Hexcel M91/IM8-GS UD Tape 145gsm with 35% RC
Material Allowables Statistical Analysis Report

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1. Introduction

This report contains statistical analysis of the Hexcel M91/IM8-GS UD Tape 145gsm with 35% RC prepreg material property data published in NCAMP Test Report CAM-RP-2025-002 -. The lamina and laminate material property data have been generated with NCAMP oversight through NCAMP Project Number NPN 062201 and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels and test specimens have been inspected by NCAMP Authorized Inspection Representatives (AIR) and the testing has been witnessed by NCAMP Authorized Engineering Representatives (AER).

B-Basis values, A-Basis values, and estimates were calculated using a variety of techniques that are detailed in section 2. The qualification material was procured to NCAMP Material Specification NMS 191/1 Rev Initial Release dated October 21, 2022. The qualification test panels were cured in accordance with NCAMP Process Specification NPS 81910 Rev B using baseline cure cycle "C" with a cure pressure of 90psi. The NCAMP Test Plan M910Q1 Rev B was used for this qualification program.

Basis numbers are labeled as 'values' when the data meets all the requirements of CMH-17 Vol 1. 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 Vol 1).

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

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

The applicability and accuracy of NCAMP material property data, material allowables, and specifications must be evaluated on case-by-case Basis by aircraft companies and certifying agencies. NCAMP assumes no liability whatsoever, expressed or implied, related to the use of the material property data, material allowables, and specifications.
Part fabricators that wish to utilize the material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test

statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of CMH-17 Vol 1. 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 Vol 1 are adequate for the given program.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 191/1. NMS 191/1 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 191/1.* NMS 191/1 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
Transverse Compression	TC
Transverse Tension	TT
Longitudinal Compression	LC
Longitudinal Tension	LT
In-Plane Shear Tension	IPST
In-Plane Shear V-Notch	IPSV
Short Beam Strength	SBS
Unnotched Tension	UNT
Interlaminar Tension	ILT

Table 1-1: Test Property Abbreviations

Test Property	Symbol
Longitudinal Compression Strength	F_1^{cu}
Longitudinal Compression Modulus	E_1^{c}
Longitudinal Tension Strength	F_1^{tu}
Longitudinal Tension Modulus	E_1^{t}
Longitudinal Tension Poisson’s Ratio	ν_{12}^{t}
Transverse Compression Strength	F_2^{cu}
Transverse Compression Modulus	E_2^{c}
Transverse Tension Strength	F_2^{tu}
Transverse Tension Modulus	E_2^{t}
In Plane Shear Strength at 5% strain	$F_{12}^{s5strain\%}$
In Plane Shear 0.2% Offset Strength	$F_{12}^{s0.2\%}$
In-Plane Shear Ultimate Strength	F_{12}^{su}
In Plane Shear Modulus	G_{12}^{s}

Table 1-2: Test Property Symbols

Environmental Condition	Abbreviation	Temperature
Cold Temperature Ambient	CTA	−65 ± 5˚F
Room Temperature Ambient	RTA	70 ± 10˚F
Elevated Temperature Wet	ETW	180 ± 5˚F

Table 1-3: Environmental Conditions Abbreviations

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

1 refers to a 25/50/25 layup. This is also referred to as "Quasi-Isotropic"
2 refers to a 10/80/10 layup. This is also referred to as “Soft”
3 refers to a 40/20/40 layup. This is also referred to as “Hard”

EX: OHT1 is an open hole tension test with a 25/50/25 layup

Detailed information about the test methods and conditions used is given in NCAMP Test Report CAM-RP-2025-002 .

1.2 Pooling Across Environments

When pooling across environments was allowable, the pooled coefficient of variation was used. CMH17 STATS (CMH17 Approved Statistical Analysis Program) 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, which are also provided by CMH17 STATS.

1.3 Basis Value Computational Process

The general form to compute engineering Basis values is: basis value = $\overline{X} - kS$ 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.

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 Vol 1. 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 CMH17 STATS. Pooling across environments will be used whenever it is permissible according to CMH-17 Vol 1 guidelines. If pooling is not permissible, the results of a single point analysis provided by CMH17 STATS is included instead. If the data does not meet CMH-17 Vol 1 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 CMH17 STATS Statistical Formulas and Computations

This section contains the details of the specific formulas CMH17 STATS uses in its computations.

2.1.1 Basic Descriptive Statistics

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

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

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

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

Where n refers to the number of specimens in the sample and X_i refers to the individual specimen measurements.

2.1.2 Statistics for Pooled Data

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

2.1.2.1 Pooled Standard Deviation

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

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

Where k refers to the number of batches, S_i indicates the standard deviation of i^{th} sample, and n_i refers to the number of specimens in the i^{th} sample.

2.1.2.2 Pooled Coefficient of Variation

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

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

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.

Basis Values:

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

2.1.3.1 K-factor computations

K_a and K_b are computed according to the methodology documented in section 8.3.5 of CMH-17 Vol 1. The approximation formulas are given below:

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

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

Where

r = the number of environments being pooled together

n_j = number of data values for environment j

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

$$f = N - r$$

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

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

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

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

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

2.1.4 Modified Coefficient of Variation

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

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

This is converted to percent by multiplying by 100%.

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

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

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

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

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

2.1.4.1 Transformation of data based on Modified CV

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

To accomplish this requires a transformation in two steps:

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

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

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

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

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

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

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

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

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

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

2.1.5 Determination of Outliers

All outliers are identified in text and graphics. If an outlier is removed from the dataset, it will be specified and the reason why will be documented in the text. Outliers are identified using the Maximum Normed Residual Test for Outliers as specified in section 8.3.3 of CMH-17 Vol 1.

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

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

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

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

2.1.6 The k-Sample Anderson Darling Test for Batch Equivalency

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

The k-sample Anderson-Darling test statistic is:

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

Where

n_i = the number of test specimens in each batch

$n = n_1 + n_2 + \ldots + n_k$

h_j = the number of values in the combined samples equal to $z_{(j)}$

H_j = the number of values in the combined samples less than $z_{(j)}$ plus ½ the number of values in the combined samples equal to $z_{(j)}$

F_{ij} = the number of values in the i^{th} group which are less than $z_{(j)}$ plus ½ the number of values in this group which are equal to $z_{(j)}$.

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

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

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

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

With

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

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

2.1.7 The Anderson Darling Test for Normality

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

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

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

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

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

$$OSL = \frac{1}{1 + e^{-0.48 + 0.78\ln(AD^*) + 4.58AD^*}}, \quad AD^* = \left(1 + \frac{4}{n} - \frac{25}{n^2}\right) AD \qquad \textbf{Equation 31}$$

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:

$$F = \frac{\sum_{i=1}^{k} n_i \left(\overline{w}_i - \overline{w} \right)^2 / (k-1)}{\sum_{i=1}^{k} \sum_{j=1}^{n_i} {}_i\left(w_{ij} - \overline{w}_i \right)^2 / (n-k)}$$ **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. CMH-17 STATS provides the appropriate critical values for F at α levels of 0.10, 0.05, 0.025, and 0.01. For more information on this procedure, see references 4, and 5.

2.1.9 Distribution Tests

In addition to testing for normality using the Anderson-Darling test (see 2.1.7), CMH17 STATS also tests to see if the Weibull or Lognormal distribution is a good fit for the data.

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

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

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

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

2.1.9.1 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 non-centrality parameter $1.282\sqrt{n}$ and n − 1 degrees of freedom. Since this is not a calculation that Excel can handle, the following approximation to the k_B values is used:

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

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

2.1.9.2 One-sided A-Basis tolerance factors, k_A, for the normal distribution

The exact computation of k_A values is $1/\sqrt{n}$ times the 0.95th quantile of the noncentral t-distribution with non-centrality 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_A values is used:

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

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

2.1.9.3 Two-parameter Weibull Distribution

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

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

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

In order to compute a check of the fit of a data set to the Weibull distribution and compute Basis values assuming Weibull, it is first necessary to obtain estimates of the population shape and scale parameters (Section 2.1.9.3.1). Calculations specific to the goodness-of-fit test for the Weibull distribution are provided in section 2.1.9.3.2.

2.1.9.3.1 Estimating Weibull Parameters

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

$$\hat{\alpha}\hat{\beta}\mathrm{n} - \frac{\hat{\beta}}{\hat{\alpha}^{\hat{\beta}-1}} \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{x}_{\mathrm{i}}^{\hat{\beta}} = 0$$ **Equation 36**

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

CMH17 STATS solves these equations numerically for $\hat{\beta}$ and $\hat{\alpha}$ in order to compute Basis values.

2.1.9.3.2 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 2.1.9.3.1, let

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

The Anderson-Darling test statistic is

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

and the observed significance level is

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

where

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

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

2.1.9.3.3 Basis value calculations for the Weibull distribution

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

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

where

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

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

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

V is the value in Table 2-1 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 2-1: Weibull Distribution Basis Value Factors

2.1.9.4 Lognormal Distribution

A probability distribution for which the probability that an observation selected at random from this population falls between a and b $\left(0 < a < b < \infty\right)$ 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.

2.1.9.4.1 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 Equation 29 above with Equation 47 below:

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

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 Equation 30 above and the observed significance level (OSL) is computed using Equation 31 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.

2.1.9.4.2 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.

2.1.10 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.

2.1.10.1 Non-parametric Basis Values for large samples

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

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

For B-Basis values:

$$r_B = \frac{n}{10} - 1.645\sqrt{\frac{9n}{100}} + 0.23 \qquad \textbf{Equation 48}$$

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 value is 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.

2.1.10.2 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 2-2. 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 2-3. For an A-Basis value that meets all the requirements of CMH-17 Vol 1, 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 2-2: 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 2-3: A-Basis Hanson-Koopmans Table

2.1.11 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.

2.1.11.1 Calculation of Basis values using ANOVA

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

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

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

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

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

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 8.3.5 of CMH-17 Vol 1 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

$$u = \frac{MSB}{MSE} \qquad \textbf{Equation 59}$$

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

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

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.

2.2 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**

2.3 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 = $\overline{X}_1 - K_{(N_1,N_2)} \cdot \overline{X}_1 \cdot \max\left(CV_1, CV_2\right)$ **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 = $\overline{X}_1 - K_{(N_1,N_2)} \cdot \overline{X}_1 \cdot Max\left(8\%, CV_1, CV_2\right)$ **Equation 63**

With:

$\overline{X}_1$ 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 2-4

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

Table 2-4: B-Basis Factors for Small Datasets Using Variability of Corresponding Large Dataset

2.4 0º Lamina Strength Derivation

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

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

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

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

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

This formula can also be found in section 2.4.2, equation 2.4.2.1(b) of CMH-17 Vol 1.

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

2.4.1 0º Lamina Strength Derivation (Alternate Formula)

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

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

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

with

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

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

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

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

This formula can also be found in section 2.4.2, equation 2.4.2.1(d) of CMH-17 Vol 1.

2.5 Specification Limits

Specification limits are calculated based in the qualification dataset only. In order to compute specification limits we make the following assumptions: a) The qualification dataset represents the population[1] b) In the future we might draw a new sample of size n=5 c) In the future we might run an acceptance test for the new sample statistics (this is a hypothesis testing approach; testing the hypothesis that the sample statistics equal the population parameters with α = 1%). Then, the specification limits are computed as the limits required by the statistics of the future sample to pass the acceptance test. The statistics to be tested are be the modulus mean, the strength mean or the strength minimum individual of the qualification dataset. In the case of modulus mean, a two-tails interval is used. In case of strength mean and strength minimum individual, a one-tail left interval is used.

Therefore, in order to compute the specification limits we need to compute the intervals around the mean and minimum individual values from the qualification dataset for some specific material property, according to the following formulas. First, assume the following:

[1] This is a different assumption than the one required for computing allowables. While computing allowables, we assume that all the future material properties values are the population and the qualification dataset is the sample.

$x =$ Some Material Strength Property
$\overline{x} =$ Mean of x
$S =$ Standard Deviation of x

Then we define:

$\mathrm{W_{mean}} =$ Specification limit for the mean
$\mathrm{W_{min\,indiv}} =$ Specification limit for the minimum individual

We compute these as the following:

$$\mathrm{W_{mean}} = \overline{x} - \mathrm{k_n^{mean}}.\mathrm{S}$$ **Equation 64**

$$\mathrm{W_{min\,indiv}} = \overline{x} - \mathrm{k_n^{min\,indiv}}.\mathrm{S}$$ **Equation 65**

Where the tolerance factor k^{mean} is found in table 8.5.17 in CMH-17 Vol 1 for n=5 and α =0.01 and tolerance factor $k^{min\ indiv}$ is found in table 8.5.18 in CMH-17 Vol 1 for n=5 and α =0.01

For modulus properties we define:

$\mathrm{W_{lower}} =$ Lower specification limit for the mean of modulus property
$\mathrm{W_{upper}} =$ Upper specification limit for the mean of modulus property

We compute these as the following:

$$\mathrm{W_{lower}} = \overline{x} - \mathrm{k.S}$$ **Equation 66**

$$\mathrm{W_{upper}} = \overline{x} + \mathrm{k.S}$$ **Equation 67**

Where the tolerance factor k is determined by the following equations:

$$k = t_c.\sqrt{(\frac{1}{N} + \frac{1}{n})}$$ **Equation 68**

and

$$t_c = t.INV(\alpha, N)$$ **Equation 69**

Where t.INV is the inverse of the cumulative Student's t-distribution, N=sample size of the qualification dataset, n=5 and α =0.01.

2.5.1.1 Specification Limits for Program

Specification limits for this program are detailed in Table 2-5 for strength properties and in Table 2-6 for modulus properties.

Test Property	Test Condition	Mean [ksi]	CV (%)	Mod CV (%)	k_mean	k_min indiv	As-is		Mod CV		Notes
							W_mean [ksi]	W_min indiv [ksi]	W_mean [ksi]	W_min indiv [ksi]	
0° Tension (LT) Strength Normalized	RTA (70°F)	464.0	4.517	6.259	1.143	3.128	440.1	399.6	430.8	374.8	Qualification Data Only
90/0° Compression (UNC0) Strength Normalized	RTA (70°F)	130.6	9.411	9.411	1.143	3.175	116.6	92.88	116.6	92.88	Qualification Data Only
0° Short Beam Strength (SBS) As-Measured	RTA (70°F)	16.22	2.418	6.000	1.143	3.215	15.78	15.02	15.11	13.23	Qualification Data Only

Table 2-5: Specification Limits for Strength Properties

Test Property	Test Condition	Mean [Msi]	CV (%)	Mod CV (%)	t_statistic	As-is		Mod CV		Notes
						Lower Limit [Msi]	Upper Limit [Msi]	Lower Limit [Msi]	Upper Limit [Msi]	
0° Tension (LT) Modulus Normalized	RTA (70°F)	25.64	1.878	6.000	2.670	25.04	26.24	23.73	27.55	Qualification Data Only
90/0° Compression (UNC0) Modulus Normalized	RTA (70°F)	12.27	1.965	6.000	2.670	11.97	12.57	11.35	13.18	Qualification Data Only

Table 2-6: Specification Limits for Modulus Properties

3. Summary of Results

The Basis values for all tests are summarized in the following tables. The NCAMP recommended B-Basis values and A-Basis values meet all requirements of CMH-17 Vol 1. 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 Vol 1 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 Basis Values

The following rules are used in determining what B-Basis and A-Basis values are included in Table 3-1 and Table 3-2 of recommended values.

1. Recommended values are NEVER estimates. Only Basis values that meet all requirements of CMH-17 Vol 1 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 values computed using five batches of data are recommended, while those with less are labeled as estimates, based on CMH-17 Vol 1 recommendations.
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 CMH-17 STATS 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 CTA-RTA-ETW trend of the Basis values is not consistent with the CTA-RTA-ETW trend of the average values), then Basis values will not be recommended.

NCAMP Recommended B-Basis Values for
Hexcel M91/IM8-GS UD Tape 145gsm with 35% RC
All B-Basis Values in this Table Meet the Standards for Publication in the CMH-17 Vol 1 Handbook
Values Are for Normalized Data Unless Noted

Lamina Strength Tests

Environment	Statistic	LT	UNC0	LC from UNC0*	TT**	TC**	SBS**
CTA (-65°F)	B-basis	420.3	124.9	233.9	6.086	43.28	19.69
	Mean	464.9	155.4	290.9	9.306	47.19	21.48
	CV	6.000	6.279	6.279	13.93	6.000	6.000
RTA (70°F)	B-basis	419.4	91.69	172.7	4.363	31.19	14.44
	Mean	464.0	130.6	246.1	9.045	35.10	16.22
	CV	6.259	9.411	9.411	16.89	6.000	6.000
ETW (180°F)	B-basis	384.1	87.63	166.2	4.695	17.18	8.559
	Mean	455.8	97.49	184.9	5.302	19.69	9.484
	CV	5.156	6.233	6.233	7.067	3.848	6.000

Environment	Statistic	IPSV**			IPST**		
		0.2% Offset Strength	Ultimate Shear Strength	Strength at 5% Strain	0.2% Offset Strength	Strength at 5% Strain	
CTA (-65°F)	B-basis	10.19	28.54	16.98	8.955	14.61	
	Mean	11.30	31.21	18.82	10.16	16.16	
	CV	6.000	6.000	6.000	6.000	6.000	
RTA (70°F)	B-basis	7.477	22.63	12.36	6.482	10.39	
	Mean	8.286	25.30	13.70	7.353	11.94	
	CV	6.000	6.000	6.000	6.000	6.000	
ETW (180°F)	B-basis	4.463	13.86	7.336	4.043	6.019	
	Mean	4.765	15.22	8.129	4.587	6.827	
	CV	3.014	3.180	6.000	6.000	6.000	

Notes: The modified CV B-Basis value is recommended when available.
The CV provided corresponds with the B-basis value given.
"NA: I" indicates insufficient specimens to compute recommended values.
Shaded empty boxes indicate that test data is not available for that property and condition.
Most transverse tension coupons failed at the tabs.
* Derived from cross-ply backout factor. Backout factor was calculated based off the conservative assumption that the poisson's ratio is 0. A new batch of sampling is being populated to obtain the actual poisson's ratio. The values will be revised once the new data is available.
**Data is as-measured rather than normalized

Table 3-1: NCAMP Recommended B-Basis Values for Lamina Test Data

NCAMP Recommended A-Basis Values for
Hexcel M91/IM8-GS UD Tape 145gsm with 35% RC
All A-Basis Values in this Table Meet the Standards for Publication in the CMH-17 Vol 1 Handbook
Values Are for Normalized Data Unless Noted

Lamina Strength Tests

Environment	Statistic	LT	UNC0	LC from UNC0*	TT**	TC**
CTA (-65°F)	A-basis	387.9	103.8	194.3	3.811	40.44
	Mean	464.9	155.4	290.9	9.306	47.19
	CV	6.000	6.279	6.279	13.93	6.000
RTA (70°F)	A-basis	387.0	64.7	121.9	1.114	28.35
	Mean	464.0	130.6	246.1	9.045	35.10
	CV	6.259	9.411	9.411	16.89	6.000
ETW (180°F)	A-basis	334.4	80.31	152.3	4.245	15.45
	Mean	455.8	97.49	184.9	5.302	19.69
	CV	5.156	6.233	6.233	7.067	3.848

Environment	Statistic	SBS*	IPSV** 0.2% Offset Strength	IPSV** Ultimate Shear Strength	IPSV** Strength at 5% Strain
CTA (-65°F)	A-basis	18.39	NA: I	26.60	NA: I
	Mean	21.48	11.30	31.21	18.82
	CV	6.000	2.914	6.000	6.000
RTA (70°F)	A-basis	13.14	6.878	20.69	11.37
	Mean	16.22	8.286	25.30	13.70
	CV	6.000	6.000	6.000	6.000
ETW (180°F)	A-basis	7.873	4.246	12.91	6.747
	Mean	9.484	4.765	15.22	8.129
	CV	6.000	3.014	3.180	6.000

Notes: The modified CV A-Basis value is recommended when available.
The CV provided corresponds with the A-Basis value given.
"NA: I" implies that tests were run but data did not meet NCAMP's recommended requirements for minimum number of specimens to compute recommended values.
Most transverse tension coupons failed at the tabs.
* Derived from cross-ply backout factor. Backout factor was calculated based off the conservative assumption that the poisson's ratio is 0. A new batch of sampling is being populated to obtain the actual poisson's ratio. The values will be revised once the new data is available.
**Data is as-measured rather than normalized

Table 3-2: NCAMP Recommended A-Basis Values for Lamina Test Data

3.2 Lamina Summary Tables

Prepreg Material:	Hexcel M91/IM8-GS UD Tape 145gsm with 35% RC		**Hexcel M91/IM8 Unitape 145 gsm 35% RC Lamina Properties Summary**
Material Specification:	NMS 191/1		
Process Specification:	NPS 81910		
Fiber:	IM8-GS UD Tape	**Resin:** M91	
Tg(ambient): 380.4 °F		**Tg(wet):** 291.9 °F	**Tg METHOD:** DMA (ASTM D7028)

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Date of fiber manufacture	9/25/2019	5/16/2020	5/16/2020	4/11/2022	4/11/2022
Date of resin manufacture	6/14/2022	6/8/2022	12/6/2022	2/12/2024	8/31/2023
Date of prepreg manufacture	6/30/2022	6/29/2022	12/19/2022	2/21/2024	2/19/2024
Date of composite manufacture	2/23/2023-2/24/2023	2/28/2023-3/1/2023	3/7/2023-3/9/2023	7/20/2023	7/28/2023
Date of testing	5/22/2024	5/22/2024	5/22/2024	9/23/2024	9/23/2024
Date of data submittal	5/22/2024	5/22/2024	5/22/2024	9/23/2024	9/23/2024
Date of analysis	September 2024 - September 2025				

LAMINA MECHANICAL PROPERTY B-BASIS SUMMARY

Data reported: As-Measured Followed by Normalized Values in Parentheses. Normalizing CPT: 0.005500 in

Values Shown in Shaded Boxes do not Meet CMH-17 Vol 1 Requirements and are Estimates Only

These Values may not be Used for Certification Unless Specifically Allowed by the Certifying Agency

Test Condition	CTA (-65 °F)			RTA (70 °F)			ETW (180 °F)		
Property	**B-Basis**	**Modified CV B-basis**	**Mean**	**B-Basis**	**Modified CV B-basis**	**Mean**	**B-Basis**	**Modified CV B-basis**	**Mean**
F_1^{tu}	413.5	411.8	454.7	424.2	411.5	454.3	382.1	NA	444.9
(ksi)	(422.3)	(420.3)	(464.9)	(429.9)	(419.4)	(464.0)	(384.1)		(455.8)
E_1^t			25.27			25.11			25.07
(Msi)			(25.84)			(25.64)			(25.67)
ν_{12}^t			0.3308			0.3473			0.3195
F_2^{tu} (ksi)	6.086	NA	9.306	4.363	NA	9.045	4.775	4.695	5.302
E_2^t (Msi)			1.470			1.293			1.051
F_1^{cu}* from UNC0	230.5	NA	281.8	175.2	NA	238.1	164.2	NA	178.8
(ksi)	(233.9)		(290.9)	(172.7)		(246.1)	(164.3)	(166.2)	(184.9)
E_1^c			21.73			21.66			21.91
(Msi)			(22.37)			(22.26)			(22.65)
F_2^{cu} (ksi)	44.44	43.28	47.19	31.60	31.19	35.10	17.18	NA	19.69
E_2^c (Msi)			1.533			1.375			1.234
UNC0 Strength	123.4	NA	150.9	93.18	NA	126.6	86.72	NA	94.43
(ksi)	(124.9)		(155.4)	(91.69)		(130.6)	(86.60)	(87.63)	(97.49)
UNC0 Modulus			11.94			11.90			12.03
(Msi)			(12.30)			(12.27)			(12.42)
IPST $F_{12}^{s0.2\%}$ (ksi)	9.301	8.955	10.16	6.672	6.482	7.353	4.101	4.043	4.587
IPST $F_{12}^{s5\%}$ (ksi)	14.04	14.61	16.16	11.56	10.39	11.94	6.501	6.019	6.827
IPST G_{12}^s (Msi)			0.8402			0.6903			0.4633
IPSV $F_{12}^{s0.2\%}$ (ksi)	10.38	10.19	11.30	7.818	7.477	8.286	4.463	NA	4.765
IPSV F_{12}^{su} (ksi)	29.48	28.54	31.21	24.68	22.63	25.30	13.86	NA	15.22
IPSV $F_{12}^{s5\%}$ (ksi)	17.29	16.98	18.82	13.38	12.36	13.70	7.663	7.336	8.129
IPSV G_{12}^s (Msi)			0.8661			0.7437			0.6431
SBS (ksi)	19.62	19.69	21.48	15.02	14.44	16.22	8.854	8.559	9.484
ILT (ksi)	17.03	NA	21.47	9.271	NA	13.69	6.215	NA	8.065
CBS (lb)	381.8	NA	495.7	200.6	NA	315.1	133.0	NA	185.8

Notes

NA indicates that basis values could not be computed.

Most transverse tension coupons failed at the tabs.

*Derived from cross-ply backout factor. Backout factor was calculated based off the conservative assumption that the poisson's ratio is 0. A new batch of sampling is being populated to obtain the actual poisson's ratio. The values will be revised once the new data is available.

Table 3-3: Summary of Test Results for Lamina Data – B-Basis

Prepreg Material:	Hexcel M91/IM8-GS UD Tape 145gsm with 35% RC		**Hexcel M91/IM8 Unitape 145 gsm 35% RC Lamina Properties Summary**
Material Specification:	NMS 191/1		
Process Specification:	NPS 81910		
Fabric:	IM8-GS UD Tape	**Resin:** M91	
Tg(ambient): 380.4 °F		**Tg(wet):** 291.9 °F	**Tg METHOD:** DMA (ASTM D7028)

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Date of fiber manufacture	9/25/2019	5/16/2020	5/16/2020	4/11/2022	4/11/2022
Date of resin manufacture	6/14/2022	6/8/2022	12/6/2022	2/12/2024	8/31/2023
Date of prepreg manufacture	6/30/2022	6/29/2022	12/19/2022	2/21/2024	2/19/2024
Date of composite manufacture	2/23/2023-2/24/2023	2/28/2023-3/1/2023	3/7/2023-3/9/2023	7/20/2023	7/28/2023
Date of testing	5/22/2024	5/22/2024	5/22/2024	9/23/2024	9/23/2024
Date of data submittal	5/22/2024	5/22/2024	5/22/2024	9/23/2024	9/23/2024
Date of analysis	September 2024 - September 2025				

LAMINA MECHANICAL PROPERTY A-BASIS SUMMARY

Data reported: As-Measured Followed by Normalized Values in Parentheses. Normalizing CPT: 0.005500 in

Values Shown in Shaded Boxes do not Meet CMH-17 Vol 1 Requirements and are Estimates Only

These Values may not be Used for Certification Unless Specifically Allowed by the Certifying Agency

Test Condition	CTA (-65 °F)			RTA (70 °F)			ETW (180 °F)		
Property	**A-Basis**	**Modified CV A-Basis**	**Mean**	**A-Basis**	**Modified CV A-Basis**	**Mean**	**A-Basis**	**Modified CV A-Basis**	**Mean**
F_1^{tu} (ksi)	384.5 (392.2)	380.7 (387.9)	454.7 (464.9)	401.8 (404.7)	380.3 (387.0)	454.3 (464.0)	338.5 (334.4)	NA	444.9 (455.8)
E_1^t (Msi)			25.27 (25.84)			25.11 (25.64)			25.07 (25.67)
ν_{12}^t			0.3308			0.3473			0.3195
F_2^{tu} (ksi)	3.811	NA	9.306	1.114	NA	9.045	4.384	4.245	5.302
E_2^t (Msi)			1.470			1.293			1.051
F_1^{cu}* from UNC0 (ksi)	194.9 (194.3)	NA	281.8 (290.9)	131.6 (121.9)	NA	238.1 (246.1)	148.0 (143.0)	NA (152.3)	178.8 (184.9)
E_1^c (Msi)			21.73 (22.37)			21.66 (22.26)			21.91 (22.65)
F_2^{cu} (ksi)	42.40	40.44	47.19	29.16	28.35	35.10	15.45	NA	19.69
E_2^c (Msi)			1.533			1.375			1.234
UNC0 Strength (ksi)	104.3 (103.8)	NA	150.9 (155.4)	69.96 (64.71)	NA	126.6 (130.6)	78.17 (75.39)	NA (80.31)	94.43 (97.49)
UNC0 Modulus (Msi)			11.94 (12.30)			11.90 (12.27)			12.03 (12.42)
IPST $F_{12}^{s0.2\%}$ (ksi)	8.692	8.102	10.16	6.186	5.864	7.353	3.754	3.658	4.452
IPST $F_{12}^{s5\%}$ (ksi)	12.53	13.55	16.16	11.28	9.331	11.94	6.268	5.445	6.827
IPST G_{12}^{s} (Msi)			0.8402			0.6903			0.4633
IPSV $F_{12}^{s0.2\%}$ (ksi)	9.738	9.374	11.30	7.488	6.878	8.286	4.246	NA	4.765
IPSV F_{12}^{su} (ksi)	28.20	26.60	31.21	24.25	20.69	25.30	12.91	NA	15.22
IPSV $F_{12}^{s5\%}$ (ksi)	16.23	15.62	18.82	13.16	11.37	13.70	7.341	6.747	8.129
IPSV G_{12}^{s} (Msi)			0.8661			0.7437			0.6431
SBS (ksi)	18.31	18.39	21.48	14.18	13.14	16.22	8.417	7.873	9.484
ILT (ksi)	13.83	NA	21.47	6.236	NA	13.69	4.944	NA	8.065
CBS (lb)	300.3	NA	495.7	122.0	NA	315.1	96.72	NA	185.8

Notes
NA indicates that basis values could not be computed.
Most transverse tension coupons failed at the tabs.
*Derived from cross-ply backout factor. Backout factor was calculated based off the conservative assumption that the poisson's ratio is 0. A new batch of sampling is being populated to obtain the actual poisson's ratio. The values will be revised once the new data is available.

Table 3-4: Summary of Test Results for Lamina Data – A- Basis

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.

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

When a dataset fails the Anderson-Darling k-sample (ADK) test for batch-to-batch variation, an ANOVA analysis is required. In order for B-Basis values to be computed using the ANOVA method, data from five batches are required. Since this qualification dataset has only three batches, the Basis values computed using ANOVA are considered estimates only. However, the Basis values resulting from the ANOVA method using only three batches may be overly conservative. The ADK test is performed again after a transformation of the data according to the assumptions of the modified CV method (see section 2.1.4 for details). If the dataset still passes the ADK test at this point, modified CV Basis values are provided. If the dataset does not pass the ADK test after the transformation, estimates may be computed using the modified CV method per the guidelines of CMH-17 Vol 1 section 8.3.10.

4.1 Longitudinal Tension (LT)

Longitudinal Tension data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the following environmental conditions: CTA, RTA and ETW.

The dataset consists of five batches of data with at least fifty-five specimens per environment, therefore A-Basis and B-Basis values where computed.

For both the normalized and as-measured datasets, the CTA and ETW failed the ADK test for batch equivalency. ANOVA was used to compute basis values for CTA and ETW and the single point normal method was used for RTA. Using the modified CV, the ETW condition failed the ADK test, so basis values were not computed for ETW. The RTA and ETW environments were pooled.

There were no statistical outliers.

Statistics and basis values are given for the LT strength data in Table 4-1 and for the modulus data in Table 4-2. The normalized data and A-Basis values are in Figure 4-1 and the normalized data and B-Basis values in Figure 4-2.

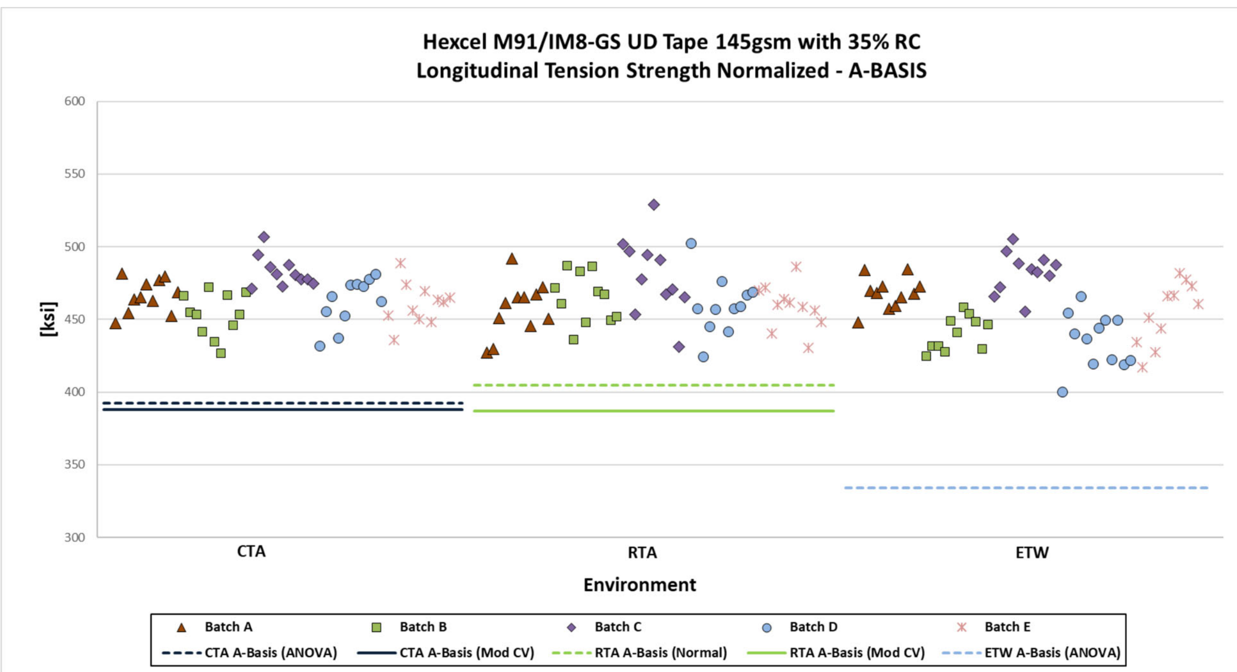

Figure 4-1: Batch Plot for LT Normalized Strength – A-Basis

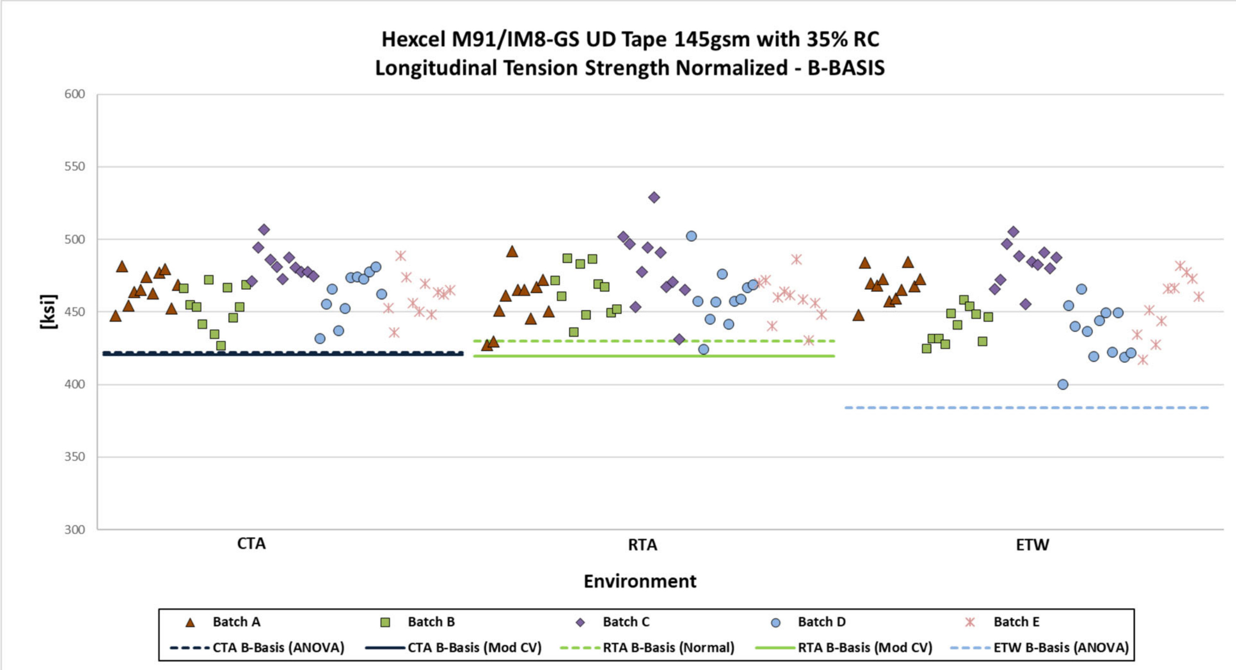

Figure 4-2: Batch Plot for LT Normalized Strength – B-Basis

Normalized Longitudinal Tension (LT) Strength Basis Values and Statistics						
	Normalized			As-Measured		
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	464.9	464.0	455.8	454.7	454.3	444.9
Stdev	16.48	20.96	23.50	16.51	18.55	20.73
CV	3.545	4.517	5.156	3.631	4.082	4.660
Mod CV	6.000	6.259	6.578	6.000	6.041	6.330
Min	426.8	424.5	400.2	415.6	415.7	395.1
Max	506.7	529.1	505.1	482.1	501.0	480.6
No. Batches	5	5	5	5	5	5
No. Spec.	55	55	56	55	55	56
Basis Values						
B-Basis Value	422.3	429.9	384.1	413.5	424.2	382.1
A-Basis Value	392.2	404.7	334.4	384.5	401.8	338.5
Method	ANOVA	Normal	ANOVA	ANOVA	Normal	ANOVA
Modified CV Basis Values						
B-Basis Value	420.3	419.4	NA	411.8	411.5	NA
A-Basis Value	387.9	387.0		380.7	380.3	
Method	Pooled	Pooled		Pooled	Pooled	

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

Longitudinal Tension (LT) Modulus Statistics						
	Normalized			As-Measured		
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	25.84	25.64	25.67	25.27	25.11	25.07
Stdev	0.5166	0.4815	0.4890	0.5221	0.5258	0.4911
CV	1.999	1.878	1.905	2.066	2.094	1.959
Min	24.62	24.26	24.71	24.45	24.06	24.18
Max	27.55	27.14	27.22	27.47	26.86	25.93
No. Batches	5	5	5	5	5	5
No. Spec.	55	55	56	55	55	56

Table 4-2: Statistics from LT Modulus Data

4.2 Transverse Tension (TT)

Transverse Tension data is not normalized. Tests were conducted in the following environmental conditions: CTA, RTA, and ETW.

The datasets consist of five batches with more than fifty-five specimens per environment, therefore A-Basis values and B-Basis values were computed.

The CTA and RTA conditions failed the ADK test for batch equivalency. ANOVA was used to compute values for CTA and RTA and the single point normal method was used for ETW. Applying the modified CV, the CTA and RTA conditions failed the ADK so basis values were not computed for those conditions. The normal method for modified CV was used for ETW.

There was one statistical outlier. The highest value in batch A of the ETW conditions was an outlier for the batch but not for the condition. It was retained for this analysis.

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

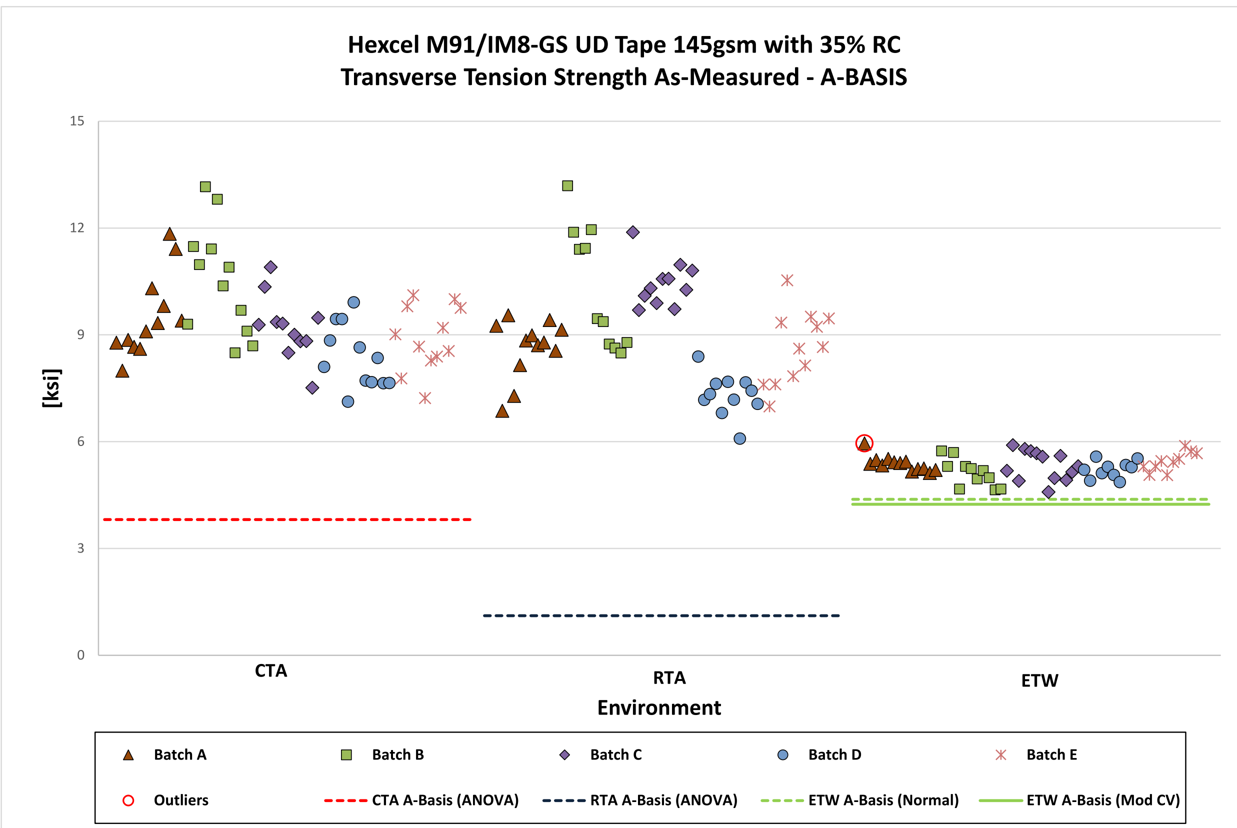

Figure 4-3: Batch Plot for TT As-Measured Strength – A-Basis

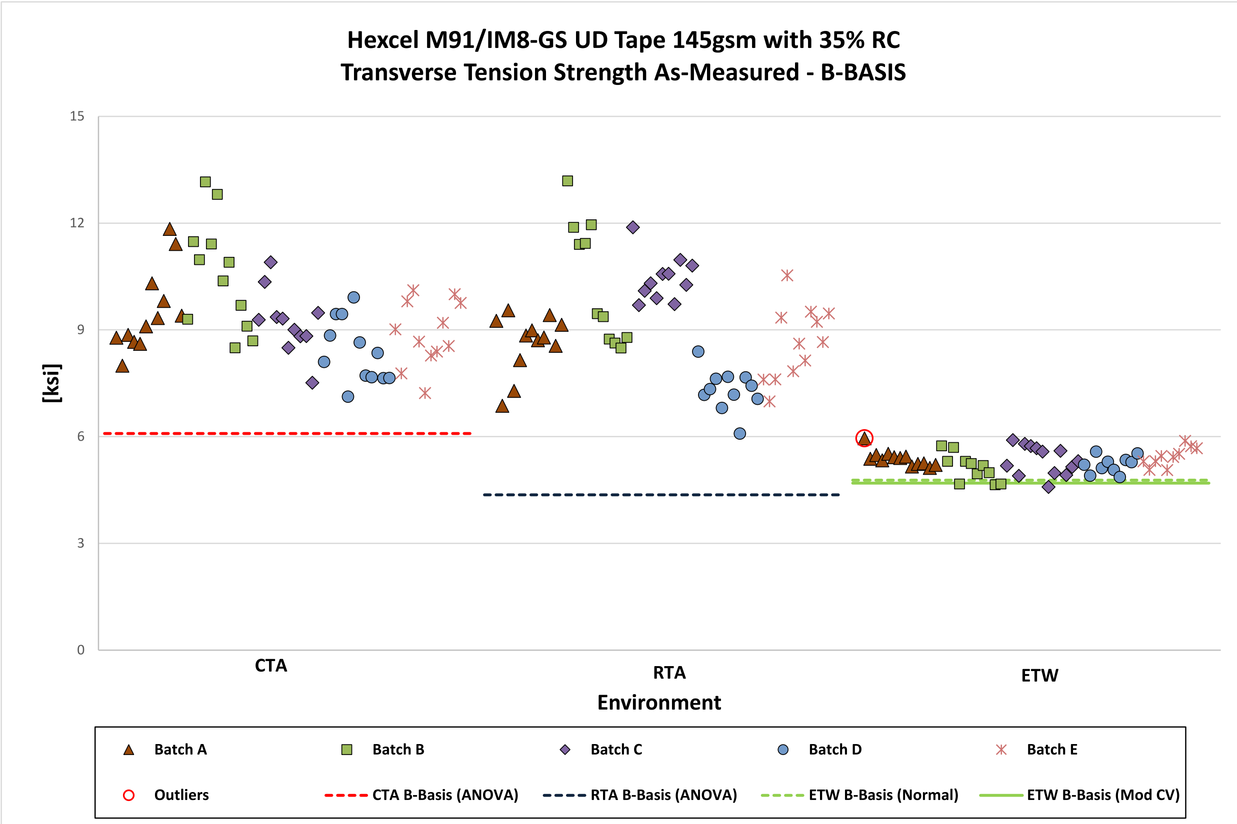

Figure 4-4: Batch Plot for TT As-Measured Strength – B-Basis

As-Measured Transverse Tension (TT) Strength Basis Values and Statistics			
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	9.306	9.045	5.302
Stdev	1.296	1.528	0.3252
CV	13.93	16.89	6.134
Mod CV	13.93	16.89	7.067
Min	7.124	6.085	4.584
Max	13.16	13.18	5.949
No. Batches	5	5	5
No. Spec.	59	57	57
Basis Values			
B-Basis Value	6.086	4.363	4.775
A-Basis Value	3.811	1.114	4.384
Method	ANOVA	ANOVA	Normal
Modified CV Basis Values			
B-Basis Value	NA	NA	4.695
A-Basis Value			4.245
Method			Normal

Table 4-3: As-Measured Statistics and Basis Values for TT Strength Data

Transverse Tension (TT) As-Measured Modulus Statistics			
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	1.470	1.293	1.051
Stdev	0.07641	0.02155	0.02540
CV	5.197	1.667	2.417
Min	1.253	1.244	1.010
Max	1.660	1.350	1.094
No. Batches	5	5	5
No. Spec.	55	56	57

Table 4-4: Statistics from TT Modulus Data

4.3 Longitudinal Compression (LC)

Longitudinal Compression strength data was computed from UNC0 strength data using the cross-ply backout factor data. Backout factor was calculated based off the conservative assumption that the Poisson's ratio is 0. A new batch of sampling is being populated to obtain the actual Poisson's ratio. The values will be revised once the new data is available. LC data is normalized by cured ply thickness. Both normalized and as-measured results are provided. Tests were conducted in the following environmental conditions: CTA, RTA, and ETW.

The datasets consist of five batches with more than fifty-five specimens per environment, therefore A-Basis values and B-Basis values were computed.

For the normalized dataset, the CTA and RTA conditions failed the ADK test for batch equivalency. ANOVA was used to compute values for CTA and RTA and the single point non-parametric method was used for ETW, as it failed all the distributions tests. Applying the modified CV, the CTA and RTA conditions failed the ADK test, therefore basis values were not computed for those. The normal method for modified CV was used for ETW.

For the as-measured dataset, the CTA and RTA conditions failed the ADK test for batch equivalency. ANOVA was used to compute values for CTA and RTA and the single point Weibull method was used for ETW, as it failed the normality test. Applying the modified CV, the CTA and RTA conditions failed the ADK test, and the ETW condition failed the normality test, therefore basis values were not computed for any condition.

There were three statistical outliers. The lowest value in batch A of the CTA condition was a batch outlier in the normalized and as-measured datasets. The lowest value in batch B of the CTA condition was a batch outlier in the normalized and as-measured datasets. The lowest value in batch D of the ETW condition was a batch outlier in the normalized dataset. The were retained for this analysis.

Statistics, Basis values and estimates are given for the LC strength data in Table 4-5 and for the modulus data in Table 4-6. The normalized data, A-estimates and A-Basis values are shown graphically in Figure 4-5 and the normalized data and B-Basis values in Figure 4-6.

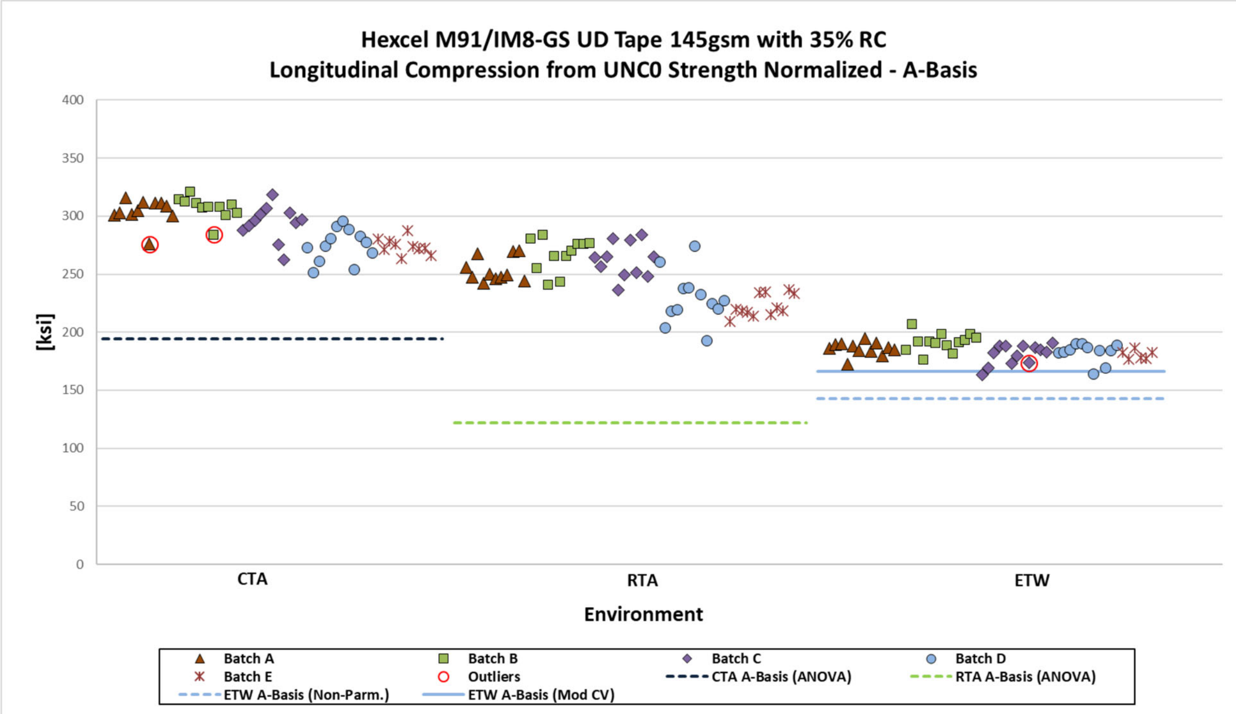

Figure 4-5: Batch Plot for LC Normalized Strength – A-Basis

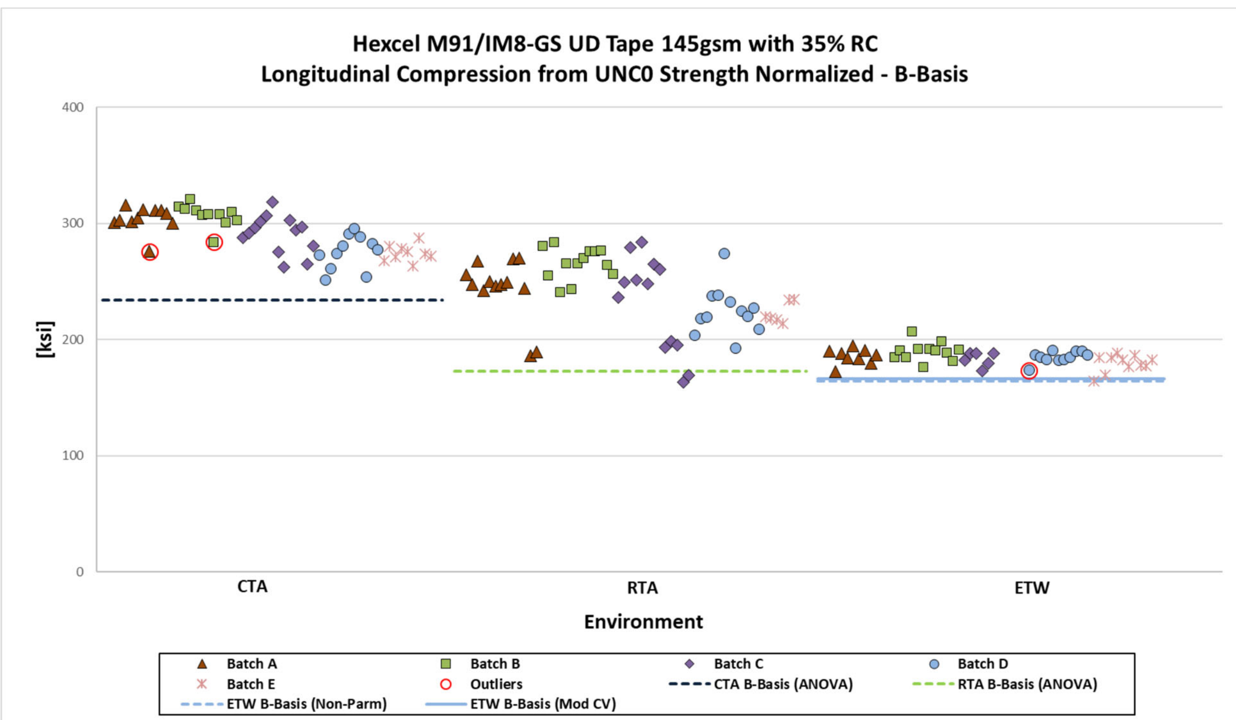

Figure 4-6: Batch Plot for LC Normalized Strength – B-Basis

Longitudinal Compression (LC) Strength from UNC0 Basis Values and Statistics						
	Normalized			As-Measured		
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	290.9	246.1	184.9	281.8	238.1	178.8
Stdev	18.26	23.16	8.259	16.90	20.61	7.984
CV	6.279	9.411	4.467	5.996	8.654	4.466
Mod CV	7.140	9.411	6.234	6.998	8.654	6.233
Min	251.4	193.0	163.3	243.9	187.1	154.4
Max	320.9	284.1	207.0	310.9	269.7	195.9
No. Batches	5	5	5	5	5	5
No. Spec.	55	57	56	55	57	56
Basis Values						
B-Basis Value	233.9	172.7	164.3	230.5	175.2	164.2
A-Basis Value	194.3	121.9	143.0	194.9	131.6	148.0
Method	ANOVA	ANOVA	Non-Parm.	ANOVA	ANOVA	Weibull
Modified CV Basis Values						
B-Basis Value	NA	NA	166.2	NA	NA	NA
A-Basis Value			152.3			
Method			Normal			

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

Longitudinal Compression (LC) Modulus Statistics						
	Normalized			As-Measured		
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	22.37	22.26	22.65	21.73	21.66	21.91
Stdev	0.7521	0.4645	0.5105	0.6130	0.4370	0.4093
CV	3.363	2.087	2.253	2.821	2.017	1.868
Min	20.78	20.83	21.70	20.51	20.79	21.12
Max	24.94	23.07	24.06	24.03	22.65	22.73
No. Batches	5	5	5	5	5	5
No. Spec.	55	55	53	55	55	53

Table 4-6: Statistics from LC Modulus Data

4.4 Transverse Compression (TC)

Transverse Compression data is not normalized Tests were conducted in the following environmental conditions: CTA, RTA, and ETW.

The datasets consist of five batches with more than fifty-five specimens per environment, therefore A-Basis values and B-Basis values were computed.

The RTA and ETW conditions failed the ADK test for batch equivalency. ANOVA was used to compute values for RTA and ETW and the single point normal method was used for CTA. Applying the modified CV, the CTA and RTA conditions were acceptable for pooling, while the ETW condition failed the ADK test, so basis values were not computed for ETW.

There were no statistical outliers.

Statistics, Basis values and estimates are given for the TC strength data in Table 4-7, and for the modulus data in Table 4-8. The as-measured data, A-estimates and A-Basis values are shown graphically in Figure 4-7 and the as-measured data and B-Basis values in Figure 4-8.

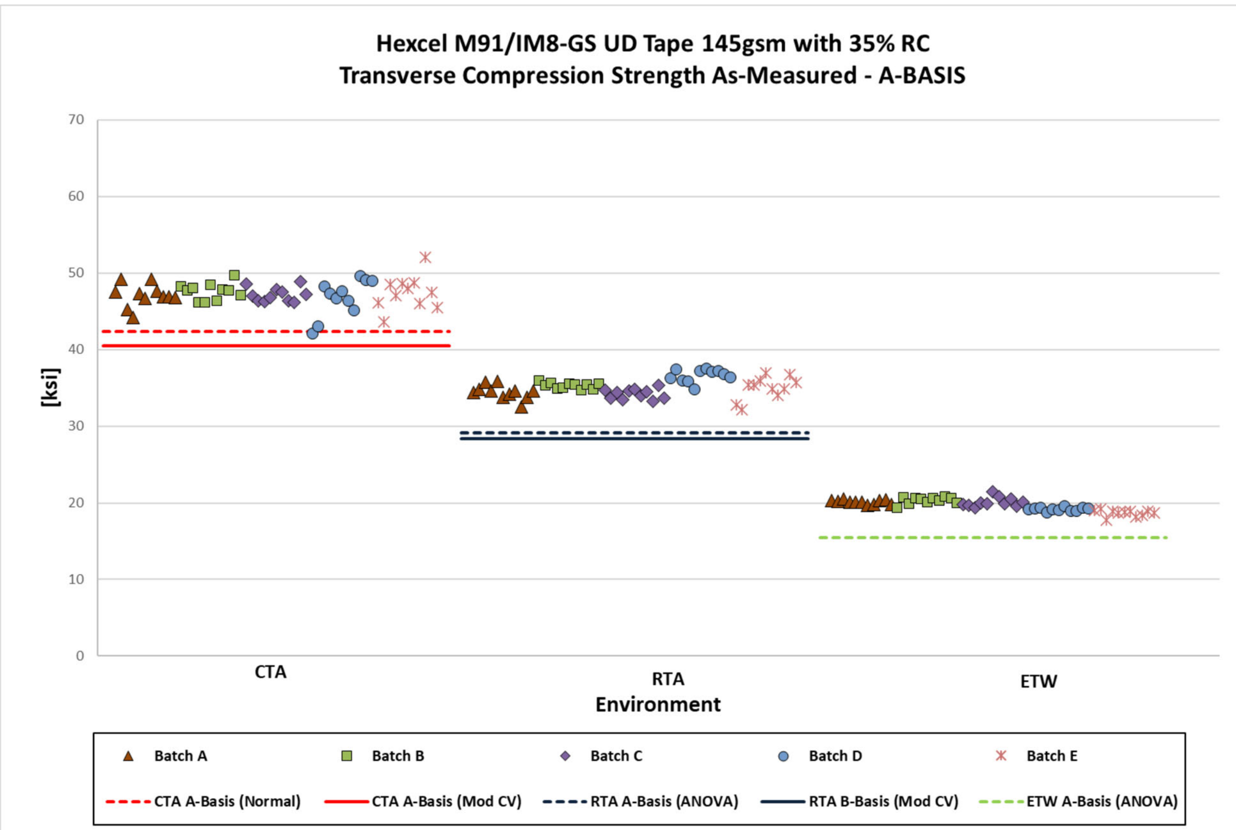

Figure 4-7: Batch Plot for TC As-Measured Strength – A-Basis

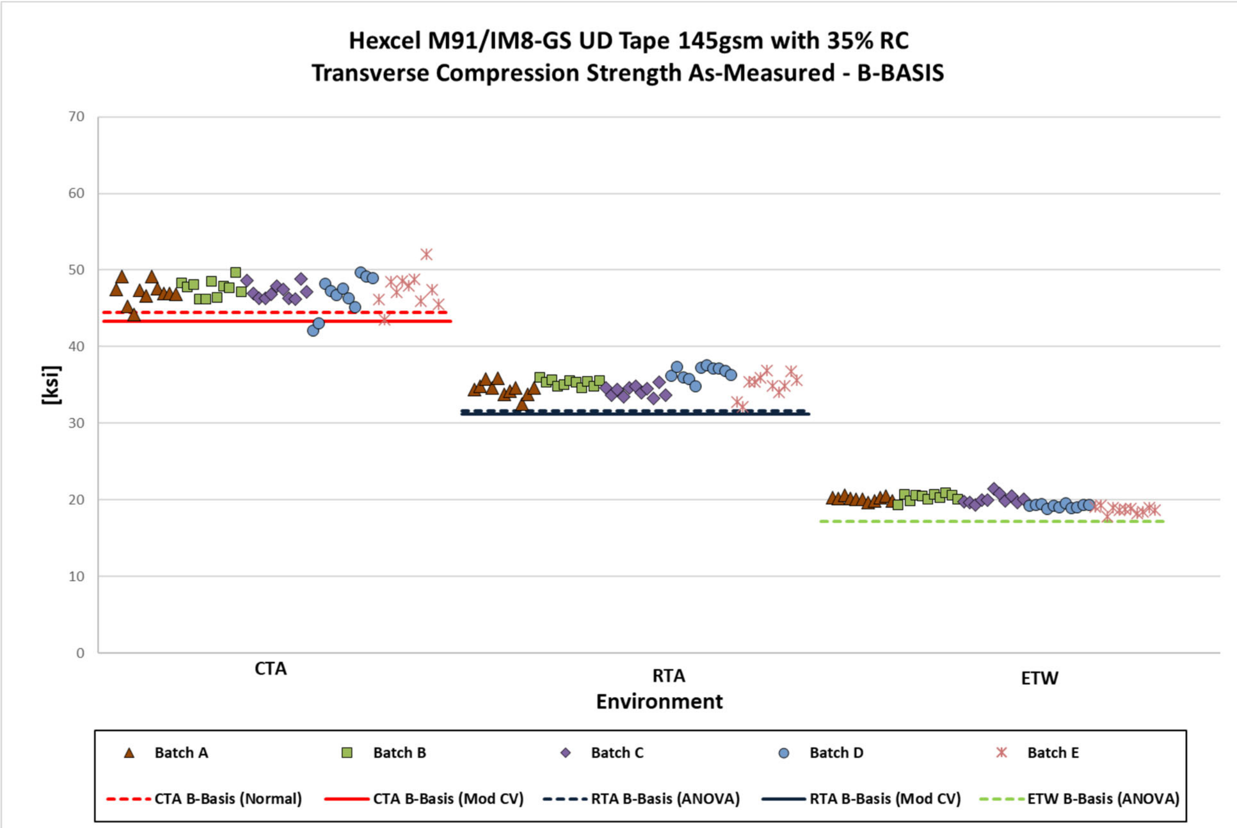

Figure 4-8: Batch Plot for TC As-Measured Strength – B-Basis

As-Measured Transverse Compression (TC) Strength Basis Values and Statistics			
Environment	**CTA (-65 °F)**	**RTA (70 °F)**	**ETW (180 °F)**
Mean	47.19	35.10	19.69
Stdev	1.692	1.236	0.7577
CV	3.586	3.521	3.848
Mod CV	6.000	6.000	6.000
Min	42.06	32.16	17.80
Max	52.01	37.51	21.48
No. Batches	5	5	5
No. Spec.	55	55	55
Basis Values			
B-Basis Value	44.44	31.60	17.18
A-Basis Value	42.40	29.16	15.45
Method	Normal	ANOVA	ANOVA
Modified CV Basis Values			
B-Basis Value	43.28	31.19	NA
A-Basis Value	40.44	28.35	
Method	Pooled	Pooled	

Table 4-7: As-Measured Statistics and Basis Values for TC Strength Data

Transverse Compression (TC) As-Measured Modulus Statistics			
Environment	**CTA (-65 °F)**	**RTA (70 °F)**	**ETW (180 °F)**
Mean	**1.533**	**1.375**	**1.234**
Stdev	**0.07109**	**0.03033**	**0.01589**
CV	**4.638**	**2.206**	**1.288**
Min	**1.314**	**1.301**	**1.197**
Max	**1.835**	**1.430**	**1.275**
No. Batches	**5**	**5**	**5**
No. Spec.	**55**	**55**	**55**

Table 4-8: Statistics for TC Modulus Data

4.5 Laminate Unnotched Compression (UNC0)

The UNC0 data is normalized by cured ply thickness. Both normalized and as-measured statistics are provided. Tests were conducted in the following environmental conditions: CTA, RTA, an ETW.

The datasets consists of five batches with more than fifty-five specimens per condition, therefore A-Basis and B-Basis values were computed.

For the normalized dataset, the CTA and RTA conditions failed the ADK test for batch equivalency. ANOVA was used to compute values for CTA and RTA and the single point non-parametric method was used for ETW. Applying the modified CV, the CTA and RTA conditions failed the ADK test, therefore basis values were not computed for those conditions. The normal method for modified CV was used for ETW.

For the as-measured dataset, the CTA and RTA conditions failed the ADK test for batch equivalency. ANOVA was used to compute values for CTA and RTA and the single point Weibull method was used for ETW. Applying the modified CV, the CTA and RTA conditions failed the ADK test and the ETW condition failed the normality test, therefore basis values were not computed for any condition.

There were three statistical outliers. The lowest normalized value in batch A of the CTA condition was an outlier for the batch but not for the condition. It was an outlier in the normalized dataset and in the as-measured dataset. The lowest normalized value in batch B of the CTA condition was an outlier for the batch but not for the condition. It was an outlier in the normalized dataset and in the as-measured dataset. The lowest normalized value in batch D of the ETW condition was an outlier for the batch but not for the condition. It was an outlier in the normalized dataset but not in the as-measured dataset. Thet were retained for this analysis.

Statistics and basis values are given for the UNC0 strength data in Table 4-9 and for the modulus data in Table 4-10. The normalized data and A-Basis values are shown graphically in Figure 4-9 and the normalized data and B-Basis values in Figure 4-10.

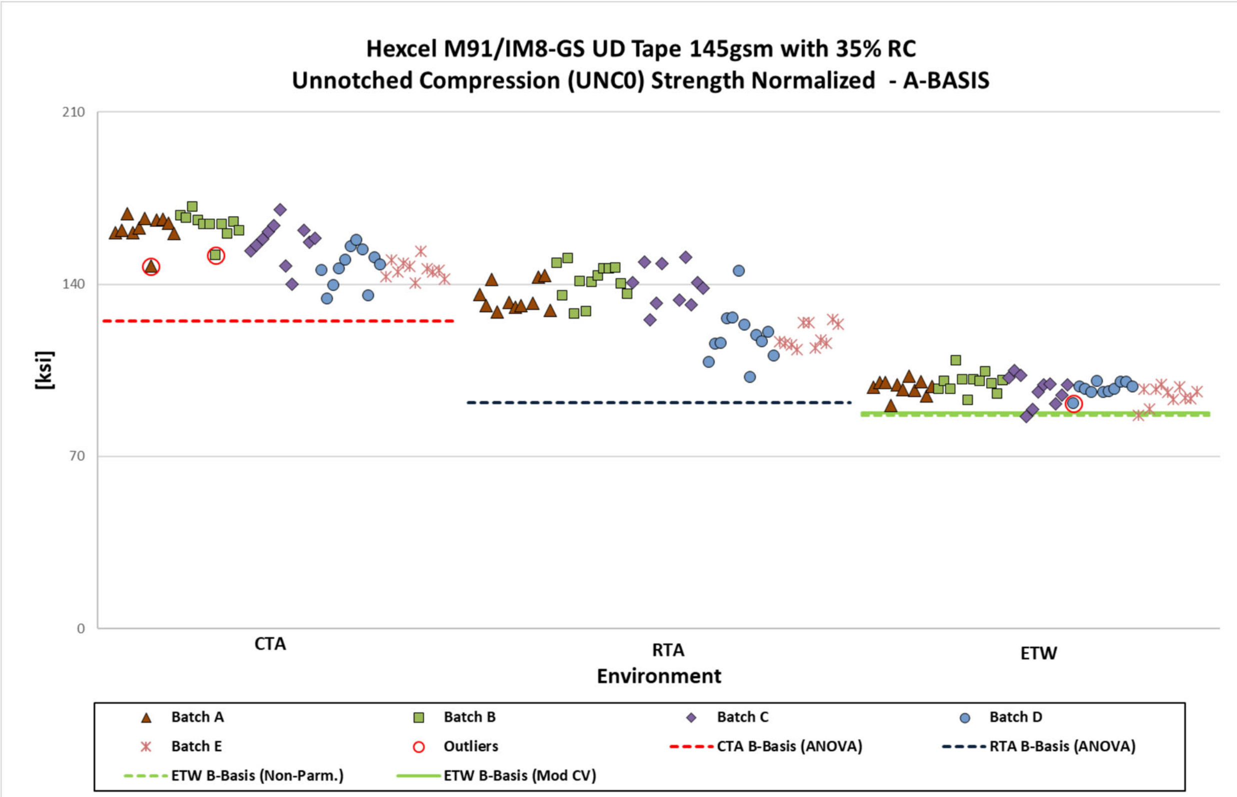

Figure 4-9: Batch Plot for UNC0 Normalized Strength – A-Basis

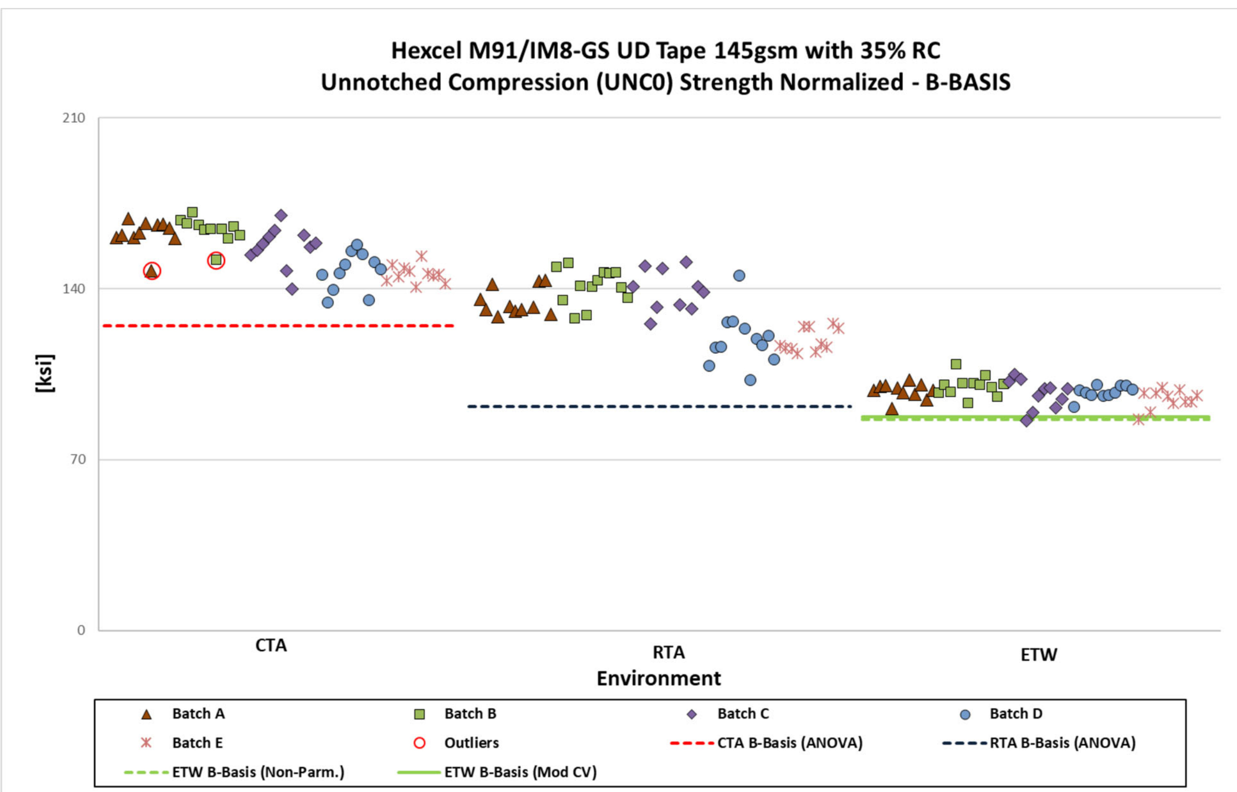

Figure 4-10: Batch Plot for UNC0 Normalized Strength - B-Basis

Unnotched Compression (UNC0) Strength Basis Values and Statistics						
	Normalized			As-Measured		
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	155.4	130.6	97.49	150.9	126.6	94.43
Stdev	9.757	12.29	4.355	9.046	10.96	4.217
CV	6.279	9.411	4.467	5.996	8.654	4.466
Mod CV	7.139	9.411	6.233	6.998	8.654	6.233
Min	134.3	102.4	86.12	130.6	99.50	81.56
Max	171.5	150.8	109.1	166.4	143.4	103.5
No. Batches	5	5	5	5	5	5
No. Spec.	55	57	56	55	57	56
Basis Values						
B-Basis Value	124.9	91.69	86.60	123.4	93.18	86.72
A-Basis Value	103.8	64.71	75.39	104.3	69.96	78.17
Method	ANOVA	ANOVA	Non-Parm.	ANOVA	ANOVA	Weibull
Modified CV Basis Values						
B-Basis Value	NA	NA	87.63	NA	NA	NA
A-Basis Value			80.31			
Method			Normal			

Table 4-9: Statistics and Basis Values for UNC0 Strength Data

Lamina Unnotched Compression (UNC0) Modulus Statistics						
	Normalized			As-Measured		
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	12.30	12.27	12.42	11.94	11.90	12.03
Stdev	0.3861	0.2411	0.3381	0.3306	0.2435	0.2534
CV	3.139	1.965	2.722	2.769	2.046	2.106
Min	11.71	11.78	11.52	11.37	11.39	11.46
Max	13.60	13.02	13.17	12.86	12.47	12.64
No. Batches	5	5	5	5	5	5
No. Spec.	55	55	55	55	55	55

Table 4-10: Statistics for UNC0 Modulus

4.6 In-Plane Shear V-Notch (IPSV)

In Plane Shear data is not normalized. Test results were available for 0.2% offset strength, strength at 5% strain and ultimate shear strength in the following environmental conditions: CTA, RTA, and ETW.

Except for the 0.2% offset strength and strength at 5% strain, CTA datasets, all the conditions for the three properties consist of five batches with fifty-five specimens, therefore A-Basis and B-Basis values were computed for those.

For the 0.2% offset strength dataset, the three conditions failed the ADK test for batch equivalency. ANOVA was used to compute basis values and estimates for all conditions. Applying the modified CV, the ETW condition failed the normality test, therefore basis values were not computed for ETW. CTA and RTA were not pooled because the pooled dataset failed the Levene's test for equality of standard deviations, therefore the normal method for modified CV was used to compute basis values and estimates for both conditions.

For strength at 5% strain, the three conditions failed the ADK test for batch equivalency. ANOVA was used to compute basis values and estimates for all conditions. Applying the modified CV, pooling was not possible because al combinations failed the Levene's test. The normal method was used for all conditions.

For the ultimate shear strength dataset, the RTA and ETW conditions failed the ADK test for batch equivalency. ANOVA was used to compute values for RTA and ETW and the single point normal method was used for CTA. Applying the modified CV, the ETW condition failed the normality test, therefore basis values were not computed for ETW. The CTA and RTA conditions were pooled.

There were seven statistical outliers. The highest value in batch B of the CTA condition in the 0.2% offset strength dataset was an outlier for the batch but not for the condition. The lowest value in batch E of the RTA condition in the 0.2% offset strength dataset was an outlier for the batch and for the condition. The highest value in batch C of the ETW condition in the 0.2% offset strength dataset was an outlier for the batch and for the condition. The highest value in batch E of the ETW condition in the 0.2% offset strength dataset was an outlier for the batch but not for the condition. The highest value in batch B of the CTA condition was a batch outlier for strength at 5% strain. The lowest value in batch B of the RTA condition was a batch outlier for the strength at 5% strain dataset. The highest value in batch D of the ETW condition in the ultimate shear strength dataset was an outlier for the batch and for the condition. They were retained for this analysis.

Statistics and basis values are given in Table 4-11 and for the modulus in Table 4-12. The as-measured data and basis values are shown graphically in Figure 4-11 through Figure 4-16.

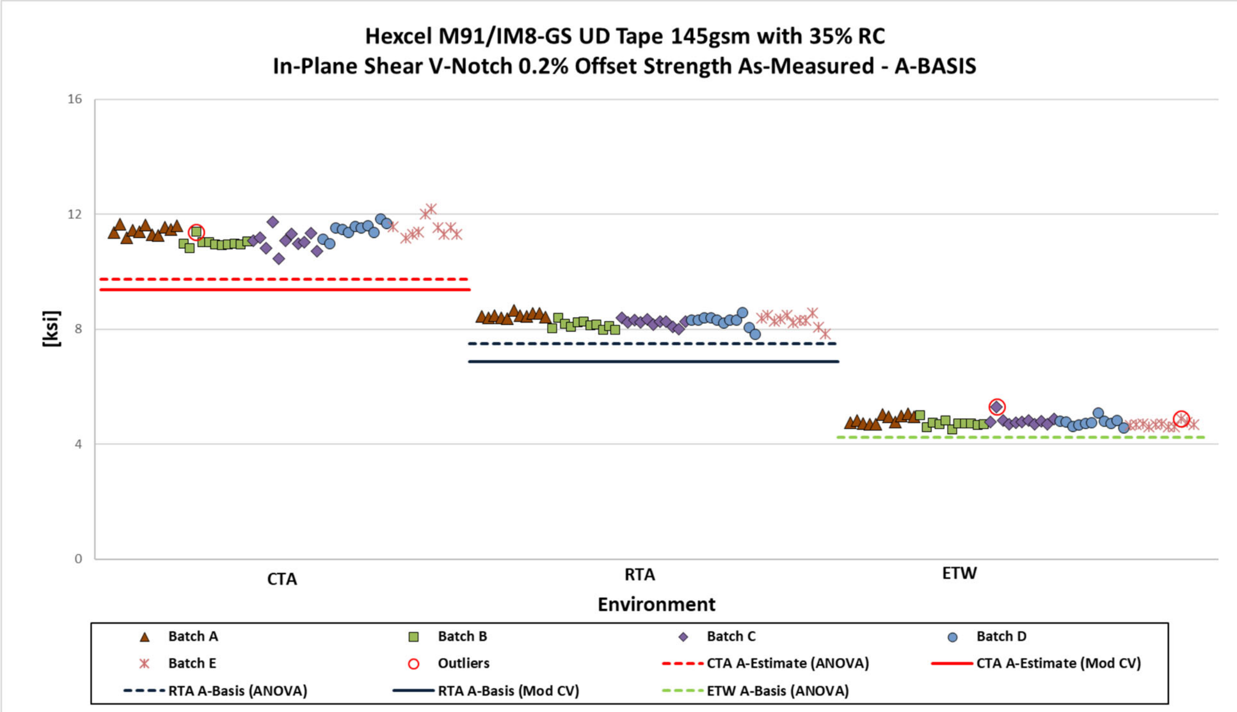

Figure 4-11: Batch Plot for IPSV 0.2% Offset As-Measured Strength Data - A-Basis

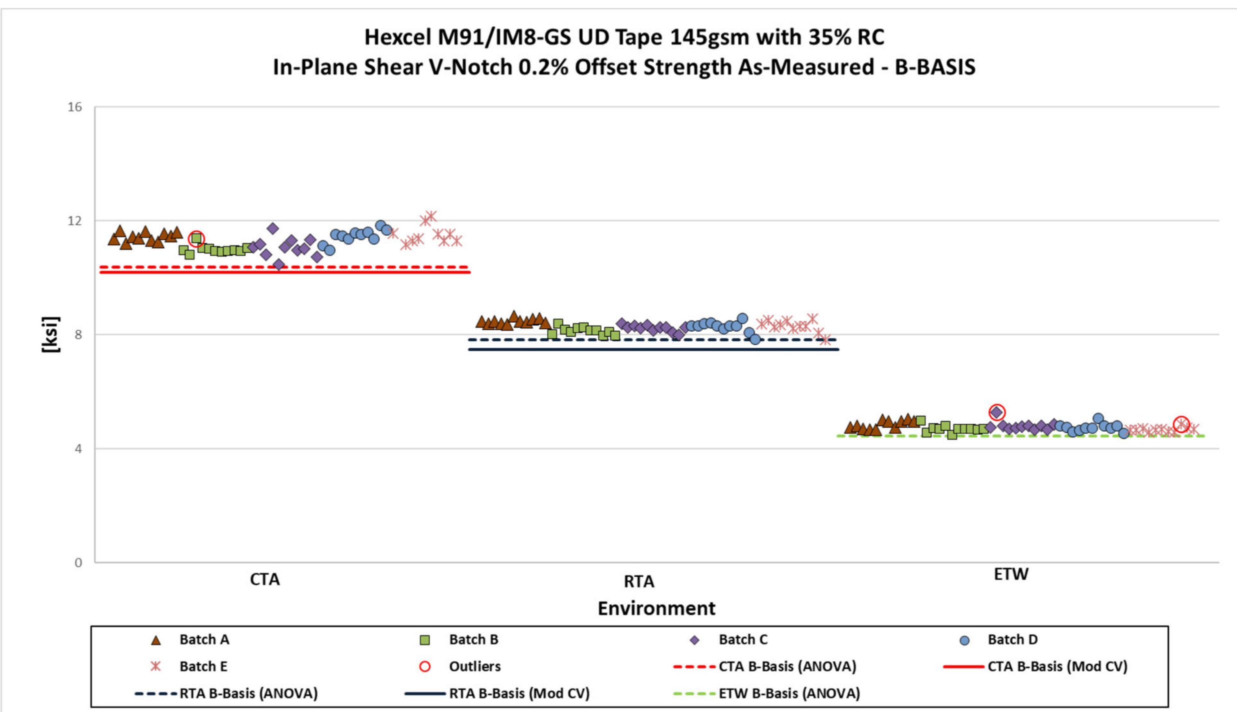

Figure 4-12: Batch Plot for IPSV 0.2% Offset As-Measured Strength Data - B-Basis

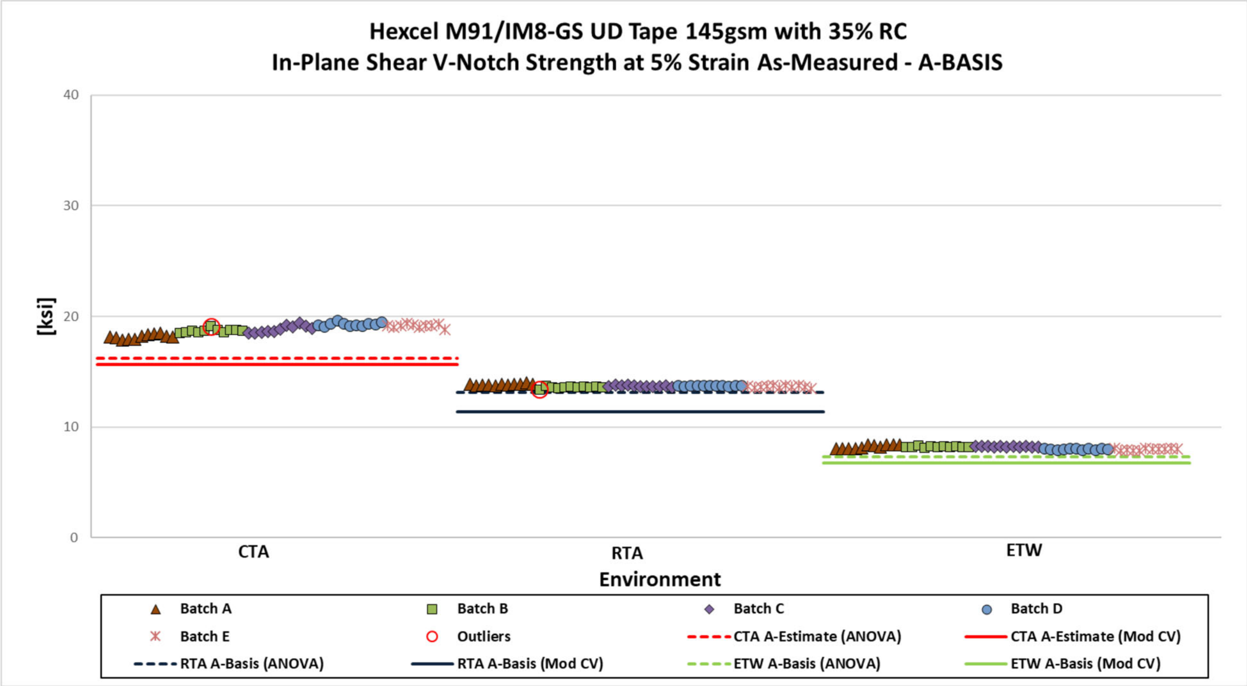

Figure 4-13: Batch Plot for IPSV Strength at 5% Strain As-Measured Data - A-Basis

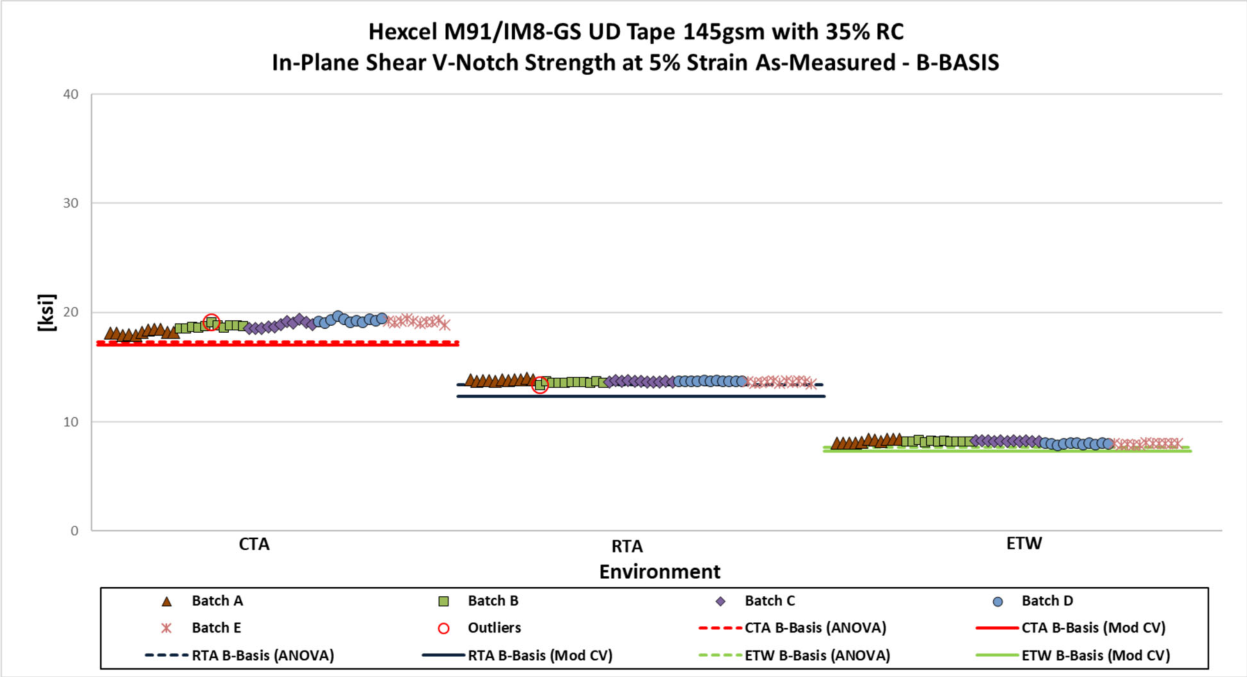

Figure 4-14: Batch Plot for IPSV Strength at 5% Strain As-Measured Data - B-Basis

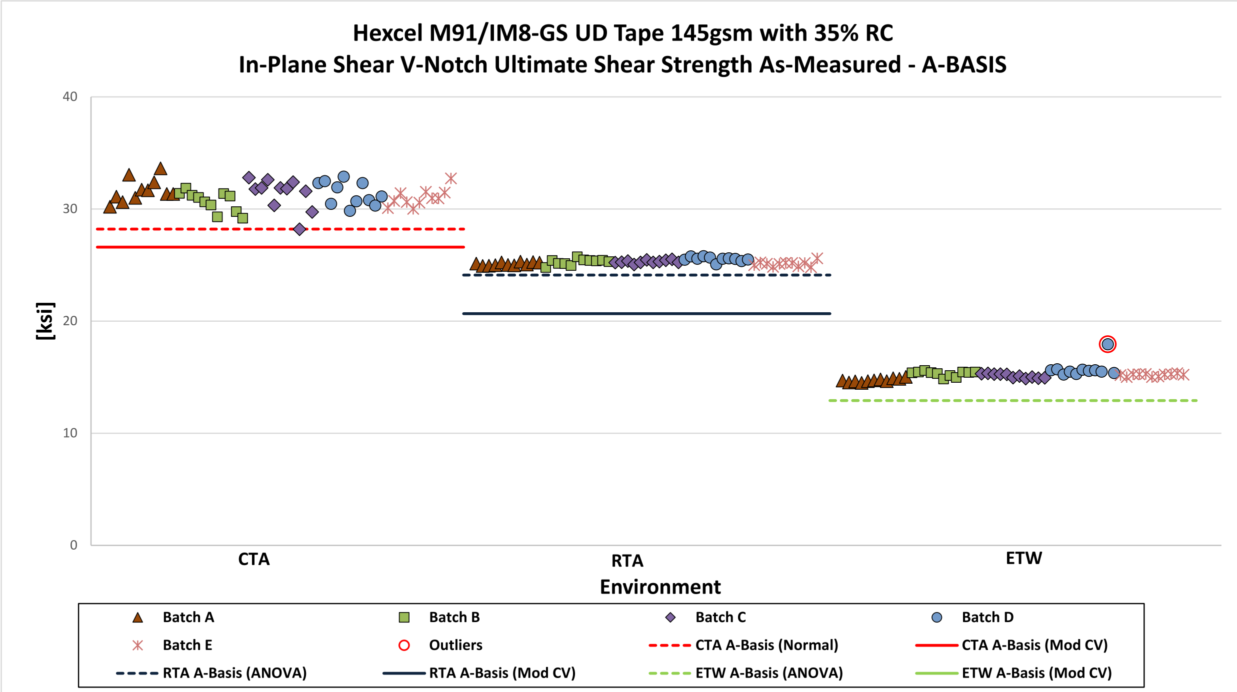

Figure 4-15: Batch Plot for IPSV Ultimate Shear As-Measured Strength Data - A-Basis

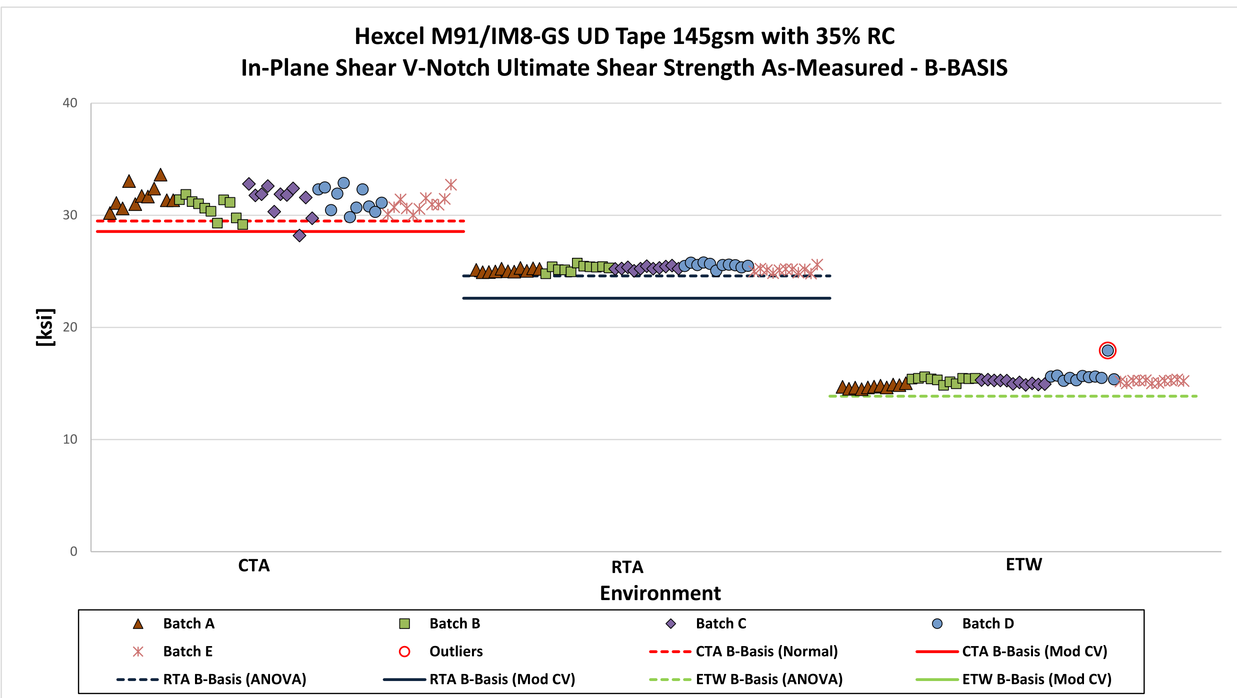

Figure 4-16: Batch Plot for IPSV Ultimate Shear As-Measured Strength Data - B-Basis

In Plane Shear V-Notch (IPSV) As-Measured Basis Values and Statistics									
	0.2% Offset Strength			Strength at 5% Strain			Ultimate Shear Strength		
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	11.30	8.286	4.765	18.82	13.70	8.129	31.21	25.30	15.22
Stdev	0.3292	0.1833	0.1436	0.4453	0.1043	0.1439	1.064	0.2444	0.4839
CV	2.914	2.212	3.014	2.366	0.7616	1.771	3.408	0.9660	3.180
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Min	10.46	7.831	4.508	17.88	13.39	7.875	28.20	24.78	14.50
Max	12.18	8.646	5.297	19.63	13.98	8.433	33.63	25.79	17.94
No. Batches	5	5	5	5	5	5	5	5	5
No. Spec.	54	55	55	54	55	55	55	55	55
Basis Values and Estimates									
B-Basis Value	10.38	7.818	4.463	17.29	13.38	7.663	29.48	24.68	13.86
A-Basis Value		7.488	4.246		13.16	7.341	28.20	24.25	12.91
A-Estimate	9.738			16.23					
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	Normal	ANOVA	ANOVA
Modified CV Basis Values and Estimates									
B-Basis Value	10.19	7.477	NA	16.98	12.36	7.336	28.54	22.63	NA
A-Basis Value		6.878			11.37	6.747	26.60	20.69	
A-Estimate	9.374			15.62					
Method	Normal	Normal		Normal	Normal	Normal	Pooled	Pooled	

Table 4-11: Statistics and Basis Values IPSV Strength Data

In Plane Shear V-Notch (IPSV) As-Measured Modulus Statistics			
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	0.8661	0.7437	0.6431
Stdev	0.02839	0.02131	0.03605
CV	3.279	2.865	5.606
Min	0.8071	0.6940	0.5427
Max	0.9446	0.7815	0.7185
No. Batches	5	5	5
No. Spec.	54	55	55

Table 4-12: Statistics for IPSV Modulus Data

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4.7 In-Plane Shear Tension (IPST)

In Plane Shear data is not normalized. Test results were available for 0.2% offset strength AND strength at 5% strain in the following environmental conditions: CTA, RTA, and ETW.

For the 0.2% offset strength dataset, the three conditions failed the ADK test for batch equivalency. ANOVA was used to compute estimates for all conditions. Applying the modified CV, the three conditions were not pooled because the pooled dataset failed the Levene's test for equality of standard deviations, therefore the normal method for modified CV was used to compute values for all conditions.

For the strength at 5% strain dataset, the three conditions failed the ADK test for batch equivalency. ANOVA was used to compute estimates for all conditions. Applying the modified CV, the CTA and RTA conditions met all the requirements for pooling and the normal method was used for ETW.

There was one statistical outlier. The highest value in batch B of the CTA condition in the 0.2% offset strength dataset was an outlier for the batch and for the condition.

Statistics, B-Basis values and estimates are given for the IPST strength data in Table 4-13 and for the modulus data in Table 4-14. The as-measured data, B-Basis values and B-estimates are shown graphically for 0.2% offset strength in Figure 4-17 and for strength at 5% strain in Figure 4-18.

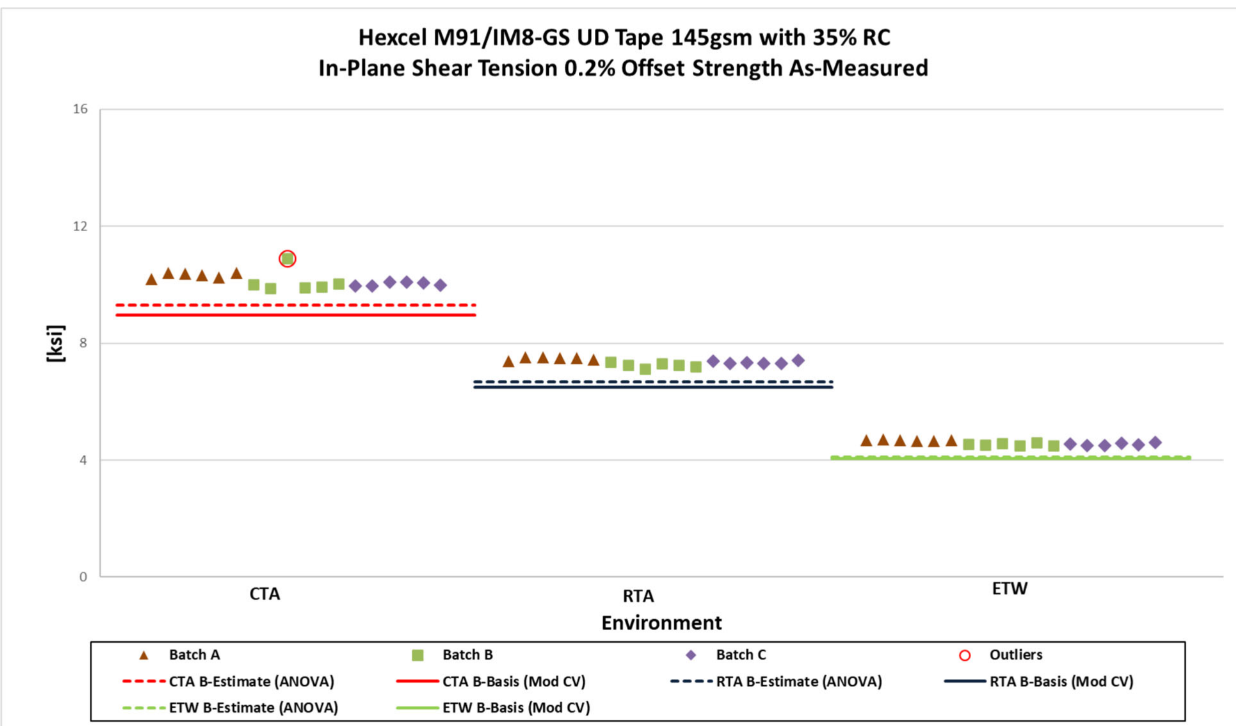

Figure 4-17: Batch Plot for IPST 0.2% Offset As-Measured Strength Data

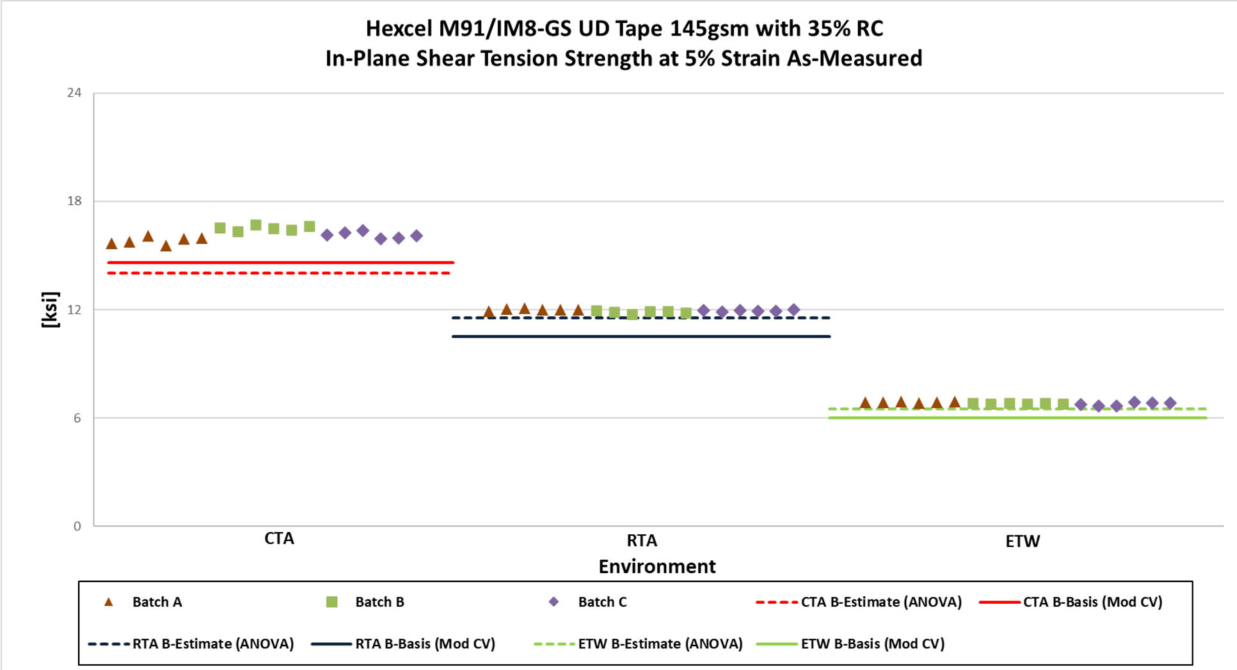

Figure 4-18: Batch Plot for IPST As-Measured Strength at 5% Strain Data

In Plane Shear Tension (IPST) As-Measured Basis Values and Statistics						
	0.2% Offset Strength			Strength at 5% Strain		
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	10.16	7.353	4.587	16.16	11.94	6.827
Stdev	0.2539	0.1114	0.07627	0.3334	0.07540	0.07355
CV	2.499	1.515	1.663	2.063	0.6315	1.077
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	9.890	7.115	4.488	15.55	11.76	6.654
Max	10.89	7.518	4.702	16.72	12.09	6.938
No. Batches	3	3	3	3	3	3
No. Spec.	18	18	18	18	18	18
Basis Value Estimates						
B-Estimate	9.301	6.672	4.101	14.04	11.56	6.501
A-Estimate	8.692	6.186	3.754	12.53	11.28	6.268
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates						
B-Basis Value	8.955	6.482	4.043	14.61	10.39	6.019
A-Estimate	8.102	5.864	3.658	13.55	9.331	5.445
Method	Normal	Normal	Normal	Pooled	Pooled	Normal

Table 4-13: Statistics and Basis Values IPST Strength Data

In Plane Shear Tension (IPST) As-Measured Modulus Statistics			
Environment	**CTA (-65 °F)**	**RTA (70 °F)**	**ETW (180 °F)**
Mean	**0.8402**	**0.6903**	**0.4633**
Stdev	**0.02206**	**0.01493**	**0.008221**
CV	**2.625**	**2.162**	**1.775**
Min	**0.7990**	**0.6616**	**0.4522**
Max	**0.8739**	**0.7151**	**0.4769**
No. Batches	**3**	**3**	**3**
No. Spec.	**18**	**18**	**18**

Table 4-14: Statistics from IPS Modulus Data

4.8 Lamina Short-Beam Strength (SBS)

The Short Beam Strength data is not normalized. Tests were conducted in the following environmental conditions: CTA, RTA and ETW.

The datasets consist of five batches with fifty-five specimens per condition, therefore A-Basis and B-Basis values were computed.

The three conditions failed the ADK test for batch equivalency. ANOVA was used to compute values for all conditions. Applying the modified CV, the three conditions were not pooled because the pooled dataset failed the Levene's test for equality of variances and the Anderson Darling test of normality. CTA and RTA were pooled and the normal method for modified CV was used for ETW.

There were no statistical outliers.

Statistics and basis values are given for the SBS data in Table 4-15. The as-measured data and A-Basis values are shown graphically in Figure 4-19 and the as-measured data and B-Basis values in Figure 4-20.

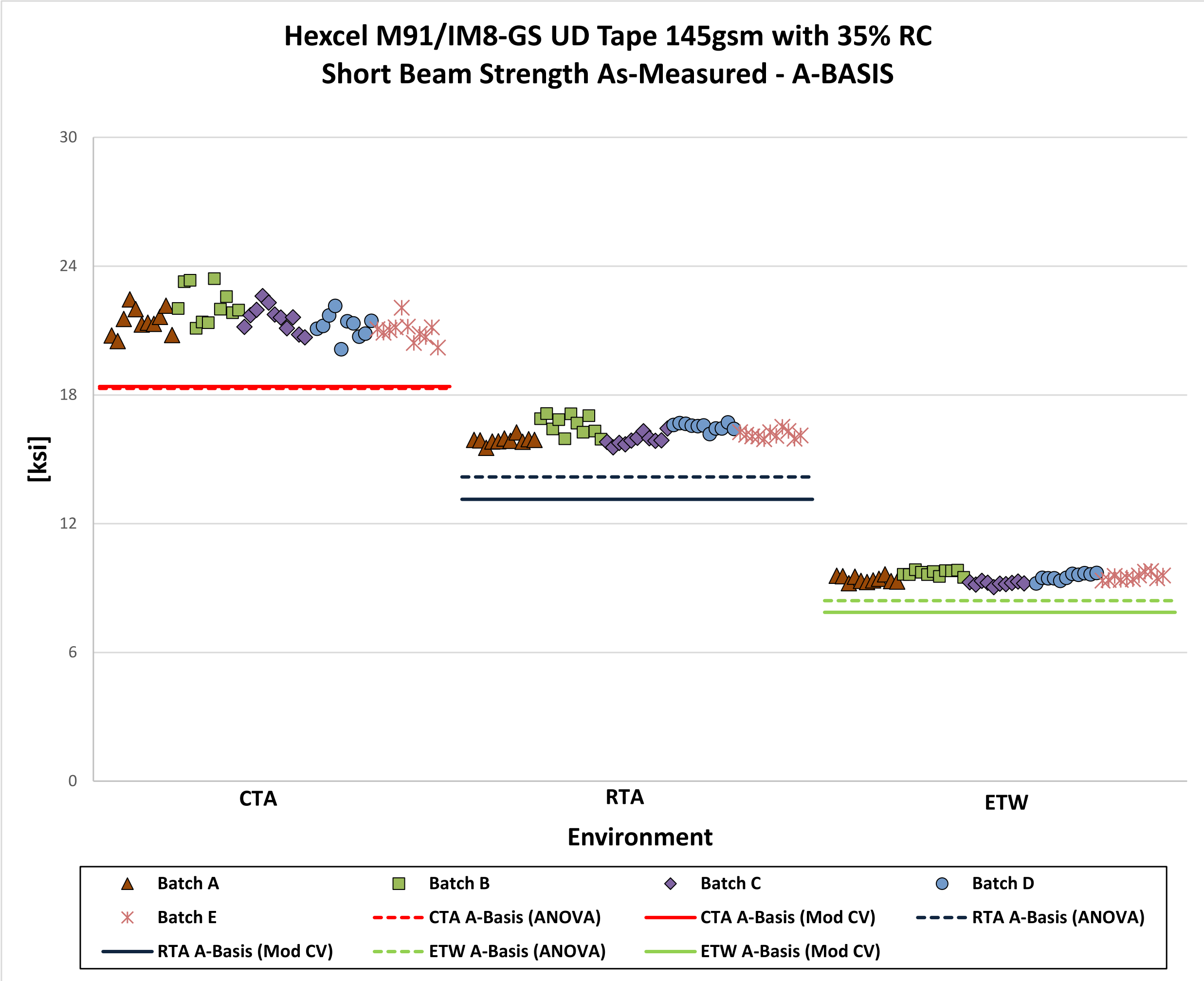

Figure 4-19: Batch Plot for SBS As-Measured Strength – A-Basis

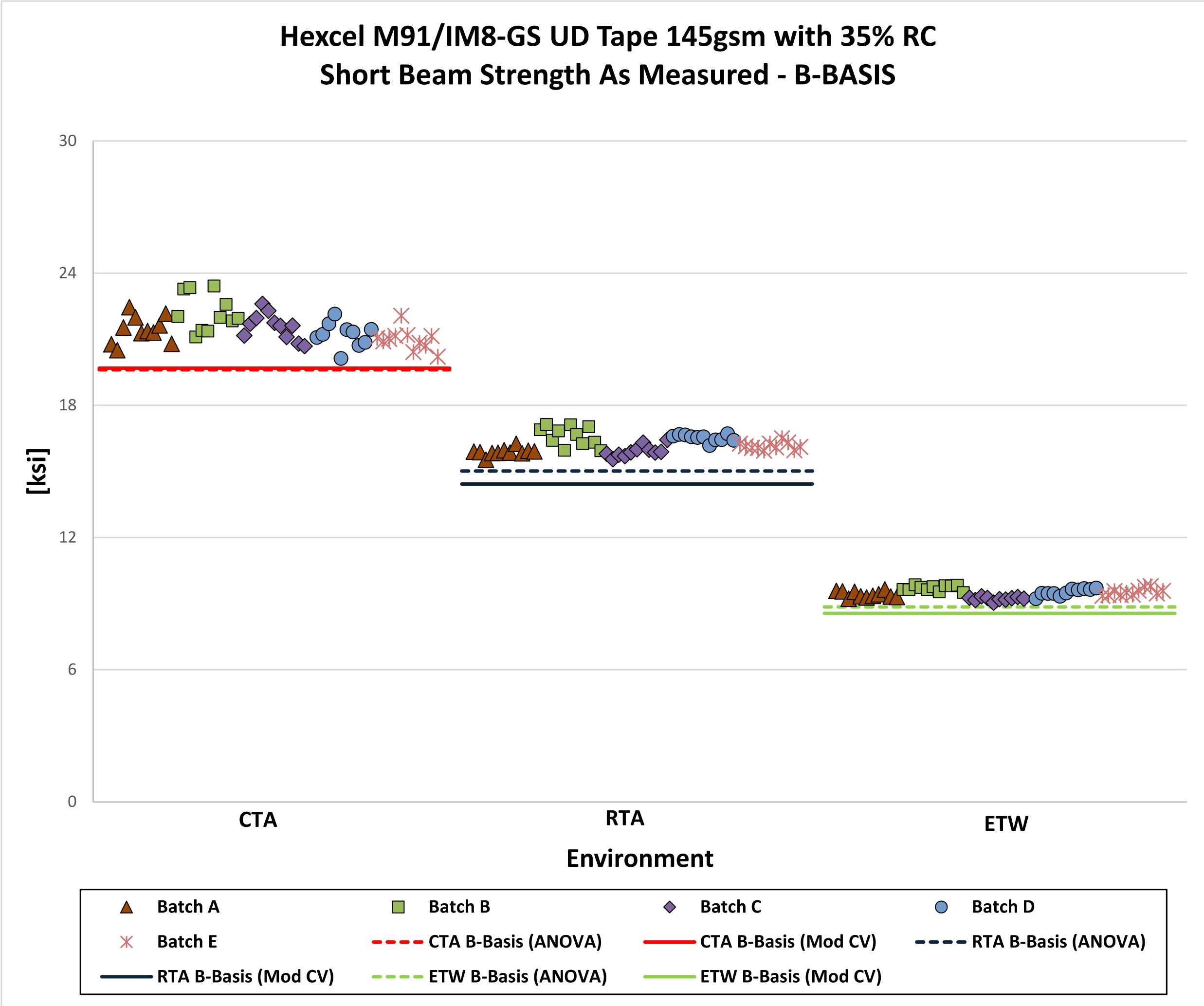

Figure 4-20: Batch Plot for SBS As-Measured Strength - B-Basis

Short Beam Strength (SBS) As-Measured Basis Values and Statistics			
Environment	**CTA (-65 °F)**	**RTA (70 °F)**	**ETW (180 °F)**
Mean	21.48	16.22	9.484
Stdev	0.7362	0.3923	0.2029
CV	3.428	2.418	2.139
Mod CV	6.000	6.000	6.000
Min	20.14	15.54	9.049
Max	23.42	17.13	9.859
No. Batches	5	5	5
No. Spec.	55	55	55
Basis Values			
B-Basis Value	19.62	15.02	8.854
A-Basis Value	18.31	14.18	8.417
Method	ANOVA	ANOVA	ANOVA
Modified CV Basis Values			
B-Basis Value	19.69	14.44	8.559
A-Basis Value	18.39	13.14	7.873
Method	Pooled	Pooled	Normal

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

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

The ILT data is not normalized. Data is reported on two properties: Interlaminar Tension Strength and Curved Beam Strength. Testing was done in the following environmental conditions: CTA, RTA, and ETW.

For both properties tested, the three conditions consist of more than fifty-five specimens distributed in five batches, therefore A-Basis values and B-Basis values were computed.

For both properties, three conditions failed the ADK test for batch equivalency. ANOVA was used to compute Basis values for all scenarios. Applying the modified CV, for both properties, all conditions failed the ADK test, therefore basis values were not computed.

There were two statistical outliers. The highest value in batch A of the CTA condition in the interlaminar tension strength dataset was an outlier for the batch and for the condition. It was also an outlier in the curved beam strength dataset. The lowest value in batch E of the RTA condition in the interlaminar tension strength dataset was an outlier for the batch but not for the condition. It was also an outlier in the curved beam strength dataset. They were retained for analysis.

Statistics and basis values are presented in for ILT in Table 4-16. The as-measured data and A-Basis values are displayed graphically in Figure 4-21 and Figure 4-22, and the as-measured data and B-Basis values are in Figure 4-23 and Figure 4-24.

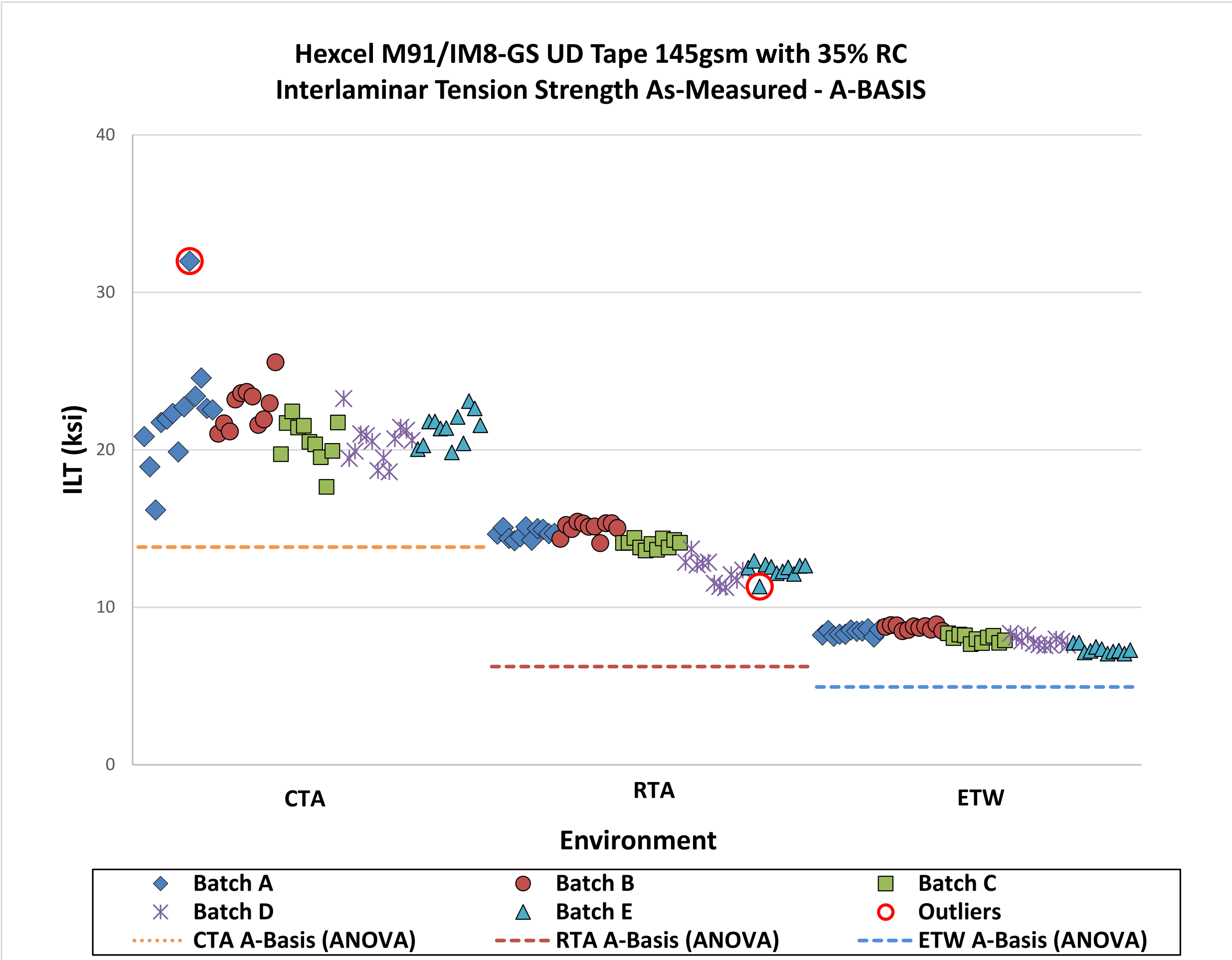

Figure 4-21: Batch Plot for Interlaminar Tension As-Measured Strength – A-Basis

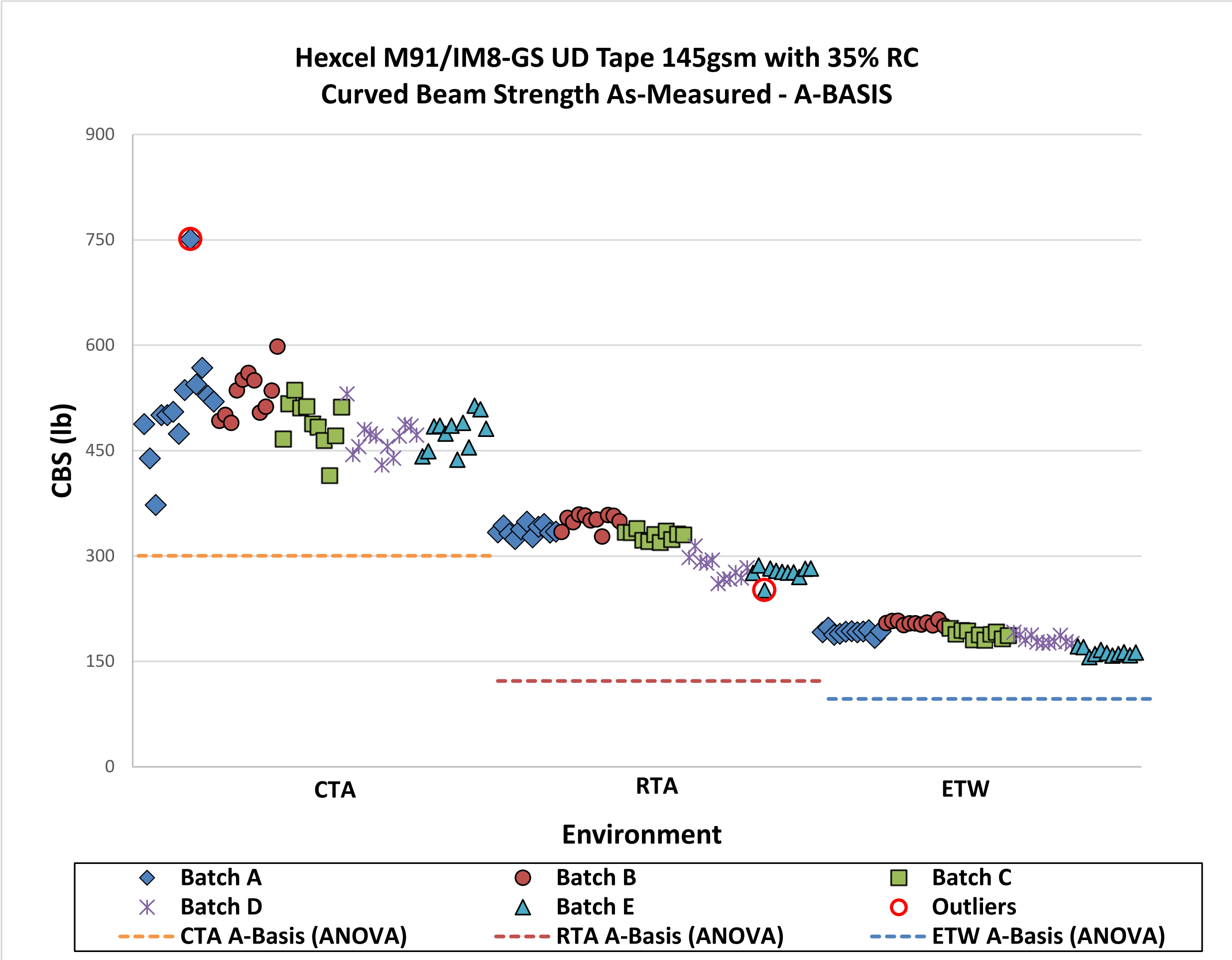

Figure 4-22: Batch Plot for Curved Beam As-Measured Strength - A-Basis

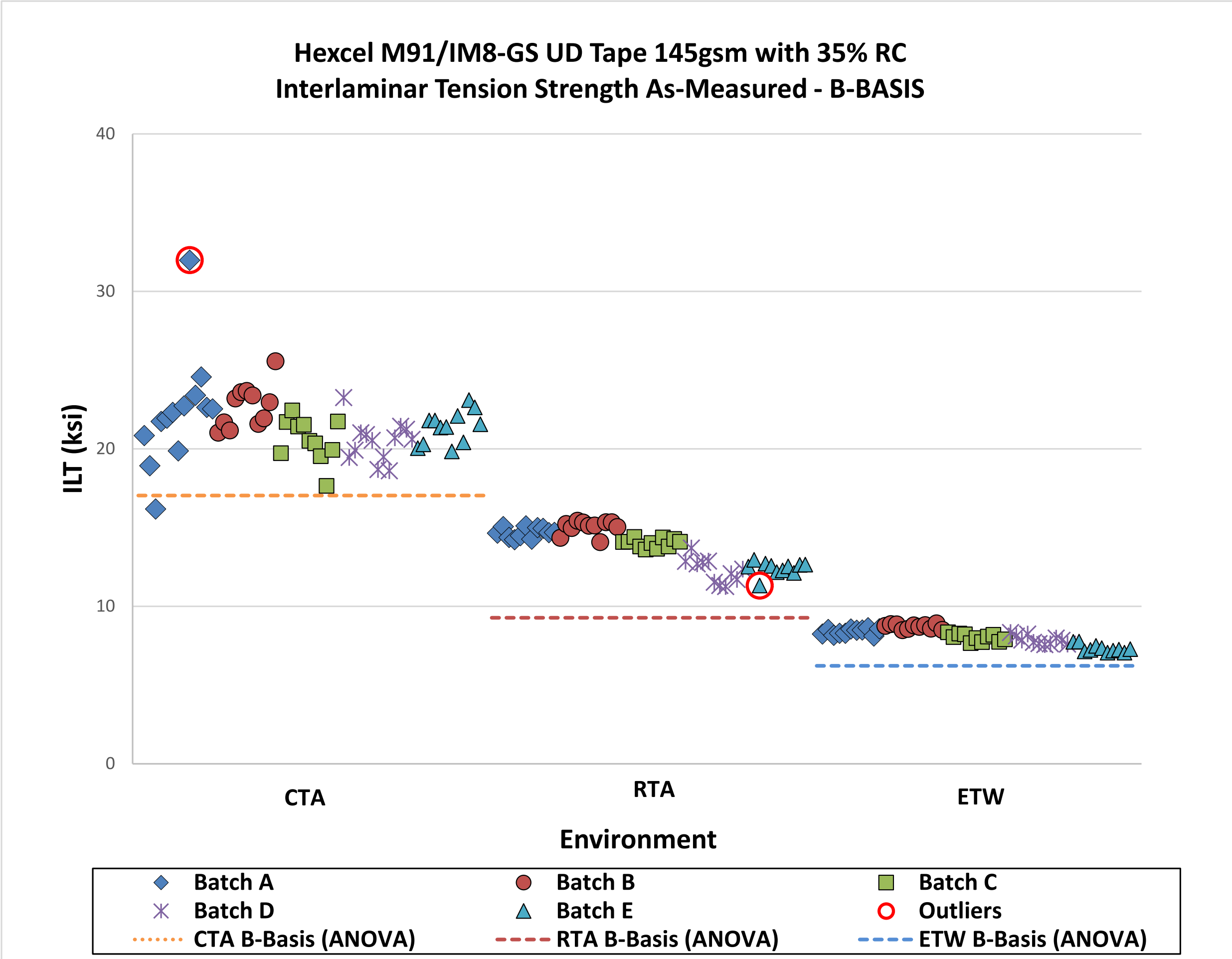

Figure 4-23: Batch Plot for Interlaminar Tension As-Measured Strength - B-Basis

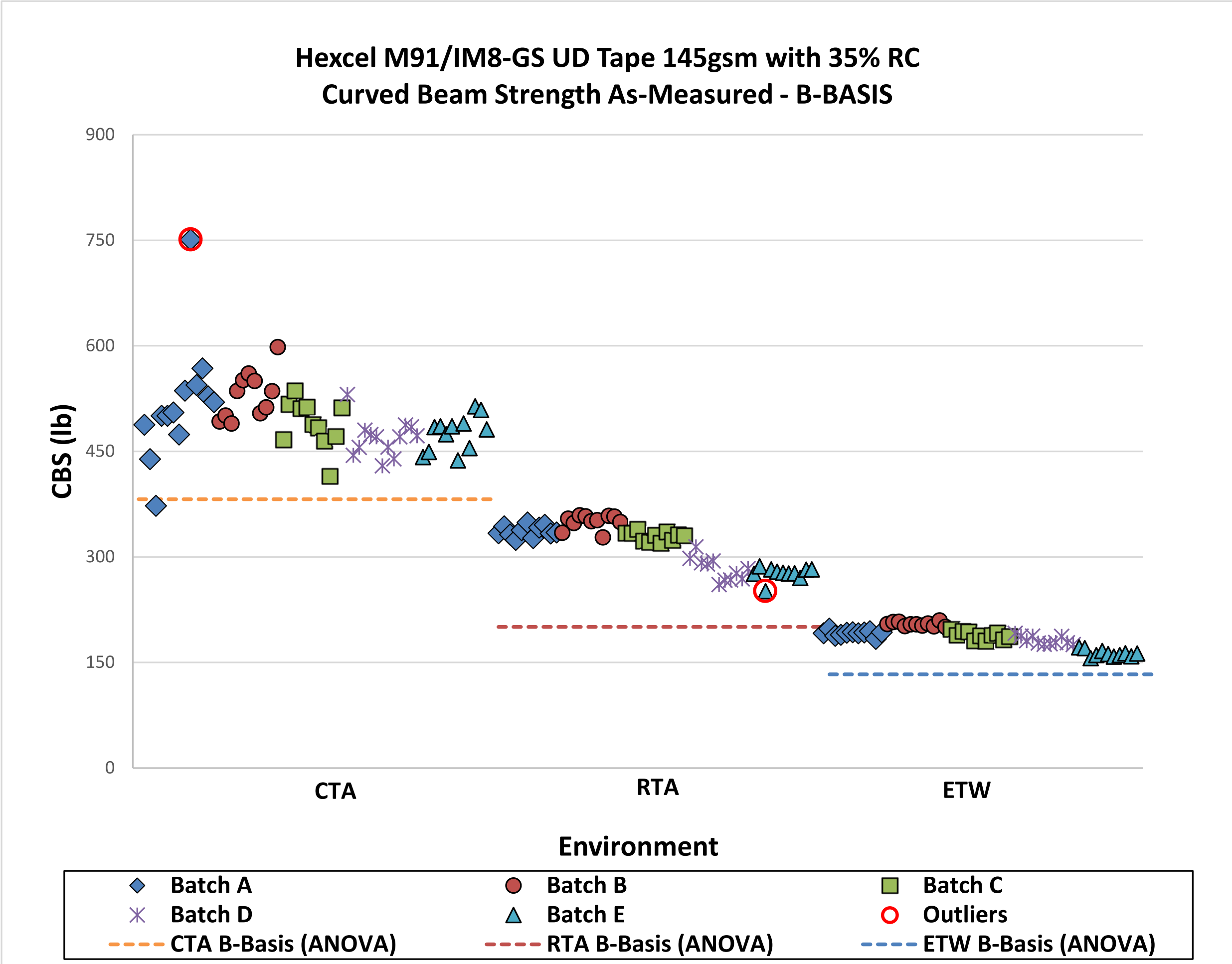

Figure 4-24: Batch Plot for Curved Beam As-Measured Strength - B-Basis

Interlaminar Tension (ILT) Strength Basis Values and Statistics						
	Interlaminar Tension Strength (ksi)			Curved Beam Strength (lb)		
Environment	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)	CTA (-65 °F)	RTA (70 °F)	ETW (180 °F)
Mean	21.47	13.69	8.065	495.7	315.1	185.8
Stdev	2.153	1.242	0.5257	52.16	31.67	14.57
CV	10.03	9.072	6.518	10.52	10.05	7.840
Min	16.18	11.26	7.063	372.7	251.5	156.2
Max	31.99	15.44	8.933	751.1	359.2	209.9
No. Batches	5	5	5	5	5	5
No. Spec.	60	55	55	60	55	55
Basis Values						
B-Basis Value	17.03	9.271	6.215	381.8	200.6	133.0
A-Basis Value	13.83	6.236	4.944	300.3	122.0	96.72
Method	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA	ANOVA

Table 4-16: Statistics and Basis Values for ILT 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 Vol 1. 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-2025-002 N/C. 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 No.	Strength		Outlier		
				Normalized Value	As Measured Value	High/Low	Batch	Condition
Curved Beam Strength	CTA (-65 °F)	A	NTPM910Q1-HXL-H35-NIAR-ILT-A-C2-1-CTA-3	NA	751.1	High	Y	Y
Curved Beam Strength	RTA (70 °F)	E	NTPM910Q1-HXL-H35-SKS-ILT-E-C1-1-RTA-3	NA	251.5	Low	Y	N
Interlaminar Tension Strength	CTA (-65 °F)	A	NTPM910Q1-HXL-H35-NIAR-ILT-A-C2-1-CTA-3	NA	31.99	High	Y	Y
Interlaminar Tension Strength	RTA (70 °F)	E	NTPM910Q1-HXL-H35-SKS-ILT-E-C1-1-RTA-3	NA	11.32	Low	Y	N
IPST 0.2% Offset Strength	CTA (-65 °F)	B	NTPM910Q1-HXL-H35-NIAR-IPST-B-C1-1-CTA-3	NA	10.89	High	Y	Y
IPSV 0.2% Offset Strength	CTA (-65 °F)	B	NTPM910Q1-HXL-H35-NIAR-IPSV-B-C1-1-CTA-3	NA	11.39	High	Y	N
IPSV 0.2% Offset Strength	ETW (180 °F)	C	NTPM910Q1-HXL-H35-NIAR-IPSV-C-C1-1-ETW-2	NA	5.297	High	Y	Y
IPSV 0.2% Offset Strength	ETW (180 °F)	E	NTPM910Q1-HXL-H35-SKS-IPSV-E-C2-1-ETW-4	NA	4.888	High	Y	N
IPSV Strength at 5% Strain	CTA (-65 °F)	B	NTPM910Q1-HXL-H35-NIAR-IPSV-B-C2-1-CTA-1	NA	19.12	High	Y	N
IPSV Strength at 5% Strain	RTA (70 °F)	B	NTPM910Q1-HXL-H35-NIAR-IPSV-B-C1-1-RTA-1	NA	13.39	Low	Y	N
IPSV Ultimate Shear Strength	ETW (180 °F)	D	NTPM910Q1-HXL-H35-FACC-IPSV-D-C2-1-ETW-5	NA	17.94	High	Y	Y
LC Strength from UNC0	CTA (-65 °F)	A	NTPM910Q1-HXL-H35-NIAR-UNC0-A-C3-1-CTA-1	275.8	270.9	Low	Y	N
LC Strength from UNC0	CTA (-65 °F)	B	NTPM910Q1-HXL-H35-NIAR-UNC0-B-C2-1-CTA-2	284.2	273.2	Low	Y	N
LC Strength from UNC0	ETW (180 °F)	D	NTPM910Q1-HXL-H35-FACC-UNC0-D-C1-1-ETW-1	173.6	NoA	Low	Y	N
TT Strength	ETW (180 °F)	A	NTPM910Q1-HXL-H35-NIAR-TT-A-C1-1-ETW-1	NA	5.949	High	Y	N
UNC0 Strength	CTA (-65 °F)	A	NTPM910Q1-HXL-H35-NIAR-UNC0-A-C3-1-CTA-1	147.4	145.0	Low	Y	N
UNC0 Strength	CTA (-65 °F)	B	NTPM910Q1-HXL-H35-NIAR-UNC0-B-C2-1-CTA-2	151.8	146.2	Low	Y	N
UNC0 Strength	ETW (180 °F)	D	NTPM910Q1-HXL-H35-FACC-UNC0-D-C1-1-ETW-1	91.53	NoA	Low	Y	N

NA: Property not normalized
NoA: Not an Outlier

Table 5-1: List of Outliers

6. References

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