factor computations

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

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

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

Where

r = the number of environments being pooled together

n_j= number of data values for environment j

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

$$f = N - r$$

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

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

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

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

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

2.1.4 Modified Coefficient of Variation

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

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

This is converted to percent by multiplying by 100%.

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

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

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

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

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

2.1.4.1 Transformation of data based on Modified CV

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

To accomplish this requires a transformation in two steps:

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

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

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

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.

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

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

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

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

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.

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

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

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

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

2.1.6 The k-Sample Anderson Darling Test for Batch Equivalency

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

The k-sample Anderson-Darling test statistic is:

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

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−α level is computed:

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

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.

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

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:

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

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

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

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

The Anderson Darling test statistic (AD) is:

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

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

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

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

2.1.8 Levene's Test for Equality of Coefficient of Variation

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

$$F = \frac{\sum_{i=1}^{k} n_i \left(\overline{w}_i - \overline{w}\right)^2 / (k-1)}{\sum_{i=1}^{k} \sum_{j=1}^{n_i} {}_i \left(w_{ij} - \overline{w}_i\right)^2 / (n-k)} \qquad \textbf{Equation 32}$$

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, **Error! Reference source not found.**, 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 $x_1, \ldots, x_n$, and the sample observations ordered from least to greatest by $x_{(1)}, \ldots, x_{(n)}$.

2.2.2 Computing Normal Distribution Basis Values

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:

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

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

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

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

$$k_A \approx 2.326 + \exp\{1.34 - 0.522\ln(n) + 3.87/n\} \qquad \textbf{Equation 34}$$

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

$$e^{-(a/\alpha)^{\beta}} - e^{-(b/\alpha)^{\beta}} \qquad \textbf{Equation 35}$$

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:

$$\hat{\alpha}\hat{\beta}n - \frac{\hat{\beta}}{\hat{\alpha}^{\hat{\beta}-1}}\sum_{i=1}^{n} x_i^{\hat{\beta}} = 0 \qquad \textbf{Equation 36}$$

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

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

$$z_{(i)} = \left[x_{(i)} / \hat{\alpha} \right]^{\hat{\beta}}, \quad \text{for } i = 1, \ldots, n \qquad \textbf{Equation 38}$$

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

$$B = \hat{q} e^{\left(-V / \hat{\beta}\sqrt{n} \right)} \qquad \textbf{Equation 42}$$

where

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

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

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

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:

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

The A-basis value is:

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

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

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

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

$$SSE = SST - SSB \qquad \textbf{Equation 54}$$

Next, the mean sums of squares are computed:

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

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

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

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

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

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

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

Denote the ratio of mean squares by

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

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

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

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

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

2.3 Single Batch and Two Batch Estimates using Modified CV

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

Estimated B-Basis $= \bar{X} - k_b S_{adj} = \bar{X} - k_b \cdot 0.08 \cdot \bar{X}$ **Equation 61**

2.4 Lamina Variability Method (LVM)

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

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

The LVM B-basis value is then computed as:

LVM Estimated B-Basis = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot \max\left(CV_1, CV_2\right)$ **Equation 62**

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

Mod CV LVM Estimated B-Basis = $\bar{X}_1 - K_{(N_1,N_2)} \cdot \bar{X}_1 \cdot Max\left(8\%, CV_1, CV_2\right)$ **Equation 63**

With:

$\bar{X}_1$ the mean of the laminate (small dataset)
N_1 the sample size of the laminate (small dataset)
N_2 the sample size of the lamina (large dataset)
CV_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													
N1+N2-2	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	4.508	0	0	0	0	0	0	0	0	0	0	0	0	0
4	3.827	3.607	0	0	0	0	0	0	0	0	0	0	0	0
5	3.481	3.263	3.141	0	0	0	0	0	0	0	0	0	0	0
6	3.273	3.056	2.934	2.854	0	0	0	0	0	0	0	0	0	0
7	3.134	2.918	2.796	2.715	2.658	0	0	0	0	0	0	0	0	0
8	3.035	2.820	2.697	2.616	2.558	2.515	0	0	0	0	0	0	0	0
9	2.960	2.746	2.623	2.541	2.483	2.440	2.405	0	0	0	0	0	0	0
10	2.903	2.688	2.565	2.484	2.425	2.381	2.346	2.318	0	0	0	0	0	0
11	2.856	2.643	2.519	2.437	2.378	2.334	2.299	2.270	2.247	0	0	0	0	0
12	2.819	2.605	2.481	2.399	2.340	2.295	2.260	2.231	2.207	2.187	0	0	0	0
13	2.787	2.574	2.450	2.367	2.308	2.263	2.227	2.198	2.174	2.154	2.137	0	0	0
14	2.761	2.547	2.423	2.341	2.281	2.236	2.200	2.171	2.147	2.126	2.109	2.093	0	0
15	2.738	2.525	2.401	2.318	2.258	2.212	2.176	2.147	2.123	2.102	2.084	2.069	2.056	0
16	2.719	2.505	2.381	2.298	2.238	2.192	2.156	2.126	2.102	2.081	2.063	2.048	2.034	2.022
17	2.701	2.488	2.364	2.280	2.220	2.174	2.138	2.108	2.083	2.062	2.045	2.029	2.015	2.003
18	2.686	2.473	2.348	2.265	2.204	2.158	2.122	2.092	2.067	2.046	2.028	2.012	1.999	1.986
19	2.673	2.459	2.335	2.251	2.191	2.144	2.108	2.078	2.053	2.032	2.013	1.998	1.984	1.971
20	2.661	2.447	2.323	2.239	2.178	2.132	2.095	2.065	2.040	2.019	2.000	1.984	1.970	1.958
21	2.650	2.437	2.312	2.228	2.167	2.121	2.084	2.053	2.028	2.007	1.988	1.972	1.958	1.946
22	2.640	2.427	2.302	2.218	2.157	2.110	2.073	2.043	2.018	1.996	1.978	1.962	1.947	1.935
23	2.631	2.418	2.293	2.209	2.148	2.101	2.064	2.033	2.008	1.987	1.968	1.952	1.938	1.925
24	2.623	2.410	2.285	2.201	2.139	2.092	2.055	2.025	1.999	1.978	1.959	1.943	1.928	1.916
25	2.616	2.402	2.277	2.193	2.132	2.085	2.047	2.017	1.991	1.969	1.951	1.934	1.920	1.907
26	2.609	2.396	2.270	2.186	2.125	2.078	2.040	2.009	1.984	1.962	1.943	1.927	1.912	1.900
27	2.602	2.389	2.264	2.180	2.118	2.071	2.033	2.003	1.977	1.955	1.936	1.920	1.905	1.892
28	2.597	2.383	2.258	2.174	2.112	2.065	2.027	1.996	1.971	1.949	1.930	1.913	1.899	1.886
29	2.591	2.378	2.252	2.168	2.106	2.059	2.021	1.990	1.965	1.943	1.924	1.907	1.893	1.880
30	2.586	2.373	2.247	2.163	2.101	2.054	2.016	1.985	1.959	1.937	1.918	1.901	1.887	1.874
40	2.550	2.337	2.211	2.126	2.063	2.015	1.977	1.946	1.919	1.897	1.877	1.860	1.845	1.832
50	2.528	2.315	2.189	2.104	2.041	1.993	1.954	1.922	1.896	1.873	1.853	1.836	1.820	1.807
60	2.514	2.301	2.175	2.089	2.026	1.978	1.939	1.907	1.880	1.857	1.837	1.819	1.804	1.790
70	2.504	2.291	2.164	2.079	2.016	1.967	1.928	1.896	1.869	1.846	1.825	1.808	1.792	1.778
80	2.496	2.283	2.157	2.071	2.008	1.959	1.920	1.887	1.860	1.837	1.817	1.799	1.783	1.769
90	2.491	2.277	2.151	2.065	2.002	1.953	1.913	1.881	1.854	1.830	1.810	1.792	1.776	1.762
100	2.486	2.273	2.146	2.060	1.997	1.948	1.908	1.876	1.849	1.825	1.805	1.787	1.771	1.757
125	2.478	2.264	2.138	2.051	1.988	1.939	1.899	1.867	1.839	1.816	1.795	1.777	1.761	1.747
150	2.472	2.259	2.132	2.046	1.982	1.933	1.893	1.861	1.833	1.809	1.789	1.770	1.754	1.740
175	2.468	2.255	2.128	2.042	1.978	1.929	1.889	1.856	1.828	1.805	1.784	1.766	1.750	1.735
200	2.465	2.252	2.125	2.039	1.975	1.925	1.886	1.853	1.825	1.801	1.781	1.762	1.746	1.732

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

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 5250-5 T650 3K70PW weave fabric prepreg

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

Lamina Strength Tests

Environment	Statistic	WT	WC	FT	FC	SBS*	IPS*		
							0.2% Offset	5% Strain	Peak before 5% Strain
CTD (-65°F)	B-basis	106.17	112.09	94.51	89.92	9.88	9.97		14.21
	Mean	119.21	124.41	107.28	107.26	11.97	11.04		16.09
	CV	6.00	6.90	6.11	8.40	8.08	6.00		6.00
RTD (70°F)	B-basis	113.10	101.07	101.66	89.34	10.14	7.49		
	Mean	126.13	113.29	114.78	103.90	11.65	8.56		
	CV	6.00	6.23	6.00	7.35	6.86	6.00		
ETD (350°F)	B-basis		77.73		59.19	6.15			
	Mean		90.10		76.52	6.94			
	CV		6.10		11.76	6.00			
ETW (350°F)	B-basis	NA (1)	NA: A	NA (1)	NA (1)	NA (1)	NA: A	NA: A	
	Mean	125.85	47.69	105.40	46.84	4.09	2.19	4.82	
	CV	3.16	16.29	3.62	7.61	5.08	10.29	10.78	

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,

NA (1): Users of ETW condition data are cautioned of the fact that ETW test temperature of 350°F is not 50°F (28°C) or more below the wet glass transition temperature as is recommended. They are advised to refer to CMH-17 Rev G section 2.2.8 and DOT/FAA/AR-01/40 for more information about establishing MOL.

Shaded empty boxes indicate that no test data is available for that property and condition.
* Data is as-measured rather than normalized
** indicates the Stat17 B-basis value is greater than 90% of the mean value.

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

NCAMP Recommended B-basis Values for
Cytec Cycom 5250-5 T650 3K70PW weave fabric prepreg

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 Ult.	SBS1*
25/50/25	CTD (-65°F)	B-basis	42.45**		43.58		76.08				
		Mean	44.85		48.78		84.85				
		CV	3.37		6.00		6.00				
	RTD (70°F)	B-basis	43.26**	41.00	44.52	NA: A	80.71	78.31	101.22	118.94**	10.11
		Mean	46.71	46.29	49.73	77.21	89.68	87.69	114.09	130.00	11.44
		CV	4.03	6.00	6.00	6.23	6.00	7.10	6.89	3.61	6.11
	ETW (350°F)	B-basis	NA (1)	NA: A	NA (1)	NA (1)	NA (1)	NA (1)	NA (1)	NA (1)	NA (1)
		Mean	50.77	26.19	51.86	33.87	83.03	39.41	73.16	90.01	4.04
		CV	3.10	6.90	2.55	10.20	3.64	10.44	8.94	4.88	5.04
10/80/10	CTD (-65°F)	B-basis	39.16		42.82		51.91				
		Mean	43.26		47.31		57.57				
		CV	6.00		6.00		6.00				
	RTD (70°F)	B-basis	38.69	35.61	42.73	52.50	52.07	56.47	100.03	119.60	
		Mean	42.80	40.33	47.22	59.55	57.97	61.64	113.28	132.69	
		CV	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
	ETW (350°F)	B-basis	NA (1)	NA: A	NA (1)	NA: I	NA (1)	NA (1)	NA: A	NA (1)	
		Mean	30.54	21.68	32.46	26.88	40.94	26.80	67.30	89.96	
		CV	3.64	6.10	2.46	7.73	7.88	5.84	11.53	6.98	
40/20/40	CTD (-65°F)	B-basis	45.35		48.75		96.16**				
		Mean	51.48		54.78		102.00				
		CV	6.13		6.24		3.28				
	RTD (70°F)	B-basis	48.68	43.44	51.19	NA: I	95.03	NA: A	93.47	110.63	
		Mean	54.82	48.00	57.23	79.62	107.96	82.02	107.16	122.36	
		CV	6.19	6.00	6.20	3.01	6.07	8.20	6.63	6.41	
	ETW (350°F)	B-basis	NA (1)	NA (1)	NA (1)	NA: I	NA (1)	NA (1)	NA: A	NA (1)	
		Mean	62.42	28.65	58.04	41.35	104.64	42.49	57.76	80.19	
		CV	4.41	7.71	3.82	5.63	2.14	5.58	7.14	4.64	

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,

NA (1): Users of ETW condition data are cautioned of the fact that ETW test temperature of 350°F is not 50°F (28°C) or more below the wet glass transition temperature as is recommended. They are advised to refer to CMH-17 Rev G section 2.2.8 and DOT/FAA/AR-01/40 for more information about establishing MOL.

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

Cytec Cycom® 5250-5 T650 3K70 Plain Weave Fabric Lamina Properties Summary

Prepreg Material: Cytec Cycom® 5250-5 T650 3K70 PW Fabric
NMS 226/3 Material Specification

Fabric: T650 3K PW **Resin:** Cytec Cycom® 5250-5

Tg(dry): 470.47° F **Tg(bone dry):** 525.40° F **Tg(wet):** 376.90° F **Tg METHOD:** DMA (SRM 18-94)

PROCESSING: NCAMP Process Speciification 81226 "C" Cure Cycle

	Batch 1, 2, 3, 4		
Date of fiber manufacture	6/29/2006, 6/14/2006, 3/23/2006, 1/1/2007	**Date of testing**	7/1/2009 to 8/18/2010
Date of resin manufacture	6/28/2007, 8/8/2007, 11/13/2007 (batch 3&4)	**Date of data submittal**	10/1/2010
Date of prepreg manufacture	6/28/2007, 8/8/2007, 11/13/2007 (batch 3&4)	**Date of analysis**	7/11/2011 to 8/31/2011
Date of composite manufacture	August 2008		

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY
Data reported: As-measured followed by normalized values in parentheses, normalizing tply: 0.0078 in
Values shown in shaded boxes do not meet CMH-17G requirements and are estimates only
These values may not be used for certification unless specifically allowed by the certifying agency

	CTD			RTD			ETD			ETW (1)		
	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean
F_1^{tu}	111.85	106.32	119.47	119.84	114.31	127.46				119.88	114.34	127.49
(ksi)	(111.38)	(106.17)	(119.21)	(118.30)	(113.10)	(126.13)				(118.02)	(112.82)	(125.85)
E_1^t			9.63			10.07						9.14
(Msi)			(9.61)			(9.95)						(9.03)
ν_{12}^t			0.066			0.040						0.041
F_2^{tu}	99.11	94.92	107.50	108.36	102.02	115.19				89.19	93.99	105.99
(ksi)	(98.47)	(94.51)	(107.28)	(107.52)	(101.66)	(114.78)				(84.06)	(93.47)	(105.40)
E_2^t			9.21			9.38						9.03
(Msi)			(9.19)			(9.35)						(8.98)
F_1^{cu}	110.19	112.84	125.70	107.39	103.63	116.38	83.43	78.80	91.71	0.00	NA	48.13
(ksi)	(110.80)	(112.09)	(124.41)	(90.16)	(101.07)	(113.29)	(82.90)	(77.73)	(90.10)	(0.25)	NA	(47.69)
E_1^c			8.93			8.91			8.85			8.44
(Msi)			(8.83)			(8.67)			(8.69)			(8.27)
F_2^{cu}	90.60	NA	108.24	93.35	91.29	105.28	58.60	NA	77.51	39.93	NA	47.26
(ksi)	(89.92)	NA	(107.26)	(75.27)	(89.34)	(103.90)	(59.19)	NA	(76.52)	(40.67)	NA	(46.84)
E_2^c			8.54			8.64			8.43			8.05
(Msi)			(8.45)			(8.52)			(8.34)			(7.96)
$F_{12}^{s0.2\%}$ (ksi)	10.76	9.97	11.04	8.28	7.49	8.56				1.09	NA	2.19
$F_{12}^{s5\%}$ (ksi)										2.03	NA	4.82
F_{12}^{smax} (ksi)	13.12	14.21	16.09									
G_{12}^s (Msi)			0.84			0.73						0.21
SBS (ksi)	9.88	NA	11.97	10.39	10.14	11.65	5.81	6.15	6.94	3.06	3.58	4.09

Note (1): Users of ETW condition data are cautioned of the fact that ETW test temperature of 350°F is not 50°F (28°C) or more below the wet glass transition temperature as is recommended. They are advised to refer to CMH-17 Rev G section 2.2.8 and DOT/FAA/AR-01/40 for more information about establishing MOL.

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

Prepreg Material:	Cytec Cycom® 5250-5 T650 3K70 PW Fabric NMS 226/3 Material Specification		**Cytec Cycom® 5250-5 T650 3K70 Plain Weave Fabric Laminate Properties Summary**
Fabric: T650 3K PW	**Resin:** Cytec Cycom® 5250-5		
Tg(dry): 470.47° F	**Tg(bone dry):** 525.40° F	**Tg(wet):** 376.90° F	**Tg METHOD:** DMA (SRM 18-94)
PROCESSING: NCAMP Process Speciification 81226 "C" Cure Cycle			

	Batch 1, 2, 3, 4 per PMC Data Collection		
Date of fiber manufacture	6/29/2006, 6/14/2006, 3/23/2006, 1/1/2007	**Date of testing**	7/1/2009 to 8/18/2010
Date of resin manufacture	6/28/2007, 8/8/2007, 11/13/2007 (batch 3&4)	**Date of data submittal**	10/1/2010
Date of prepreg manufacture	6/28/2007, 8/8/2007, 11/13/2007 (batch 3&4)	**Date of analysis**	7/11/2011 to 8/31/2011
Date of composite manufacture	August 2008		

LAMINATE MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported as normalized used a normalizing t_{ply} of 0.0078 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	Layup:		Quasi Isotropic 25/50/25			"Soft" 10/80/10			"Hard" 40/20/40		
		Test Condition	Unit	B-value	Mod. CV B-value	Mean	B-value	Mod. CV B-value	Mean	B-value	Mod. CV B-value	Mean
OHT (normalized)	Strength	CTD	ksi	42.45	NA	44.85	40.24	39.16	43.26	47.34	45.35	51.48
		RTD	ksi	43.26	NA	46.71	41.07	38.69	42.80	50.67	48.68	54.82
		ETW(1)	ksi	47.78	44.97	50.77	28.83	26.48	30.54	49.47	56.34	62.42
OHC (normalized)	Strength	RTD	ksi	44.14	41.00	46.29	34.26	35.61	40.33	44.50	43.44	48.00
		ETW(1)	ksi	16.20	22.76	26.19	14.47	18.95	21.68	25.20	24.16	28.65
UNT (normalized)	Strength	CTD	ksi	80.63	76.08	84.85	51.22	51.91	57.57	96.16	NA	102.00
	Modulus		Msi	---	---	6.92	---	---	4.74	---	---	8.65
	Strength	RTD	ksi	85.37	80.71	89.68	55.84	52.07	57.97	99.15	95.03	107.96
	Modulus		Msi	---	---	6.77	---	---	4.45	---	---	8.44
	Strength	ETW(1)	ksi	68.31	74.14	83.03	34.86	35.13	40.94	100.37	92.68	104.64
	Modulus		Msi	---	---	6.17	---	---	3.38	---	---	8.28
UNC (normalized)	Strength	RTD	ksi	79.09	78.31	87.69	58.81	56.47	61.64	57.45	NA	82.02
	Modulus		Msi	---	---	6.42	---	---	4.39	---	---	7.85
	Strength	ETW(1)	ksi	30.88	30.11	39.41	23.99	21.68	26.80	37.92	36.93	42.49
	Modulus		Msi	---	---	5.72	---	---	3.21	---	---	7.12
SBS1 (as-measured)	Strength	RTD	ksi	10.52	10.11	11.44	---	---	---	---	---	---
		ETW(1)	ksi	3.19	3.54	4.04	---	---	---	---	---	---
FHT (normalized)	Strength	CTD	ksi	45.71	43.58	48.78	45.82	42.82	47.31	50.61	48.75	54.78
		RTD	ksi	46.66	44.52	49.73	45.73	42.73	47.22	53.06	51.19	57.23
		ETW(1)	ksi	45.93	46.60	51.86	30.96	27.93	32.46	53.83	51.95	58.04
FHC (normalized)	Strength	RTD	ksi	0.00	63.89	77.21	57.36	52.50	59.55	74.67	69.74	79.62
		ETW(1)	ksi	27.91	NA	33.87	21.98	21.81	26.88	36.05	34.94	41.35
Single Shear Bearing (normalized)	2% Offset Strength	RTD	ksi	102.32	101.22	114.09	106.63	100.03	113.28	96.29	93.47	107.16
		ETW(1)	ksi	61.53	60.45	73.16	37.36	NA	67.30	38.56	49.43	57.76
	Ultimate Strength	RTD	ksi	118.94	NA	130.00	126.81	119.60	132.69	113.60	110.63	122.36
		ETW(1)	ksi	67.64	79.07	90.01	78.23	77.09	89.96	71.48	68.52	80.19
CAI (normalized)	Strength	RTD	ksi	---	---	32.17	---	---	---	---	---	---
ILT (as-measured)	Strength	CTD	ksi	---	---	8.89	---	---	---	---	---	---
		RTD	ksi	---	---	8.45	---	---	---	---	---	---
		ETW	ksi	---	---	2.59	---	---	---	---	---	---
CBS (as-measured)	Strength	CTD	lb	---	---	300.83	---	---	---	---	---	---
		RTD	lb	---	---	289.70	---	---	---	---	---	---
		ETW	lb	---	---	90.67	---	---	---	---	---	---

Note (1): Users of ETW condition data are cautioned of the fact that ETW test temperature of 350°F is not 50°F (28°C) or more below the wet glass transition temperature as is recommended. They are advised to refer to CMH-17 Rev G section 2.2.8 and DOT/FAA/AR-01/40 for more information about establishing MOL.

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

4. Individual Test Summaries, 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.

For organic matrix composites, the typical rule of thumb is to maintain a 50 degree margin between the materials maximum operating limit (MOL) and its wet glass transition temperature. Users of ETW condition data are cautioned of the fact that ETW test temperature of 350°F is not 50°F (28°C) or more below the wet glass transition temperature as is recommended. They are advised to refer to CMH-17 Rev G section 2.2.8 and DOT/FAA/AR-01/40 for more information about establishing MOL.

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

When a dataset fails the Anderson-Darling k-sample (ADK) test for batch-to-batch variation an ANOVA analysis is required. In order for B-basis values computed using the ANOVA method, data from five batches is required. Since this qualification dataset has only three batches, the basis values computed using ANOVA are considered estimates only. However, the basis values resulting from the ANOVA method using only three batches may be overly conser vative. 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 of CMH17 Rev G section 8.3.10.

4.1 Warp (0º) Tension Properties (WT)

The Warp Tension data is normalized so both normalized and as-measured statistics are provided. There were no test failures or outliers in the Warp Tension datasets. Pooling was acceptable.

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

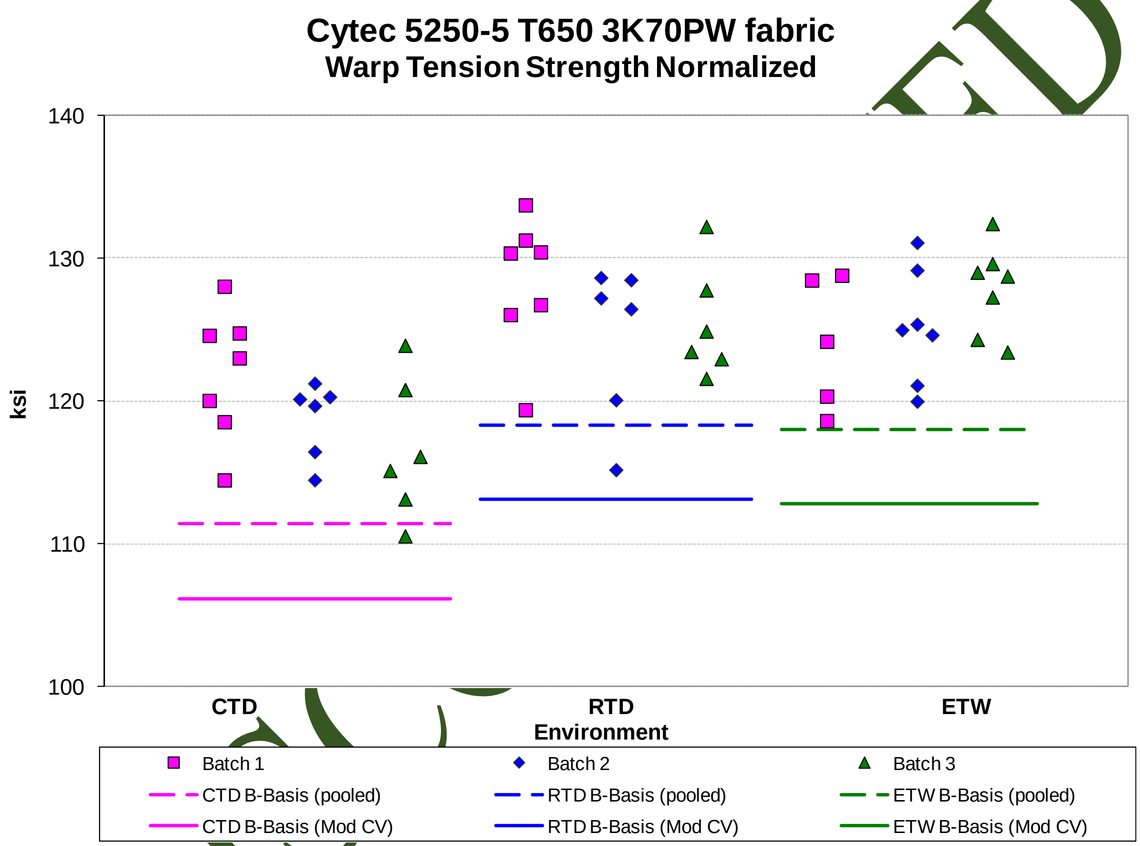

Figure 4-1 Batch plot for WT normalized strength

Warp Tension Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	119.21	126.13	125.85	119.47	127.46	127.49
Stdev	4.56	4.80	3.98	3.50	4.83	4.58
CV	3.83	3.81	3.16	2.93	3.79	3.59
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	110.53	115.17	118.60	112.85	116.07	118.91
Max	128.02	133.71	132.41	124.82	136.33	135.20
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	19	19	19	19
Basis Values and/or Estimates						
B-basis Value	111.38	118.30	118.02	111.85	119.84	119.88
A-Estimate	106.13	113.05	112.77	106.75	114.74	114.77
Method	pooled	pooled	pooled	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	106.17	113.10	112.82	106.32	114.31	114.34
A-Estimate	97.44	104.36	104.08	97.50	105.49	105.53
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-1: Statistics and Basis values for WT Strength Data

Warp Tension Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	9.61	9.95	9.03	9.63	10.07	9.14
Stdev	0.24	0.41	0.23	0.24	0.44	0.26
CV	2.50	4.08	2.55	2.52	4.37	2.87
Mod CV	6.00	6.04	6.00	6.00	6.18	6.00
Min	9.09	9.52	8.43	9.16	9.53	8.44
Max	9.88	10.95	9.41	10.04	11.03	9.61
No. Batches	3	3	3	3	3	3
No. Spec.	20	19	21	20	19	21

Table 4-2: Statistics from WT Modulus Data

4.2 Fill (90º) Tension Properties (FT)

The Fill Tension data was normalized so both normalized and as-measured statistics are provided. The ETW 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 ETW datasets were transformed according to the assumptions of the modified CV method, they both passed the ADK test, so the modified CV basis values are provided. The pooled datasets, both normalized and as-measured, did not pass the normality test, so pooling across environments remained unacceptable for both the as-measured and the normalized data.

There was one outlier. It was an outlier in both the normalized and the as-measured datasets. The outlier was from batch two. It was the lowest value in the CTD dataset. It was an outlier for batch two only, not for the CTD condition. It was retained for this analysis.

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

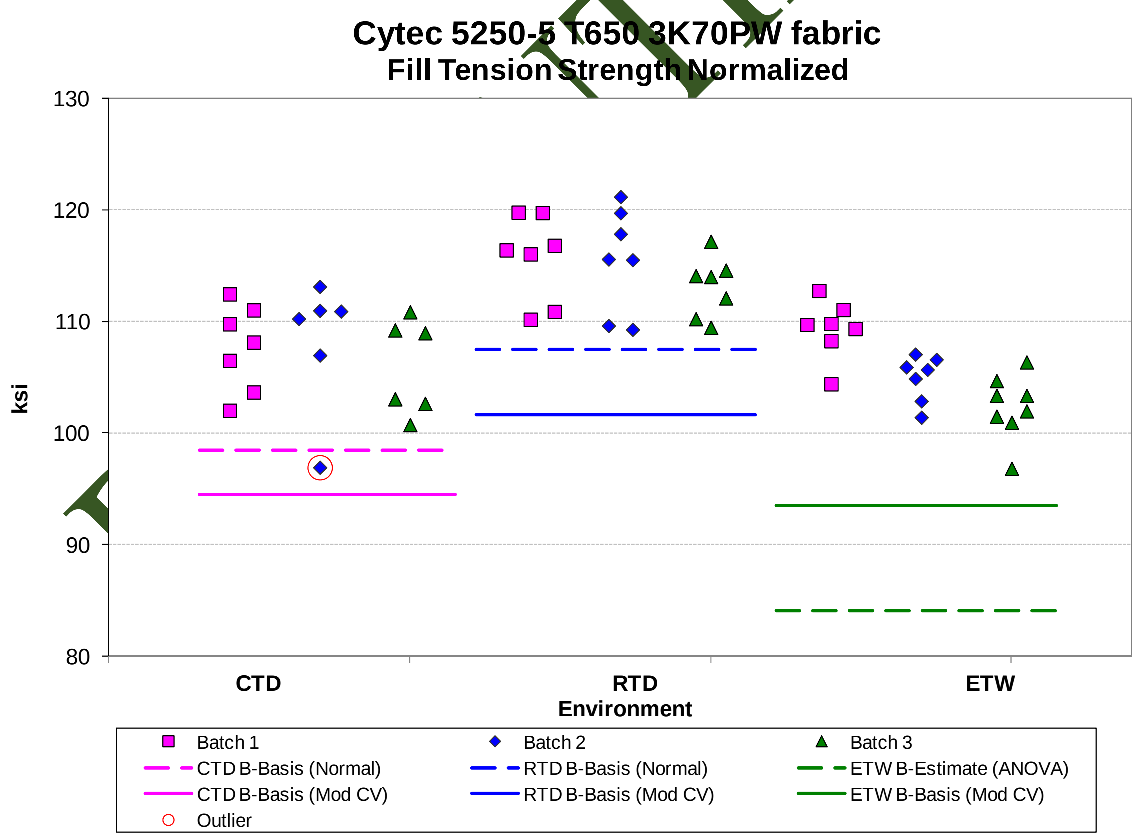

Figure 4-2: Batch Plot for FT normalized strength

Fill Tension Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	107.28	114.78	105.40	107.50	115.19	105.99
Stdev	4.52	3.81	3.82	4.31	3.59	3.54
CV	4.21	3.32	3.62	4.00	3.11	3.34
Mod CV	6.11	6.00	6.00	6.00	6.00	6.00
Min	96.92	109.29	96.82	98.46	108.48	97.68
Max	113.13	121.18	112.76	112.90	121.21	113.00
No. Batches	3	3	3	3	3	3
No. Spec.	19	21	22	19	21	22
Basis Values and Estimates						
B-basis Value	98.47	107.52		99.11	108.36	
B-Estimate			84.06			89.19
A-Estimate	92.21	102.35	68.83	93.15	103.49	77.19
Method	Normal	Normal	ANOVA	Normal	Normal	ANOVA
Modified CV Basis Values and/or Estimates						
B-basis Value	94.51	101.66	93.47	94.92	102.02	93.99
A-Estimate	85.46	92.31	84.95	86.00	92.64	85.43
Method	Normal	Normal	Normal	Normal	Normal	Normal

Table 4-3: Statistics and Basis Values for FT Strength Data

Fill Tension Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	9.19	9.35	8.98	9.21	9.38	9.03
Stdev	0.21	0.28	0.50	0.20	0.28	0.49
CV	2.24	2.97	5.53	2.12	3.00	5.48
Mod CV	6.00	6.00	6.76	6.00	6.00	6.74
Min	8.67	8.81	7.65	8.75	8.96	7.72
Max	9.42	9.78	9.71	9.47	9.95	9.78
No. Batches	3	3	3	3	3	3
No. Spec.	19	21	22	19	21	22

Table 4-4: Statistics from FT Modulus Data

4.3 Warp (0º) Compression Properties (WC)

The Warp Compression data was normalized so both normalized and as-measured statistics are provided. The normalized RTD, and both the normalized and as-measured ETW, 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.

The as-measured CTD, RTD and ETD datasets could not be pooled due to a failure of Levene's test for equality of variance, but these datasets passed Levene's test after the modified CV transformation was applied. The normalized RTD dataset passed the ADK test after applying the modified CV transformation to the data and could be pooled with the CTD and ETD datasets to compute the modified CV basis values.

The normalized and as-measured ETW datasets did not pass the ADK test after the modified CV transformation was applied. Since the ETW data had a CV greater than 8%, the modified CV method could not be used. Basis value estimates were computed for the ETW datasets by overriding the ADK test results and using the normal distribution.

There were no outliers in either the normalized or the as-measured datasets. Statistics, basis values and estimates are given for strength data in Table 4-5 and for the modulus data in Table 4-6. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-3.

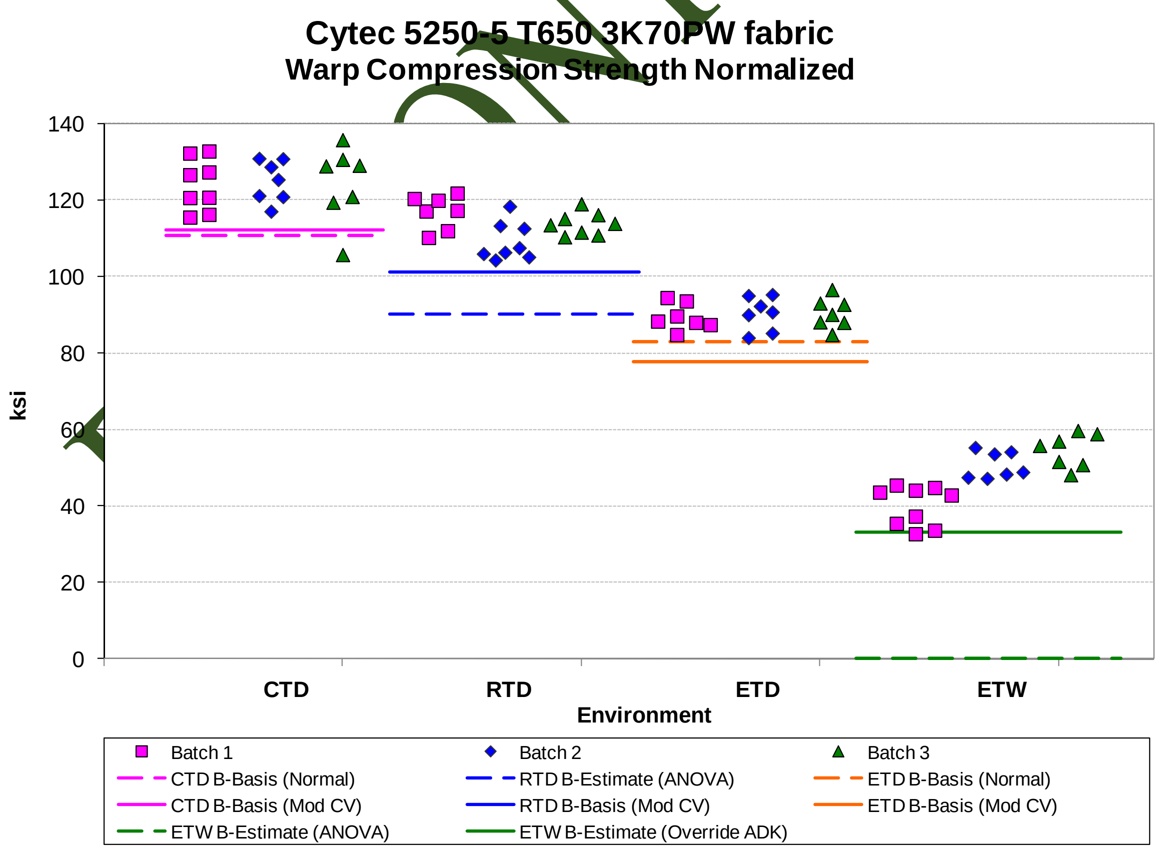

Figure 4-3 Batch plot for WC normalized strength

Warp Compression Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	124.41	113.29	90.10	47.69	125.70	116.38	91.71	48.13
Stdev	7.22	5.06	3.78	7.77	8.22	4.85	4.34	8.40
CV	5.80	4.47	4.19	16.29	6.54	4.17	4.74	17.45
Mod CV	6.90	6.23	6.10	16.29	7.27	6.08	6.37	17.45
Min	105.73	104.31	84.01	32.72	108.19	107.78	83.98	32.18
Max	135.75	121.77	96.57	59.71	140.59	125.46	100.15	61.75
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	22	24	21	23	22	24	21	23
Basis Values and/or Estimates								
B-basis Value	110.80		82.90		110.19	107.39	83.43	
B-Estimate		90.16		0.25				0.00
A-Estimate	101.08	73.63	77.77	0.00	99.12	100.95	77.54	0.00
Method	Normal	ANOVA	Normal	ANOVA	Normal	Normal	Normal	ANOVA
Basis Values and Estimates with override of ADK test								
B-Estimate				33.18				32.44
A-Estimate				22.79				21.21
Method				Normal				Normal
Modified CV Basis Values and/or Estimates								
B-basis Value	112.09	101.07	77.73		112.84	103.63	78.80	
A-Estimate	103.75	92.70	69.39		104.14	94.90	70.10	
Method	pooled	pooled	pooled		pooled	pooled	pooled	

Table 4-5: Statistics and Basis Values for WC Strength Data

Warp Compression Modulus Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	8.83	8.67	8.69	8.27	8.93	8.91	8.85	8.44
Stdev	0.20	0.15	0.17	0.25	0.22	0.22	0.22	0.39
CV	2.26	1.75	1.91	3.07	2.47	2.49	2.53	4.65
Mod CV	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.33
Min	8.49	8.34	8.45	7.76	8.54	8.51	8.33	7.68
Max	9.23	8.88	9.26	8.73	9.52	9.30	9.18	9.14
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	22	21	21	21	22	21	21	21

Table 4-6: Statistics from WC Modulus Data

4.4 Fill (90º) Compression Properties (FC)

The Fill Compression data was normalized so both normalized and as-measured statistics are provided. The normalized RTD data 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 for that dataset. The pooled datasets for the as-measured data did not pass the Levene's test for equality of variance, so pooling across environments was not acceptable.

Modified CV basis values are not provided for the normalized and as-measured CTD, ETD and ETW datasets. This is because the CTD, ETD and as-measured ETW datasets have a CV greater than 8% and because the normalized ETW dataset failed the normality test.

There was one outlier. It was the highest value in batch three from the ETW condition. It was an outlier for both the normalized and as-measured data. It was an outlier for the ETW condition, but not for batch three. It was 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 normalized data and B-basis values are shown graphically in Figure 4-4.

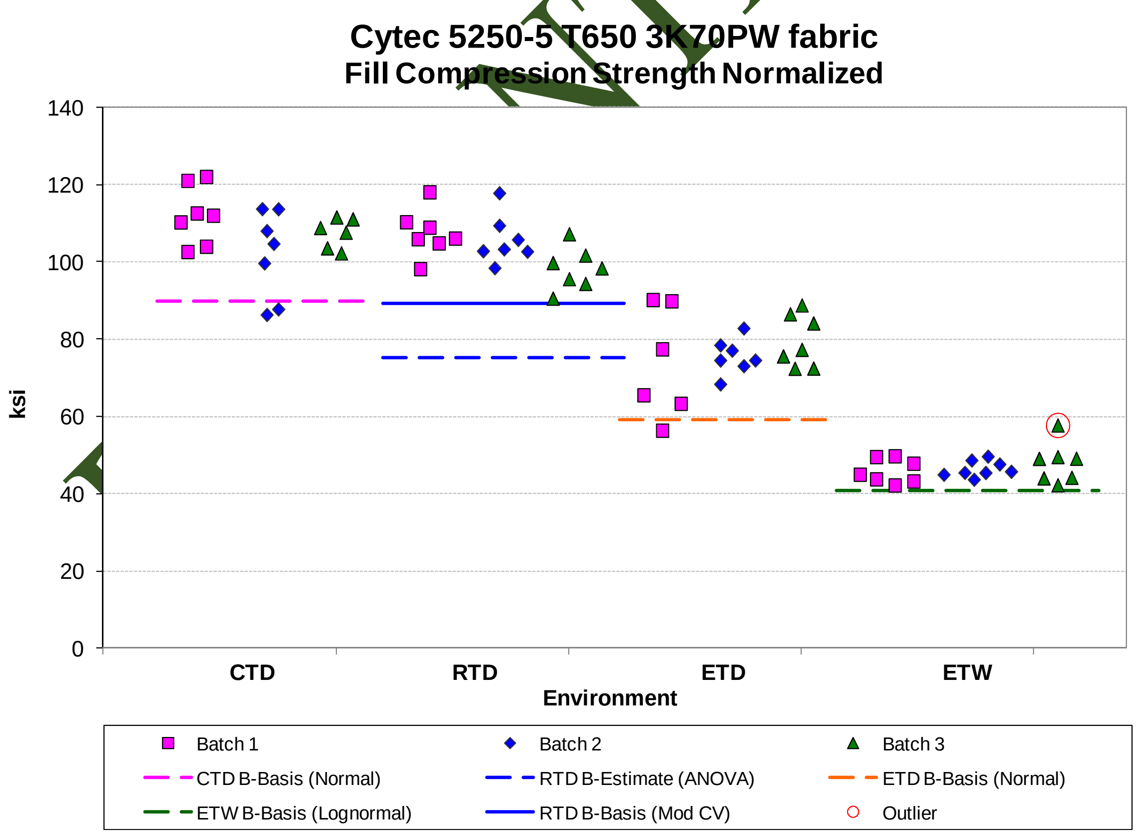

Figure 4-4: Batch Plot for FC normalized strength

Fill Compression Strength Basis Values and Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	107.26	103.90	76.52	46.84	108.24	105.28	77.51	47.26
Stdev	9.00	6.96	9.00	3.56	9.16	6.26	9.82	3.89
CV	8.40	6.70	11.76	7.61	8.47	5.95	12.67	8.23
Mod CV	8.40	7.35	11.76	7.80	8.47	6.97	12.67	8.23
Min	86.42	90.64	56.47	42.28	86.84	92.46	55.72	41.89
Max	122.12	118.14	90.27	57.82	120.79	117.49	93.66	59.17
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	20	21	20	22	20	21	20	22
Basis Values and/or Estimates								
B-basis Value	89.92		59.19	40.67	90.60	93.35	58.60	39.93
B-Estimate		75.27						
A-Estimate	77.58	54.84	46.86	36.84	78.04	84.85	45.14	34.69
Method	Normal	ANOVA	Normal	Lognormal	Normal	Normal	Normal	Normal
Modified CV Basis Values and/or Estimates								
B-basis Value	NA	89.34	NA	NA	NA	91.29	NA	NA
A-Estimate	NA	78.98	NA	NA	NA	81.32	NA	NA
Method	NA	Normal	NA	NA	NA	Normal	NA	NA

Table 4-7: Statistics and Basis Values for FC Strength Data

Fill Compression Modulus Statistics								
	Normalized				As-measured			
Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	8.45	8.52	8.34	7.96	8.54	8.64	8.43	8.05
Stdev	0.58	0.19	0.53	0.49	0.60	0.27	0.63	0.51
CV	6.83	2.28	6.36	6.19	6.98	3.16	7.42	6.35
Mod CV	7.42	6.00	7.18	7.10	7.49	6.00	7.71	7.18
Min	6.32	8.11	7.03	6.99	6.35	8.20	6.94	7.00
Max	9.63	8.84	9.15	9.27	9.64	9.17	9.37	9.31
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	21	21	22	21	21	21	22	21

Table 4-8: Statistics from FC Modulus Data

4.5 In-Plane Shear Properties (IPS)

In-Plane Shear data is not normalized. There was insufficient data to produce basis values for strength at 5% strain data from the ETW condition. Estimates only are provided. There was no data available from the CTD or RTD conditions for the strength at 5% strain; Peak strength before 5% stain is available only for the CTD condition.

The ETW datasets, for both 0.2% offset strength and strength at 5% strain, and the CTD dataset for peak strength before 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. Since the ETW data had a CV greater than 8%, the modified CV method could not be used. Additional basis value estimates were computed for this dataset by overriding the ADK test results and using the normal distribution.

The CTD and RTD 0.2% offset strength datasets could be pooled together to compute basis values. When the CTD peak strength before 5% strain 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.

There were two outliers. In the 0.2% offset strength data, the lowest value in the RTD data was in batch three. It was an outlier for the RTD condition, but not for batch three. The highest value in batch one of the ETW data was an outlier for batch one, but not for the ETW condition. Both outliers were retained for this analysis.

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

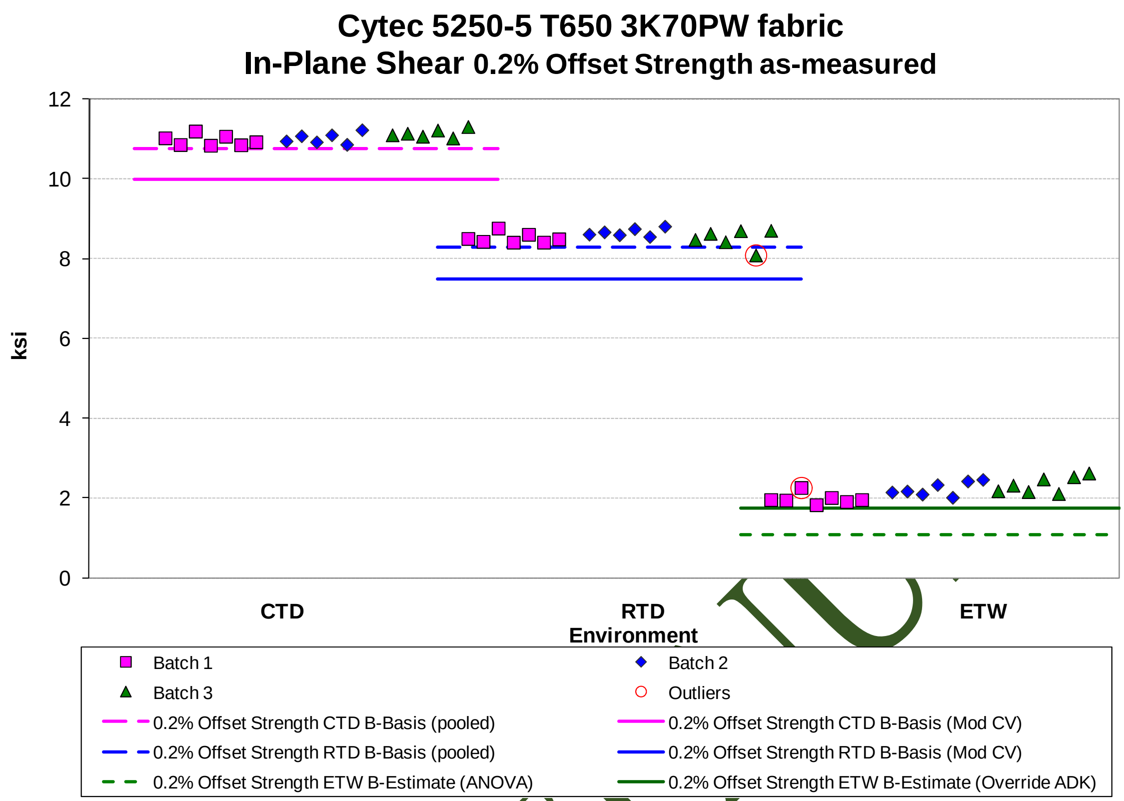

Figure 4-5: Batch plot for IPS 0.2% Offset Strength as-measured

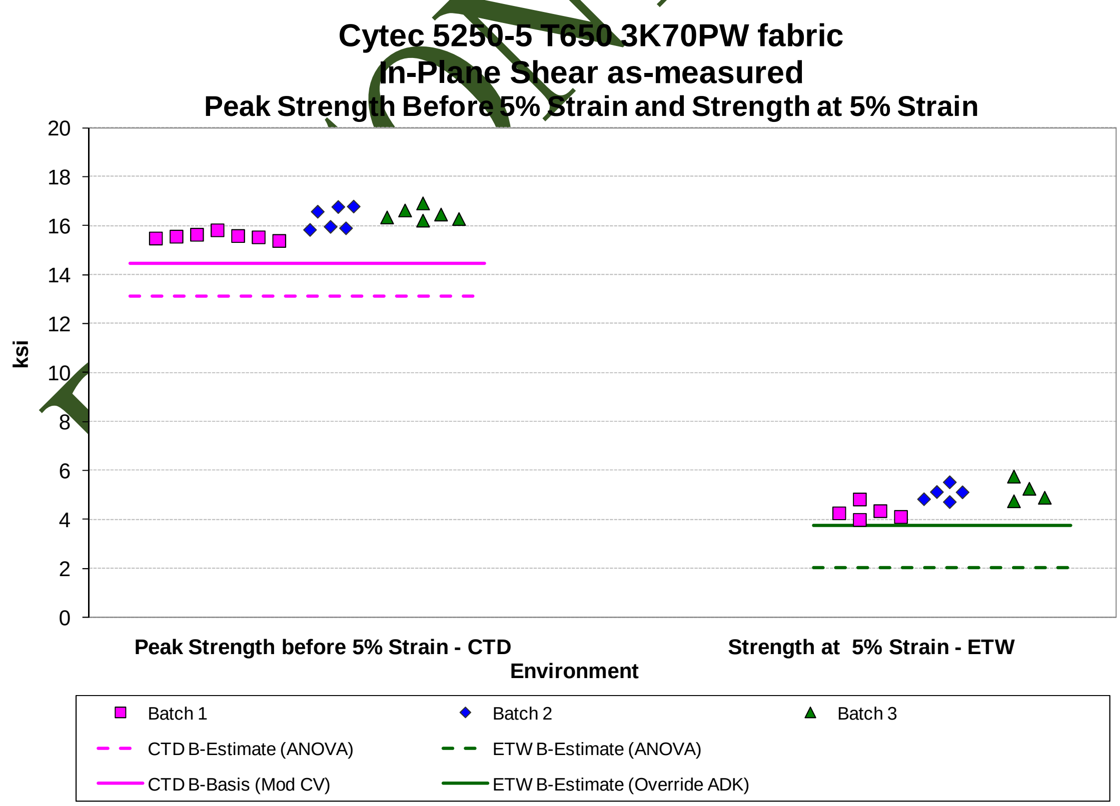

Figure 4-6: Batch plot for IPS Peak Strength Before 5% Strain and Strength at 5% Strain as-measured

In-Plane Shear Strength Basis Values and Statistics					
	0.2% Offset Strength			Peak Strength Before 5%	Strength at 5% Strain
Env	CTD	RTD	ETW	CTD	ETW
Mean	11.04	8.56	2.19	16.09	4.82
Stdev	0.14	0.17	0.23	0.50	0.52
CV	1.28	1.99	10.29	3.12	10.78
Mod CV	6.00	6.00	10.29	6.00	10.78
Min	10.84	8.09	1.83	15.38	3.99
Max	11.31	8.81	2.63	16.92	5.76
No. Batches	3	3	3	3	3
No. Spec.	19	19	21	19	14
Basis Values and Estimates					
B-basis Value	10.76	8.28			
B-Estimate			1.09	13.12	2.03
A-Estimate	10.56	8.08	0.30	11.01	0.03
Method	pooled	pooled	ANOVA	ANOVA	ANOVA
Basis Value Estimates with override of ADK test					
B-Estimate			1.76		3.73
A-Estimate			1.45		2.96
Method			Normal		Normal
Modified CV Basis Values and Estimates					
B-basis Value	9.97	7.49		14.21	
A-Estimate	9.24	6.76		12.87	
Method	pooled	pooled		Normal	

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

In-Plane Shear Modulus Statistics			
Env	CTD	RTD	ETW
Mean	0.84	0.73	0.21
Stdev	0.01	0.01	0.02
CV	1.54	1.85	11.18
Mod CV	6.00	6.00	11.18
Min	0.81	0.69	0.17
Max	0.86	0.75	0.26
No. Batches	3	3	3
No. Spec.	19	19	21

Table 4-10: Statistics for IPS Modulus Data

4.6 Short Beam Strength (SBS) Data

The Short Beam Strength data is not normalized. The CTD dataset failed the normality test. The Weibull distribution had the best fit for the data from that condition. The ETD and ETW 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 ETD and ETW 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 across environments was not acceptable due to Levene's test failure.

There were no outliers. Statistics, basis values and estimates are given for SBS data in Table 4-11. The data, B-estimates and B-basis values are shown graphically in Figure 4-7.

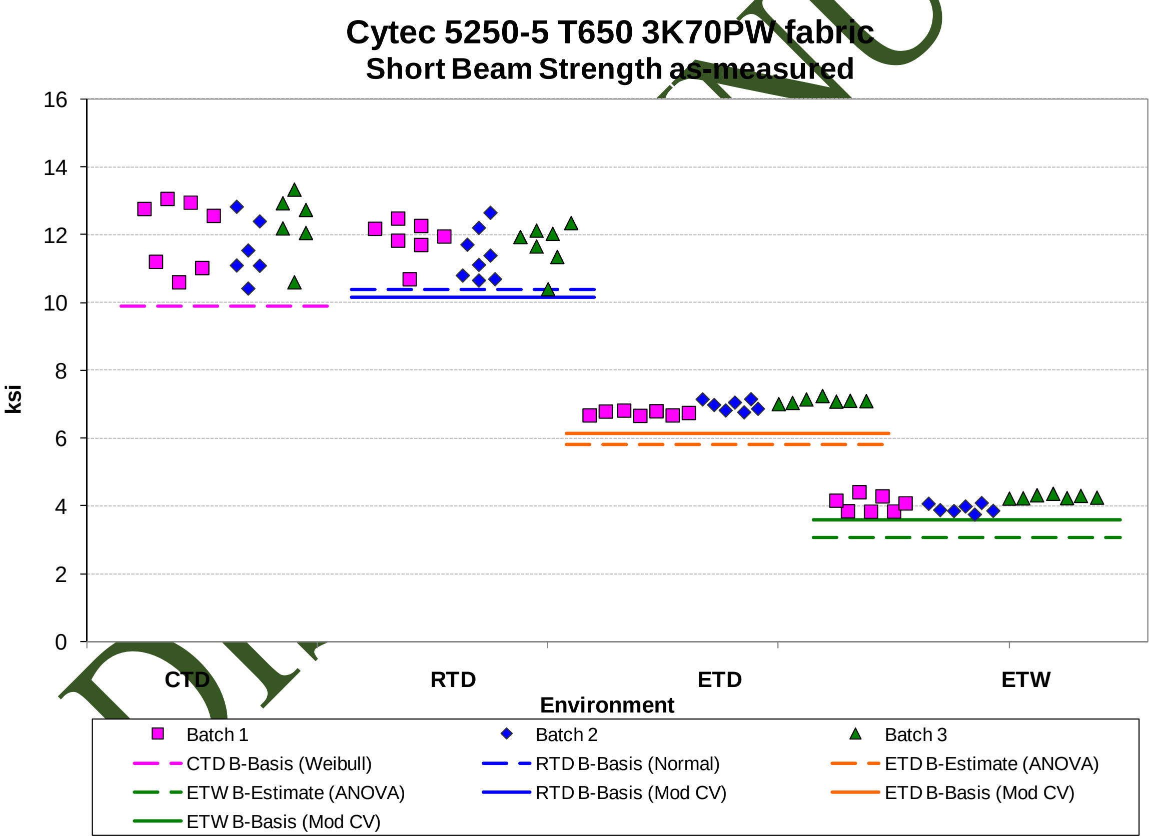

Figure 4-7: Batch plot for Short Beam Strength as-measured

Short Beam Strength (SBS) As-measured				
Env	CTD	RTD	ETD	ETW
Mean	11.97	11.65	6.94	4.09
Stdev	0.97	0.67	0.19	0.21
CV	8.08	5.71	2.68	5.08
Mod CV	8.08	6.86	6.00	6.54
Min	10.42	10.40	6.66	3.75
Max	13.34	12.65	7.25	4.41
No. Batches	3	3	3	3
No. Spec.	19	22	21	21
Basis Values and Estimates				
B-basis Value	9.88	10.39		
B-Estimate			5.81	3.06
A-Estimate	7.93	9.50	5.01	2.32
Method	Weibull	Normal	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	NA	10.14	6.15	3.58
A-Estimate	NA	9.06	5.58	3.22
Method	NA	Normal	Normal	Normal

Table 4-11: Statistics and Basis Values for Short Beam Strength Data

4.7 Quasi Isotropic Unnotched Tension Properties (UNT1)

The UNT1 data is normalized so both normalized and as-measured statistics are provided. The ETW datasets (as-measured and normalized) 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 ETW 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. The CTD and RTD data could be pooled for the basis value computations. The ETW data could be added to the pooled data for the modified CV basis value computations.

There were no outliers. Statistics, basis values and estimates are given for UNT1 strength data in Table 4-12 and for the modulus data in Table 4-13. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-8.

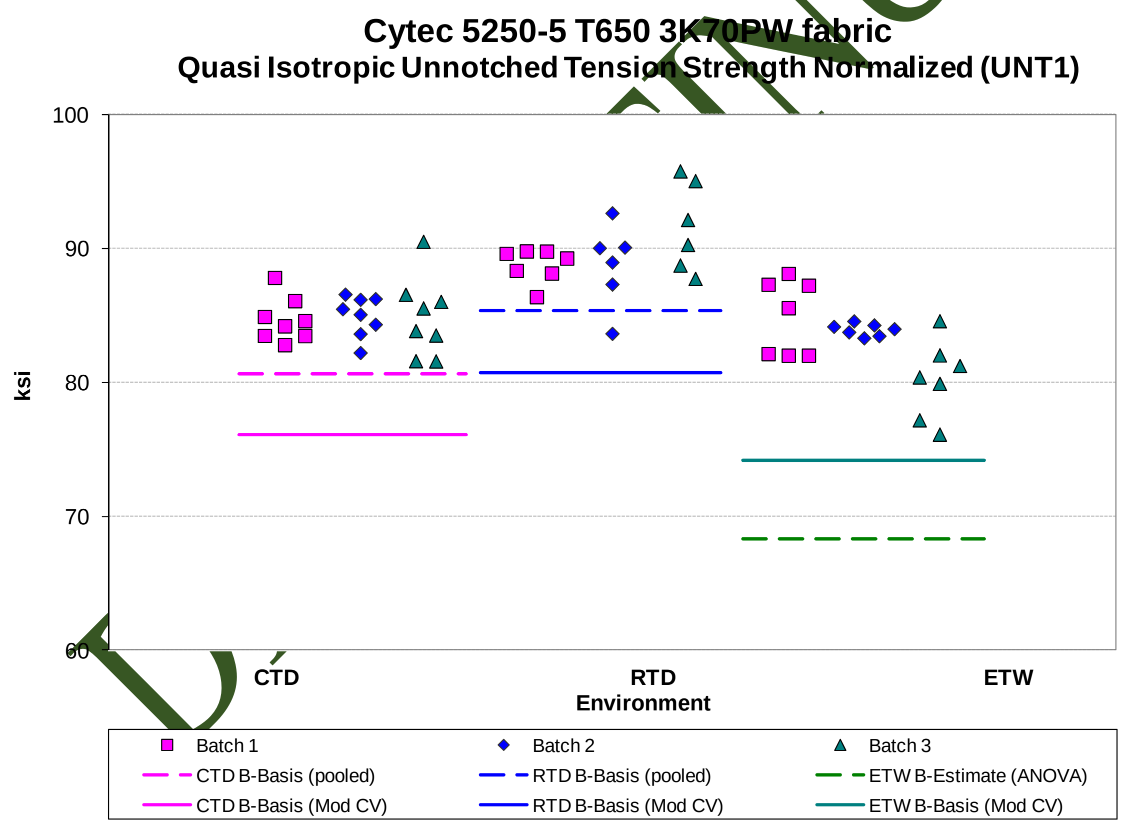

Figure 4-8: Batch Plot for UNT1 normalized strength

Unnotched Tension (UNT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	84.85	89.68	83.03	84.60	89.79	82.63
Stdev	2.04	2.83	3.03	2.09	3.01	2.64
CV	2.40	3.15	3.64	2.47	3.36	3.19
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	81.60	83.66	76.14	81.16	84.22	77.05
Max	90.52	95.78	88.13	90.42	95.85	86.26
No. Batches	3	3	3	3	3	3
No. Spec.	24	19	21	24	19	21
Basis Values and						
B-basis Value	80.63	85.37		80.16	85.26	
B-Estimate			68.31			70.70
A-Estimate	77.68	82.44	57.79	77.06	82.19	62.19
Method	pooled	pooled	ANOVA	pooled	pooled	ANOVA
Modified CV Basis						
B-basis Value	76.08	80.71	74.14	75.84	80.84	73.77
A-Estimate	70.06	74.73	68.15	69.83	74.87	67.78
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-12: Statistics and Basis Values for UNT1 Strength Data

Unnotched Tension (UNT1) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	6.92	6.77	6.17	6.90	6.78	6.14
Stdev	0.10	0.14	0.13	0.13	0.15	0.12
CV	1.39	2.13	2.10	1.87	2.21	1.93
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	6.74	6.47	5.87	6.69	6.46	5.89
Max	7.13	7.13	6.38	7.17	7.22	6.37
No. Batches	3	3	3	3	3	3
No. Spec.	24	19	21	24	19	21

Table 4-13: Statistics from UNT1 Modulus Data

4.8 “Soft” Unnotched Tension Properties (UNT2)

The UNT2 data is normalized so both normalized and as-measured statistics are provided. The CTD datasets (as-measured and normalized) and 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 these datasets were transformed according to the assumptions of the modified CV method, the as-measured RTD and the normalized CTD datasets passed the ADK test, but the as-measured CTD dataset did not. Modified CV basis values are provided for the as-measured RTD and normalized CTD datasets, but estimates only could be computed for the as-measured CTD dataset. The normalized data passed Levene's test when the data for all three conditions was transformed to match the assumptions of the modified CV method and could be pooled for the modified CV basis value computations.

There was one outlier. It was in batch three of the as-measured CTD dataset. It was an outlier only for batch three, not for the CTD condition and only for the as-measured dataset, not for the normalized dataset. It was retained for this analysis.

Statistics, basis values and estimates are given for UNT2 strength data in Table 4-14 and for the modulus data in Table 4-15. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-9.

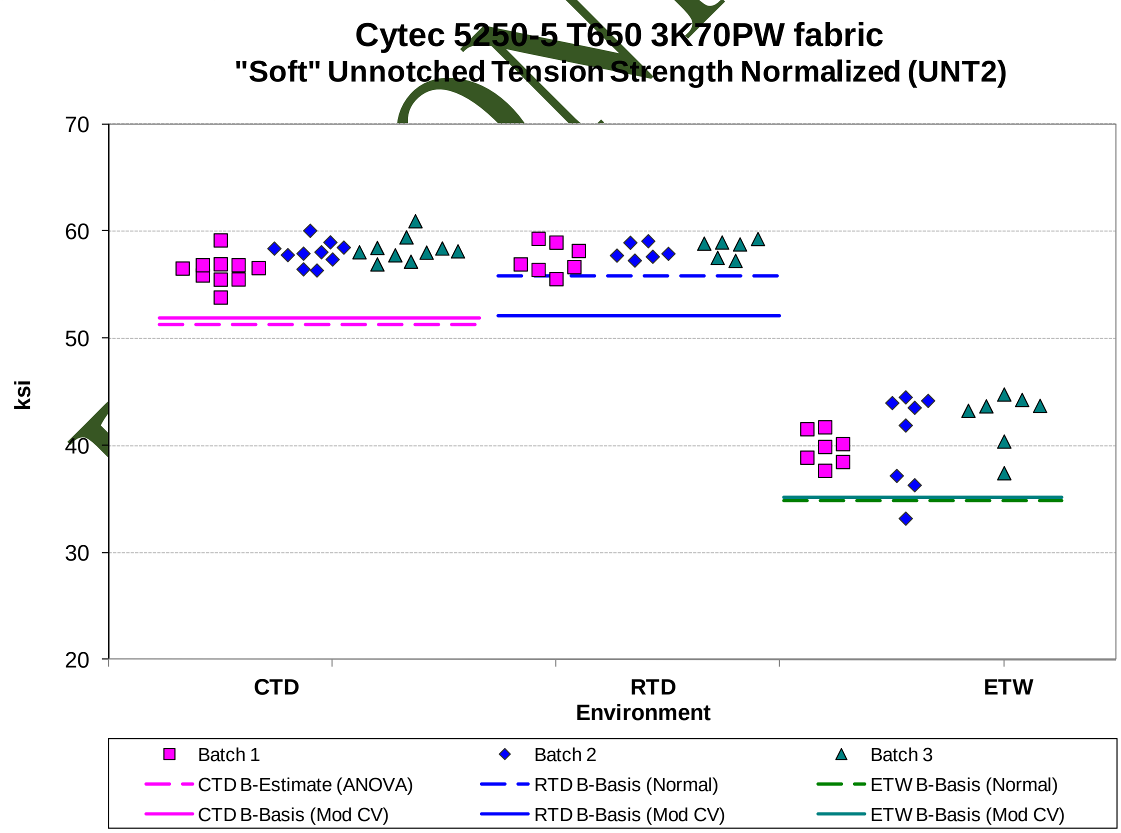

Figure 4-9: Batch Plot for UNT2 normalized strength

Unnotched Tension (UNT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	57.57	57.97	40.94	57.04	57.36	40.48
Stdev	1.46	1.10	3.23	2.09	1.49	3.24
CV	2.54	1.89	7.88	3.66	2.59	7.99
Modified CV	6.00	6.00	7.94	6.00	6.00	8.00
Min	53.83	55.56	33.20	52.50	54.22	33.31
Max	60.97	59.32	44.78	61.43	59.29	44.34
No. Batches	3	3	3	3	3	3
No. Spec.	30	19	22	30	19	22
Basis Values and						
B-basis Value		55.84	34.86			34.38
B-Estimate	51.22			44.99	48.66	
A-Estimate	46.66	54.32	30.51	36.38	42.46	30.02
Method	ANOVA	Normal	Normal	ANOVA	ANOVA	Normal
Modified CV Basis						
B-basis Value	51.91	52.07	35.13		50.66	34.37
				50.96		
A-Estimate	47.95	48.16	31.19	46.56	45.90	30.01
Method	pooled	pooled	pooled	Normal	Normal	Normal

Table 4-14: Statistics and Basis Values for UNT2 Strength Data

Unnotched Tension (UNT2) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	4.74	4.45	3.38	4.74	4.40	3.34
Stdev	0.10	0.16	0.16	0.10	0.17	0.16
CV	2.02	3.53	4.82	2.18	3.93	4.76
Modified CV	6.00	6.00	6.41	6.00	6.00	6.38
Min	4.55	4.15	3.02	4.53	4.05	3.01
Max	4.90	4.70	3.68	4.87	4.68	3.67
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	22	19	19	22

Table 4-15: Statistics from UNT2 Modulus Data

4.9 "Hard" Unnotched Tension Properties (UNT3)

The UNT3 data is normalized so both normalized and as-measured statistics are provided. The as-measured 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. The as-measured RTD and ETW datasets could not be pooled due to a failure of Levene's test.

When the as-measured 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 across environments was acceptable for the modified CV basis value computations for the as-measured data.

The normalized CTD data failed the normality test. The Weibull distribution had the best fit for the data. Modified CV basis values are not provided due to the non-normality of the CTD normalized data and the normalized data could not be pooled across environments due to the pooled dataset failing the normality test.

There were two outliers. The lowest value in batch one of the CTD condition was an outlier for both batch one and the CTD condition and in both the normalized and as-measured datasets. The lowest value in batch three of the CTD condition was an outlier for both batch three and the CTD condition. It was an outlier only for the as-measured dataset, not for the normalized dataset. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for UNT3 strength data in Table 4-16 and for the modulus data in Table 4-17. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-10.

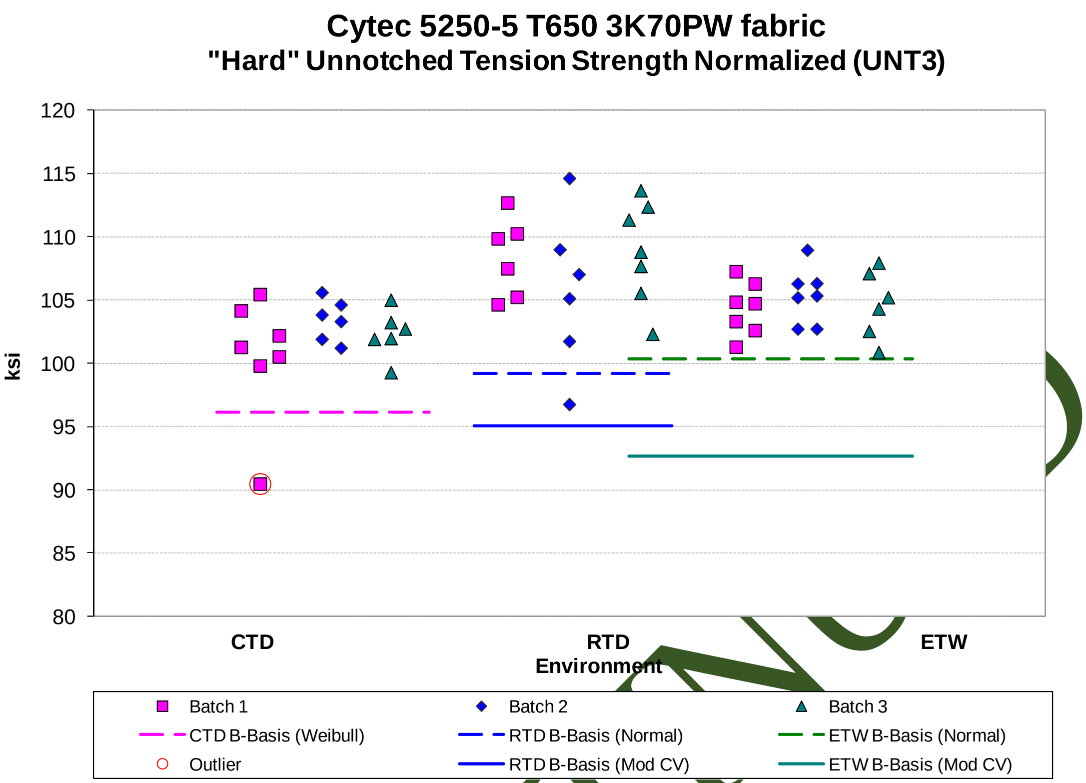

Figure 4-10: Batch Plot for UNT3 normalized strength

Unnotched Tension (UNT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	102.00	107.96	104.64	101.29	108.90	104.03
Stdev	3.34	4.46	2.24	4.18	4.86	2.59
CV	3.28	4.13	2.14	4.13	4.46	2.49
Modified CV	6.00	6.07	6.00	6.06	6.23	6.00
Min	90.45	96.73	100.83	89.82	97.46	100.26
Max	105.57	114.59	108.92	106.36	116.55	109.25
No. Batches	3	3	3	3	3	3
No. Spec.	19	18	21	19	18	21
Basis Values and						
B-basis Value	96.16	99.15	100.37		99.30	99.09
B-Estimate				86.23		
A-Estimate	89.76	92.91	97.32	75.51	92.50	95.57
Method	Weibull	Normal	Normal	ANOVA	Normal	Normal
Modified CV Basis						
B-basis Value	NA	95.03	92.68	90.09	97.64	92.94
A-Estimate	NA	85.89	84.16	82.60	90.16	85.42
Method	NA	Normal	Normal	pooled	pooled	pooled

Table 4-16: Statistics and Basis Values for UNT3 Strength Data

Unnotched Tension (UNT3) Modulus Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	8.65	8.44	8.28	8.59	8.52	8.23
Stdev	0.08	0.16	0.16	0.28	0.21	0.22
CV	0.93	1.92	1.99	3.23	2.45	2.70
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	8.48	8.16	7.95	7.67	8.21	7.82
Max	8.79	8.79	8.57	8.98	8.95	8.63
No. Batches	3	3	3	3	3	3
No. Spec.	19	18	21	19	18	21

Table 4-17: Statistics from UNT3 Modulus Data

4.10 Quasi Isotropic Unnotched Compression (UNC1)

The UNC1 data is normalized so both normalized and as-measured statistics are provided. 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 still did not pass the ADK test therefore only estimates could be computed for the as-measured RTD dataset. The normalized data has no test failures and pooling across the two environments was acceptable. Since the as-measured ETW data had a CV greater than 8%, the modified CV method could not be used for that dataset.

There was one outlier. It was in batch two of the as RTD datasets, both normalized and as-measured. It was an outlier only for batch two, not for the RTD condition. It was retained for this analysis.

Statistics, basis values and estimates are given for UNC1 strength data in Table 4-18 and for the modulus data in Table 4-19. The normalized data and B-basis values are shown graphically in Figure 4-11.

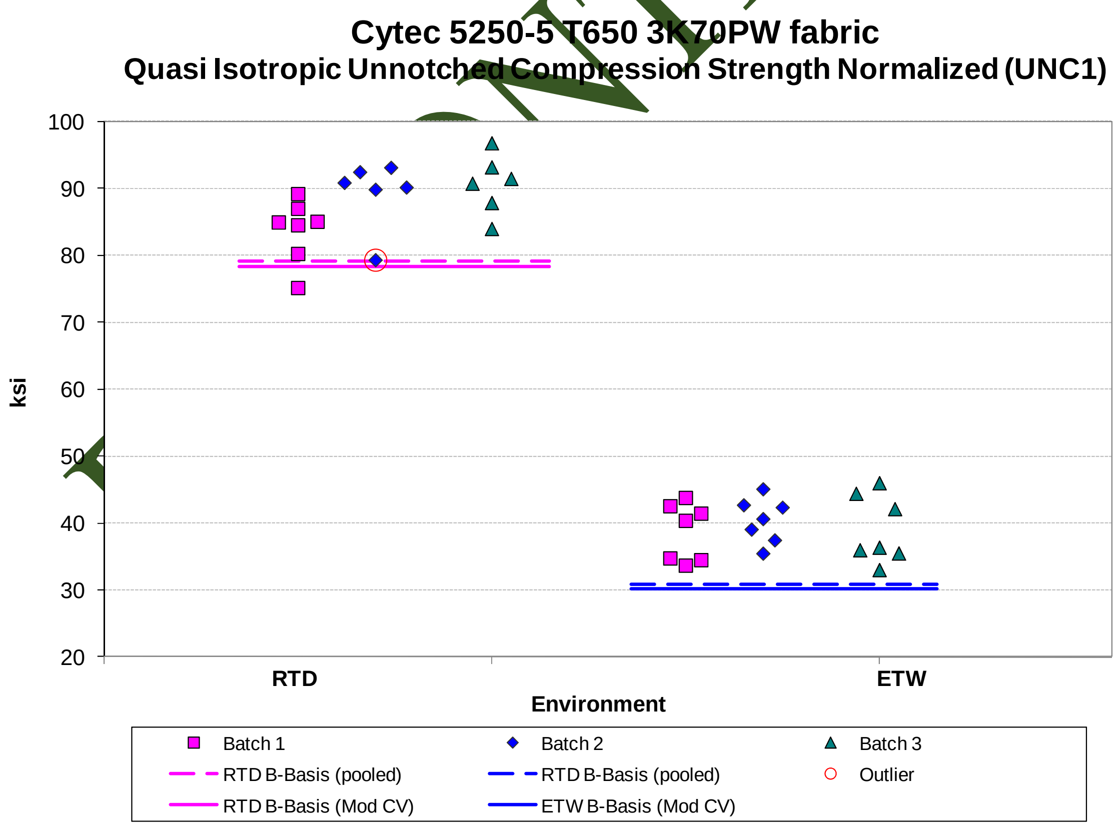

Figure 4-11: Batch plot for UNC1 normalized strength

Unnotched Compression (UNC1) Strength Basis Values				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	87.69	39.41	88.63	39.30
Stdev	5.44	4.11	6.25	4.08
CV	6.21	10.44	7.05	10.39
Modified CV	7.10	10.44	7.52	10.39
Min	75.16	33.03	75.43	33.15
Max	96.79	46.01	99.43	45.96
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and Estimates				
B-basis Value	79.09	30.88		31.52
B-Estimate			59.53	
A-Estimate	73.23	25.01	38.77	25.98
Method	pooled	pooled	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	78.31	30.11		NA
B-Estimate			75.63	
A-Estimate	71.92	23.70	66.42	NA
Method	pooled	pooled	Normal	NA

Table 4-18: Statistics and Basis Values for UNC1 Strength Data

Unnotched Compression (UNC1) Modulus				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	6.42	5.72	6.49	5.72
Stdev	0.15	0.17	0.18	0.19
CV	2.28	3.03	2.74	3.29
Modified CV	6.00	6.00	6.00	6.00
Min	6.22	5.30	6.18	5.25
Max	6.73	6.03	6.79	6.08
No. Batches	3	3	3	3
No. Spec.	20	20	20	20

Table 4-19: Statistics from UNC1 Modulus Data

4.11 “Soft” Unnotched Compression (UNC2)

The UNC2 data is normalized so both normalized and as-measured statistics are provided. There were no test failures in the normalized datasets. 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 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 across environments was acceptable for the modified CV basis value computations for the as-measured data.

There were no outliers. Statistics, basis values and estimates are given for UNC2 strength data in Table 4-20 and for the modulus data in Table 4-21. The normalized data and B-basis values are shown graphically in Figure 4-12.

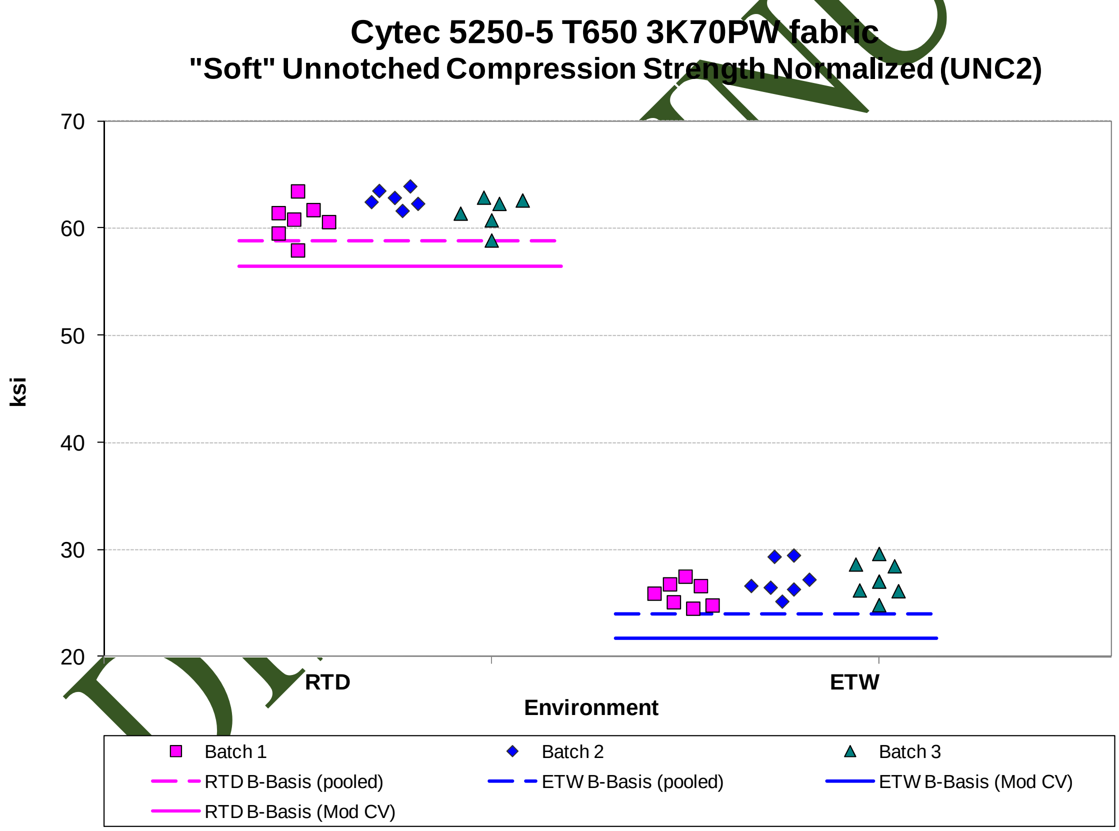

Figure 4-12: Batch plot for UNC2 normalized strength

Unnotched Compression (UNC2) Strength Basis Values				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	61.64	26.80	61.92	26.65
Stdev	1.59	1.56	2.03	1.61
CV	2.59	5.84	3.28	6.02
Modified CV	6.00	6.92	6.00	7.01
Min	57.96	24.51	56.87	24.40
Max	63.94	29.62	64.37	29.48
No. Batches	3	3	3	3
No. Spec.	19	21	19	21
Basis Values and Estimates				
B-basis Value	58.81	23.99		23.60
B-Estimate			52.45	
A-Estimate	56.87	22.05	45.69	21.42
Method	pooled	pooled	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	56.47	21.68	56.72	21.50
A-Estimate	52.95	18.14	53.18	17.95
Method	pooled	pooled	pooled	pooled

Table 4-20: Statistics and Basis Values for UNC2 Strength Data

Unnotched Compression (UNC2) Modulus				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	4.39	3.21	4.41	3.20
Stdev	0.11	0.10	0.10	0.11
CV	2.51	3.05	2.36	3.49
Modified CV	6.00	6.00	6.00	6.00
Min	4.13	3.06	4.22	3.00
Max	4.54	3.39	4.59	3.42
No. Batches	3	3	3	3
No. Spec.	19	21	19	21

Table 4-21: Statistics from UNC2 Modulus Data

4.12 “Hard” Unnotched Compression (UNC3)

The UNC3 data is normalized so both normalized and as-measured statistics are provided. The normalized RTD dataset and the as-measured ETW 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.

Both the as-measured and normalized RTD datasets had a CV greater than 8%, so the modified CV method could not be used. Additional basis value estimates were computed for this dataset by overriding the ADK test results and using the normal distribution. The as-measured ETW dataset failed the ADK test even after applying the modified CV transformation. Modified CV Basis value estimates were computed for the as-measured ETW dataset by overriding the ADK test results.

There was one outlier. It was in batch three of the as RTD datasets, both normalized and as-measured. In the as-measured data it was an outlier for both batch three and the RTD condition, but in the normalized data it was an outlier only for batch three, not for the RTD condition. It was retained for this analysis.

Statistics, basis values and estimates are given for UNC3 strength data in Table 4-22 and for the modulus data in Table 4-23. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-13.

Figure 4-13: Batch plot for UNC3 normalized strength

Unnotched Compression (UNC3) Strength Basis Values				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	82.02	42.49	83.99	43.01
Stdev	6.73	2.37	6.72	2.89
CV	8.20	5.58	8.01	6.71
Modified CV	8.20	6.79	8.01	7.35
Min	71.24	37.68	72.73	37.51
Max	98.89	46.98	103.08	48.81
No. Batches	3	3	3	3
No. Spec.	20	20	20	20
Basis Values and Estimates				
B-basis Value		37.92	71.04	
B-Estimate	57.45			28.44
A-Estimate	39.93	34.67	61.83	18.04
Method	ANOVA	Normal	Normal	ANOVA
Basis Values and Estimates with override of ADK test				
B-Estimate	69.06			
A-Estimate	59.86			
Method	Normal			
Modified CV Basis Values and Estimates				
B-basis Value		36.93		
B-Estimate				36.92
A-Estimate		32.98		32.59
Method		Normal		Normal

Table 4-22: Statistics and Basis Values for UNC3 Strength Data

Unnotched Compression (UNC3) Modulus				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	7.85	7.12	8.05	7.20
Stdev	0.11	0.20	0.19	0.25
CV	1.46	2.87	2.36	3.49
Modified CV	6.00	6.00	6.00	6.00
Min	7.62	6.49	7.68	6.45
Max	8.03	7.36	8.41	7.46
No. Batches	3	3	3	3
No. Spec.	20	20	20	20

Table 4-23: Statistics from UNC3 Modulus Data

4.13 Laminate Short Beam Strength (SBS1) Data

The Laminate Short Beam Strength data is not normalized. The ETW 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 ETW 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 across environments was not acceptable for the modified CV basis value computations for the as-measured data because the pooled dataset failed Levene's test.

There were no outliers. Statistics, basis values and estimates are given for LSBS strength data in Table 4-24. The data, B-estimates and B-basis values are shown graphically in Figure 4-14.

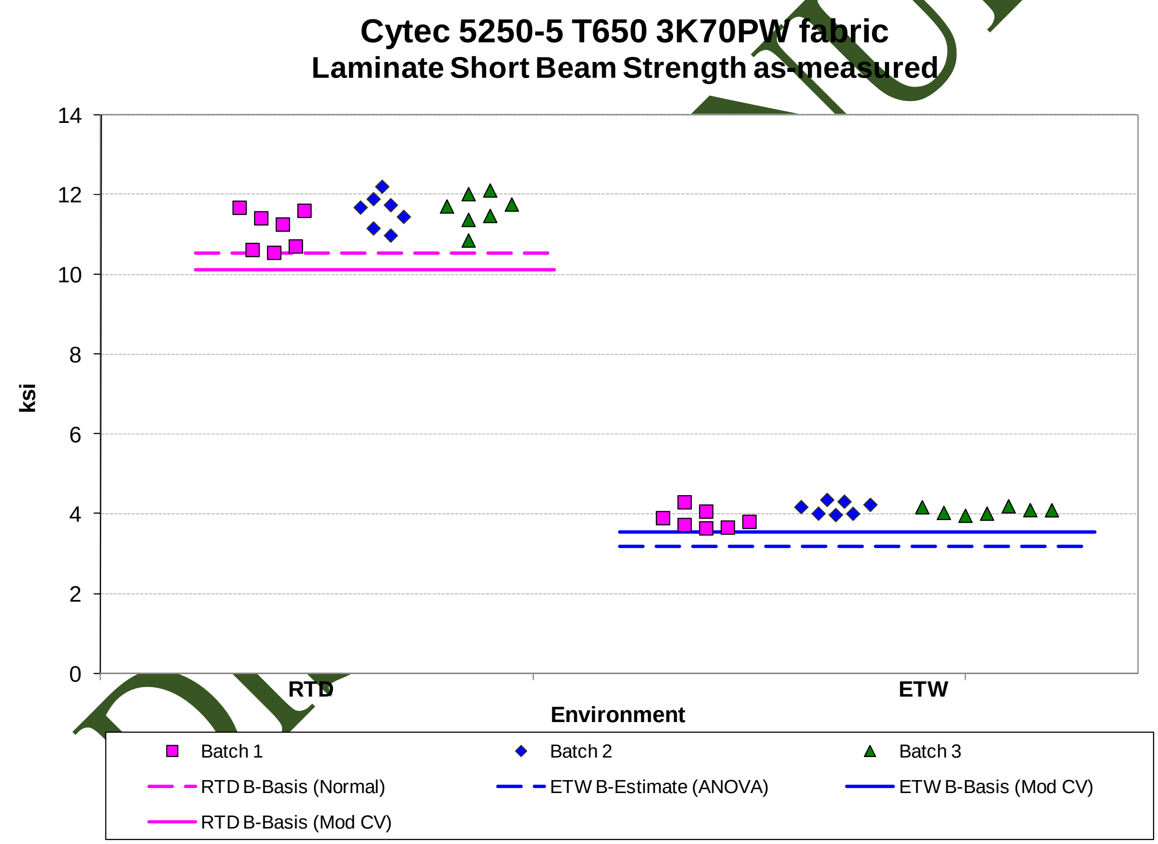

Figure 4-14: Batch plot for SBS1 strength as-measured

Laminate Short Beam Strength (SBS1)		
Env	RTD	ETW
Mean	11.44	4.04
Stdev	0.48	0.20
CV	4.22	5.04
Modified CV	6.11	6.52
Min	10.55	3.65
Max	12.21	4.36
No. Batches	3	3
No. Spec.	21	21
Basis Value Estimates		
B-basis Value	10.52	
B-Estimate		3.19
A-Estimate	9.87	2.58
Method	Normal	ANOVA
Modified CV Basis Values and Estimates		
B-basis Value	10.11	3.54
A-Estimate	9.16	3.18
Method	Normal	Normal

Table 4-24: Statistics and Basis Values for SBS1 Strength Data

4.14 Quasi Isotropic Open Hole Tension Properties (OHT1)

The OHT1 data is normalized so both normalized and as-measured statistics are provided. The as-measured data had no test failures and pooling was acceptable. The pooled normalized data failed the normality test, so pooling was not acceptable. The normalized CTD and RTD datasets both failed the normality test, so modified CV basis values are not provided.

There were no outliers. Statistics, basis values and estimates are given for OHT1 strength data in Table 4-25. The normalized data, B-basis values and B-estimates are shown graphically in Figure 4-15.

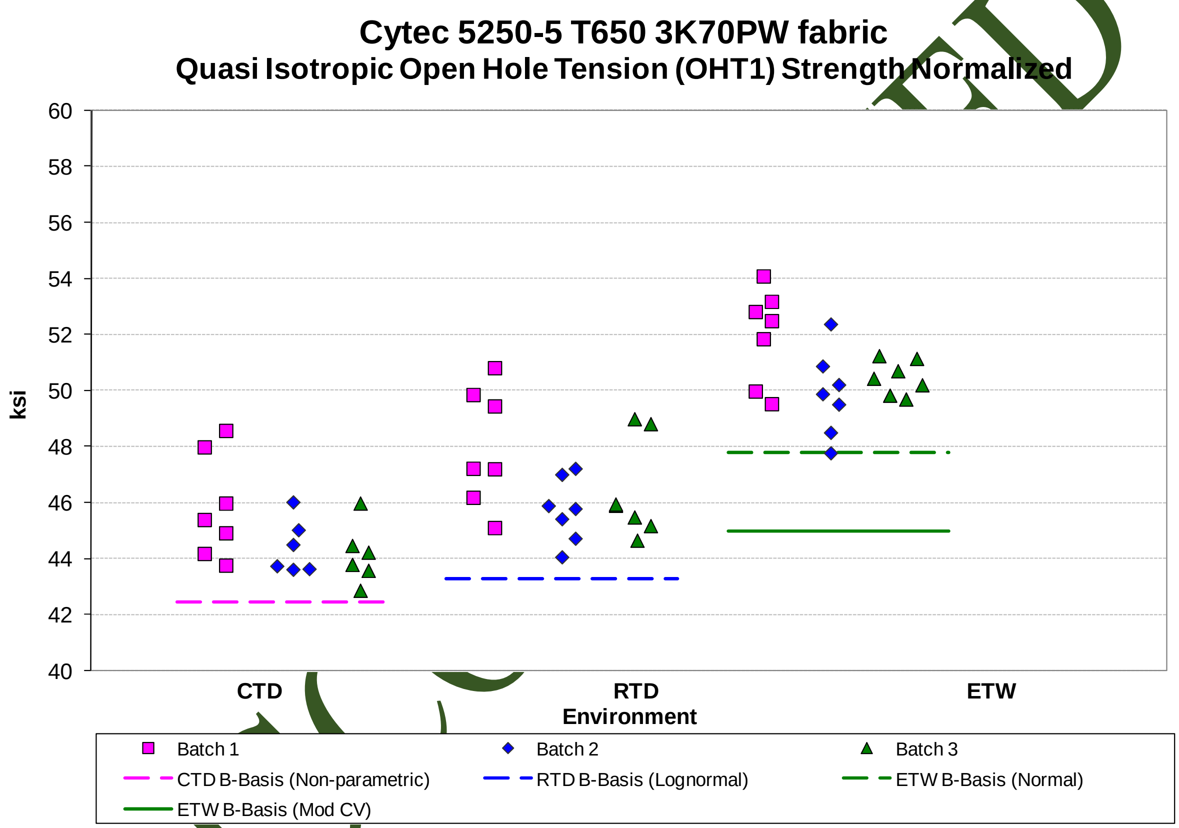

Figure 4-15: Batch Plot for OHT1 normalized strength

Open Hole Tension (OHT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	44.85	46.71	50.77	44.92	47.03	50.86
Stdev	1.51	1.88	1.57	1.49	1.79	1.26
CV	3.37	4.03	3.10	3.32	3.80	2.48
Modified CV	6.00	6.02	6.00	6.00	6.00	6.00
Min	42.87	44.06	47.77	42.61	44.55	47.87
Max	48.57	50.81	54.08	48.77	51.15	52.53
No. Batches	3	3	3	3	3	3
No. Spec.	19	21	21	19	21	21
Basis Values and Estimates						
B-basis Value	42.45	43.26	47.78	42.24	44.38	48.21
A-Estimate	35.86	40.99	45.64	40.46	42.59	46.42
Method	Non-Parametric	Lognormal	Normal	pooled	pooled	pooled
Modified CV Basis Values and/or Estimates						
B-basis Value	NA	NA	44.97	39.91	42.07	45.89
A-Estimate	NA	NA	40.83	36.56	38.71	42.54
Method	NA	NA	Normal	pooled	pooled	pooled

Table 4-25: Statistics and Basis Values for OHT1 Strength Data

4.15 “Soft” Open Hole Tension Properties (OHT2)

The OHT2 data is normalized so both normalized and as-measured statistics are provided. The normalized CTD dataset and all three of the as-measured 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 these datasets were transformed according to the assumptions of the modified CV method, all four passed the ADK test, so the modified CV basis values are provided.

Pooling across environments was acceptable for the modified CV basis value computations for the as-measured data. The normalized RTD and ETW datasets could be pooled together and the CTD dataset could be included for computing the modified CV basis values.

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

Statistics, basis values and estimates are given for OHT2 strength data in Table 4-26. The normalized data and B-basis values are shown graphically in Figure 4-16.

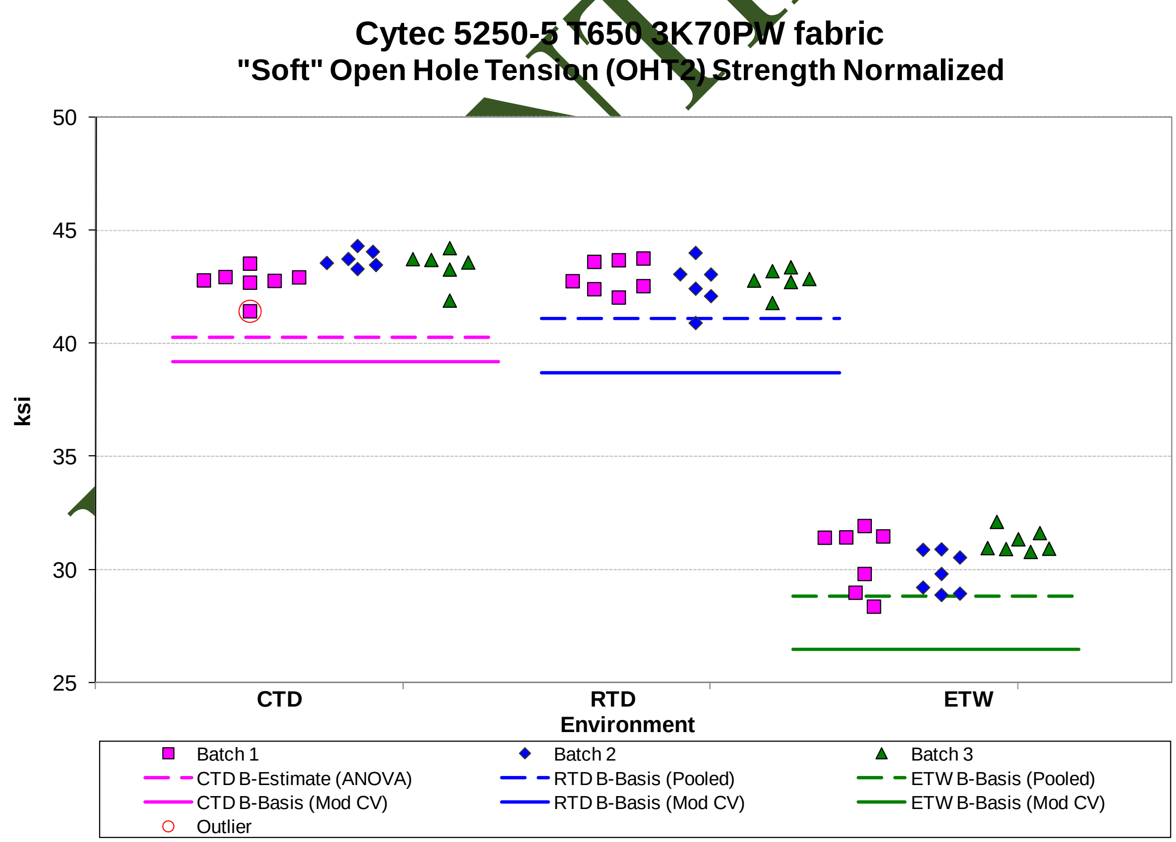

Figure 4-16: Batch Plot for OHT2 normalized strength

Open Hole Tension (OHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	43.26	42.80	30.54	43.00	43.12	30.37
Stdev	0.74	0.76	1.11	1.30	0.96	1.28
CV	1.71	1.78	3.64	3.03	2.23	4.21
Modified CV	6.00	6.00	6.00	6.00	6.00	6.11
Min	41.43	40.91	28.38	39.99	41.06	27.74
Max	44.31	44.01	32.12	44.61	44.89	32.42
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	21	19	19	21
Basis Values and Estimates						
B-basis Value		41.07	28.83			
B-Estimate	40.24			35.25	38.54	23.91
A-Estimate	38.08	39.89	27.65	29.72	35.27	19.30
Method	ANOVA	pooled	pooled	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	39.16	38.69	26.48	38.88	39.00	26.29
A-Estimate	36.41	35.95	23.73	36.13	36.25	23.53
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-26: Statistics and Basis Values for OHT2 Strength Data

4.16 "Hard" Open Hole Tension Properties (OHT3)

The OHT3 data is normalized so both normalized and as-measured statistics are provided. There were no test failures in the as-measured datasets. The normalized ETW 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 ETW 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 across environments was acceptable for the normalized CTD and RTD datasets and the ETW dataset could be included in the pooling for the modified CV basis value computations.

There were two outliers. The highest value in batch two of the CTD datasets was an outlier only for batch two, not for the CTD condition. It was an outlier for both the normalized and the as-measured CTD datasets. The highest value in batch one of the as-measured RTD dataset was an outlier for batch one, not for the RTD condition and only for the as-measured RTD dataset, not for the normalized RTD dataset. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for OHT3 strength data in Table 4-27. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-17.

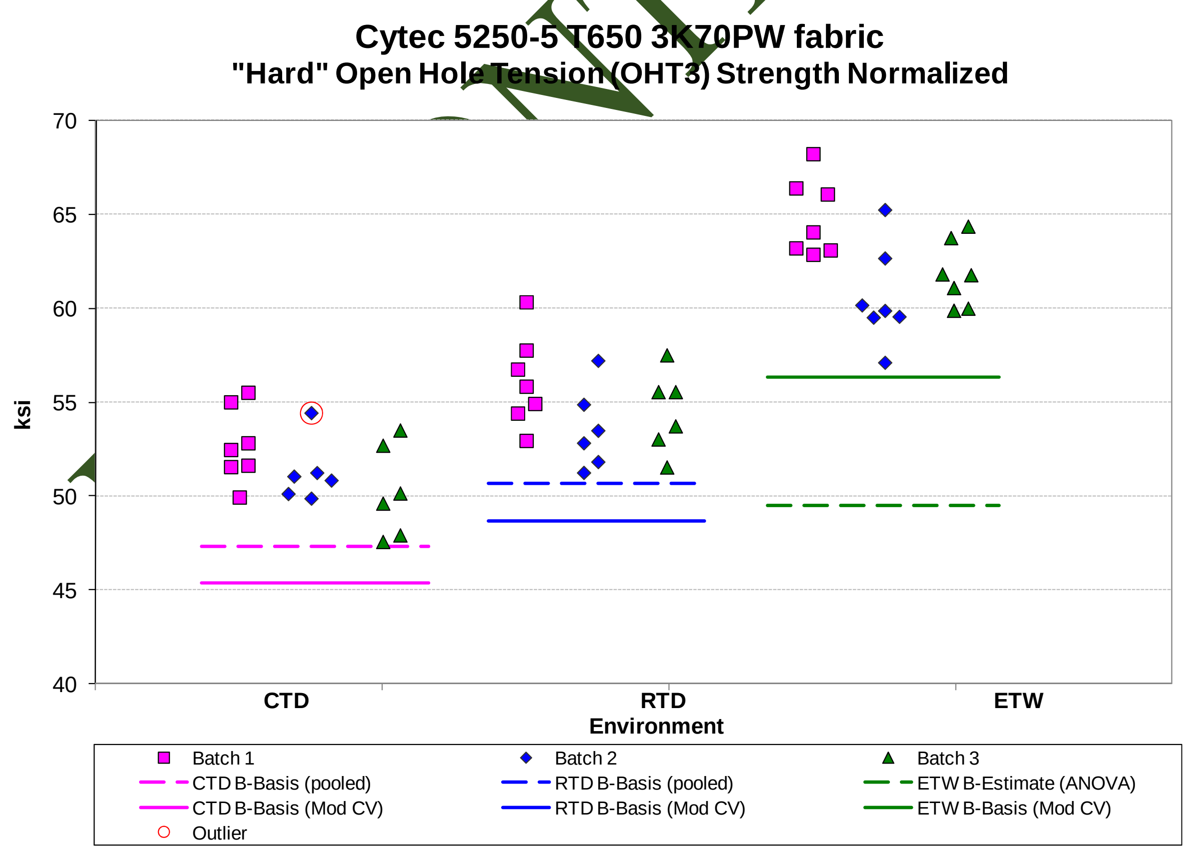

Figure 4-17: Batch Plot for OHT3 normalized strength

Open Hole Tension (OHT3) Strength (ksi) Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	51.48	54.82	62.42	51.16	55.33	62.21
Stdev	2.19	2.40	2.75	2.25	2.48	2.37
CV	4.25	4.38	4.41	4.40	4.47	3.81
Modified CV	6.13	6.19	6.20	6.20	6.24	6.00
Min	47.59	51.26	57.12	47.57	52.40	57.28
Max	55.52	60.33	68.22	55.82	61.44	66.76
No. Batches	3	3	3	3	3	3
No. Spec.	19	19	21	19	19	21
Basis Value Estimates						
B-basis Value	47.34	50.67		47.01	51.19	58.10
B-Estimate			49.47			
A-Estimate	44.50	47.84	40.23	44.23	48.41	55.32
Method	pooled	pooled	ANOVA	pooled	pooled	pooled
Modified CV Basis Values and Estimates						
B-basis Value	45.35	48.68	56.34	45.08	49.26	56.19
A-Estimate	41.24	44.58	52.23	41.01	45.19	52.11
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-27: Statistics and Basis Values for OHT3 Strength Data

4.17 Quasi Isotropic Filled Hole Tension (FHT1)

The FHT1 data is normalized so both normalized and as-measured statistics are provided. The as-measured datasets failed Levene's test so pooling was not acceptable, but after applying the modified CV transform to the three datasets, they passed Levene's so pooling the three environments was acceptable for computing the modified CV basis values.

The normalized ETW 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 ETW 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 across environments was acceptable for the normalized CTD and RTD datasets and the ETW dataset could be included in the pooling for the modified CV basis value computations.

There were two outliers. One outlier was the highest value in batch two of the normalized CTD dataset. It was an outlier only for batch two, not for the CTD condition. It was an outlier only for the normalized data, not for the as-measured data. The second outlier was the lowest value in batch two of the ETW data, both normalized and as-measured. It was an outlier only for batch two, not for the ETW condition. It was retained for this analysis.

Statistics, basis values and estimates are given for FHT1 strength data in Table 4-28. The normalized data and B-basis values are shown graphically in Figure 4-18.

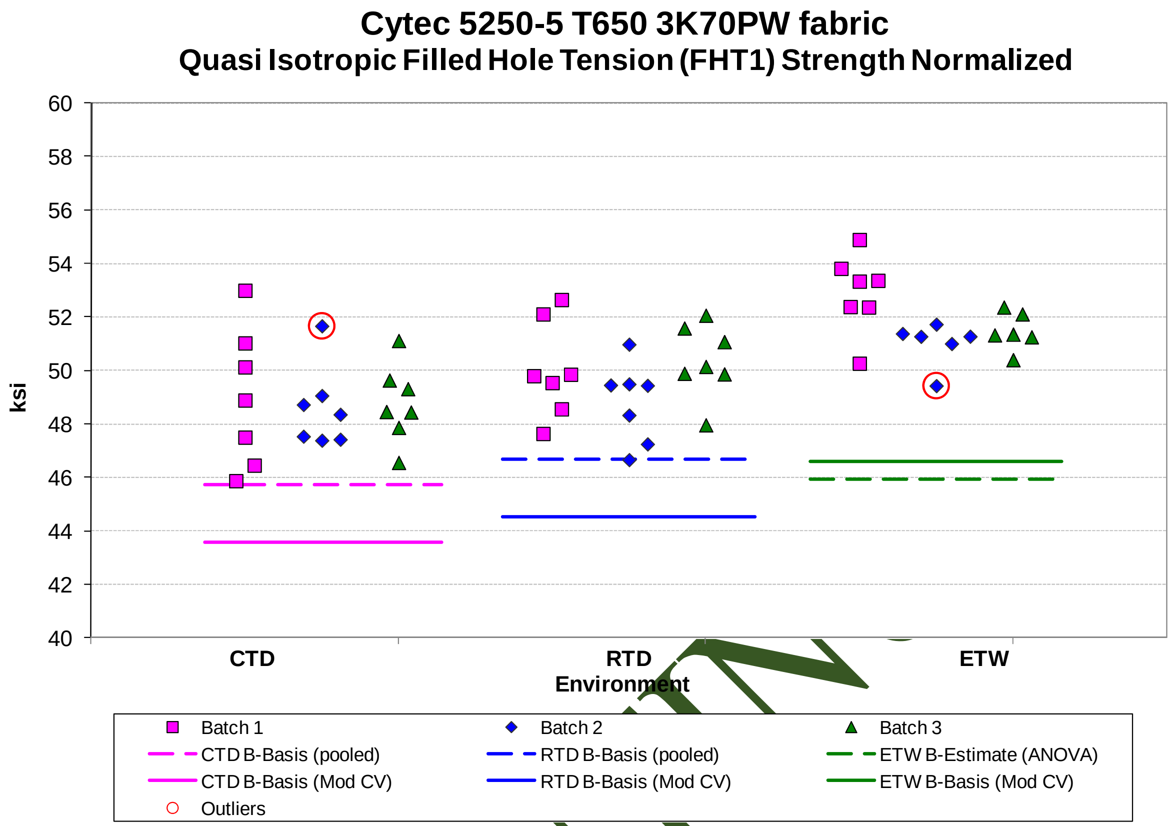

Figure 4-18: Batch plot for FHT1 normalized strength

Filled Hole Tension (FHT1) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	48.78	49.73	51.86	48.90	50.24	51.73
Stdev	1.82	1.63	1.32	2.18	1.93	1.05
CV	3.74	3.28	2.55	4.47	3.85	2.03
Modified CV	6.00	6.00	6.00	6.23	6.00	6.00
Min	45.87	46.66	49.43	45.38	47.00	49.54
Max	52.99	52.65	54.89	53.78	53.39	53.54
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	19	21	21	19
Basis Values and Estimates						
B-basis Value	45.71	46.66		44.74	46.55	49.68
B-Estimate			45.93			
A-Estimate	43.60	44.55	41.71	41.78	43.92	48.23
Method	pooled	pooled	ANOVA	Normal	Normal	Normal
Modified CV Basis Values and Estimates						
B-basis Value	43.58	44.52	46.60	43.61	44.95	46.39
A-Estimate	40.06	41.00	43.09	40.04	41.37	42.82
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-28: Statistics and Basis Values for FHT1 Strength Data

4.18 "Soft" Filled Hole Tension (FHT2)

The FHT2 data is normalized so both normalized and as-measured statistics are provided. There were no test failures in the normalized datasets.

The as-measured datasets for all three 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 datasets were transformed according to the assumptions of the modified CV method, all three passed the ADK test, so the modified CV basis values are provided and pooling across environments was acceptable for the modified CV basis value computations.

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

Statistics, basis values and estimates are given for FHT2 strength data in Table 4-29. The normalized data and the B-basis values are shown graphically in Figure 4-19.

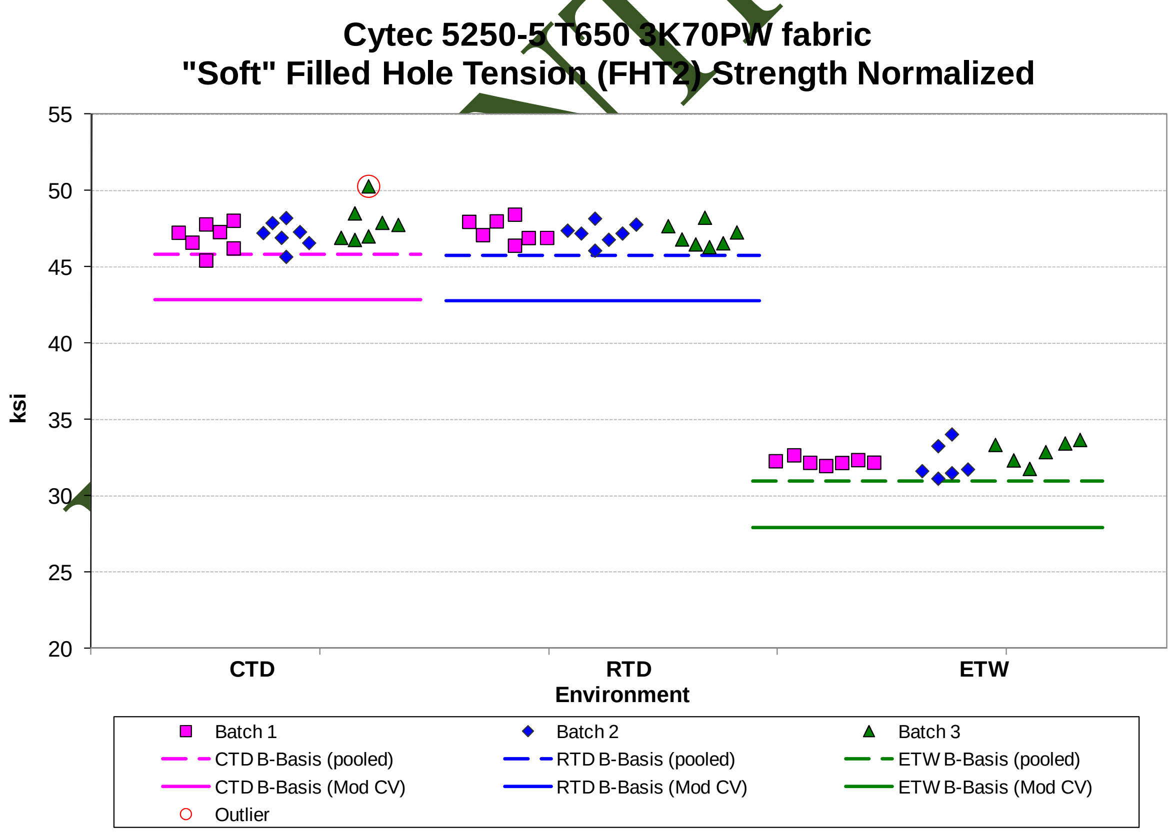

Figure 4-19: Batch plot for FHT2 normalized strength

Filled Hole Tension (FHT2) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	47.31	47.22	32.46	47.40	47.58	32.28
Stdev	1.05	0.69	0.80	1.59	1.22	1.05
CV	2.21	1.46	2.46	3.36	2.56	3.25
Modified CV	6.00	6.00	6.00	6.00	6.00	6.00
Min	45.43	46.07	31.15	44.86	45.75	31.08
Max	50.29	48.43	34.04	51.21	49.75	34.20
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	19	21	21	19
Basis Values and Estimates						
B-basis Value	45.82	45.73	30.96			
B-Estimate				38.52	42.10	26.90
A-Estimate	44.81	44.72	29.95	32.17	38.20	23.06
Method	pooled	pooled	pooled	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-basis Value	42.82	42.73	27.93	42.90	43.07	27.73
A-Estimate	39.78	39.69	24.90	39.85	40.02	24.69
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-29: Statistics and Basis Values for FHT2 Strength Data

4.19 "Hard" Filled Hole Tension (FHT3)

The FHT3 data is normalized so both normalized and as-measured statistics are provided. The normalized datasets had no test failures. 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 and pooling across the environments was acceptable for the modified CV basis value computations.

There were two outliers. Both outliers were in the as-measured datasets but not the corresponding normalized dataset. The lowest value in batch one of the as-measured CTD dataset and the largest value in batch one of the as-measured RTD dataset were outliers for batch one but not for their respective conditions. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for FHT3 strength data in Table 4-30. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-20.

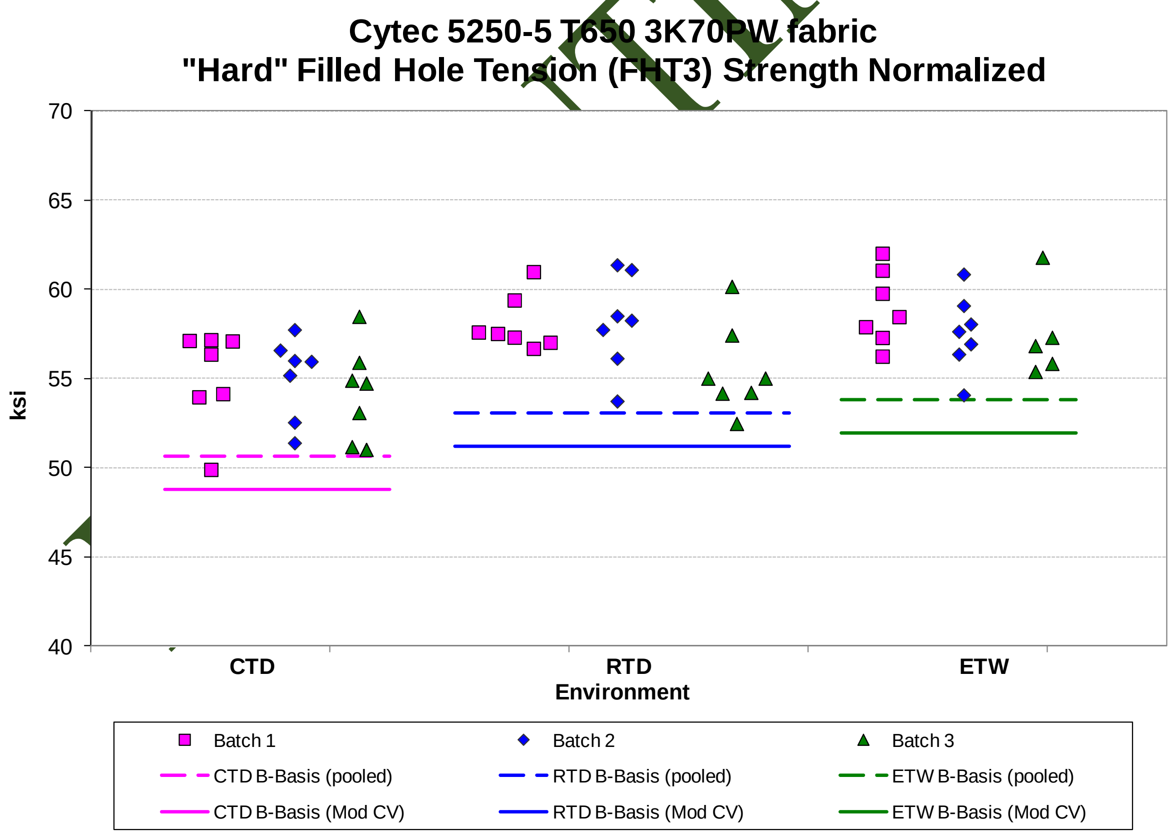

Figure 4-20: Batch plot for FHT3 normalized strength

Filled Hole Tension (FHT3) Strength Basis Values and Statistics						
	Normalized			As-measured		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	54.78	57.23	58.04	55.11	57.90	57.87
Stdev	2.45	2.52	2.22	3.03	2.93	2.16
CV	4.48	4.41	3.82	5.50	5.06	3.73
Modified CV	6.24	6.20	6.00	6.75	6.53	6.00
Min	49.90	52.47	54.07	48.19	53.33	54.69
Max	58.47	61.36	62.01	60.14	64.48	61.97
No. Batches	3	3	3	3	3	3
No. Spec.	21	21	19	21	21	19
Basis Values and Estimates						
B-basis Value	50.61	53.06	53.83	49.34		53.66
B-Estimate					45.85	
A-Estimate	47.79	50.24	51.02	45.23	37.25	50.67
Method	pooled	pooled	pooled	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates						
B-basis Value	48.75	51.19	51.95	48.76	51.55	51.46
A-Estimate	44.66	47.11	47.88	44.47	47.26	47.18
Method	pooled	pooled	pooled	pooled	pooled	pooled

Table 4-30: Statistics and Basis Values for FHT3 Strength Data

4.20 Quasi Isotropic Open Hole Compression (OHC1)

The OHC1 data is normalized so both normalized and as-measured statistics are provided. The normalized and as-measured ETW 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 ETW datasets were transformed according to the assumptions of the modified CV method, they still did not pass the ADK test therefore only estimates could be computed for the ETW datasets. Since the as-measured ETW data had a CV greater than 8%, the modified CV method could not be used. Basis value estimates were computed for the ETW datasets by overriding the ADK test results and using the normal distribution.

There were two outliers. Both outliers were in the as-measured RTD dataset but not the normalized RTD dataset. The largest values in both batch one and batch two were outliers for their respective batches but not for the RTD condition. Both outliers were retained for this analysis.

Statistics, B-basis values and estimates are given for OHC1 strength data in Table 4-31. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-21.

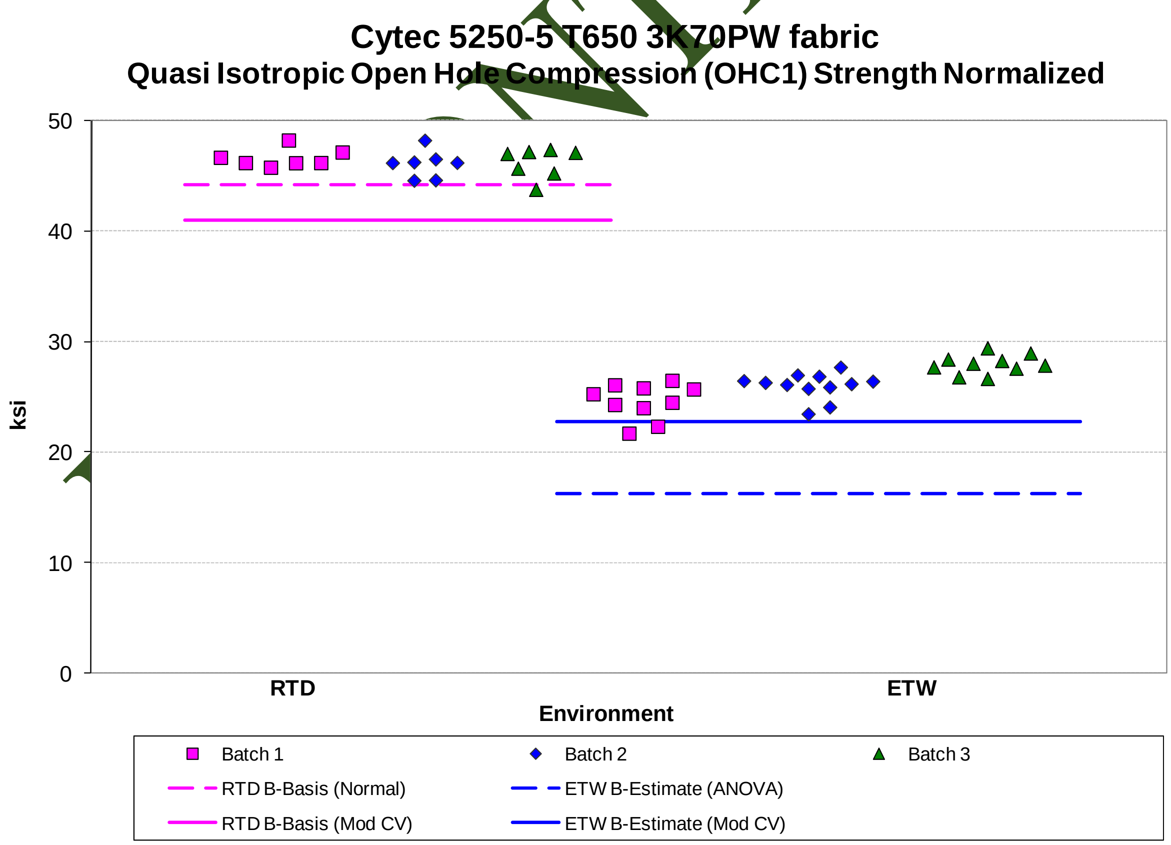

Figure 4-21: Batch plot for OHC1 normalized strength

Open Hole Compression (OHC1) Strength Basis Values				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	46.29	26.19	45.96	26.24
Stdev	1.13	1.81	1.08	2.32
CV	2.43	6.90	2.36	8.83
Modified CV	6.00	7.45	6.00	8.83
Min	43.76	21.71	44.31	20.89
Max	48.21	29.42	48.71	30.35
No. Batches	3	3	3	3
No. Spec.	21	32	21	32
Basis Values and Estimates				
B-basis Value	44.14		43.90	
B-Estimate		16.20		12.54
A-Estimate	42.62	9.06	42.43	2.75
Method	Normal	ANOVA	Normal	ANOVA
Basis Values and Estimates with override of ADK test				
B-Estimate				22.17
A-Estimate				19.22
Method				Normal
Modified CV Basis Values and Estimates				
B-basis Value	41.00		40.71	
B-Estimate		22.76		
A-Estimate	37.23	20.27	36.96	
Method	Normal	Normal	Normal	

Table 4-31: Statistics and Basis Values for OHC1 Strength Data

4.21 “Soft” Open Hole Compression (OHC2)

The OHC2 data is normalized so both normalized and as-measured statistics are provided. The normalized RTD dataset and both the normalized and the as-measured ETW 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 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. When the ETW datasets were transformed according to the assumptions of the modified CV method, they still did not pass the ADK test therefore only estimates could be computed for the ETW datasets.

There were two outliers, both in the ETW condition. The lowest value in batch one of both the normalized and the as-measured ETW datasets was an outlier for the ETW condition. It was not an outlier for batch one. The largest value in batch two of the as-measured ETW dataset was an outlier for batch two, but not for the ETW condition. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for OHC2 strength data in Table 4-32. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-22.

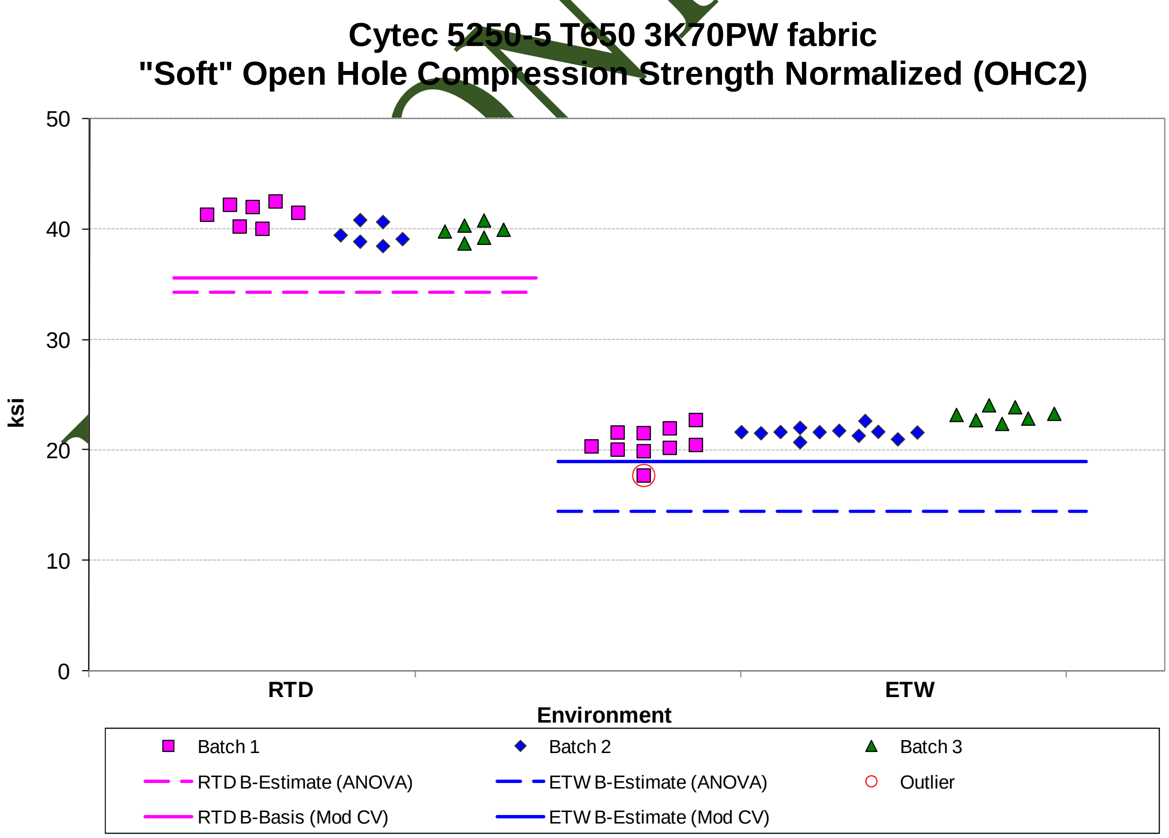

Figure 4-22: Batch plot for OHC2 normalized strength

Open Hole Compression (OHC2) Strength Basis Values and				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	40.33	21.68	40.62	21.79
Stdev	1.21	1.32	0.91	1.61
CV	2.99	6.10	2.23	7.39
Modified CV	6.00	7.05	6.00	7.70
Min	38.49	17.74	38.94	17.12
Max	42.53	24.08	42.00	24.72
No. Batches	3	3	3	3
No. Spec.	19	29	19	29
Basis Values and Estimates				
B-basis Value			38.85	
B-Estimate	34.26	14.47		11.88
A-Estimate	29.94	9.30	37.60	4.81
Method	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values and Estimates				
B-basis Value	35.61		35.87	
B-Estimate		18.95		18.79
A-Estimate	32.27	16.98	32.50	16.62
Method	Normal	Normal	Normal	Normal

Table 4-32: Statistics and Basis Values for OHC2 Strength Data

4.22 "Hard" Open Hole Compression (OHC3)

The OHC3 data is normalized so both normalized and as-measured statistics are provided. The pooled as-measured data failed the normality test so pooling across the environments was not acceptable for the as-measured data. There were no test failures in the normalized data. Since the as-measured ETW data had a CV greater than 8%, the modified CV method could not be used.

There were no outliers. Statistics, basis values and estimates are given for OHC3 strength data in Table 4-33. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-23.

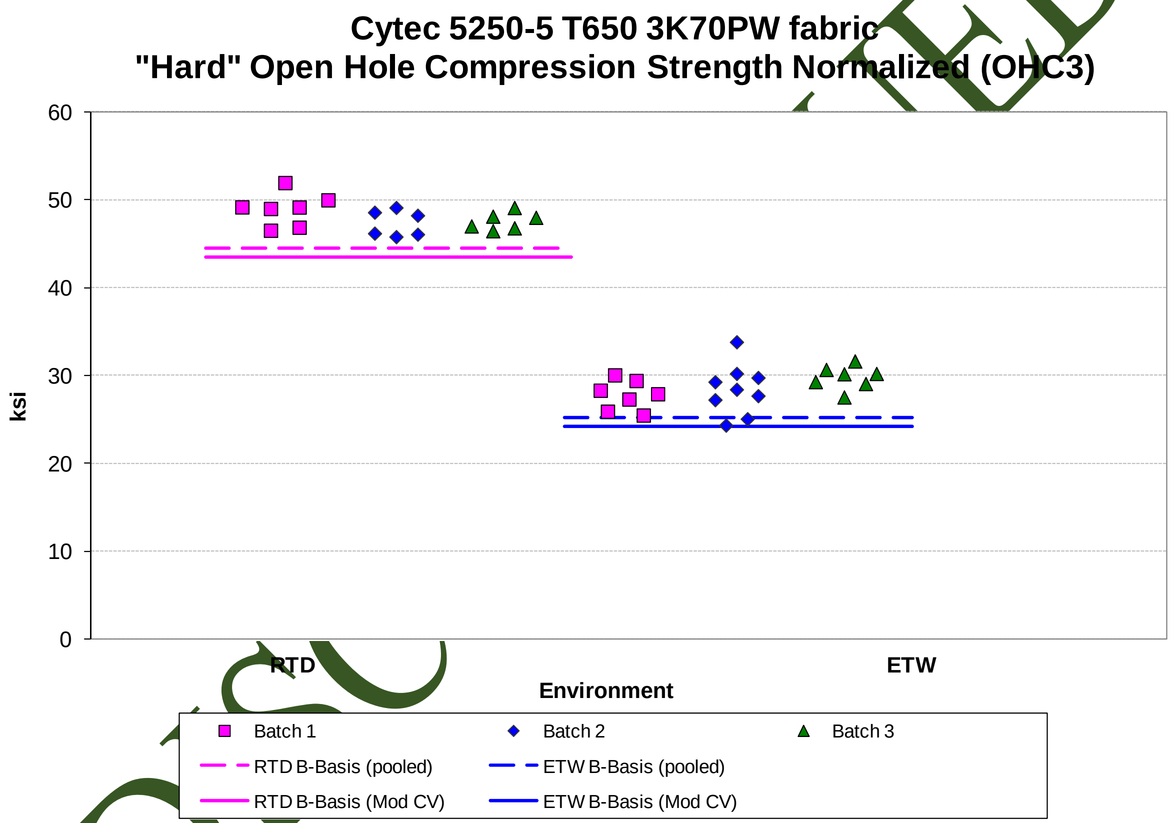

Figure 4-23: Batch plot for OHC3 normalized strength

Open Hole Compression (OHC3) Strength Basis Values and				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	48.00	28.65	48.68	29.00
Stdev	1.60	2.21	1.10	2.44
CV	3.34	7.71	2.25	8.43
Modified CV	6.00	7.86	6.00	8.43
Min	45.80	24.34	46.95	24.55
Max	51.95	33.82	50.86	33.94
No. Batches	3	3	3	3
No. Spec.	19	23	19	23
Basis Values and Estimates				
B-basis Value	44.50	25.20	46.54	24.44
A-Estimate	42.11	22.80	45.02	21.17
Method	pooled	pooled	Normal	Normal
Modified CV Basis Values and Estimates				
B-basis Value	43.44	24.16	42.99	NA
A-Estimate	40.33	21.03	38.95	NA
Method	pooled	pooled	Normal	NA

Table 4-33: Statistics and Basis Values for OHC3 Strength Data

4.23 Quasi Isotropic Filled Hole Compression (FHC1)

The FHC1 data is normalized so both normalized and as-measured statistics are provided. The RTD data had only 13 specimens from two batches available, so only estimates could be provided for that condition. The normalized and as-measured 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.

The ETW datasets failed the normality test. The lognormal distribution had an adequate fit to the normalized ETW data, but the as-measured ETW data did not adequately fit any of the tested distribution so the non-parametric method was used to compute the basis values. In addition to the non-normality, the ETW datasets had a CV over 8%, so modified CV basis values are not provided.

There were no outliers. Statistics, basis values and estimates are given for FHC1 strength data in Table 4-34. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-24.

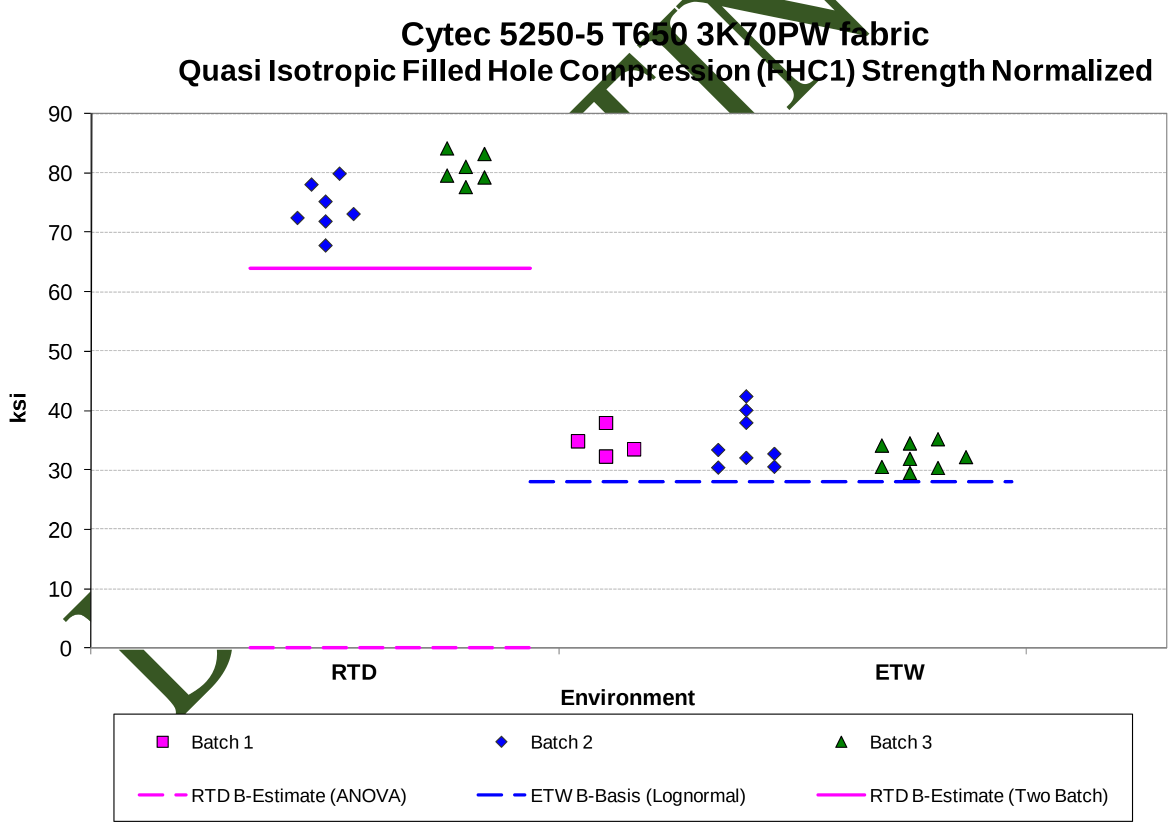

Figure 4-24: Batch plot for FHC1 normalized strength

Filled Hole Compression (FHC1) Strength Basis Values and				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	77.21	33.87	79.31	34.21
Stdev	4.81	3.45	4.94	3.45
CV	6.23	10.20	6.22	10.08
Modified CV	8.00	10.20	8.00	10.08
Min	67.85	29.55	70.19	30.33
Max	84.19	42.44	87.42	42.66
No. Batches	2	3	2	3
No. Spec.	13	20	13	20
Basis Values and Estimates				
B-basis Value		27.91		29.66
B-Estimate	0.00		0.00	
A-Estimate	NA	24.41	NA	19.03
Method	ANOVA	Lognormal	ANOVA	Non-Parametric
Modified CV Basis Values and Estimates				
B-basis Value		NA		NA
B-Estimate	63.89		65.63	
A-Estimate	54.60	NA	56.09	NA
Method	Two Batch	NA	Two Batch	NA

Table 4-34: Statistics and Basis Values for FHC1 Strength Data

4.24 “Soft” Filled Hole Compression (FHC2)

The FHC2 data is normalized so both normalized and as-measured statistics are provided. There was insufficient data for the ETW condition for basis value computations to meet the requirements of CMH-17, therefore only estimates are available for ETW condition and the ETW condition data could not be pooled with the RTD condition data.

The as-measured RTD dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability. When as-measured RTD dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test.

The as-measured ETW dataset had a CV greater than 8%, so the modified CV method could not be used. Even though there were specimens available from three batches for the normalized ETW dataset, due to the small number of specimens available the modified CV basis values were computed per section 2.3 rather than section 2.1.4, which sets the CV to 8% rather than 7.87% for the modified CV basis value computations.

There were no outliers. Statistics, basis values and estimates are given for FHC2 strength data in Table 4-35. The normalized data and the B-basis values are shown graphically in Figure 4-25.

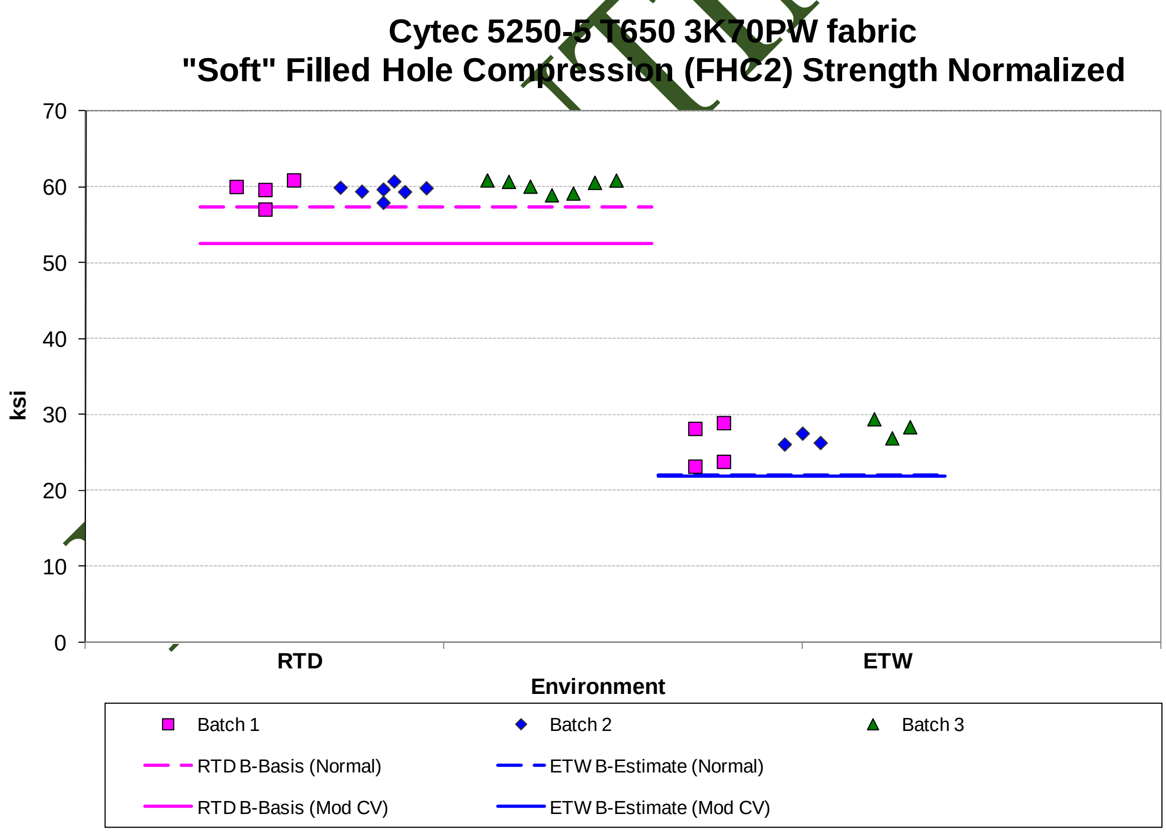

Figure 4-25: Batch plot for FHC2 normalized strength

Filled Hole Compression (FHC2) Strength Basis Values and				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	59.55	26.88	59.79	26.83
Stdev	1.11	2.08	1.43	2.30
CV	1.87	7.73	2.39	8.56
Modified CV	6.00	8.00	6.00	8.56
Min	57.04	23.19	56.80	22.56
Max	60.87	29.42	62.00	29.86
No. Batches	3	3	3	3
No. Spec.	18	10	18	10
Basis Values and Estimates				
B-basis Value	57.36			
B-Estimate		21.98	52.34	21.42
A-Estimate	55.81	18.60	47.02	17.69
Method	Normal	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-basis Value	52.50		52.71	
B-Estimate		21.81		NA
A-Estimate	47.51	18.31	47.70	NA
Method	Normal	Normal	Normal	NA

Table 4-35: Statistics and Basis Values for FHC2 Strength Data

4.25 “Hard” Filled Hole Compression (FHC3)

The FHC3 data is normalized so both normalized and as-measured statistics are provided. There was insufficient data for basis value computations to meet the requirements of CMH-17, therefore only estimates are available for FHC3 test results.

The as-measured RTD dataset failed the Anderson Darling k-sample test (ADK test) for batch to batch variability. When as-measured RTD dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test.

There were two outliers, both in the ETW condition. The largest value in batch one of both the normalized and the as-measured ETW datasets was an outlier for batch one but not for the ETW condition. The lowest value in batch three of the normalized ETW dataset was an outlier for batch three, but not for the ETW condition. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for FHC3 strength data in Table 4-36. The normalized data, B-estimates and the B-basis values are shown graphically in Figure 4-26.

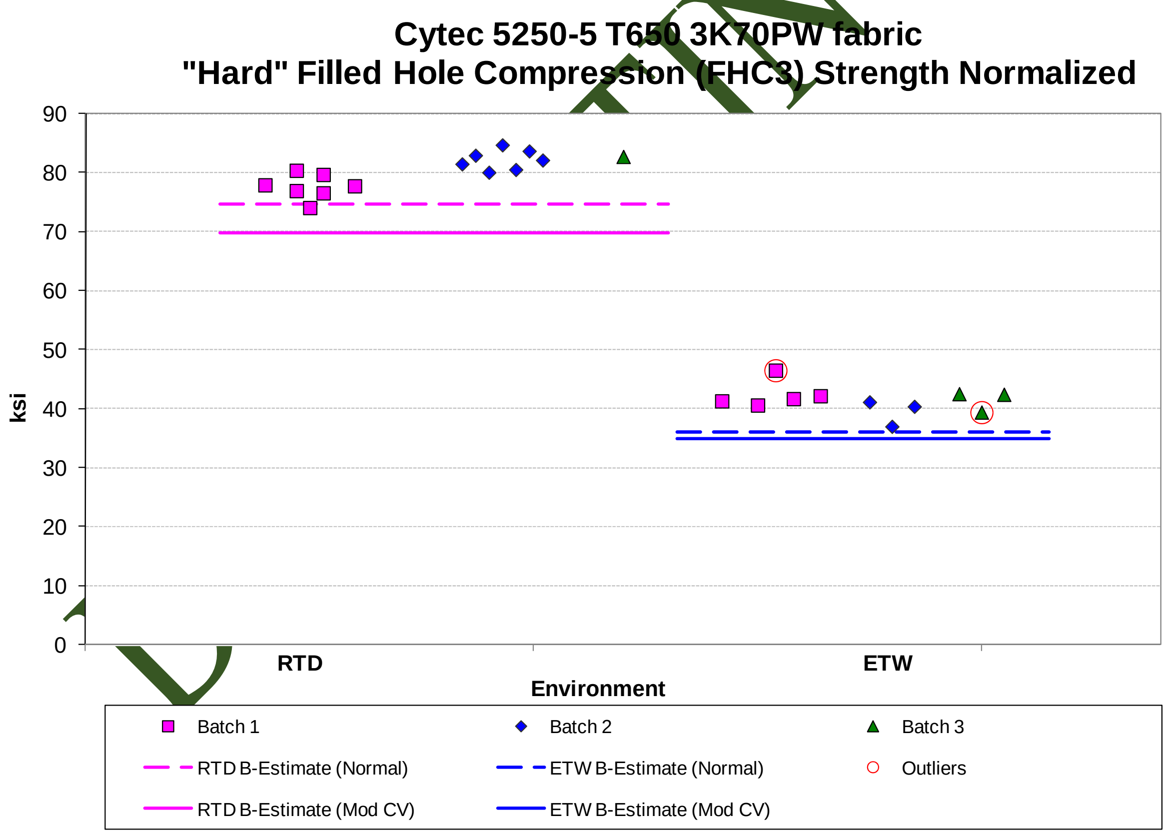

Figure 4-26: Batch plot for FHC3 normalized strength

Filled Hole Compression (FHC3) Strength Basis Values				
	Normalized		As-measured	
Env	RTD	ETW	RTD	ETW
Mean	79.62	41.35	80.08	41.50
Stdev	2.40	2.33	2.98	2.08
CV	3.01	5.63	3.72	5.02
Modified CV	6.00	6.81	6.00	6.51
Min	74.54	36.97	74.04	38.62
Max	83.48	46.47	84.67	45.96
No. Batches	3	3	3	3
No. Spec.	15	11	15	11
Basis Values and Estimates				
B-Estimate	74.67	36.05	61.69	36.76
A-Estimate	71.19	32.38	48.58	33.47
Method	Normal	Normal	ANOVA	Normal
Modified CV Basis Values and Estimates				
B-Estimate	69.74	34.94	70.14	35.35
A-Estimate	62.80	30.49	63.16	31.09
Method	Normal	Normal	Normal	Normal

Table 4-36: Statistics and Basis Values for FHC3 Strength Data

4.26 Quasi Isotropic Single Shear Bearing (SSB1)

The SSB1 data is normalized so both normalized and as-measured statistics are provided. The 2% offset datasets had no test failures.

The normalized ultimate strength RTD dataset did not have an adequate fit to any of the tested distributions, so the non-parametric method was used to compute basis values. No modified CV basis values are provided for this dataset due to its non-normality.

The ETW datasets, both as-measured and normalized, 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 ultimate strength ETW datasets were transformed according to the assumptions of the modified CV method, both datasets passed the ADK test, so the modified CV basis values are provided. Pooling across the environments was acceptable for the modified CV basis value computations for the as-measured ultimate strength dataset, but the pooled normalized ultimate strength dataset failed the normality test.

There were no outliers in the 2% offset strength data. There were two outliers in the ultimate strength data. The highest value in batch three of both the RTD and ETW datasets were outliers for their respective conditions but not batch three. Both were outliers for the as-measured and the normalized datasets. Both outliers were retained for this analysis.

Statistics, basis values and estimates are given for the SSB1 strength data in Table 4-37. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-27.

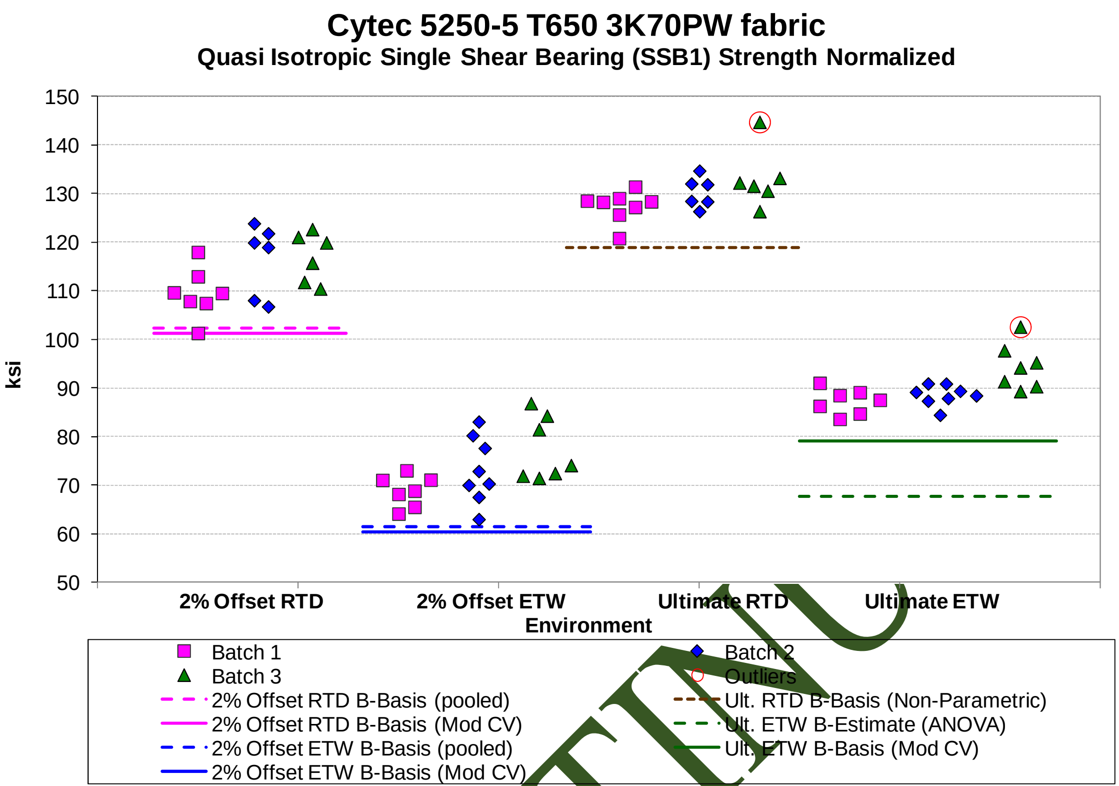

Figure 4-27: Batch plot for SSB1 normalized strength

Single Shear Bearing (SSB1) Strength Basis Values and Statistics								
	Normalized				As-measured			
Property	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	114.09	73.16	130.00	90.01	116.73	74.05	132.92	91.09
Stdev	6.60	6.54	4.69	4.40	6.55	7.12	5.61	4.89
CV	5.78	8.94	3.61	4.88	5.61	9.62	4.22	5.37
Modified CV	6.89	8.94	6.00	6.44	6.81	9.62	6.11	6.69
Min	101.30	63.01	120.81	83.63	104.23	63.31	123.52	84.55
Max	123.87	86.87	144.74	102.60	126.64	88.69	150.74	104.78
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	22	20	22	19	22	20	22
Basis Values and								
B-basis Value	102.32	61.53	118.94		104.42	61.91	122.11	
B-Estimate				67.64				66.01
A-Estimate	94.30	53.48	94.38	51.67	96.05	53.50	114.43	48.10
Method	pooled	pooled	Non-Parametric	ANOVA	pooled	pooled	Normal	ANOVA
Modified CV Basis								
B-basis Value	101.22	60.45	NA	79.07	103.26	60.76	120.22	78.50
A-Estimate	92.46	51.65	NA	71.27	94.09	51.56	111.54	69.79
Method	pooled	pooled	NA	Normal	pooled	pooled	pooled	pooled

Table 4-37: Statistics and Basis Values for SSB1 Strength Data

4.27 "Soft" Single Shear Bearing (SSB2)

The SSB2 data is normalized so both normalized and as-measured statistics are provided. There were no test failures for the RTD datasets. The 2% offset strength ETW datasets (both normalized and as-measured) and the as-measured ultimate strength ETW 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 ultimate strength ETW 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 across the environments was acceptable for both the ultimate strength normalized and as-measured data for modified CV basis value computations.

The 0.2% offset strength ETW datasets, both normalized and as-measured, had a CV greater than 8%, so the modified CV method could not be used. Basis value estimates were computed for the 0.2% offset ETW datasets by overriding the ADK test results and using the normal distribution.

There were no outliers. Statistics, basis values and estimates are given for the SSB2 strength data in Table 4-38. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-28.

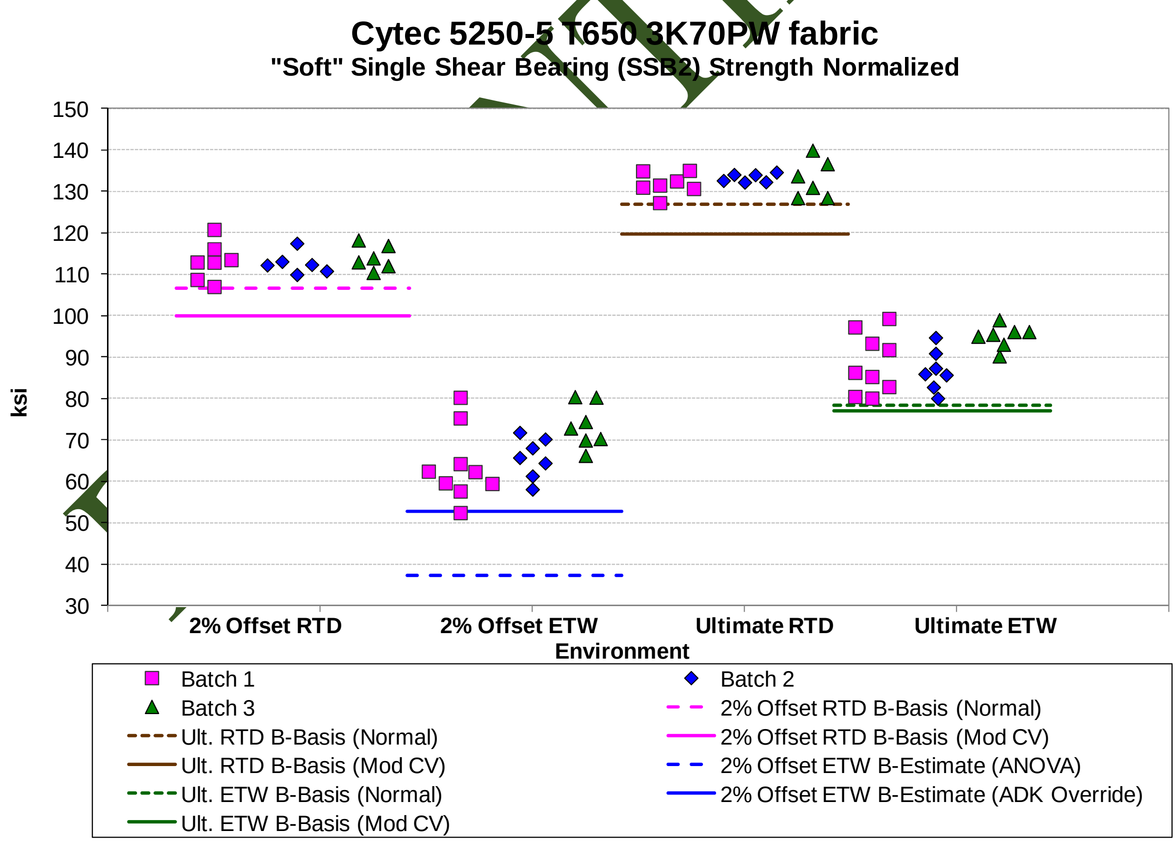

Figure 4-28: Batch plot for SSB2 normalized strength

Single Shear Bearing (SSB2) Strength Basis Values and Statistics								
	Normalized				As-measured			
Property	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	113.28	67.30	132.69	89.96	114.75	68.57	134.44	91.63
Stdev	3.41	7.76	3.02	6.28	3.71	8.13	4.49	6.48
CV	3.01	11.53	2.27	6.98	3.23	11.86	3.34	7.07
Modified CV	6.00	11.53	6.00	7.49	6.00	11.86	6.00	7.53
Min	107.04	52.45	127.27	80.05	108.64	53.77	125.37	80.62
Max	120.79	80.43	139.93	99.31	122.82	83.63	145.33	100.96
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	19	23	19	23	19	23	19	23
Basis Values and								
B-basis Value	106.63		126.81	78.23	107.52		125.69	
B-Estimate		37.36				35.55		64.24
A-Estimate	101.90	15.96	122.63	69.83	102.39	11.97	119.47	44.68
Method	Normal	ANOVA	Normal	Normal	Normal	ANOVA	Normal	ANOVA
Basis Values and								
B-Estimate		52.80				53.38		
A-Estimate		42.42				42.51		
Method		Normal				Normal		
Modified CV Basis								
B-basis Value	100.03		119.60	77.09	101.33		121.11	78.53
A-Estimate	90.64		110.70	68.15	91.82		112.05	69.42
Method	Normal		pooled	pooled	Normal		pooled	pooled

Table 4-38: Statistics and Basis Values for SSB2 Strength Data

4.28 "Hard" Single Shear Bearing (SSB3)

The SSB3 data is normalized so both normalized and as-measured statistics are provided. There were no test failures for the RTD datasets.

Both the as-measured and the normalized 2% offset strength ETW 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 2% offset strength ETW datasets were transformed according to the assumptions of the modified CV method, the as-measured dataset passed the ADK test but the normalized dataset did not. Modified CV basis values are provided for the as-measured dataset but only estimates are given for the normalized ETW dataset for that reason.

Pooling across the environments was not acceptable for the as-measured datasets because the pooled data failed Levene's test for equality of variance for both the 2% offset strength and the ultimate strength.

There were no outliers. Statistics, basis values and estimates are given for the SSB3 strength data in Table 4-39. The normalized data, B-estimates and B-basis values are shown graphically in Figure 4-29.

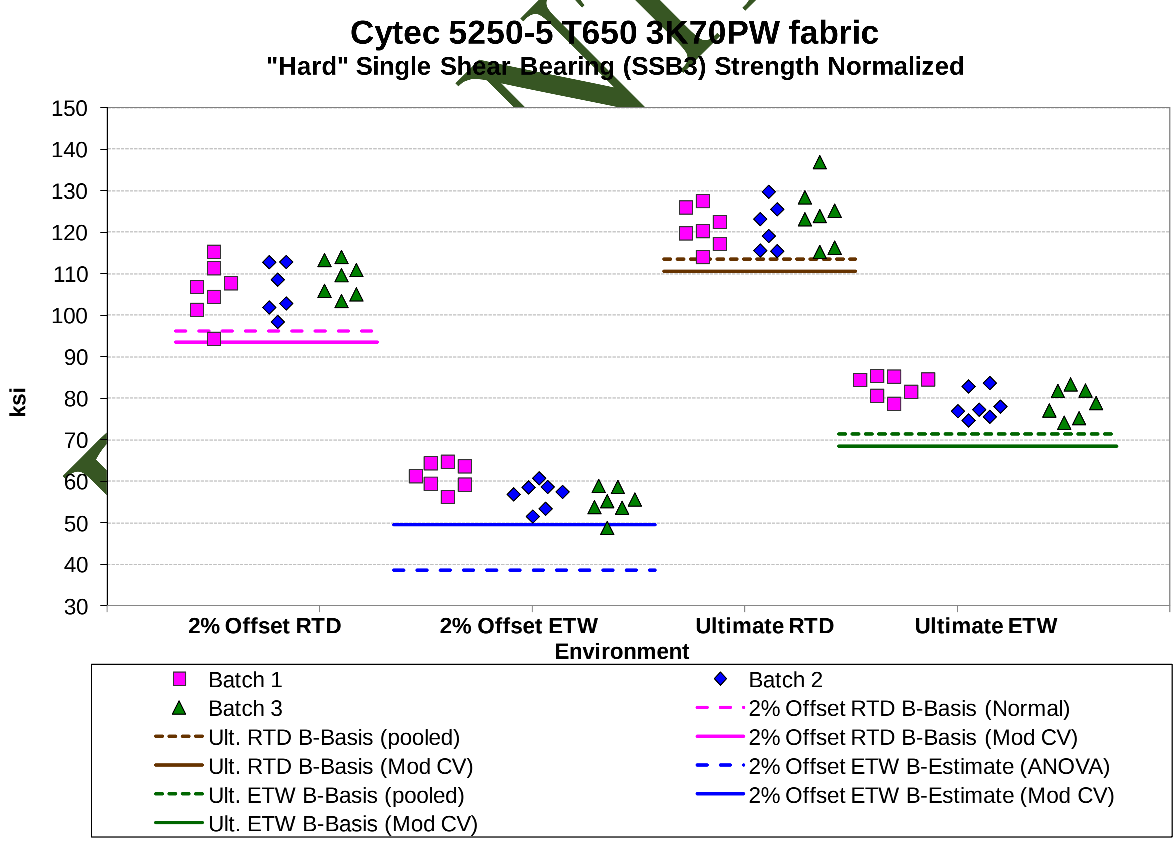

Figure 4-29: Batch plot for SSB3 normalized strength

Single Shear Bearing (SSB3) Strength Basis Values and Statistics								
	Normalized				As-measured			
Property	2% Offset Strength		Ultimate Strength		2% Offset Strength		Ultimate Strength	
Env	RTD	ETW	RTD	ETW	RTD	ETW	RTD	ETW
Mean	107.16	57.76	122.36	80.19	108.42	58.59	123.79	81.35
Stdev	5.64	4.12	5.90	3.72	6.22	4.00	6.54	3.45
CV	5.26	7.14	4.82	4.64	5.73	6.82	5.29	4.24
Modified CV	6.63	7.57	6.41	6.32	6.87	7.41	6.64	6.12
Min	94.44	48.90	114.16	74.26	96.54	50.71	113.82	76.30
Max	115.41	64.83	137.01	85.50	117.92	66.47	139.81	87.66
No. Batches	3	3	3	3	3	3	3	3
No. Spec.	20	21	20	21	20	21	20	21
Basis Values and								
B-basis Value	96.29		113.60	71.48	96.45		111.19	74.78
B-Estimate		38.56				40.32		
A-Estimate	88.56	24.85	107.60	65.47	87.93	27.28	102.23	70.09
Method	Normal	ANOVA	pooled	pooled	Normal	ANOVA	Normal	Normal
Modified CV Basis								
B-basis Value	93.47		110.63	68.52	94.08	50.32	107.95	71.86
B-Estimate		49.43						
A-Estimate	83.74	43.49	102.61	60.48	83.88	44.42	96.69	65.10
Method	Normal	Normal	pooled	pooled	Normal	Normal	Normal	Normal

Table 4-39: Statistics and Basis Values for SSB3 Strength Data

4.29 Compression After Impact (CAI)

The CAI data is normalized so both normalized and as-measured statistics are provided. Basis values are not computed for this property. Testing is done only for the RTD condition. Summary statistics are presented in Table 4-40 and the data are displayed graphically in Figure 4-30. There were no outliers. Only one batch of material was tested.

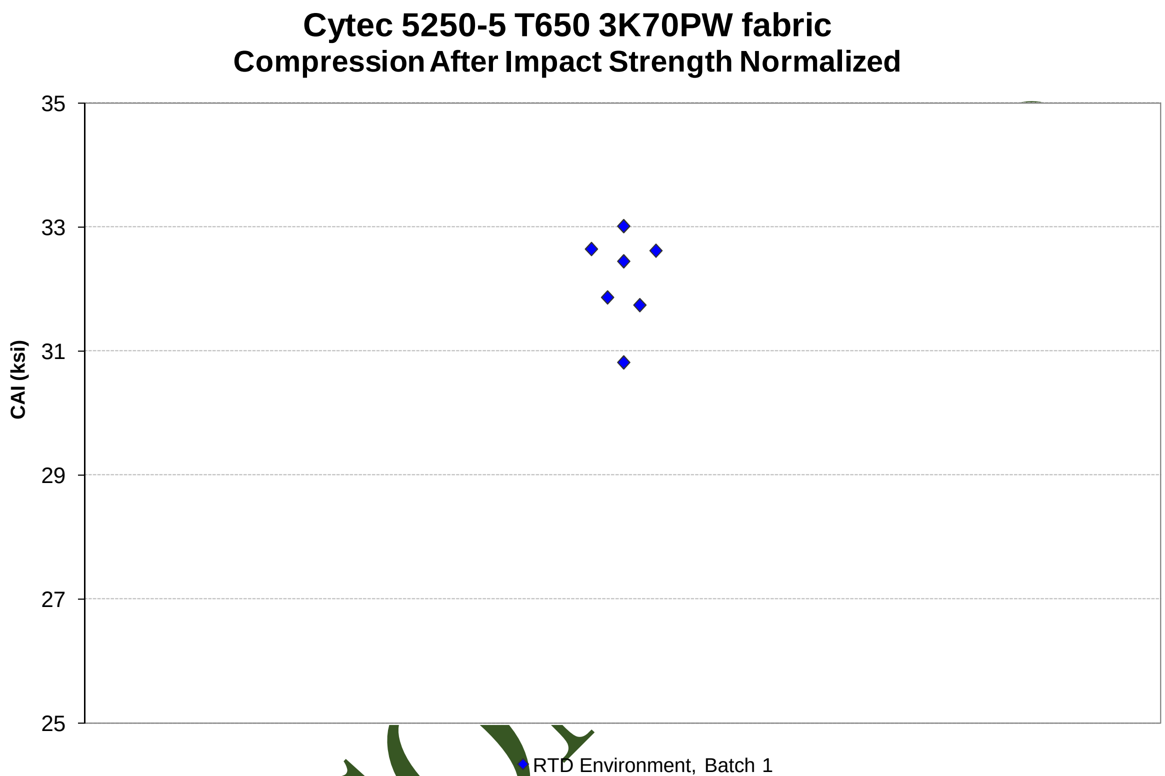

Figure 4-30: Plot for Compression After Impact normalized strength

Compression After Impact Strength (ksi)		
	Normalized	As-measured
Env	RTD	RTD
Mean	32.17	31.37
Stdev	0.74	0.81
CV	2.31	2.57
Modified CV	6.00	6.00
Min	30.82	30.05
Max	33.02	32.24
No. Batches	1	1
No. Spec.	7	7

Table 4-40: Statistics for Compression After Impact Strength Data

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

The ILT and CBS data is not normalized. Basis values are not computed for these properties. However the summary statistics are presented in Table 4-41 and the data are displayed graphically in Figure 4-31. There were no outliers. Only one batch of material was tested.

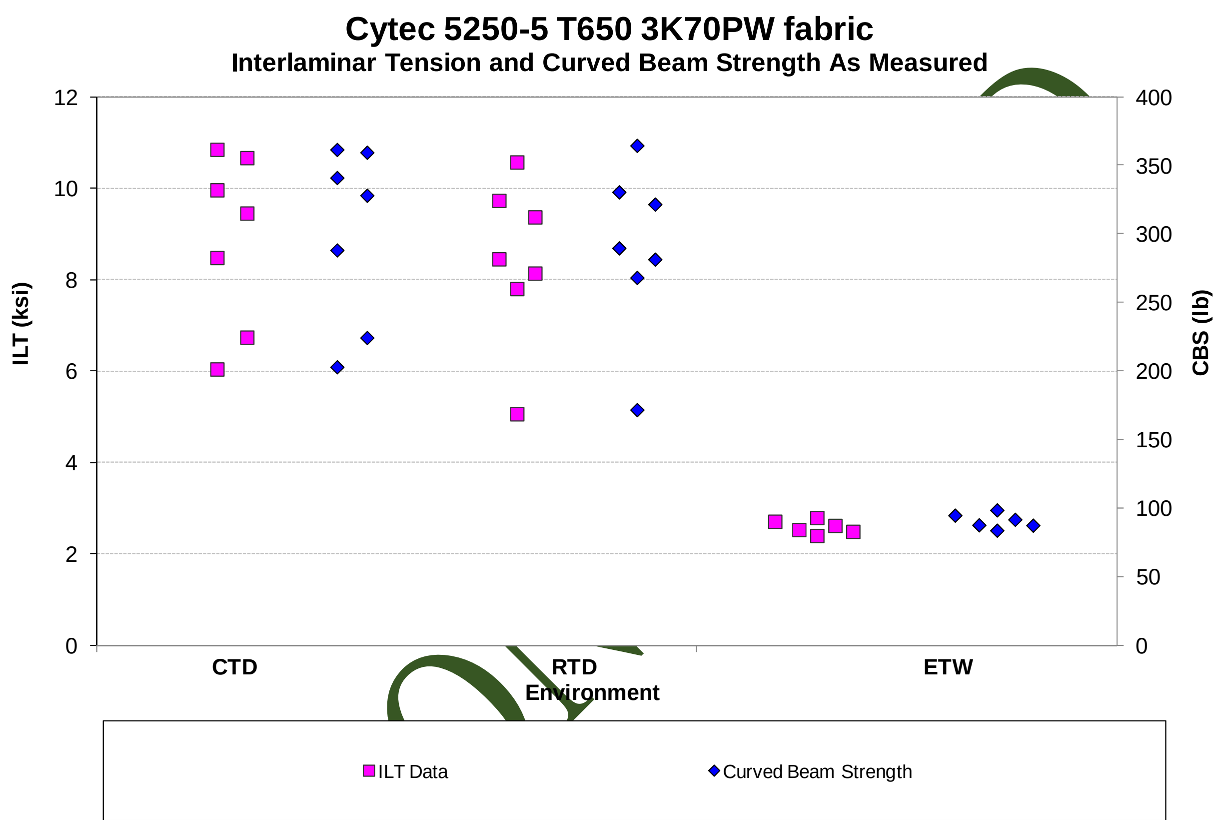

Figure 4-31: Plot for Interlaminar Tension and Curved Beam Strength

Interlaminar Tension (ILT) and Curved Beam Strength (CBS) Statistics						
	ILT (As-measured)			CBS (As-measured)		
Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	8.89	8.45	2.59	300.83	289.70	90.67
Stdev	1.89	1.78	0.15	64.64	61.55	5.42
CV	21.24	21.06	5.64	21.49	21.25	5.98
Modified CV	21.24	21.06	6.82	21.49	21.25	6.99
Min	6.04	5.06	2.40	202.99	171.77	83.78
Max	10.85	10.57	2.79	361.56	364.51	98.61
No. Batches	1	1	1	1	1	1
No. Spec.	7	7	6	7	7	6

Table 4-41: 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-2010-082 Rev B.

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
FC	ETW	3	CNCZC11HJ	57.82	59.17	H	N	Y
FT	CTD	2	CNCUB217B	96.92	98.46	L	Y	N
IPS 0.2% Offset	RTD	3	CNCNC211A	NA	8.09	L	N	Y
IPS 0.2% Offset	ETW	1	CNCNA217J	NA	2.26	H	Y	N
IPS Max. Strength	RTD	3	CNCNC211A	NA	12.89	L	Y	Y
UNT2	CTD	3	CNCBC219B	Not an Outlier	61.43	H	Y	N
UNT3	CTD	1	CNCCA216B	90.45	89.82	L	Y	Y
UNT3	CTD	3	CNCCC218B	Not an Outlier	92.64	L	Y	Y
UNC1	RTD	2	CNCWB214A	79.33	80.46	L	Y	N
UNC3	RTD	3	CNCYC111A	98.89	103.08	H	Y	Y- as meas, N-norm
FHT1	CTD	2	CNC4B118B	51.66	Not an Outlier	H	Y	N
FHT1	ETW	2	CNC4B21GJ	49.43	49.83	L	Y	N
FHT2	CTD	3	CNC5C11AB	50.29	Not an Outlier	H	N	Y
FHT3	CTD	1	CNC6A118B	Not an Outlier	48.19	L	Y	N
FHT3	RTD	1	CNC6A215A	Not an Outlier	59.89	H	Y	N
FHC3	ETW	1	CNC9A11CJ	46.47	45.96	H	Y	N
FHC3	ETW	3	CNC9C217J	39.37	Not an Outlier	L	Y	N
OHT2	CTD	1	CNCEA118B	41.43	Not an Outlier	L	Y	N
OHT3	RTD	1	CNCFA211A	Not an Outlier	61.44	H	Y	N
OHT3	CTD	2	CNCFB116B	54.44	54.36	H	Y	N
OHC1	RTD	1	CNCGA211A	Not an Outlier	46.38	H	Y	N
OHC1	RTD	2	CNCGB211A	Not an Outlier	48.71	H	Y	N
OHC2	ETW	1	CNCHA218J	17.74	17.12	L	N	Y
OHC2	ETW	2	CNCHB218J	Not an Outlier	23.02	H	Y	N
SSB1 - Ult. Str.	RTD	3	CNC1C212A	144.74	150.74	H	N	Y
SSB1 - Ult. Str.	ETW	3	CNC1C116J	102.60	104.78	H	N	Y

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.
3. Scholz, F.W. and Stephens, M.A., "K-Sample Anderson-Darling Tests of Fit," *Journal of the American Statistical Association*, Vol. 82, 1987, pp. 918-924.
4. Lehmann, E.L., *Testing Statistical Hypotheses*, John Wiley & Sons, 1959, pp. 274-275.
5. Levene, H., "Robust Tests for Equality of Variances," in *Contributions to Probability and Statistics*, ed. I. Olkin, Palo, Alto, CA: Stanford University Press, 1960.
6. Lawless, J.F., *Statistical Models and Methods for Lifetime Data*, John Wiley & Sons, 1982, pp. 150, 452-460.
7. *Metallic Materials and Elements for Aerospace Vehicle Structures*, MIL-HDBK-5E, Naval Publications and Forms Center, Philadelphia, Pennsylvania, 1 June 1987, pp. 9-166,9-167.
8. Hanson, D.L. and Koopmans, L.H., "Tolerance Limits for the Class of Distribution with Increasing Hazard Rates," *Annals of Math. Stat.*, Vol 35, 1964, pp. 1561-1570.
9. Vangel, M.G., "One-Sided Nonparametric Tolerance Limits," *Communications in Statistics: Simulation and Computation*, Vol. 23, 1994, p. 1137.
10. Vangel, M.G., "New Methods for One-Sided Tolerance Limits for a One-Way Balanced Random Effects ANOVA Model," *Technometrics*, Vol 34, 1992, pp. 176-185.
11. Odeh, R.E. and Owen, D.B., *Tables of Normal Tolerance Limits, Sampling Plans and Screening*, Marcel Dekker, 1980.
12. Tomblin, John and Seneviratne, Waruna, *Laminate Statistical Allowable Generation for Fiber-Reinforced Composites Material: Lamina Variability Method,* U.S. Department of Transportation, Federal Aviation Administration, May 2006.
13. Tomblin, John, Ng, Yeow and Raju, K. Suresh, *Material Qualifciation and Equivalency for Polymer Matrix Composite Material Systems: Updated Procedure,* U.S. Department of Transportation, Federal Aviation Administration, September 2003.
14. CMH-17 Rev G, Volume 1, 2012. SAE International, 400 Commonwealth Drive, Warrendale, PA 15096