TenCate Advance Composites
IM7 GP Unitape with BT250E-6 Resin
Material Allowables
Statistical Analysis Report

Report Date: October 20, 2017

Report Number: NCP-RP-2015-019 N/C

Elizabeth Clarkson, Ph.D.

Prepared by:

Elizabeth Clarkson

Reviewed by:

Vinsensius Tanoto Evelyn Lian

Approved by: Royal Lovingfoss

Digitally signed by Royal Lovingfoss
DN: cn=Royal Lovingfoss, o=NIAR, ou=NCAMP, email=rlovingfoss@niar.wichita.edu, c=US
Date: 2018.01.30 10:22:32 -06'00'

Royal Lovingfoss

REVISIONS:

Rev	By	Date	Pages Revised or Added
N/C	Elizabeth Clarkson	10/20/2017	Document Initial Release

Table of Contents

1.

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-17-1G. 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-17-1G are adequate for the given program.

Aircraft companies should not use the data published in this report without specifying NCAMP Material Specification NMS 250/1. NMS 250/1 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 250/1. NMS 250/1 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
Longitudinal Compression	LC
Longitudinal Tension	LT
Transverse Compression	TC
Transverse Tension	TT
In-Plane Shear	IPS
Short Beam Strength	SBS
Unnotched Compression	UNC0

Table 1-1: Test Property Abbreviations

Test Property	Symbol
Longitudinal Compression Strength	F_1^{cu}
Longitudinal Compression Modulus	E_1^{c}
Longitudinal Compression Poisson's Ratio	$_{12}^{c}$
Longitudinal Tension Strength	F_1^{tu}
Longitudinal Tension Modulus	E_1^{t}
Longitudinal Tension Poisson's Ratio	$_{12}^{t}$
Transverse Compression Strength	F_2^{cu}
Transverse Compression Modulus	E_2^{c}
Transverse Compression Poisson's Ratio	$_{21}^{c}$

1.2 Pooling Across Environments

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-17-1G 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-17-1G 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

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 i

Step 1: Apply the modified CV rules to each batch and compute the modified standard deviation

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 $z_{(1)}$, $z_{(2)}$,… $z_{(L)}$, 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:

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

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

$$a \quad (4g \quad 6)(k \quad 1) \quad (10 \quad 6g)S$$

$$b \quad (2g \quad 4)k^2 \quad 8Tk \quad (2g \quad 14T \quad 4)S \quad 8T \quad 4g \quad 6$$

$$c \quad (6T \quad 2g \quad 2)k^2 \quad (4T \quad 4g \quad 6)k \quad (2T \quad 6)S \quad 4T$$

$$d \quad (2T \quad 6)k^2 \quad 4Tk$$

$$S \quad {}_{i\,1}^{k} \frac{1}{n_i}$$

$$T \quad {}_{i\,1}^{n\,1} \frac{1}{i}$$

$$g \quad {}_{i\,1}^{n\,2} \; {}_{j\,i\,1}^{n\,1} \frac{1}{(n \quad i)\,j}$$

An observed significance level (OSL) based on an 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

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

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

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

2.2.2.3.2 Goodness-of-fit test for the Weibull distribution

The two-parameter Weibull distribution is considered by comparing the cumulative Weibull distribution function that best fits the data with the cumulative distribution function of the data.

$$V_A = 6.649 + \exp\left\{2.55 - 0.526\ln(n) + \frac{4.76}{n}\right\} \quad \text{Equation 46}$$

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

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

Table 2-2: Weibull Distribution Basis Value Factors

2.2.2.4 Lognormal Distribution

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

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

2.2.2.4.1 Goodness-of-fit test for the Lognormal distribution

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

$$z_i = \frac{\ln(x_i) - \bar{x}_L}{s_L}, \quad \text{for } i = 1, \ldots, n \quad \text{Equation 47}$$

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

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

2.2.2.4.2 Basis value calculations for the Lognormal distribution

If the data set is assumed to be from a population with a lognormal distribution, basis values are calculated using the equation above in section 3.2.1. 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

2.2.3.2 Non-parametric Basis Values for small samples

The Hanson-Koopmans method (references 8 and 9) is used for obtaining a B-basis value for sample sizes not exceeding 28 and A-basis values for sample sizes less than 299. This procedure requires the assumption that the observations are a random sample from a population for which

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

2.2.4.1 Calculation of basis values using ANOVA

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

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

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

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

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

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

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

Next, the mean sums of squares are computed:

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

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

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

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

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

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

Two k-factors ap0 computed using the methodologyTf 4section 2.2.2 using a sample sizeof 4 n

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:

$$\text{LVM Estimated B-Basis} = \bar{X}_1 \quad K_{N_1,N_2} \quad \bar{X}_1 \max \ CV_1, CV_2 \qquad \text{Equation 62}$$

When used in conjunction with the modified CV

3. Summary of Results

The basis values for all tests are summarized in the following tables. The NCAMP recommended B-basis values meet all requirements of CMH-17-1G. 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-17-1G are shown in shaded boxes and labeled as estimates. Basis values computed with the modified coefficient of variation (CV) are presented whenever possible. Basis values and estimates computed without that modification are presented for all tests.

3.1 NCAMP Recommended B-basis Values

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

1. Recommended values are NEVER estimates. Only B-basis values that meet all requirements of CMH-17-1G are recommended.
2. Modified CV basis values are preferred. Recommended values will be the modified CV basis value when available. The CV provided with the recommended basis value will be the one used in the computation of the basis value.
3. Only normalized basis values are given for properties that are normalized.
4. ANOVA B-basis values are not recommended since only three batches of material are available and CMH-17-1G recomm

Lamina Strength Tests

						0.2% Offset	5% Strain	
B-basis	302.313	NA:A	4.507	26.073	NA:A	7.837	11.156	NA:A
Mean	353.063	221.839	5.957	33.194	12.422	8.849	12.706	86.009
CV	7.772	7.150	13.027	11.482	11.151	6.000	6.000	7.150
B-basis	295.892	184.907	NA:A	NA:A	NA:A	5.942	8.918	70.218
Mean	346.642	205.905	5.701	27.527	9.874s9.8(2)04(8)-05e9.899.009			

4 (b a) f (5) - 6

3.2 Lamina Summary Tables

Prepreg Material:	TenCate Advance Composites IM7 GP Unitape with BT250E-6 Resin				
Material Specification:	NMS 250/1				
Process Specification:	NPS 81250				
Fiber:	IM7 12k Unitape	Resin:	TenCate BT250E-6		
	Tg(dry): 281.24 °F	Tg(wet):	241.92 °F	Tg METHOD:	ASTM D7028

	Batch 1	Batch 2	Batch 3		
Date of fiber manufacture	1/29/11	8/26/10	4/14/11	Date of testing	Nov 2011 - Apr 2012
Date of resin manufacture *	3/8/11	5/10/11	5/10/11	Date of data submittal	Jul-12
Date of prepreg manufacture	3/15/11	5/17/11	5/19/11	Date of analysis	Nov-15
Date of composite manufacture					

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

	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean	B-Basis	Modified CV B-basis	Mean
F_1^{tu}	307.133	305.990	356.822	306.096	304.953	355.785				280.184	279.041	329.872
(ksi)	(244.362)	(302.313)	(353.063)	(292.880)	295.892	(346.642)				(273.022)	(276.035)	(326.785)
E_1^t			22.576			22.603						23.133
(Msi)			(22.334)			(22.015)						(22.922)
$_{12}^{t}$			0.322			0.309						0.324
F_2^{tu} (ksi)	4.507	NA	5.957	3.211	4.641	5.701				0.845	1.742	2.249
E_2^t (Msi)			1.364			1.248						0.939
F_1^{cu} (ksi)	151.947	191.481	223.275	195.164	192.029	213.784	153.051	149.546	173.865	120.605	117.494	139.077
from UNC0 **	(144.794)	(189.815)	(221.839)	(182.648)	(184.907)	(205.905)	(142.033)	(145.435)	(168.908)	(101.495)	(116.869)	(137.700)
E_1^c			20.430			20.228			NA			19.804
(Msi)			(20.308)			(19.426)			NA			(19.401)
F_2^{cu} (ksi)	26.073	NA	33.194	16.877	23.527	27.527			5.8075 (3869822173.			

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

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

All individual specimen results are graphed for each test by batch and environmental condition with a line indicating the recommended basis values for each environmental condition. The data is jittered (moved slightly to the left or right) in order for all specimen values to be clearly visible. The strength values are always graphed on the vertical axis with the scale adjusted to include all data values and their corresponding basis values. The vertical axis may not include

4.1 Longitudinal Tension (LT)

The longitudinal tension strengths are normalized. Pooling across the environments was acceptable with the exception of the normalized DCT dataset. That dataset failed the Anderson Darling k-sample test (ADK test)

4.2

Transverse Tension Strength Basis Values and Statistics			
As-measured			
Env	CTD	RTD	ETW
Mean	5.957	5.701	2.249
Stdev	0.776	0.556	0.266
CV	13.027	9.754	11.845
Mod CV	13.027	9.754	11.845
Min	4.424	4.573	1.682
Max	7.017	6.832	2.798
No. Batches	3	3	3
No. Spec.	23	21	21
Basis Values and Estimates			
B-basis Value	4.507		
B-estimate		3.211	0.845
A-estimate	3.469	1.433	NA
Method	Normal	ANOVA	ANOVA
Basis Value Estimates with Override of ADK test			
B-estimate	NA	4.641	1.742
A-estimate		3.887	1.380
Method		Normal	Normal

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

Env CTD RTD ETW

Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	221.839	205.905	168.908	137.700	223.275	213.784	173.865	139.077

4.4 Transverse Compression (TC)

Transverse Compression data is not normalized for unidirectional tape. The RTD and ETW datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17-1G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the ETW dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided. The dataset for the RTD condition failed the ADK test after the modified CV transform, so only estimates are provided for that condition. No modified CV basis values are provided for the CTD condition due to the CV being above 8%.

Env	CTD	RTD	ETW
Mean	33.194	27.527	14.267
Stdev	3.811	2.078	0.694
CV	11.482	7.550	4.865
Mod CV	11.482	7.775	6.432
Min	26.212	22.367	12.970
Max	40.379	31.136	15.844
No. Batches	3	3	3
No. Spec.	23	23	21

4.5 In-Plane Shear (IPS)

In Plane Shear data is not normalized. The strength at 5% strain datasets for the CTD and RTD conditions failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17-1G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When these datasets were transformed according to the assumptions of the modified CV method, both passed the ADK test, so the modified CV basis values are provided.

There were two outliers, both in the CTD condition. The largest value in batch three of the strength at 5% strain dataset and the largest value in batch two of the 0.2% offset strength dataset

Env	CTD	RTD	ETW	CTD	RTD	ETW
Mean	12.706	10.084	5.137	8.849	6.709	3.617
Stdev	0.316	0.232	0.203	0.119	0.109	0.135
CV	2.484	2.296	3.955	1.344	1.619	3.726
Mod CV	6.000	6.000	6.000	6.000	6.000	6.000
Min	11.893	9.663	4.666	8.603	6.415	3.325
Max	13.128	10.385	5.482	9.124	6.857	3.849

4.6 "33/0/67" Unnotched Compression 0 (UNC0)

The UNC0 data is normalized. The CTD datasets both normalized and as-measured, and the normalized ETW dataset all failed the Anderson-Darling k-sample test (ADK test) for batch to batch variability, which meant that pooling across environments was not acceptable and CMH-17-1G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is considered an estimate.

When the normalized ETW dataset was transformed according to the assumptions of the modified CV method, it passed the ADK test, so the modified CV basis values are provided. The datasets for the CTD condition failed the ADK test after the modified CV transform, so only estimates are provided for that condition.

There were no outliers.

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

Env	CTD	RTD	ETD	ETW	CTD	RTD	ETD	ETW
Mean	86.009	78.244	63.676	53.636	85.971	79.747	65.748	53.636
Stdev	6.150	4.639	3.898	3.052	5.971	4.807	4.092	3.091
CV	7.150	5.929	6.122	5.691	6.945	6.027	6.224	5.764

4.7 Lamina Short-Beam Strength (SBS)

The Short Beam Strength data is not normalized. The SBS datasets failed the Anderson Darling k-sample test (ADK test) for batch to batch variability, which means that pooling across environments was not acceptable and CMH-17-1G guidelines required using the ANOVA analysis. With fewer than 5 batches, this is c

Short Beam Strength (SBS) Basis Values and Statistics As-measured				
Env	CTD	RTD	ETD	ETW
Mean	12.422	9.874	8.029	5.171
Stdev	1.385	0.917	0.601	0.477
CV	11.151	9.291	7.488	9.229
Mod CV	11.151	9.291	7.744	9.229
Min	9.811	8.236	7.026	4.404
Max	14.800	11.417	8.762	5.922
No. Batches	3	3	3	3
No. Spec.	21	21	22	21
Basis Values and Estimates				
B-estimate	3.789	4.035	3.891	2.749
A-estimate	NA	NA	0.936	1.020
Method	ANOVA	ANOVA	ANOVA	ANOVA
Modified CV Basis Values and Estimates				
B-estimate	9.783	8.126	6.856	4.261
A-estimate	7.902	6.880	6.019	3.614
Method	Normal	Normal	Normal	Normal

Table 4-13: Statistics and Basis Values for SBS 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-17-1G. 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-2015-038 Rev N/C.

Outliers for which no causes could be identified are