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A Comparison of Equivalence Criteria and Basis Values for HEXCEL 8552 IM7 Unidirectional Tape computed from the NCAMP shared database

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1. Introduction

The National Center for Advanced Materials Processing (NCAMP) was set up to facilitate data sharing among multiple users. Sharing test data could reduce testing requirements for the individual users, thus reducing the cost of development for the use of new materials. To make the best use of this larger dataset, new techniques had to be developed to establish equivalence criteria and engineering A- and B-basis values that could be applied across different manufacturing facilities. This paper details the results of these different methodologies applied to an NCAMP dataset, allowing a comparison of the results of the current approved methodology as documented in the Composite Materials Handbook (CMH17 Rev G) and the new approach developed at NCAMP to compute more generally applicable basis values and acceptance criteria.

There is a disconnect in the CMH17 approved statistical procedures for computing basis values (section 8.3) and equivalency (section 8.4). This disconnect has not been an issue until recently because only small datasets have been available to date (through Rev G) for composite materials. However, as more information is available, the disconnect between the computational formulas detailed in those sections results in basis values and equivalency criteria that are not optimum for use across different manufacturing facilities.

Generic basis values are conservative (lower) when compared with the method of computing basis values detailed in CMH-17 Rev G Section 8.3 and liberal (lower) with regard to computations for equivalence described in section 8.4. Comparing the results of the generic approach to the CMH17 methodology, the drop in design values is exceeded by the drop in acceptance criteria.

Another advantage of the generic approach is that those basis values can be used even when the production facility for a composite part has not yet been identified because computations for both the equivalency criteria and the generic basis values includes the variability between different Composite Part Manufacturing (CPM) facilities.

The major difference between the CMH17 methodology in section 8.4 and the NCAMP generic approach is how equivalence is defined. The CMH17 methodology assumes equivalence and then rejects that hypothesis if a statistically significant difference is detected between the mean of the original sample and the mean of the new sample. The larger the dataset used to make the comparison, the more likely it is that small differences will be detected.

With 20 to 40 different properties tested for equivalence, the probability of at least one failure due to chance alone, even if identical panels were used, is quite high. All detected differences must them be subjectively evaluated by experienced engineers familiar with the particular application to determine if the detected difference is sufficiently large to justify rejection of the hypothesis of equivalency.

Since rejection of this hypothesis may result in a lengthy delay in the use of the material until further testing can be conducted and/or requires adjustment of the basis values, this can be quite costly. The end result is a system where the incentives for CPM's wishing to establish equivalence promote the use of the smallest allowable sample size because, in addition to lower testing costs, it also decreases the probability that small differences will be detected.

In contrast, the generic approach assumes that the new sample does NOT fall within the defined equivalence region. When a new sample meets the equivalency criteria and is accepted as equivalent, the probability of doing so in error is set at 5%. These differences between the two approaches are enumerated in Table 1.

Table 1: Differences between CMH17 and Generic Approaches

	CMH17	Generic
Definition of Equivalence	Statistically indistinguishable from original Qualification mean	95% confidence region for means of all units of the material
Probability of incorrectly concluding a new sample is equivalent	Unknown. Exact probability is dependent on size of the difference.	$\leq$ 5%
Probability of incorrectly concluding a new sample is NOT equivalent	5%	$\leq$ 5%
Effect of larger samples	Increases the probability of failing equivalence tests due to better detection of small differences.	Decreases probability of making an incorrect decision to reject equivalence.
Subjective Engineering Judgment Requirements	Nearly all samples require subjective engineering judgment to determine if the CPM produced equivalent material and may use the basis values set with the original qualification sample.	Only units that fall outside the acceptance region or have excessive variability require engineering judgment to determine if the CPM produced equivalent material and may use generic basis values.

1.1 NCAMP Dataset Details

A unit for the purpose of this analysis is the data from one batch of material produced by a CPM.

A complete NCAMP dataset consists of one *qualification sample* and two to twelve *equivalency samples.* An *equivalency sample* is consists of one batch of the same material made into panels and tested to determine equivalence with the original qualification sample. Each *equivalency sample* is produced by a different company or facility. There are nine equivalency samples for the 8552 IM7 Unidirectional material analyzed in this report.

Equivalency tests are performed to determine if the differences between test results can be reasonably explained as the result of the expected random variation of the material and testing processes. If so, it can be concluded that the two sets of tests are from “equivalent” materials, and the facility that made the panels from only one batch of material can use the basis-values that were computed from the original qualification sample.

All CPM's participating in this NCAMP project were provided with prepreg fabric to produce panels for test specimens. This dataset allows the computation of the expected variability between different composite part manufacturing facilities.

An NCAMP *qualification sample* consists of at least three batches of material made into panels by a single producer and tested to determine material property B-basis values. This is the minimum sample size required to produce B-basis values that will be considered for publication in the Composite Materials Handbook, referred to as CMH-17 Rev G. CMH-17 was originally Military Handbook 17. Engineering basis values computing following this methodology were reported in NCP-RP-2009-028 Rev B.

An *equivalency sample* is consists of one batchof the same material made into panels and tested to determine equivalence with the original qualification sample. Each *equivalency sample* is produced by a different company or facility. CMH-17 Rev G section 8.4 gives details on equivalence testing for individual properties, but provides little guidance for making an overall determination based on multiple test results. Details of the test results for each equivalency sample were published in NCAMP Test Reports NCP-RP-2010-024 N/C, NCP-RP-2010-019 N/C, NCP-RP-2010-026 N/C, NCP-RP-2010-025 Rev B, NCP-RP-2010-027 N/C, NCP-RP-2010-020 N/C, NCP-RP-2010-021 N/C, NCP-RP-2010-022 N/C, and NCP-RP-2010-023 N/C.

The lamina and laminate material property data have been generated with FAA oversight through FAA Special Project Number SP4614WI-Q and also meet the requirements outlined in NCAMP Standard Operating Procedure NSP 100. The test panels, test specimens, and test setups have been conformed by the FAA and the testing has been witnessed by the FAA.

The material was procured to NCAMP Material Specification NMS 128/2 Rev - Initial Release dated February 6, 2007. The qualification panels were fabricated at Cessna Aircraft company, 5800 E. Pawnee, Wichita, KS 67218. Ten other companies participated in this program by fabricating panels at their facilities for an equivalency sample. Company codes are used to identify the equivalency samples.

The qualification test panels were cured in accordance with Baseline Cure Cycle (M) of NCAMP Process Specification NPS 81228 Rev A June 7, 2007. The NCAMP Test Plan NTP 1828Q1 Rev B was used for this qualification program.

Generic basis values were computed using the technique detailed in section 2. They are designed to be appropriate for at least 95% of all users of the material when all procurement, curing and processing procedures are followed. Users always have the option of developing a full qualification test sample and computing basis values for their specific facility and/or establishing equivalence to the original qualification sample using the methodology of CMH17 Rev G section 8.4. Generic basis values have not yet been approved by the CMH-17 organization.

2. Generic Computations for Equivalency

For CMH17 methodology, equivalency tests are performed to determine if the differences between test results can be reasonably explained as to the result of expected random variation of the material and testing processes. If so, we can conclude that the two sets of tests are from "equivalent" materials, and the new user can use the basis values that were computed from the *qualification sample.*

The comparison performed for equivalency is as follows: Two mutually exclusive hypotheses, termed the null (H_0) and the alternative (H_1), are set up. The null hypothesis is assumed true and must contain the equality. M_1 and M_2 represent the unknown means of the populations from which the samples are drawn. Slightly different tests are used for modulus properties (two-sided) and strength properties (one-sided).

Modulus Equivalence Hypotheses:

$$H_0 : M_1 = M_2$$
$$H_1 : M_1 \neq M_2$$

Strength Equivalence Hypotheses:

$$H_0 : M_1 \geq M_2$$
$$H_1 : M_1 < M_2$$

In addition, a value designated by the Greek letter alpha (α) is specified and represents the probability of incorrectly rejecting H_0.

A test statistic is computed using data from the sample tests. The probability of the actual test result is computed under the assumption of the null hypothesis. If that result is sufficiently unlikely, then the null is rejected and the alternative hypothesis is accepted as true. If not, then the null hypothesis is retained as plausible.

As illustrated in Figure 1, there are four possible outcomes: two correct conclusions and two erroneous conclusions. The two wrong conclusions are termed Type I and Type II errors to distinguish them. The probability of making a Type I error is specified by alpha (α), while the Type II error is not easily computed or controlled. In the previous paragraph, the term "sufficiently unlikely" means, in more precise terminology, that the probability of the computed test statistic under the assumption of the null hypothesis is less than α.

Figure 1 – Type 1 and Type II Errors for CMH-17 Equivalence Testing

	Materials are equivalent	***Materials are not equivalent***
Conclude materials are equivalent	***Correct Decision***	***Type II error Consumer's Risk***
Conclude materials are not equivalent	***Type I error Producer's Risk***	***Correct Decision***

The consumer's risk is the risk of accepting material that should have been rejected, and the producer's risk is the risk of rejecting material that should have been accepted. With CMH-17 Rev G methodology, as with almost all other sampling-acceptance schemes in use today, the producer's risk is set to α and used to determine the acceptance criteria.

When a material fails the equivalency test, the null hypothesis is rejected. We can conclude at the $1 - \alpha$ level of confidence that a true difference exists between the two materials. When a material passes this type of test, the null hypothesis is not rejected and there is no level of confidence associated with this conclusion unless a specific difference has been hypothesized and the power of the test associated with that difference computed.

CMH-17 Rev G recommends that α be set at 0.05, which corresponds to a confidence level of 95%. This means that if we reject the null and say that the two materials are not equivalent with respect to a particular test, then the probability that this is a correct decision is no less than 95%. The consumer's risk, the probability of wrongly concluding that two materials are equivalent, is not computed but can be expected to be considerably larger than 0.05 when using sample sizes as small as the typical equivalency test sample recommended for composite materials.

Using the methods of CMH-17, attaining equivalency through testing only one batch of material was found to be quite difficult. Every manufacturing facility was slightly different—not much but enough for failures to occur far more frequently than was originally expected. In essence, the CMH-17 tests for equivalence based on the original qualification sample used only *within facility* variance of the manufacturer of the original qualification sample. It failed to take into account that producers of equivalency samples had additional *between–facilities* variance. Since the basis values were set using the qualification sample, any facility that did not achieve equivalence by the CMH-17 methods could not use the basis values computed from that sample.

Generic equivalence testing was developed with the goal that 95% or more of all production facilities following proper procedures for a material would be considered equivalent and could safely be assumed to produce material that would meet or exceed the generic basis values.

Generic basis values and acceptance limits are computed using a multivariate analysis. The data is combined across different test properties and environmental conditions using the combination of Prepreg batch and manufacturing facility to define the unit of analysis. In addition, the equivalence hypothesis test was altered to adjust for the multivariate approach and to set the Type I error (α) to be the consumer's risk thereby controlling the probability of erroneously accepting material that should not be considered equivalent and protecting the basis values. This is illustrated in Figure 2.

The type II error now represents the probability of erroneous rejecting material from a population with a mean vector that lies on the **border** of the acceptance region. Since the acceptance criteria was designed such that 95% of all producers will have population mean vectors **within** the acceptance region, the producer's risk has effectively been set at 5%.

Figure 2 – Type 1 and Type II Errors for Generic Equivalence Testing

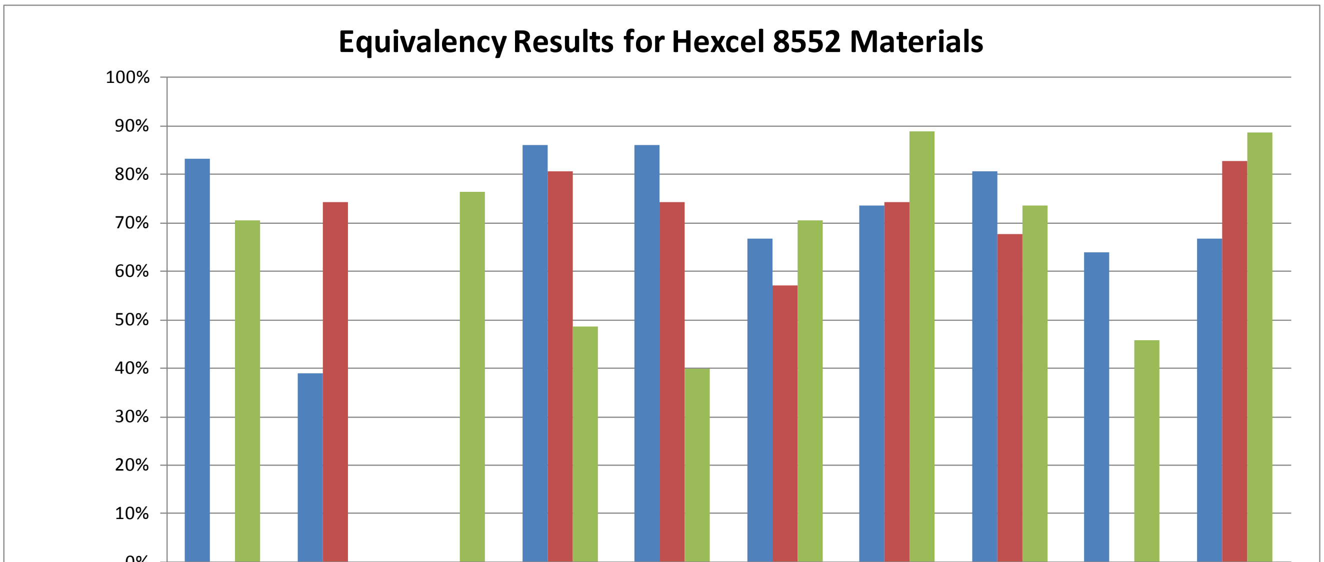
	Materials are equivalent	***Materials are not equivalent***
Conclude materials are equivalent	***Correct Decision***	***Type I error Consumer's Risk***
Conclude materials are not equivalent	***Type II error***	***Correct Decision***

2.1 Results of CMH17 Equivalency Tests for HEXCEL 8552 Materials

All companies participating in this NCAMP project were provided with prepreg fabric from same batch of material as was used for one of the three qualification batches. Companies A5 and A12 chose to use different cure cycle procedures (AH and AL) but all other companies used the M cure cycle procedure. Testing was delayed until NCAMP had received the fabricated test panels from all companies so that testing could be done during the same time period. To the extent possible, the same testing machine and operator was used. This minimized the variability due to the material or testing procedures. This maximized the probability of the company passing equivalency tests and allowed a more accurate measure of the between company variability. In other words, these results are as good as it gets from this equivalency testing and comparison procedure.

The results of the equivalency testing for the HEXCEL material forms were as shown in Figure 3 below. Each material form had a total of 34 to 36 different equivalency tests performed for strength and modulus properties. Not a single manufacturer was able to achieve 100% success on equivalency testing for any form of the material. That is, we can state with 95% confidence that at least one statistically significant difference exists for every company that produced an equivalency sample. As mentioned in the previous section, this result is expected.

Figure 3 – HEXCEL 8552 Equivalency Testing Results



	A2	A3	A4	A5	A6	A8	A9	A10	A11	A12
AS4 PW	83.33%	38.89%		86.11%	86.11%	66.67%	73.53%	80.56%	63.89%	66.67%
AS4 UNI		74.29%		80.56%	74.29%	57.14%	74.29%	67.65%		82.86%
IM7	70.59%		76.47%	48.57%	40.00%	70.59%	88.89%	73.53%	45.71%	88.57%

The results clearly demonstrate that every manufacturing facility is somewhat different. In essence, the CMH-17 tests for equivalence are based on the original qualification sample and use only *within facility* variance of the manufacturer of the original qualification sample. Thus, these tests fail to take into account the additional *between–facilities* variance that producers of equivalency samples exhibit. Prior to the NCAMP database being developed, the amount of variation between manufacturing facilities was unknown.

2.2 Analysis Unit for Computing Generic Basis Values

One batch of prepreg material processed by a production facility constitutes the unit of analysis. Since units represent different companies as well as different batches and different cure-cycle recipes, these values can be considered a solid floor for basis values such that any user of the material should be able to produce parts that will maintain the generic basis values if they follow the proper procedures in preparing and processing the composite material.

The properties being evaluated need to be grouped for a multivariate assessment. The generic method has a theoretical limitation on the maximum number of tested properties that can be analyzed together. It is two less than the number of complete units available for analysis.

The NCAMP dataset is not yet large enough to combine all test properties into a single computation. Grouping related properties together and creating separate groups for relatively independent properties makes the best use of the relationships between the variables.

The tested properties are grouped as follows for assessment.

- Compression Tests Strength Results
- Tension Tests Strength Results
- Shear Tests Strength Results

For each group of test results, a vector of the mean results for each test property is computed for each unit. These vectors have a multivariate normal distribution and are termed “unit mean vectors.” A complete unit mean vector is one with data available for every property in the group being assessed. Complete unit mean vectors are required to compute the covariance matrix, although incomplete unit mean vectors can still be evaluated to determine whether or not they fall within the generic acceptance limits. The mean vector of all units is computed for this analysis using the entire NCAMP dataset including incomplete vectors and data from additional sources, such as the HEXCEL product information.

2.3 Defining the Generic Acceptance Region

While CMH17 does have an approved procedure for computing the acceptance criteria for individual properties, no equivalence region is explicitly defined. Instead, CMH17 methodology implicitly defines the qualification mean for modulus properties as equivalence and while the qualification sample mean and variability are the minimum acceptable values for equivalence with strength properties. Any detectable difference indicates that the two samples are not equivalent. The acceptance criteria are based on this implicit criteria of equality or better with the qualification sample. When the basis values are set using the qualification sample, this approach is necessary to maintain support of those basis values.

The Generic approach defines the acceptance region and then computes equivalency criteria and basis values assuming the most extreme values possible in the acceptance region.

2.3.1 Computing the Generic Acceptance Region

The generic acceptance region for modulus equivalence is defined to be the multivariate 95% confidence ellipsoid based on the NCAMP dataset. The boundary of the generic acceptance region for strength equivalence is defined to be lower edge of the multivariate 90% confidence ellipsoid for a single unit mean vector based on the NCAMP dataset. These regions are computed using the population covariance matrix, Σ, the population mean vector.

The equation for the generic acceptance region:

$$N\left(v-M_1\right)'\Sigma^{-1}\left(v-M_1\right)\le c$$

where

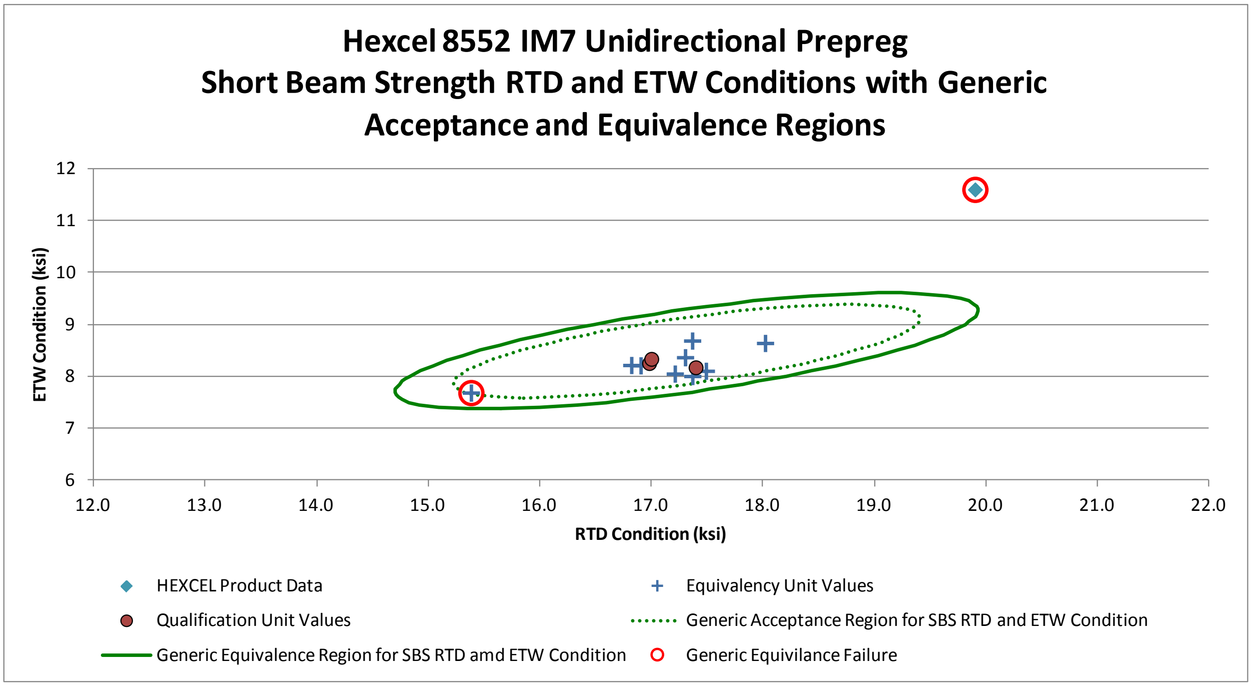
- *M* is the *p*-dimensional mean vector computed from all units in the NCAMP database.
- Σ is the *pxp* covariance matrix computed from all complete units in the NCAMP database.
- *v* is any *p*-dimensional vector such that the equation is true
- *c* is the appropriate percentile of a χ_p^2 distribution
- *p* is the number of different tests in a complete unit.
- *N = 1* because this is the region for a single unit.

When only two properties are in a group, the acceptance and equivalency regions are ellipses. For more than two properties, the concept is extended to a multi-dimensional ellipsoid. This multidimensional ellipsoid is projected to a 2-dimensional ellipse for the graphical representation of those properties.

In the example shown in Figure 4, the dotted green ellipse defines the limits of the generic acceptance area for Short Beam Strength (SBS) tests in the RTD and ETW conditions. The solid green ellipse defines the limits of the generic equivalence area. The generic acceptance and equivalency areas follow the general pattern of the data itself, with the correlation between the different properties being imbedded into the computation.

Notice that all but one of the NCAMP units are contained within the generic acceptance region. Further investigation revealed that that unit also had excessive variability, so it was deemed unacceptable. This graph also shows that the normal production process used by fabricators is not achieving the strength values reported in the HEXCEL product data information for this property, although the different ETW condition results may be due to the temperature difference, 180°F for the HEXCEL Product data versus 250°F for the NCAMP results.

Figure 4: Generic Acceptance and Equivalence Areas for SBS RTD and ETW Conditions



2.4 Determining Equivalence of a Composite Part Manufacturer (CPM)

There are two aspects to determining equivalence of a CPM. The sample from a new production facility must pass both criteria in order to be considered equivalent.

1. The mean vector must fall within the generic acceptance region
2. The variance of each property must pass an F-test ($\alpha = 0.05$) comparing it to the variance used to compute the generic basis values.

To test whether or not the mean vector from a new production facility falls within the generic acceptance region, the equation is altered as shown below:

Mean Vector Test: $$N\left(\bar{X} - M\right)' \Sigma^{-1}\left(\bar{X} - M\right) \le c \qquad (1)$$

- M is the p-dimensional mean vector computed from all units in the NCAMP database. The mean of all units rather than the mean of all complete units or the mean of all specimens is used for computing generic basis values so that each unit gets equal weight in computing the mean vector for the material.

- $\overline{X}$ is the p-dimensional mean vector of the sample being tested for equivalency
- Σ is the *pxp* covariance matrix computed from all complete units in the NCAMP database.
- *N* is the number of units in the sample being evaluated.
- *c* is the appropriate percentile of a χ_p^2 distribution

If this results in equation 1 being a true statement, the new production facility can be considered equivalent and make use of the generic basis values. If equation 1 is false, then the new production facility cannot be considered equivalent by this method. However, each property can be evaluated separately and may be found ‘Acceptable but NOT Equivalent’ (see section 2.6).

2.5 Equivalence of Variance

This approach to equivalence requires the assumption that the covariance matrix of the new sample is equal to Σ. This is not a trivial assumption and must be checked. While tests for equivalency of the covariance matrix are available, equivalency samples do not have sufficient data to run the test of that assumption. However, we can check the variances of the individual properties using an F-test.

The basis values are computed using the generic method are based on the between company variance. An F test can be performed to determine if the assumption that the between units variance $\left(S_{BU}^2\right)$ exceeds the within-company $\left(S_{WC}^2\right)$ variance for that CPM. Since the between units variance and the F-distribution are known values, given a sample size for new CPM, a maximum value can be computed for the standard deviation. If the within company variance exceeds this criteria, Production facilities with samples that fail this variance check should not be considered equivalent.

$$F_{.95} \le \frac{S_{BU}^2}{S_{WC}^2} \Rightarrow \sqrt{S_{WC}^2} \le \sqrt{\frac{S_{BU}^2}{F_{.95}}}$$

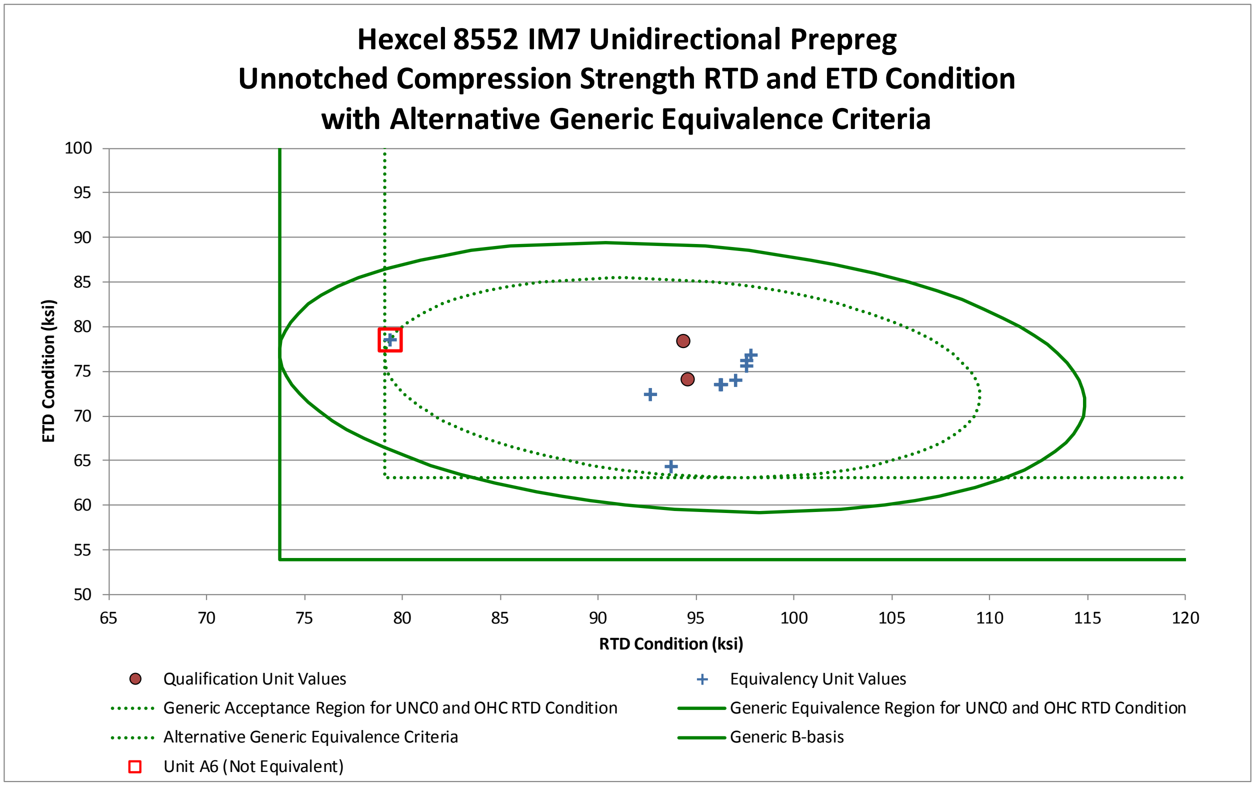
If the mean of a sample that fails the F test is sufficiently high that the increased variance does not pose a risk to support of the generic basis values, engineering judgment may be used to judge the sample as 'Acceptable but not Equivalent'.

When the generic alternative computation is used (see section 3.2.1), then the maximum standard deviation is computed using the average within-company variance from the NCAMP dataset.

2.6 Alternative Generic Acceptance Criteria: Acceptable but not Equivalent

For Strength properties, a sample may be considered acceptable but not equivalent if the test results indicate that the new sample fails equivalency but can still be considered to support the generic basis values. The acceptance region (the inner ellipsoid) is expanded to the rectangular area that encompasses it, as shown in Figure 5.

Figure 5: Alternative Generic Equivalence Criteria for UNC0 RTD and ETD Conditions



While a sample that lies in the alternative acceptance region may not be equivalent according to the statistical criteria, as long as the within property variance passes an F-test for equality of variance when compared with the NCAMP database variance for those properties, the new facility can be assumed to support the generic basis values and be deemed acceptable. If the sample fails the F-test, then a normal distribution B-basis computation (see section 3.2.1) is made using the sample mean and standard deviation to determine if the production process that produced it can be expected to support the generic basis values. If the B-basis computed this way is above the generic B-basis, the sample is considered 'Acceptable but not Equivalent'.

3. Computing Generic Basis Values

Having defined the generic acceptance region, it is possible that a population with a mean falling outside that region could produce a test sample with results that lie inside the acceptance region and be accepted as equivalent. So before computing the generic basis values, we need to find the lowest possible mean value that has probability $\geq \alpha$ of producing a sample that would be accepted.

This is done by defining an *equivalence* region, Θ, such that if the sample mean vector of a new production facility lies within the acceptance region, we can conclude that the true population mean for the new facility lies within the *equivalence* region, Θ, with a specified level of confidence (1−α). The generic basis values are then computed for each strength property with the mean set to the lowest possible value within Θ.

A population with a mean vector outside Θ has a probability less than α of producing a sample that falls within the acceptance region and being erroneously classified as equivalent. Figure 4 illustrates both the acceptance region and the equivalence region.

3.1 Defining the equivalence region

The null (H_0) and the alternative (H_1) hypotheses given in section 2 are altered as follows:

$H_0 : M_2 \notin \Theta$ The mean vector produced by a new production facility lies outside Θ

$H_1 : M_2 \in \Theta$ The mean vector produced by a new production facility lies within Θ

M_2 represents the true unknown mean vector of the material properties from the new production facility. If the null is rejected, then the hypothesis that the equivalency sample lies inside Θ is accepted at the (1−α)% level of confidence.

The following test statistic[1] is used with this hypothesis test:

$$T = \frac{n_1 n_2}{n_1 + n_2}\left(\bar{X}_1 - \bar{X}_2\right)' \Sigma^{-1}\left(\bar{X}_1 - \bar{X}_2\right) \qquad (2)$$

where

- n_1 is the number of units in the NCAMP database.
- n_2 is the number of units in the sample being evaluated for equivalency.
- $\bar{X}_1$ is the *p*-dimensional mean vector computed from the NCAMP database.
- $\bar{X}_2$ is the p-dimensional mean vector of the sample being tested for equivalency .
- Σ is the *pxp* covariance matrix computed from the NCAMP database.

Under this null hypothesis, T has a non-central chi-squared distribution, $T \sim \chi_p^2\left(\frac{n_1 n_2}{n_1+n} d'\Sigma^{-1} d\right)$, with *d* being any vector in the boundary of Θ which equates to the largest possible value of the non-centrality parameter (NCP) for the hypothesis test. The null hypothesis can be rejected and the new production facility concluded equivalent when T < α^{th} percentile of $\chi_p^2\left(\frac{n_1 n_2}{n_1+n} d'\Sigma^{-1}d\right)$.

To determine Θ it is necessary to find a value for the non-centrality parameter $NCP = \frac{n_1 n_2}{n_1+n} d'\Sigma^{-1}d$ such that the critical value of the test statistic T is greater than the value of the corresponding χ_p^2 distribution used to compute the acceptance ellipsoid.

For example, if there are six tests in the grouping being evaluation and the NCP of a non-central chi-square distribution with 6 degrees of freedom is 17.871, then the critical value to reject the null in that case is 10.645 > 10.6446 = $\chi_{p,0.90}^2$. This value of 17.871 is then used to define Θ.

$$\Theta = \left\{ v \in R^p : \left(v - M_1\right)' \Sigma^{-1} \left(v - M_1\right) < 17.871 \right\} \tag{3}$$

With Θ so defined, the rejection region for H_0 will contain the acceptance region previously established in section 2.3. Thus any sample vector that falls within the acceptance region has a probability of less than α of falling outside the equivalence region and a probability of at least (1−α) of lying within the equivalence region.

3.2 Computing Generic Basis Values

Key to developing generic basis values and equivalency criteria is separating the variability **between** different composite part manufacturers and the variability **within** a composite part manufacturing facility.

By defining units to be the mean test value for each property from a particular combination of a CPM and material batch, the generic acceptance region is based on the variability **between** CPM's and is designed to include at least 90% of CPM's who produce such units.

To compute the generic basis values, the lowest possible value in Θ is computed for each property. This is the lowest value of a 95% confidence interval for the 10th percentile of the distribution of that property, which is the definition of a B-basis value. For an A-basis value, the lowest value of a 95% confidence interval for the 1st percentile of the distribution of that property is computed based on the p-dimensional multivariate distribution.

The extreme values for all dimensions of a p-dimensional ellipsoid can be found via standard calculus formulas applied to the equation for the boundary of Θ as shown in equation 4.

$$\left(v - M_1\right)' \Sigma^{-1} \left(v - M_1\right) = c \tag{4}$$

where c is a constant from Table 2 selected based on the number of dimensions, p . Use c_B to compute generic B-basis values and c_A for generic A-basis values

Table 2 Critical values for computing the equivalency region

p	c_B	c_A
2	13.0240	27.4146
3	14.5727	29.8256
4	15.8280	31.7945
5	16.9086	33.4981
6	17.8708	35.0201
7	18.7461	36.4080
8	19.5542	37.6916
9	20.3083	38.8910
10	21.0180	40.0209
11	21.6901	41.0919
12	22.3300	42.1122

The steps for computing the generic basis values are as follows:

1. Define the set of material properties being evaluated together. While this could include all properties, the limited amount of data currently available does not permit this. Therefore, the properties should be evaluated in groups that can be expected to be related. For example, tension tests might form one group, compression tests another, shear tests a third.

2. For the set of material properties being evaluated, compute the mean vector and the covariance matrix from the set of all complete units for those properties.

3. Using the mean vector and inverse of the covariance matrix, compute the 90% confidence ellipse for the mean vector. This is the equivalency region.

4. Using the mean vector and inverse of the covariance matrix, compute the 95% confidence ellipsoid, Θ, around the 90% confidence ellipsoid.

5. Compute the lowest point for each of the properties in Θ. This is the generic B-basis for those properties, meeting the definition of the low end of a 95% confidence region containing the 90th percentile of the data if all assumptions are met.

6. Compute the **within** CPM/material variability using the specimen level data. This can be done using SAS GLM procedure or some other statistical software analysis package.

7. Using an F-test, verify the assumption that the variability **between** CPM's is greater than or equal to the variability **within** CPM's. Setting $\alpha = 0.10$ is recommended for this test. If

this assumption fails, the alternative method should be used to compute the generic basis values for that property.

3.2.1 Alternate Computation for Generic Basis Values

When the within company variance is statistically significantly larger than the between unit variance (recommended alpha = 0.10), the 95% confidence ellipsoid for the 90% ellipsoid may not be conservative. An alternative computation is recommended based on the normal distribution in this situation.

The lowest value in the acceptance region is used as the mean value $\left(\overline{x}\right)$, the within company standard deviation for s, and k-factors are selected based on n equal to the pooled sample size minus the number of units in the analysis. The alternate generic basis values are then computed using the usual formula of mean minus the appropriate k-factor multiplied by the standard deviation:

$$\begin{aligned} \text{Alternate Generic B-basis} &= \overline{x} - k_b * s \\ \text{Alternate Generic A-basis} &= \overline{x} - k_a * s \end{aligned} \tag{5}$$

See CMH17 Rev G Section chapter 8 for more information on computing A- and B-basis values.

3.3 Summary of Equivalency Test Results for Strength Properties

The equivalency results of the 12 units from the ten different samples from companies are shown for the 21 different compression strength properties tested are shown in Table 3 for each of the different basis value computations. There was one unit that did not fall inside the acceptance area defined for the generic basis values.

Table 3 Compression Strength Equivalence Results by Method

Property	Qualification Basis Values		Pooled Basis Values		Generic Basis Values	
Total	**Mean**	**Minimum**	**Mean**	**Minimum**	**Mean**	**Std Dev**
Qualification				1		
Unit A01				1		
Unit A02						
Unit A03				1		1
Unit A2	2	1				
Unit A4	5	4	2	1		
Unit A5	11	6	3	1		
Unit A6	12	9	8	4	Acc. but not Eq.	

Unit A8	9	4	3			1
Unit A9	2	3		1		
Unit A10	5	5		1		
Unit A11	16	11	16	9	Shear	4
Unit A12	2	1				
% Failures	36.5%		15.1%		2.4%	

Unit A6 was outside the equivalency area for compression strength properties, but it can be considered 'Acceptable but not Equivalent' with regard to the generic basis values for compression properties. It was equivalent with respect to the Tension and Shear properties.

Unit A11 was outside the equivalency area for shear strength properties although it was above the minimum acceptable mean value for all seven shear properties. Unit A11 cannot be considered acceptable with respect to the generic basis values for the shear strength properties. It can, however, be considered acceptable with respect to the generic basis values for tension strength and compression strength.

3.4 Compression Strength Results

The NCAMP Compression Strength Data is normalized. Data are available for Unnotched Compression (UNC0) tests (layup $[90/0/90]_5$) for the RTD, ETD and ETW conditions. Data are available for Quasi-Isotropic (layup $[45/0/-45/90]_{3S}$) Open Hole Compression tests (OHC1) for the RTD and ETW conditions. The data are shown by unit in Table 4.

Table 4 Compression Strength Units

Property	**UNC0**			**OHC1**	
Environment	**RTD**	**ETD**	**ETW**	**RTD**	**ETW**
Unit A01	NA	NA	NA	49.7776	36.5261
Unit A02	94.5802	74.0958	64.8118	48.7187	35.2038
Unit A03	94.3659	78.3914	63.2988	48.6380	34.6467
Unit A2	96.2747	73.5424	69.2822	49.0295	35.7920
Unit A4	93.7557	64.3706	67.2491	49.2890	35.9984
Unit A5	92.6674	72.4021	65.1376	49.8663	34.9689
Unit A6	79.3685	78.5173	64.1723	49.3351	35.0254
Unit A8	97.0097	74.0357	66.0642	48.9825	35.4048
Unit A9	97.6087	75.5440	67.5306	48.5799	35.2421
Unit A10	97.6081	76.1733	64.9995	48.4162	35.0181
Unit A11	96.2567	73.5567	63.1538	50.3488	35.8527
Unit A12	97.8144	76.8109	65.9994	49.2527	36.8756
Unit Average	94.3009	74.3127	65.6090	49.1862	35.5462

*Unit A6 fails the generic equivalence test for the mean values of the compression strength properties

The means of the units rather than the individual specimen values are used for computing the average so that each unit gets equal weight in computing the material mean vector. The covariance matrix used to compute the generic basis values requires datasets that have values for all the properties in the unit. In this case, the first qualification unit (A01) was included in the computations for averages, but not for the covariance matrix. Unit A6 did not fall within the generic acceptance area, but calculations for the individual compression properties indicated that it is ‘Acceptable but not Equivalent’.

The results of the different basis value computations are shown in Table 5 and the corresponding equivalency criteria for sample means are shown in Table 7. Acceptance criteria computations include a factor based on sample size. A sample size of 8 was used for these computations. In order to assure that basis values are upheld, samples must meet criteria not only for the mean, but also for the variability of the sample. The approach used by CMH17 is to place a minimum criteria on the lowest specimen value in a sample. The approach used with generic basis values is to place a maximum value on the standard deviation. Table 8 gives this criteria for the compression strength basis values.

NCAMP longitudinal compression tests do not report strength values. Instead, compression strength values for 0^0 properties are computed via the formulas specified in section 2.5 of that NCAMP report NCP-RP-2009-028 Rev B. The same formula was used to compute generic basis values based on the UNC0 generic basis values. These, along with the original qualification basis values for longitudinal compression are shown in Table 6.

Table 5 UNC0 and OHC1 Strength Equivalence Acceptance Limits, Basis Values and Estimates

Test Property	**UNC0**			**OHC1**	
Environment	**RTD**	**ETD**	**ETW**	**RTD**	**ETW**
Qualification B-Basis or B-Estimate	84.42	65.44	54.90	46.15	32.58
Qualification A-Estimate	78.25	59.27	48.61	44.14	30.57
Pooled Data B-basis (ANOVA)	79.05	61.89	56.63	46.74	33.12
Pooled Data A-basis (ANOVA)	68.20	53.05	49.78	44.88	31.31
Generic B-basis	73.72	53.86*	50.94*	45.06*	31.48*
Generic A-basis	65.35	46.89*	43.95*	43.22*	29.79*

* Alternate Generic Basis Value Method used due to large within company variance

Table 6 Equivalence Acceptance Limits and Basis Values for 0° Compression

Test Property	0° Compression Strength from UNC0 Data		
Environment	**RTD**	**ETD**	**ETW**
Qualification B-Estimate	222.07	175.06	148.02
Qualification A-Estimate	205.65	158.64	131.27
Generic B-basis	193.85	144.02	136.94
Generic A-basis	171.81	125.38	118.14

Table 7 Compression Strength Equivalence Acceptance Limits for Unit Means

Test Property	UNC0			OHC1	
Environment	**RTD**	**ETD**	**ETW**	**RTD**	**ETW**
Minimum Allowable Mean (Qual)	90.71	72.14	60.69	47.87	34.53
Minimum Allowable Mean (Pooled)	89.06	69.47	61.66	48.11	34.55
Minimum Allowable Mean (Generic)	76.10	63.11	60.20	47.51	33.72

Table 8 Compression Strength Equivalence Acceptance Limits for Sample Minimum and Standard Deviation

Test Property	UNC0			OHC1	
Environment	**RTD**	**ETD**	**ETW**	**RTD**	**ETW**
Minimum acceptable specimen value (Qual)	79.42	62.05	50.00	44.24	31.61
Minimum acceptable specimen value (Pooled)	73.67	55.89	49.70	44.90	31.54
Maximum acceptable standard deviation (Generic)	9.29	10.55	10.62	2.81	2.57

Figure 6 shows the different basis values and mean acceptance limits for the UNC0 tests. Figure 7 shows the different basis values and mean acceptance limits for the OHC1 tests. A two dimensional projections of the acceptance region and equivalence region are shown for the OHC1 RTD and ETW tests in Figure 8. Figure 9 shows the two dimensional projections of the acceptance region and equivalence region for the UNC0 RTD and OHC1 RTD tests. Figure 10 shows the two dimensional projections of the acceptance region and equivalence region for the UNC0 RTD and ETD conditions.

Figure 6: Unnotched Compression B-basis Values and Mean Acceptance Limits

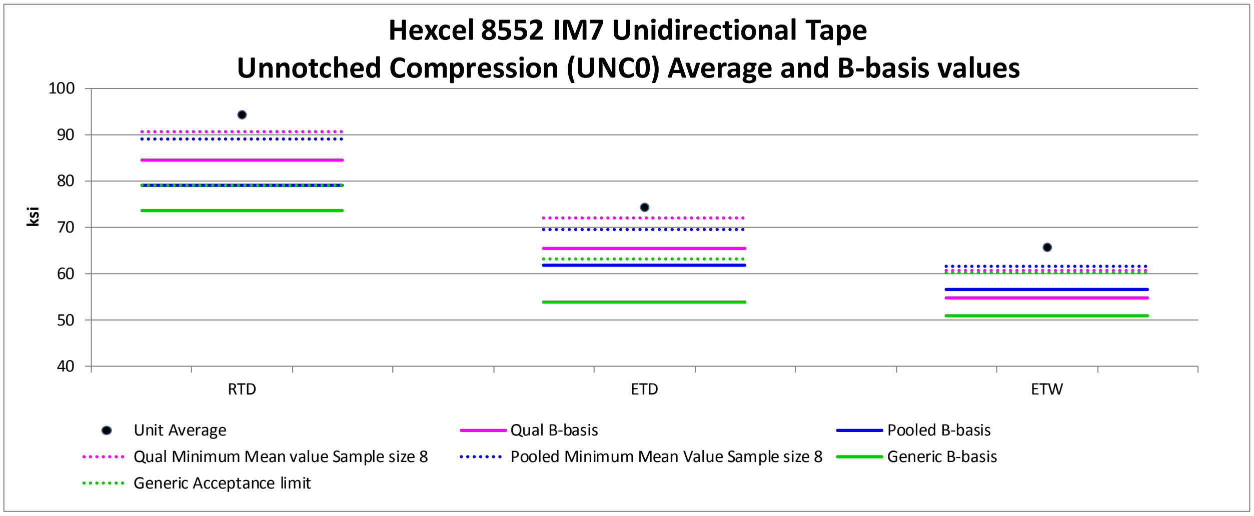


Figure 7: Open Hole Compression B-basis Values and Mean Acceptance Limits

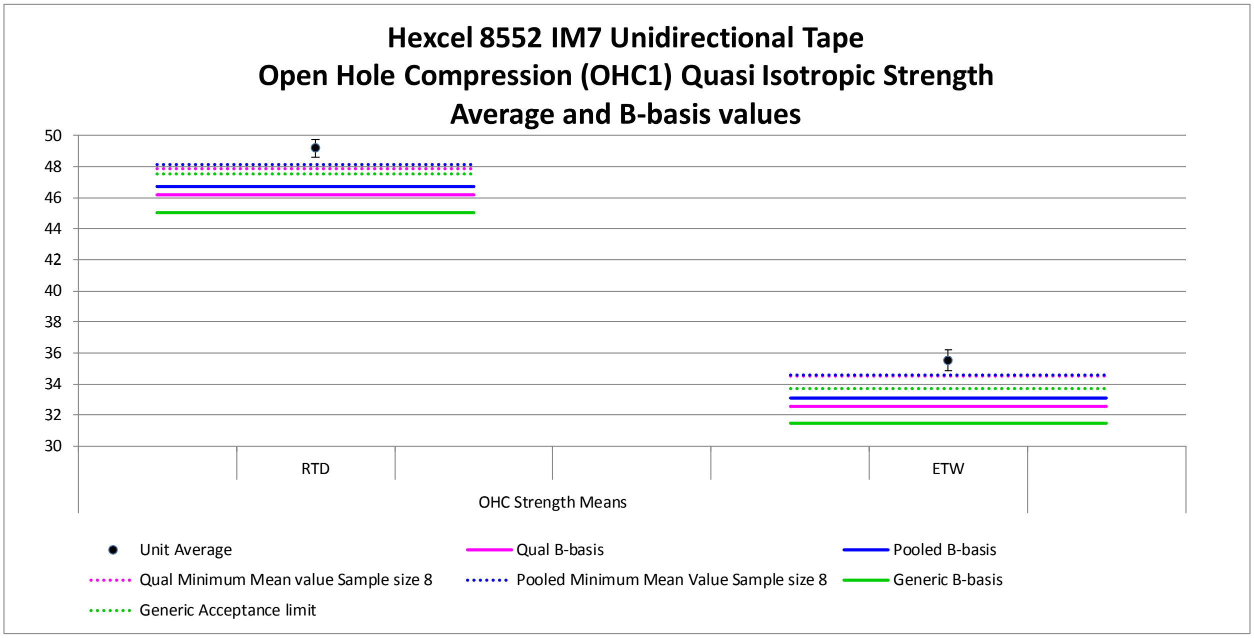


Figure 8: Open Hole Compression Strength RTD and ETW Conditions Acceptance and Equivalence Ellipses

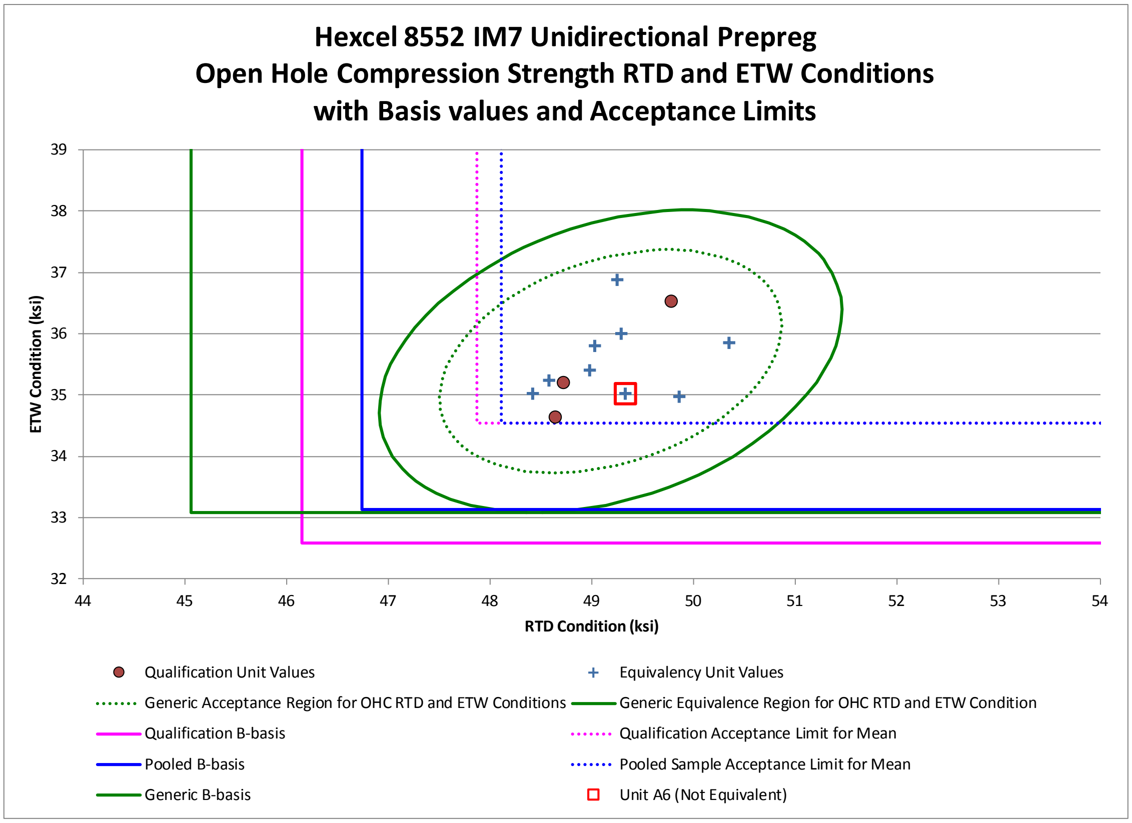


Figure 9: UNC0 and OHC1 Strength RTD Condition Acceptance and Equivalence Ellipses

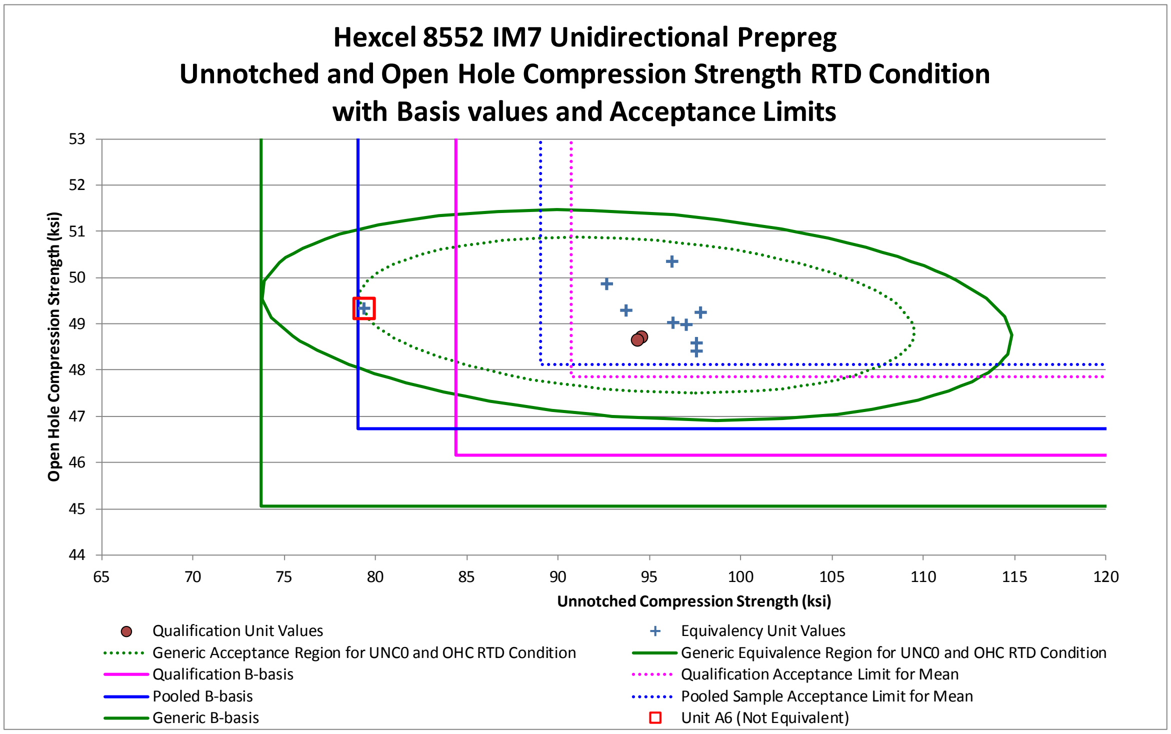
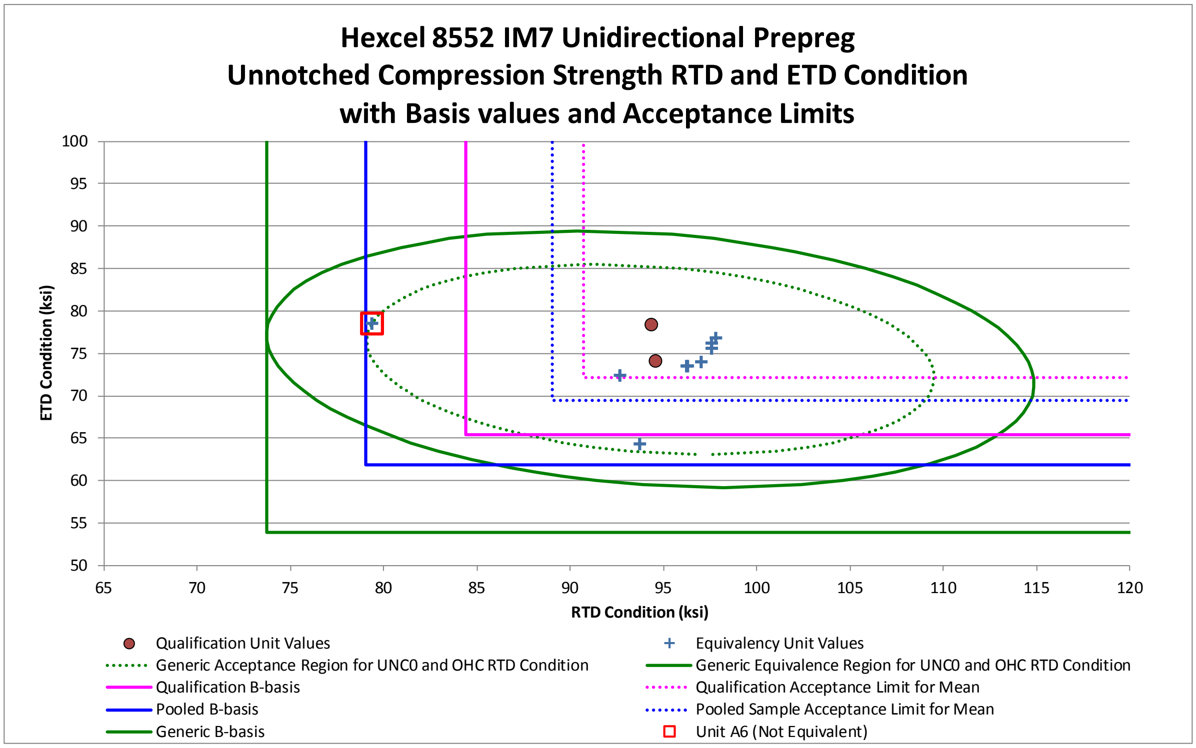


Figure 10: UNC0 RTD and ETD Conditions Acceptance and Equivalence Ellipses



3.5 Tension Strength Results

NCAMP Tension Strength Data is normalized. Data are available for Longitudinal Tension (LT) tests, Unnotched Tension (UNT0) tests (layup $[0/90]_{2s}$) and for Quasi-Isotropic (layup $[45/0/-45/90]_{2S}$) Open Hole Tension tests (OHT1) for the CTD, RTD and ETW conditions. The data are shown by unit in Table 9. Additional data was provided by the Army and available via the Hexcel company product information , but only for LT tests.

Table 9 Tension Strength Units

Property	Longitudinal Tension			Unnotched Tension			Open Hole Tension		
Environm	**CTD**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**
Unit A01	351.0320	357.4946	317.5174	150.3135	172.7483	178.7057	55.6527	57.6876	65.5433
Unit A02	363.5426	371.2816	342.2871	151.4152	169.1497	175.6726	57.8846	58.6289	67.7007
Unit A03	357.6595	359.3027	348.9640	156.3816	172.2565	183.3173	60.0763	60.9131	67.7603
Unit A2	350.1586	379.1181	315.6127	160.5452	178.8597	183.9735	57.8861	60.0071	68.8052
Unit A4	371.5482	361.1002	331.0850	160.7040	183.0869	173.6907	57.7528	60.6131	65.5552
Unit A5	337.7599	366.2555	336.1728	141.9117	165.1766	177.5706	54.4372	58.6046	64.1320
Unit A6	343.4442	343.1527	327.7140	133.8409	160.5384	165.4421	55.9633	58.3777	64.7328
Unit A8	333.9087	346.5323	332.2169	143.0282	163.7844	175.6588	53.1533	56.6409	65.4513
Unit A9	347.3367	381.9309	373.0609	156.6349	181.5081	178.9732	58.3098	61.3172	67.3902
Unit A10	346.2347	346.3821	334.1439	160.9649	180.8723	179.9383	54.0256	59.9221	69.8164
Unit A11	321.6418	330.6077	289.0183	126.7326	155.6357	171.3294	49.1134	51.9466	62.6640
Unit A12	392.3781	400.7486	360.1096	170.8795	188.4269	181.9095	61.9959	64.4384	69.3114
HEXCEL	373	395	NA	NA	NA	NA	NA	NA	NA
ARMY	NA	384	NA	NA	NA	NA	NA	NA	NA
Unit Avg	353.0496	365.9219	333.9918	151.1126	172.6702	177.1817	56.35425	59.09144	66.57190

The means of the units rather than the individual specimen values are used for computing the average so that each unit gets equal weight in computing the material mean vector. The covariance matrix used to compute the generic basis values requires datasets that have values for all the properties in the unit. In this case, the data supplied by HEXCEL and the army were included in the computations for averages, but not for the covariance matrix.

The results of the different basis value computations are shown in Table 10 and the corresponding equivalency criteria for sample means are shown in Table 11. Acceptance criteria computations include a factor based on sample size. A sample size of 8 was used for these computations. In order to assure that basis values are upheld, samples must meet criteria not only for the mean, but also for the variability of the sample. The approach used by CMH17 is to place a minimum criteria on the lowest specimen value in a sample. The approach used with generic basis values is to place a maximum value on the standard deviation. Table 12 gives this criteria for the tension strength basis values.

Table 10 LT, UNT0 and OHT1 Strength Equivalence Acceptance Limits and Basis Values

Test Property	LT			UNT0			OHT1		
Environment	**CTD**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**
Qual. B-Basis or B-Estimate	332.10	336.95	263.95	139.85	158.59	166.44	44.35	54.29	62.28
Qualification A-Estimate	314.58	319.53	201.74	131.31	150.06	157.91	34.78	51.08	59.06
Pooled Data B-basis (ANOVA)	302.31	305.61	273.84	121.62	147.56	161.60	47.87	51.52	60.65
Pooled Data A-basis (ANOVA)	267.92	265.01	229.91	100.95	129.61	150.47	42.00	46.19	56.43
Generic B-basis	273.31	282.13	240.28	96.37	129.03	150.54*	41.60	46.04	56.98
Generic A-basis	242.70	249.97	204.31	75.36	112.27	142.51*	35.94	41.03	53.30

* Alternate Generic Basis Value Method used due to large within company variance

Table 11 Tension Strength Equivalence Acceptance Limits for Unit Means

Test Property	LT			UNT0			OHT1		
Environment	**CTD**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**
Minimum Allowable Mean (Qual)	348.82	351.79	307.14	149.07	165.07	174.67	56.10	57.41	65.03
Minimum Allowable Mean (Pooled)	334.20	341.71	313.00	142.19	164.74	171.39	53.54	56.64	64.55
Minimum Allowable Mean (Generic)	285.24	294.68	254.31	104.57	135.56	157.76	43.81	47.99	58.42

Table 12 Tension Strength Equivalence Acceptance Limits for Sample Minimum and Standard Deviation

Test Property	LT			UNT0			OHT1		
Environment	**CTD**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**
Min. specimen value (Qual)	323.31	319.34	228.61	138.61	146.26	161.092	51.18	52.66	59.27
Min. specimen value (Pooled)	285.50	281.54	248.00	115.34	140.27	154.70	45.61	49.39	58.54
Max. std. dev. (Generic)	32.73	34.39	37.70	22.46	17.91	12.19	6.05	5.36	3.94

Figure 11 shows the different basis values and mean acceptance limits for the LT tests. Figure 12 shows the different basis values and mean acceptance limits for the UNT0 tests. Figure 13 the different basis values and mean acceptance limits for the OHT1 tests.

Two dimensional projections of the acceptance region and equivalence region are shown in Figure 14, Figure 15, Figure 16, Figure 17, Figure 18, and Figure 19. The CTD, RTD and ETW conditions are overlaid onto the same graphs for UNT0 and OHT1 in Figure 20 and for LT and OHT1 in Figure 21.

Figure 11: Longitudinal Tension B-basis Values and Mean Acceptance Limits

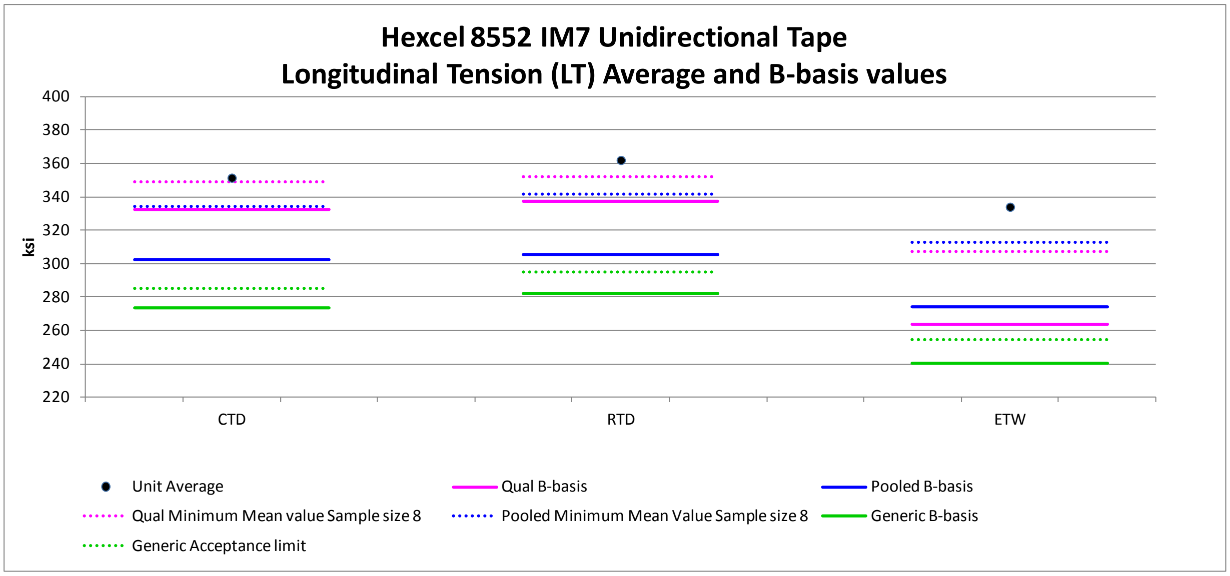


Figure 12: UNT0 B-basis Values and Mean Acceptance Limits

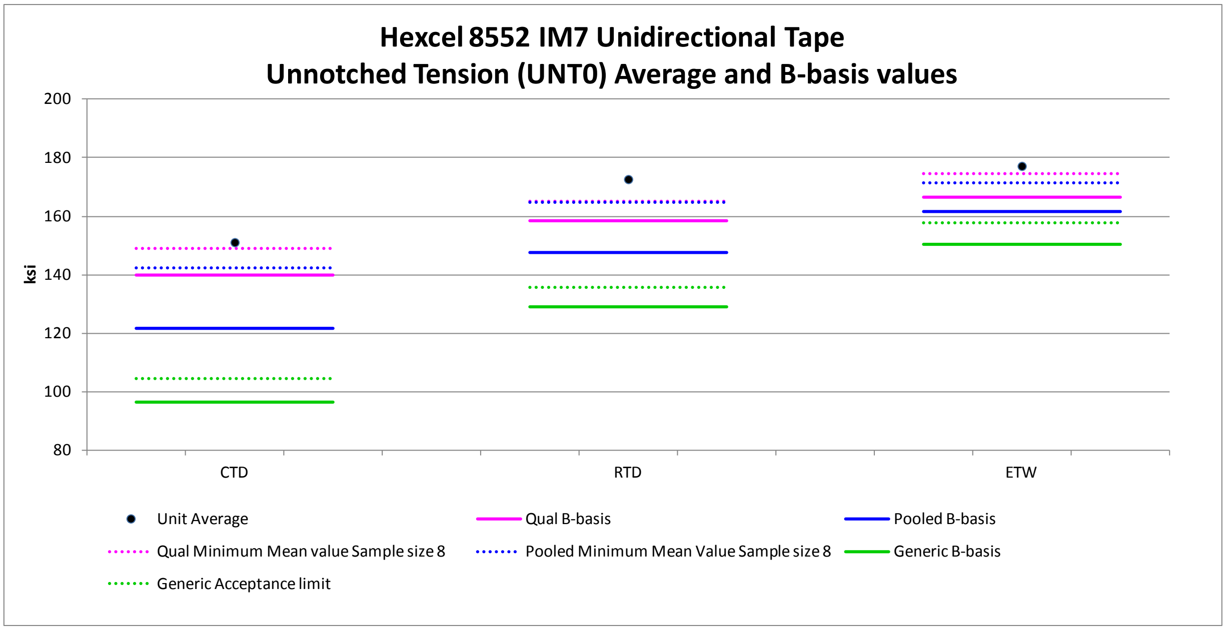


Figure 13: OHT1 B-basis Values and Mean Acceptance Limits

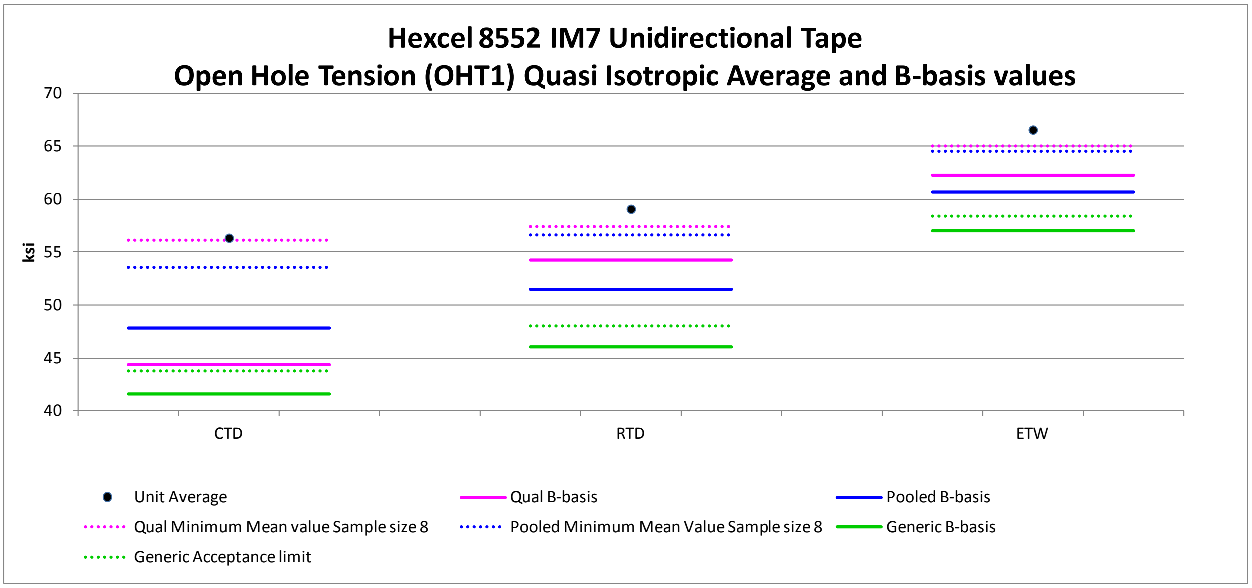


Figure 14: UNT0 and OHT1 Strength RTD Condition Acceptance and Equivalence Ellipses

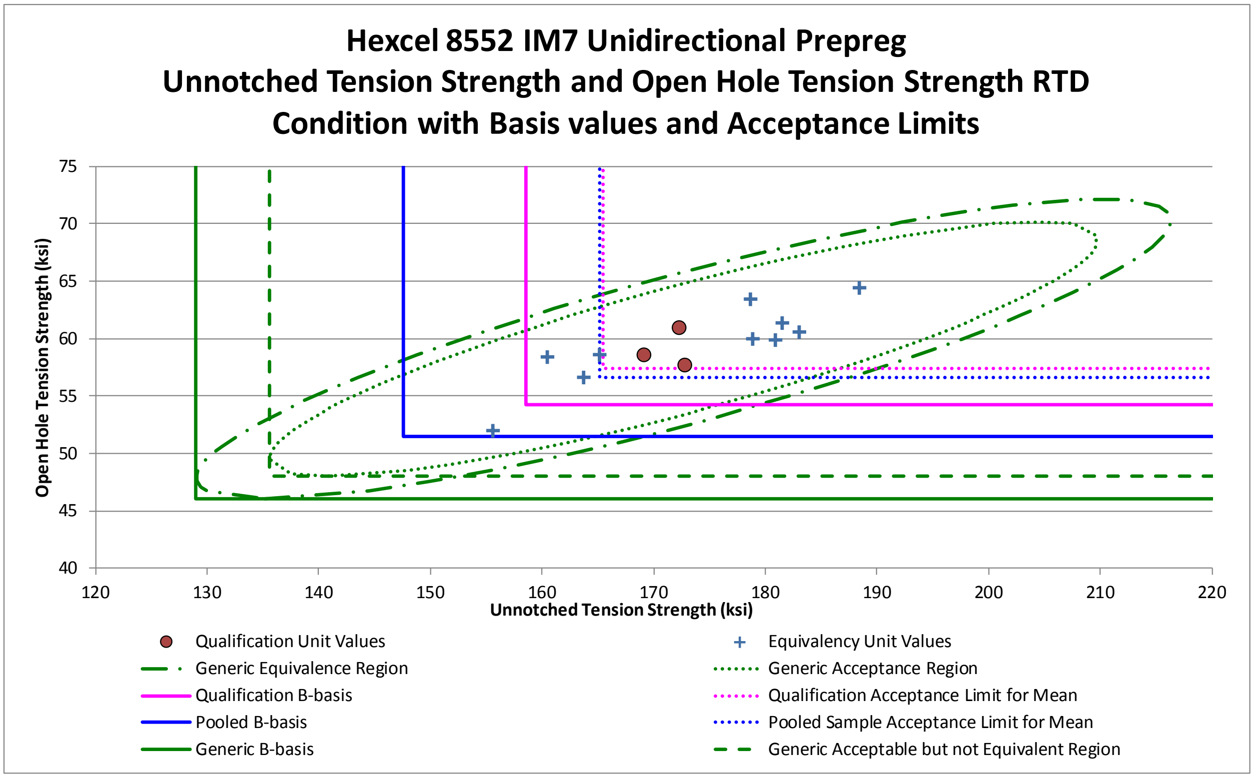


Figure 15: UNT0 and OHT1 Strength CTD Condition Acceptance and Equivalence Ellipses

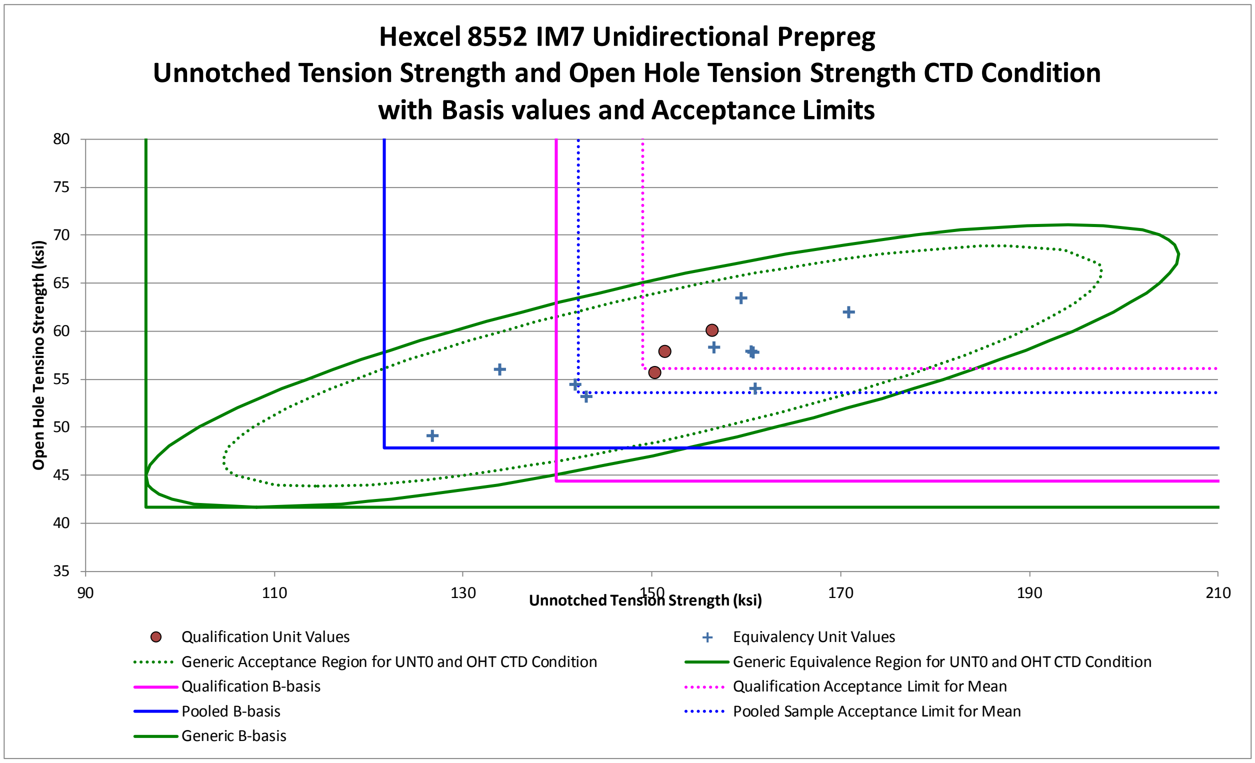


Figure 16: UNT0 and OHT1 Strength ETW Conditions Acceptance and Equivalence Ellipses

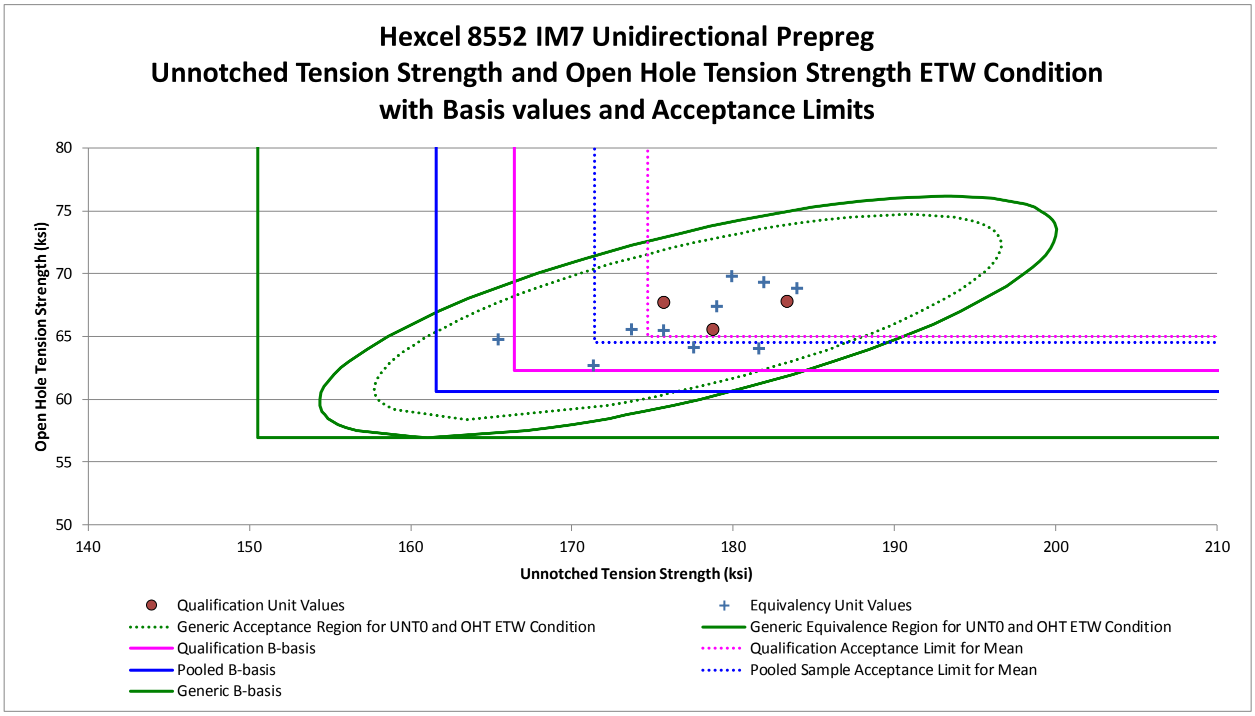


Figure 17: LT and OHT1 Strength CTD Conditions Acceptance and Equivalence Ellipses

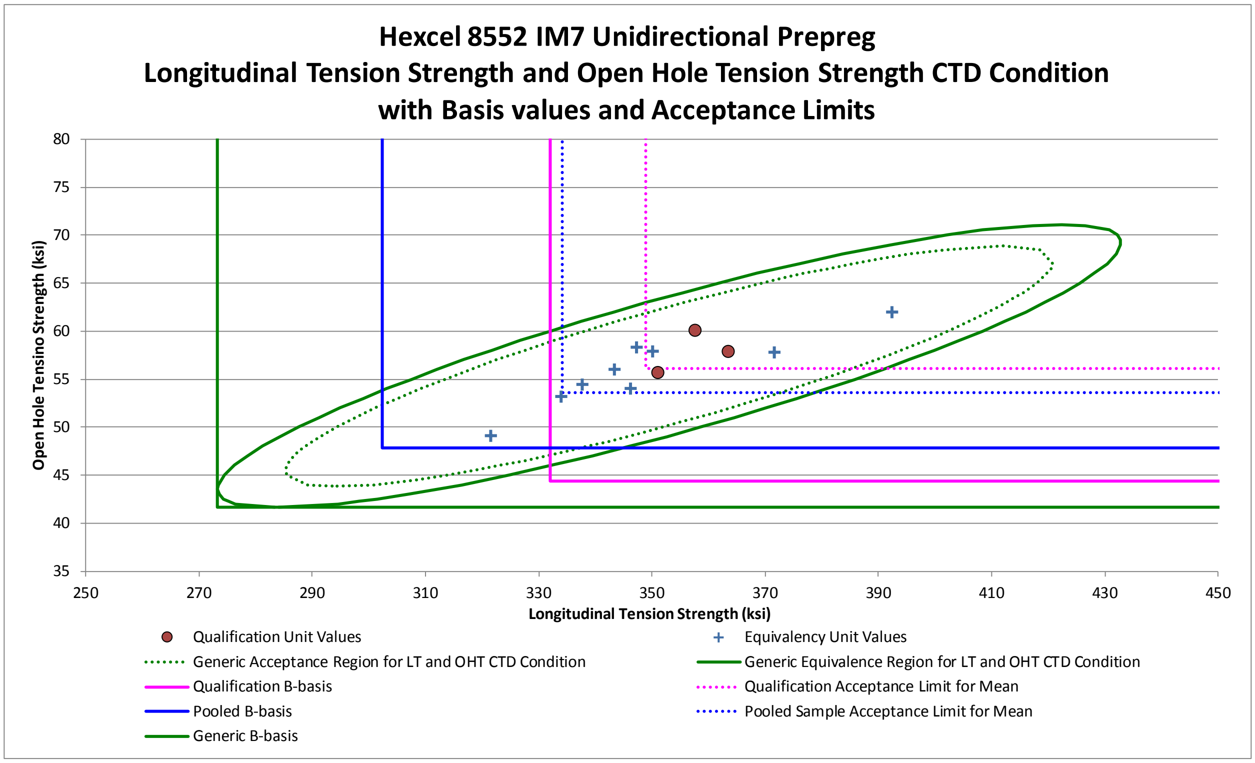


Figure 18: LT and OHT1 Strength RTD Conditions Acceptance and Equivalence Ellipses

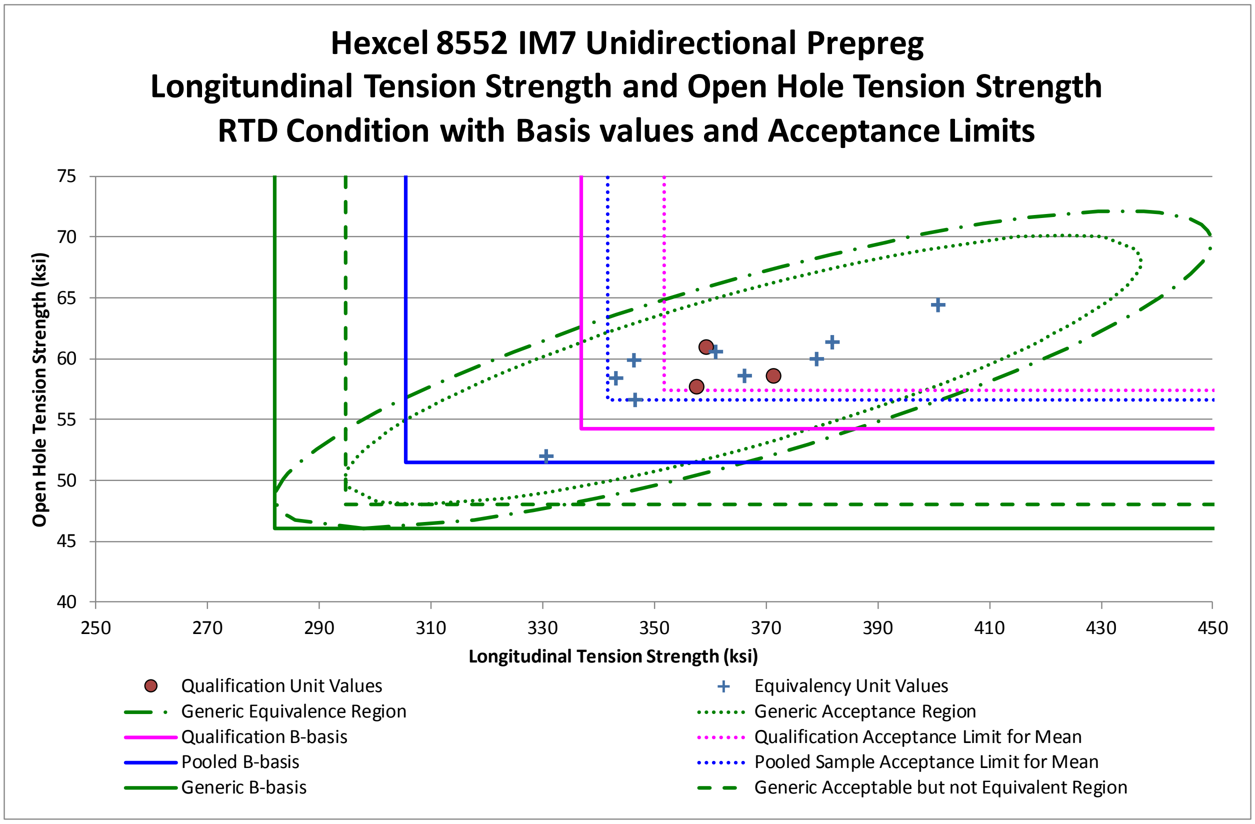


Figure 19: LT and OHT1 Strength ETW Conditions Acceptance and Equivalence Ellipses

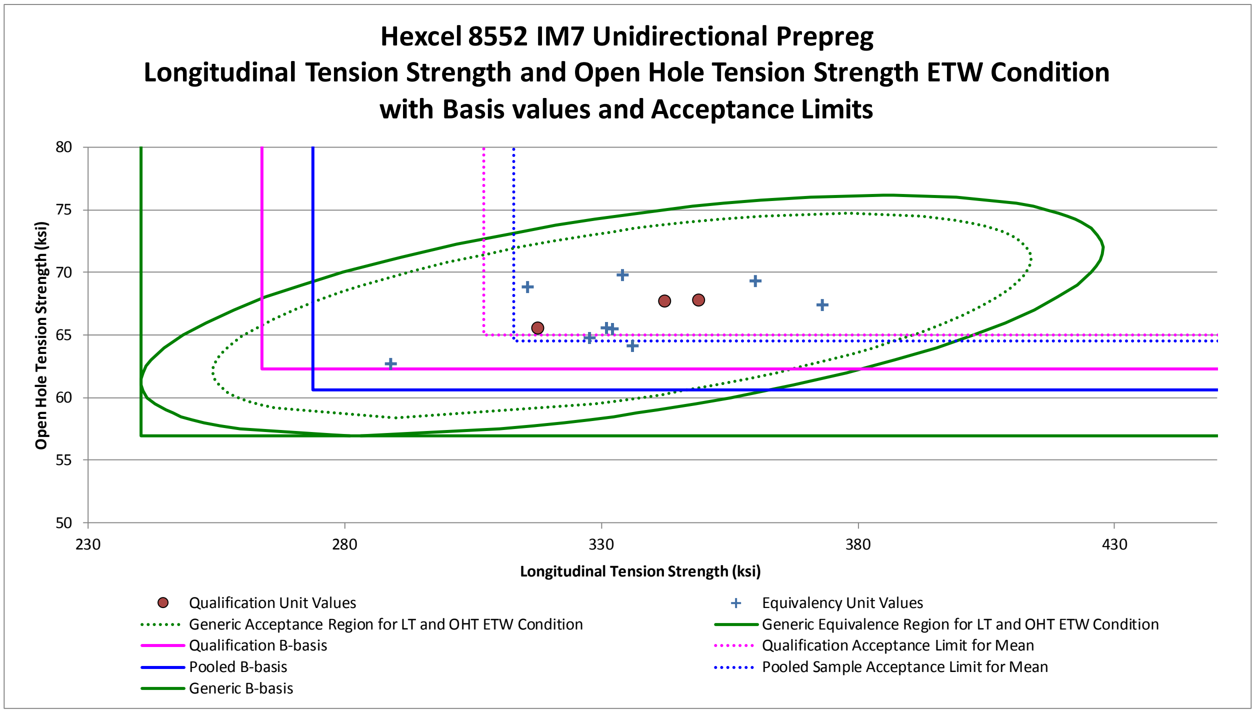


Figure 20: UNT0 and OHT1 Strength CTD, RTD and ETW Conditions Acceptance and Equivalence Ellipses

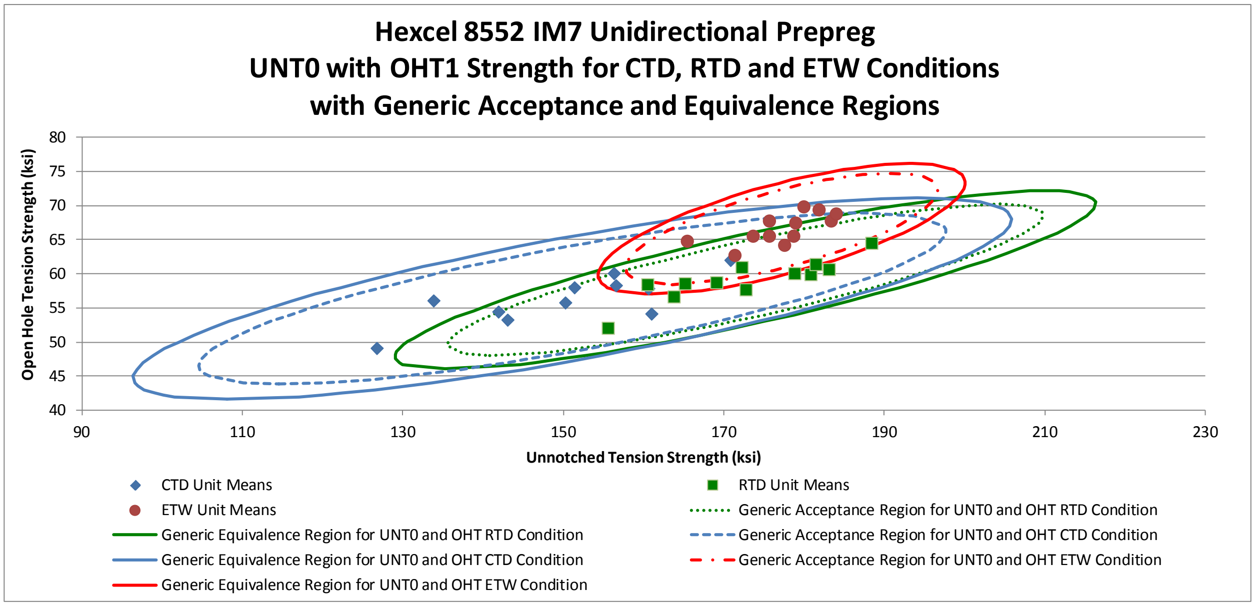
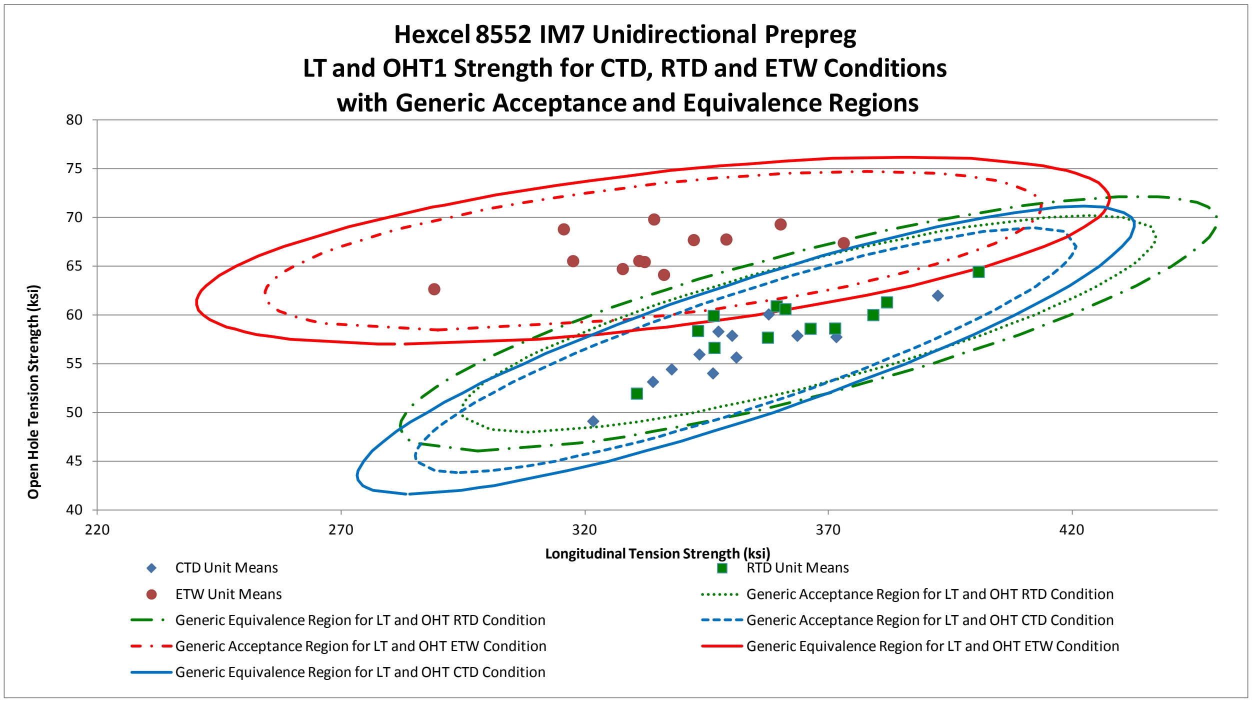


Figure 21: LT and OHT1 Strength CTD, RTD and ETW Conditions Acceptance and Equivalence Ellipses



3.6 Shear Strength

The NCAMP Shear Strength Data is not normalized. Data are available for In-Plane Shear (IPS) tests (layup $[45/-45]_{3s}$) with data available for strength at 5% strain in the RTD & ETW conditions and 0.2% offset strength in the CTD, RTD and ETW conditions. Data are available for Short Beam Strength (SBS) tests (layup [0]34) for the RTD and ETW conditions. The data are shown by unit in Table 13.

Table 13 Shear Strength Units

Property	Short Beam Strength		In-Plane Shear Strength @ 5% Strain		In-Plane Shear 0.2% Offset Strength		
Environment	**RTD**	**ETW**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**
Unit A01	17.3965	8.1751	13.0357	5.5692	11.0907	7.5913	3.3250
Unit A02	16.9797	8.2567	13.2380	5.6957	11.3737	7.7992	3.4069
Unit A03	16.9992	8.3377	13.4008	5.3430	11.4197	7.8687	3.1691
Unit A2	17.3021	8.3685	13.2828	5.5231	10.7332	7.8106	3.1542
Unit A4	17.4888	8.1074	13.1634	5.2817	10.4560	7.6322	3.1376
Unit A5	17.3672	8.0070	13.0516	5.2250	10.6050	7.5683	3.1287
Unit A6	16.9036	8.2122	12.9588	5.3020	10.3254	7.4333	3.0933

Unit A8	18.0190	8.6433	13.0779	5.4912	10.9147	7.7718	3.2598
Unit A9	17.3656	8.6895	13.1779	5.4811	10.8985	7.6934	3.2634
Unit A10	16.8199	8.2190	13.4464	5.5872	10.7120	7.8001	3.2734
Unit A11*	15.3827	7.6878	12.8466	5.2022	10.4723	7.4405	2.9678
Unit A12	17.2102	8.0537	13.4287	5.7775	10.5827	7.7973	3.4195
HEXCEL	19.9	11.6	NA	NA	NA	NA	NA
ARMY	NA	NA	13.22	NA	NA	NA	NA
Unit Avg	17.1029	8.2298	13.1757	5.4566	10.7987	7.6839	3.2166

*Unit A11 fails the generic equivalence test for the mean values of the shear strength properties

The means of the units rather than the individual specimen values are used for computing the average so that each unit gets equal weight in computing the material mean vector. The covariance matrix used to compute the generic basis values requires datasets that have values for all the properties in the unit. In this case, the data supplied by HEXCEL and the army were included in the computations for averages, but not for the covariance matrix.

Unit A11 did not fall within the generic acceptance area. Calculations indicate that unit A11 can be considered 'Acceptable but not Equivalent' for only three of these seven properties: IPS 0.2% Offset Strength for the RTD and ETW conditions and IPS Strength at 5% Strain for the ETW condition. Additional testing of shear properties is recommended for company A11.

The results of the different basis value computations are shown in Table 14 and the corresponding equivalency criteria for sample means are shown in Table 15. Acceptance criteria computations include a factor based on sample size. A sample size of 8 was used for these computations. In order to assure that basis values are upheld, samples must meet criteria not only for the mean, but also for the variability of the sample. The approach used by CMH17 requires that samples meet minimum criteria on both the mean and the lowest specimen value in a sample. The approach used with generic basis values is criteria specifying a minimum value the mean must exceed and a maximum that the standard deviation may not exceed. Table 16 gives criteria for the shear strength basis values.

Table 14 Shear Strength Equivalence Acceptance Limits and Basis Values

Test Property	**Short Beam Strength**		**In-Plane Shear Strength @ 5% Strain**		**In-Plane Shear 0.2% Offset Strength**		
Environment	**RTD**	**ETW**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**
Qualification B-Basis	16.28	7.78	12.76	4.49	10.25	7.38	2.61
Qualification A-Estimate	15.67	6.67	12.43	3.75	9.50	6.32	2.12
Pooled Data B-basis	15.48	7.47	12.65	4.98	9.93	7.29	2.88
Pooled Data A-basis	14.33	6.93	12.28	4.64	9.33	7.01	2.64
Generic B-basis	14.70	7.37	12.38	4.68	9.34	7.07	2.67
Generic A-basis	13.68	6.92	12.07	4.38	8.76	6.82	2.45

* Alternate Generic Basis Value Method used due to large within company variance

Table 15 Shear Strength Equivalence Acceptance Limits for Unit Means

Test Property	Short Beam Strength		In-Plane Shear Strength @ 5% Strain		In-Plane Shear 0.2% Offset Strength		
Environment	**RTD**	**ETW**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**
Minimum Allowable Mean (Qual)	16.83	8.09	13.08	5.41	11.13	7.61	3.20
Minimum Allowable Mean (Pooled)	16.56	7.97	12.98	5.29	10.50	7.55	3.10
Minimum Allowable Mean (Generic)	15.23	7.59	12.54	4.84	9.63	7.19	2.78

Table 16 Shear Strength Equivalence Acceptance Limits for Sample Minimum and Standard Deviation

Test Property	Short Beam Strength		In-Plane Shear Strength @ 5% Strain		In-Plane Shear 0.2% Offset Strength		
Environment	**RTD**	**ETW**	**RTD**	**ETW**	**CTD**	**RTD**	**ETW**
Min. specimen value (Qual)	15.96	7.60	12.66	5.03	10.65	7.17	2.89
Min. specimen value (Pooled)	14.98	7.18	12.45	4.83	9.66	7.15	2.77
Max. std. dev. (Generic)	1.116	0.480	0.339	0.330	0.625	0.264	0.235

Figure 22 shows the different basis values and mean acceptance limits for the SBS tests. Two dimensional projections of the acceptance region and equivalence region are shown for the SBS tests in Figure 23. The lowest value in the equivalency region is the generic B-basis value. This graph also shows that the normal production process used by fabricators is not achieving the strength values reported in the HEXCEL product data information for this property, although the different ETW conditions results may be due to the temperature difference, 180°F for the HEXCEL Product data versus 250°F for the NCAMP results.

Figure 22: Short Beam Strength B-basis Values and Mean Acceptance Limits

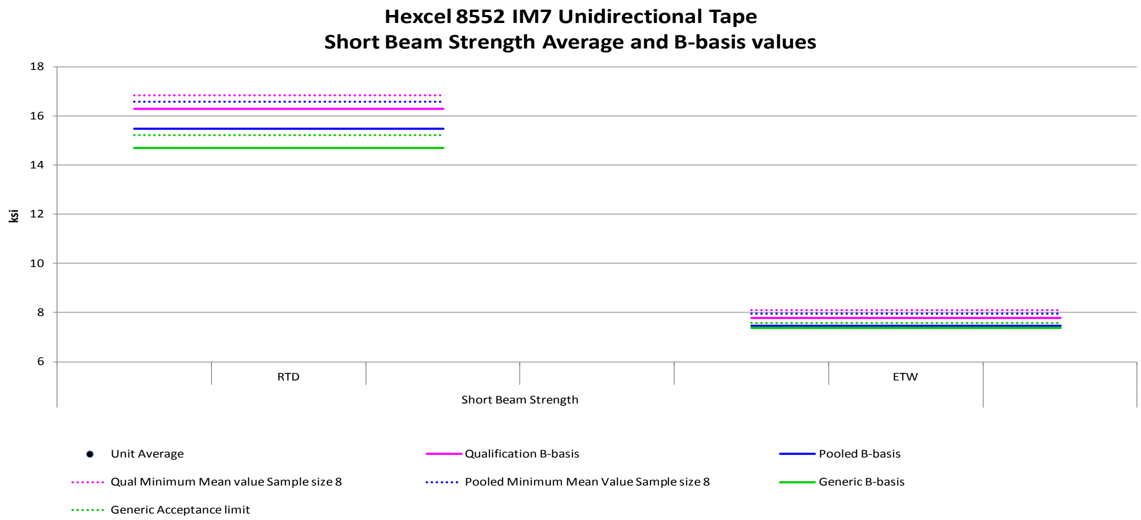


Figure 23: SBS RTD and ETW Conditions Data with Generic Acceptance and Equivalence Ellipses

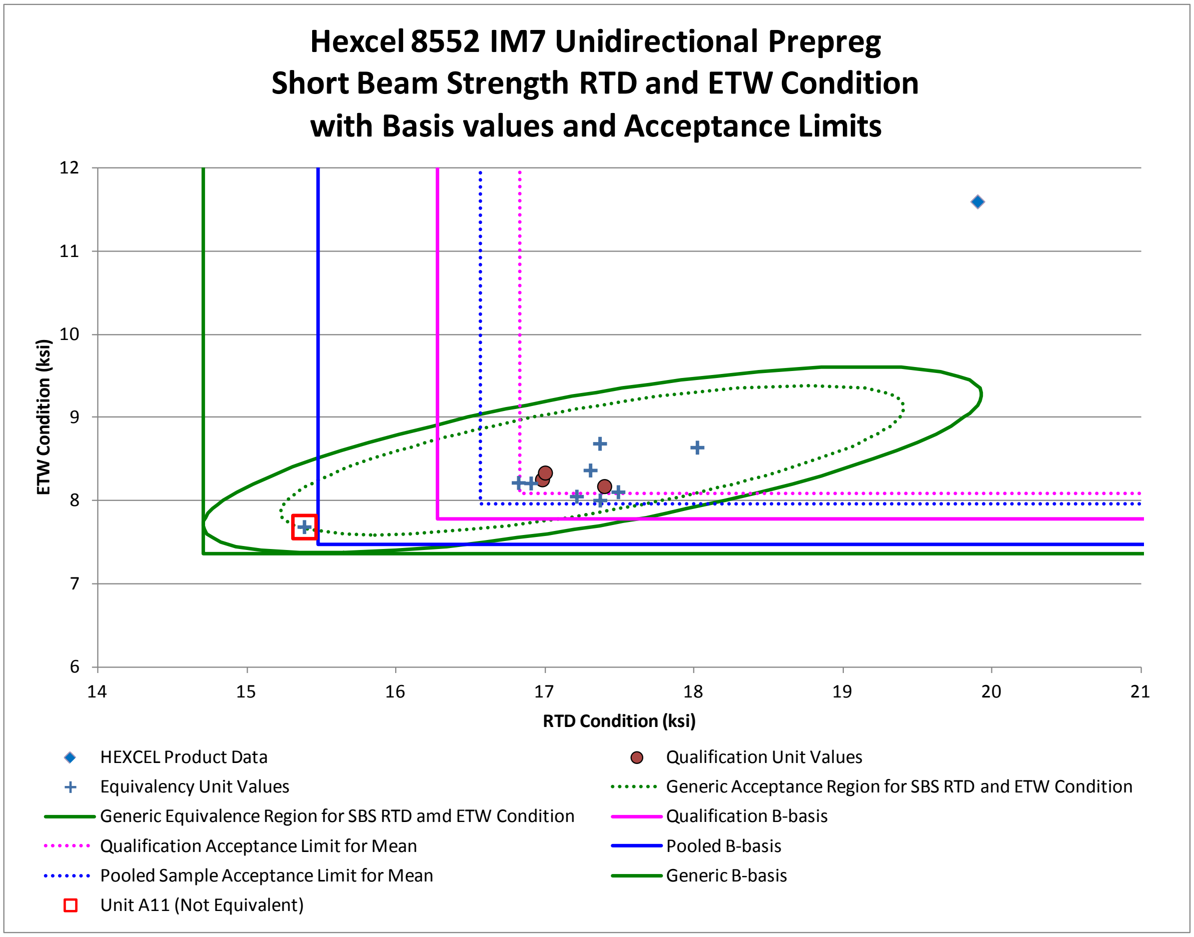


Figure 24 shows the different basis values and mean acceptance limits for the IPS tests. A two dimensional projections of the acceptance region and equivalence region are shown for the IPS RTD tests in Figure 25 and the IPS ETW tests in Figure 26. The lowest value in the equivalency region is the generic B-basis value.

Figure 24: In-Plane Shear Strength B-basis Values and Mean Acceptance Limits

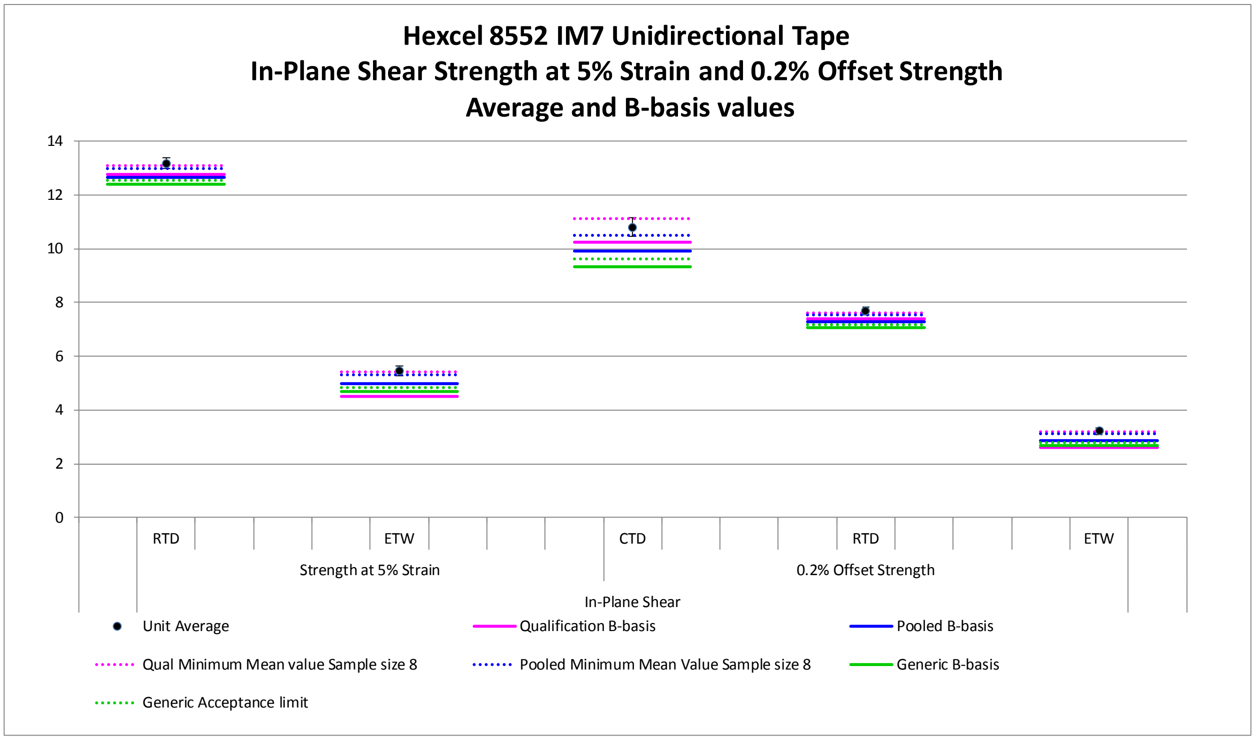


Figure 25: In-Plane Shear 0.2% Offset Strength and Strength at 5% Strain RTD Condition Acceptance and Equivalence Ellipses

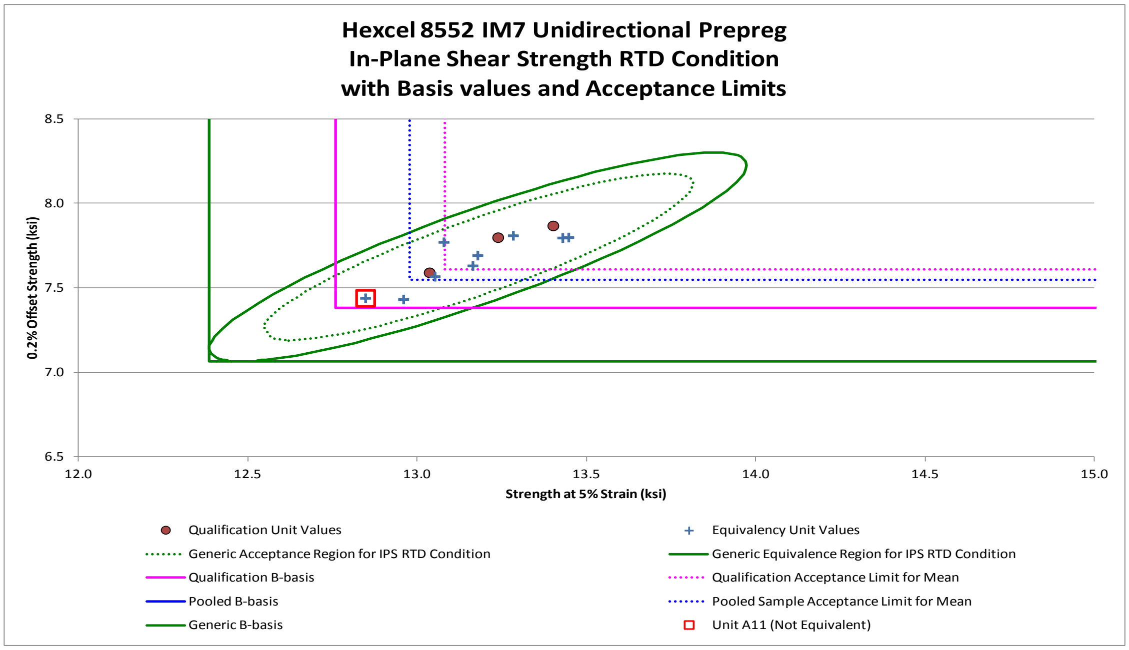
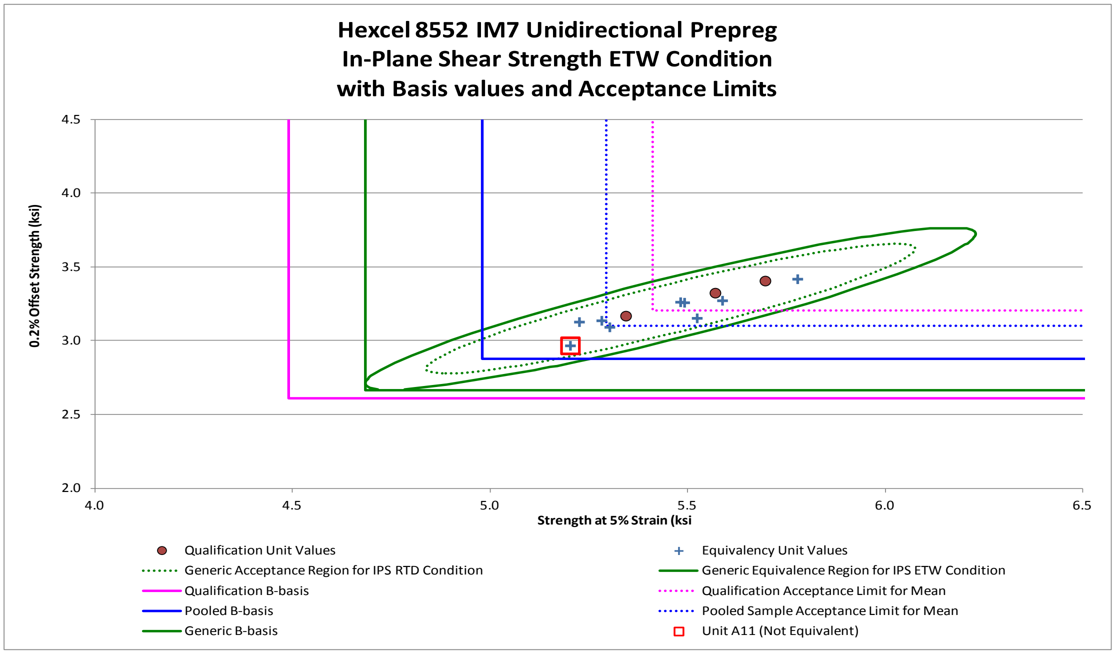


Figure 26: In-Plane Shear 0.2% Offset Strength and Strength at 5% Strain ETW Condition Acceptance and Equivalence Ellipses



4. Individual Test Results

4.1 Compression Strength

4.1.1 UNC0 RTD Condition

There were a total of 88 specimens from the ten different companies in the NCAMP dataset. One specimen was identified as a statistical outlier. It was the lowest value from company A6. It was an outlier for the pooled dataset but not for the A6 dataset.

The within company standard deviation was slightly higher than the between units standard deviation, but not significantly higher. The standard deviation from company A4 failed the F-test, but calculations indicate that company A4 should be considered 'Acceptable but not Equivalent' for this property.

Using the HYTEQ software to run equivalency tests for strength, there were two companies (A4, A6) that failed equivalency for strength. Unit A6 failed equivalency when compared with both the qualification dataset and the pooled dataset. It failed the equivalency test for both the mean and the minimum specimen value in both cases. Unit A4 failed equivalency when compared with the qualification dataset but not when compared with the pooled dataset. It failed equivalency only for the minimum specimen value, the mean was acceptable.

Unit A6 failed the generic basis values equivalency criteria for strength, but was above the minimum criteria for this property and passed the F-test for equal variance, so it can be considered ‘Acceptable, but not Equivalent’ for this property.

The summary statistics for all units are shown in Table 17 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 27. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 28. The standard deviations for strength by company are shown in Figure 29. All outliers and test failures are indicated in these graphs.

Table 17 UNC0 RTD Strength Summary Statistics by Unit

UNC0 Normalized Strength RTD Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	94.509		94.580	94.366	96.275	93.756	92.667	79.368	97.010	97.609	97.608	96.257	97.814	94.234
Std Dev.	5.587		4.750	8.272	3.413	9.282	5.368	8.404	3.089	3.699	6.090	3.900	4.690	7.618
Coeff Var.	5.91%	NA	5.02%	8.77%	3.55%	9.90%	5.79%	10.59%	3.18%	3.79%	6.24%	4.05%	4.80%	8.08%
Max	99.743		99.743	99.525	101.340	102.875	100.673	92.672	102.721	103.350	105.115	102.890	106.013	106.013
Min	84.825		85.878	84.825	92.211	75.436	84.434	68.767	93.751	91.767	86.510	92.096	92.161	68.767
Count	9		6	3	9	9	9	9	8	9	9	8	9	88

Figure 27: UNC0 RTD Strength Specimen Data

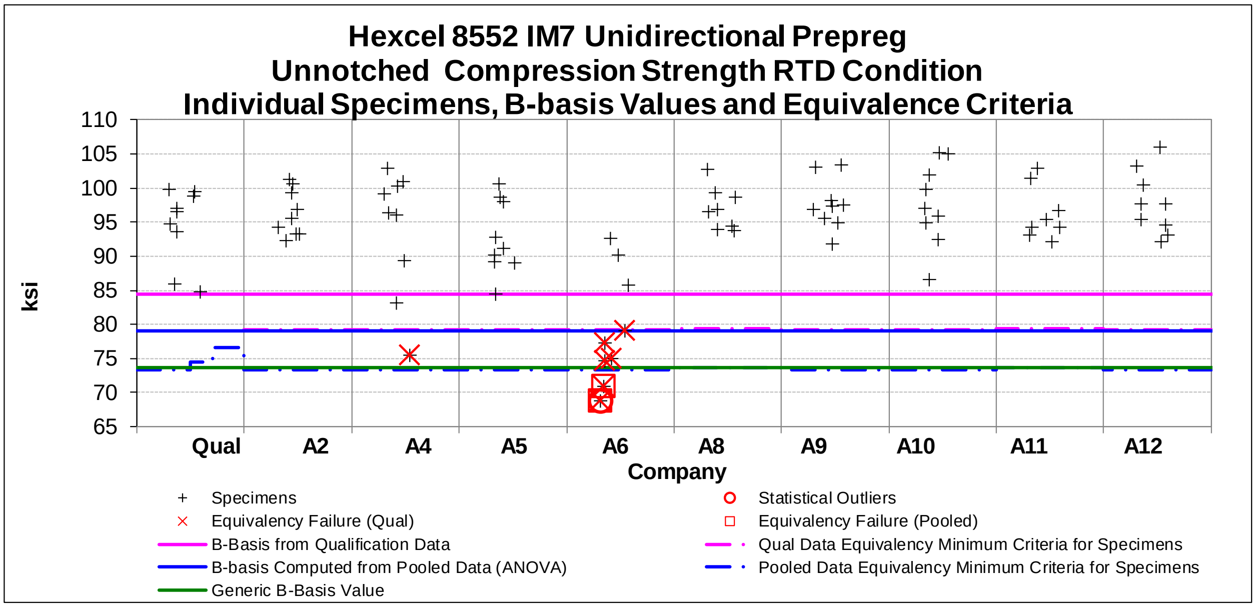


Figure 28: UNC0 RTD Strength Means by company

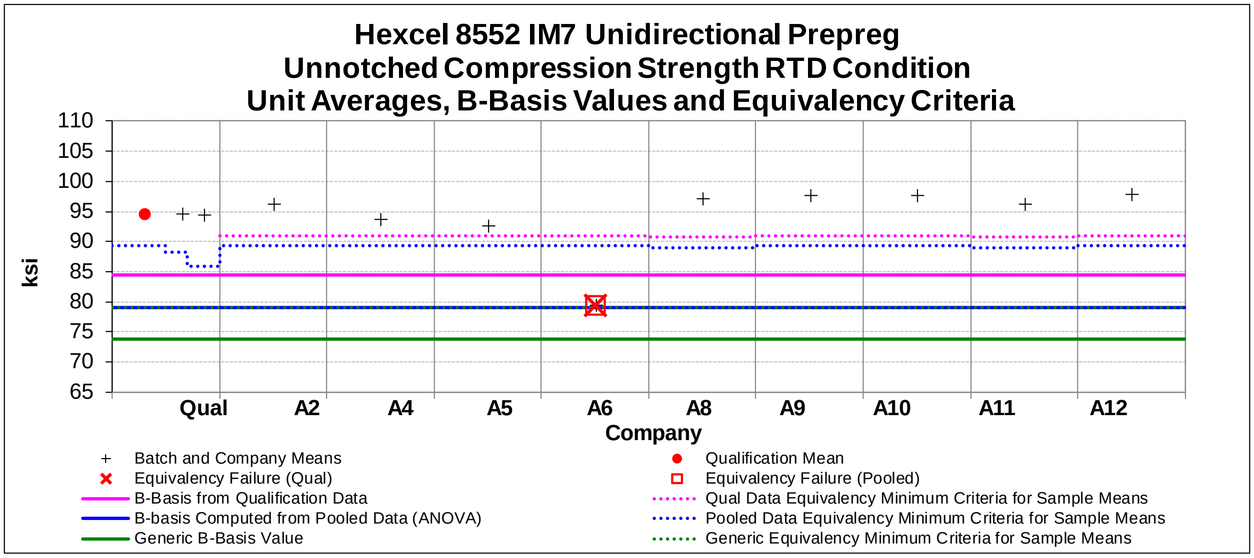
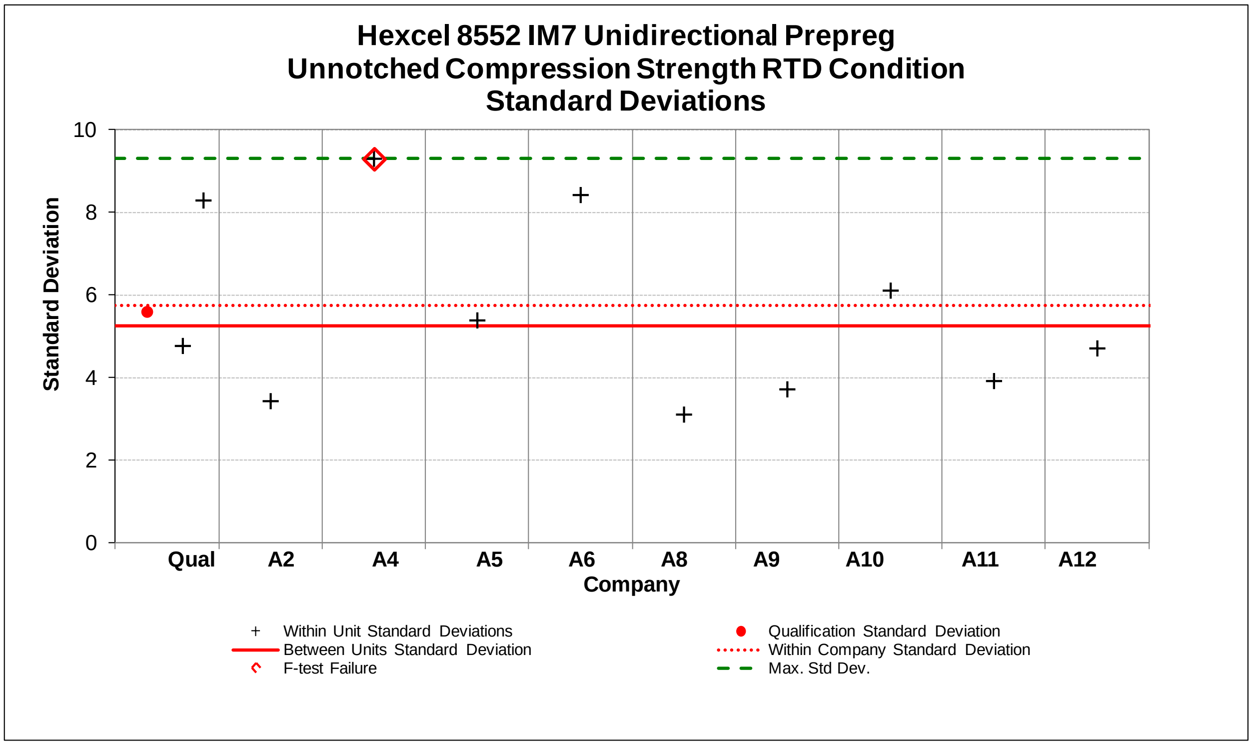


Figure 29: UNC0 RTD Strength Standard Deviations by Company



4.1.2 UNC0 ETD Condition

There were a total of 93 specimens from the ten different companies in the NCAMP dataset. There were no statistical outliers.

The within company standard deviation was significantly higher than the between units standard deviation, so the alternate formula for computing the generic basis value was used. There were no failures of the F-test when comparing the unit standard deviations to the within company standard deviation.

Using the HYTEQ software to run equivalency tests for strength, there were three units (A4, A5, A10) that failed equivalency for strength. Unit A4 failed equivalency when compared with both the qualification dataset and the pooled dataset. Units A5 and A10 failed equivalency when compared with the qualification dataset but not when compared with the pooled dataset.

Unit A4 failed equivalency due to both the mean and minimum specimen value being too low when compared with the qualification dataset but only for the mean being too low when compared with the pooled dataset. Unit A5 unit failed the equivalency test for both the mean and the minimum specimen value. Unit A10 failed equivalency only for the minimum specimen value, the mean was acceptable.

Unit A6 failed the generic basis values equivalency criteria for strength, but was above the minimum criteria for this property and passed the F-test for equal variance, so it can be considered 'Acceptable, but not Equivalent' for this property.

The summary statistics for all units are shown in Table 18. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 30. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 31. The standard deviations for strength by company are shown in Figure 32. All outliers and test failures are indicated in these graphs.

Table 18 UNC0 ETD Strength Summary Statistics by Unit

UNC0 Normalized Strength ETD Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	Dataset
Average	75.528	NA	74.096	78.391	73.542	64.371	72.402	78.517	74.036	75.544	76.173	73.557	76.811	74.029
Std Dev.	4.992		5.045	4.196	4.675	3.875	9.664	6.705	4.063	1.987	7.972	6.978	3.399	6.720
Coeff Var.	6.61%		6.81%	5.35%	6.36%	6.02%	13.35%	8.54%	5.49%	2.63%	10.47%	9.49%	4.43%	9.08%
Max	81.341		79.697	81.341	80.106	69.285	90.012	90.070	79.610	78.981	82.644	87.108	80.216	90.070
Min	66.781		66.781	73.587	65.292	57.193	58.826	68.447	69.236	72.769	61.592	65.099	71.335	57.193
Count	9		6	3	9	9	11	9	9	10	9	9	9	93

Figure 30: UNC0 ETD Strength Specimen Data

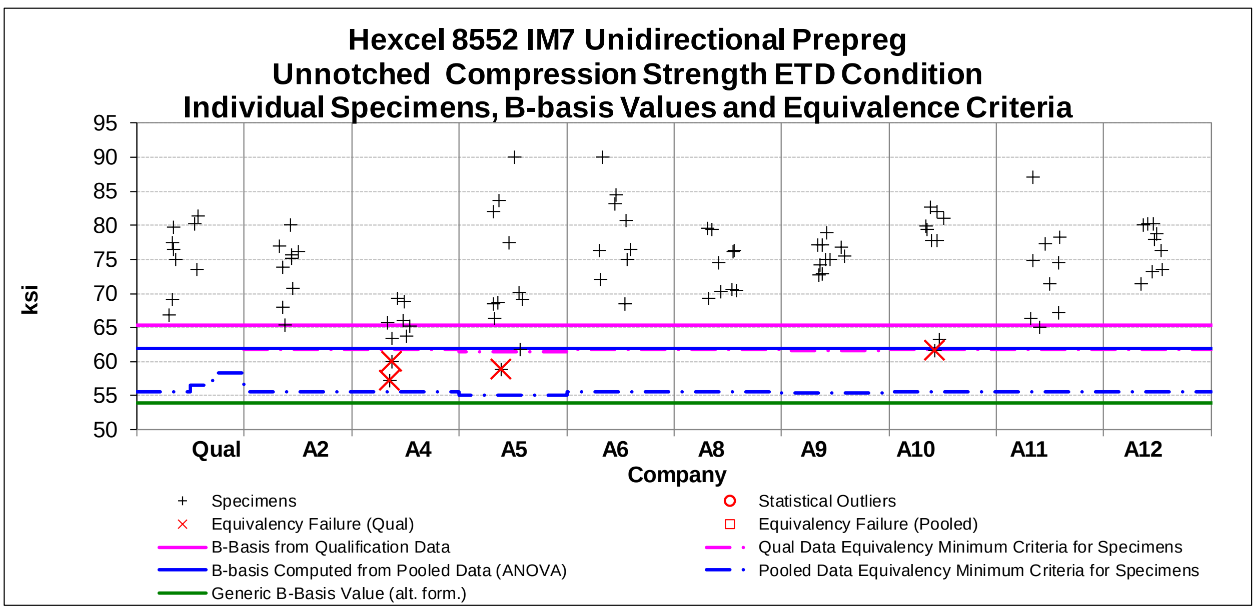


Figure 31: UNC0 ETD Strength Means by company

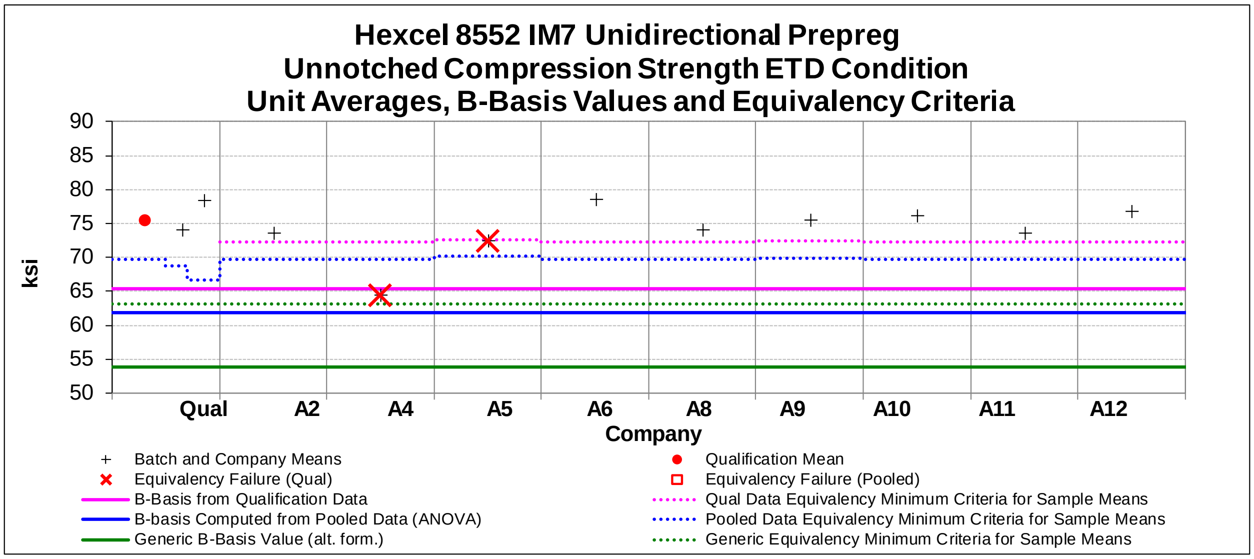
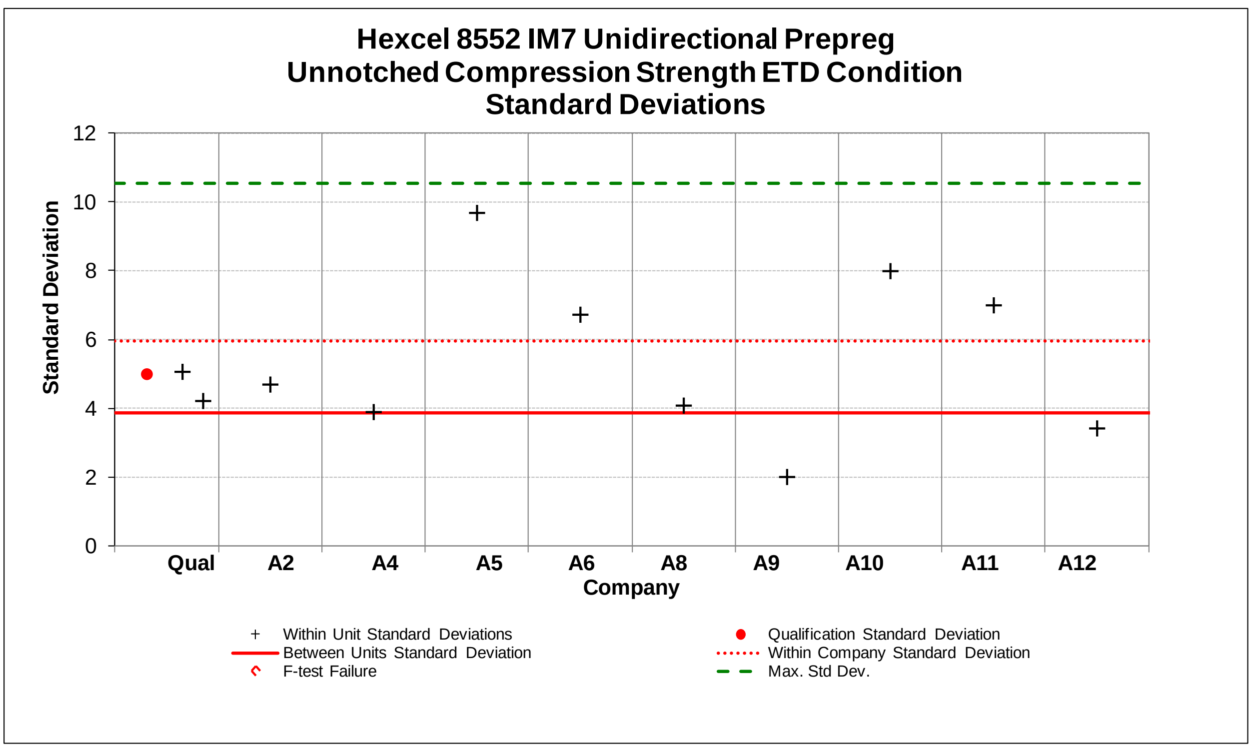


Figure 32: UNC0 ETD Strength Standard Deviations by Company



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4.1.3 UNC0 ETW Condition

There were a total of 98 specimens from the ten different companies in the NCAMP dataset. There were no statistical outliers.

The within company standard deviation was significantly higher than the between units standard deviation, so the alternate formula for computing the generic basis value was used. There were no failures of the F-test when comparing the unit standard deviations to the within company standard deviation.

Using the HYTEQ software to run equivalency tests for strength, the unit A6 failed equivalency for strength. It failed equivalency when compared with both the qualification dataset and the pooled dataset. It failed equivalency due to the minimum specimen value being below the minimum criteria. The unit mean was acceptable.

Unit A6 failed the generic basis values equivalency criteria for strength, but was above the minimum criteria for this property and passed the F-test for equal variance, so it can be considered 'Acceptable, but not Equivalent' for this property.

The summary statistics for all units are shown in Table 19 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 33. The mean values for strength for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 34. The standard deviations for strength for each company are shown in Figure 35. All outliers and equivalence failures are indicated in these graphs.

Table 19 UNC0 ETW Strength Summary Statistics by Unit

UNC0 Normalized Strength ETW Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	64.278	NA	64.812	63.299	69.282	67.249	65.138	64.172	66.064	67.531	65.000	63.154	65.999	65.675
Std Dev.	5.289		5.181	5.834	8.504	3.886	4.855	6.979	5.744	7.964	2.861	5.265	5.554	5.916
Coeff Var.	8.23%		7.99%	9.22%	12.27%	5.78%	7.45%	10.88%	8.69%	11.79%	4.40%	8.34%	8.41%	9.01%
Max	70.950		70.950	69.827	80.962	72.860	74.624	73.658	71.253	80.766	69.565	70.912	74.475	80.962
Min	53.938		53.938	54.357	57.983	61.830	59.480	48.662	54.001	55.529	60.534	52.695	55.198	48.662
Count	17		11	6	9	9	8	10	10	9	7	9	10	98

Figure 33: UNC0 ETW Strength Specimen Data

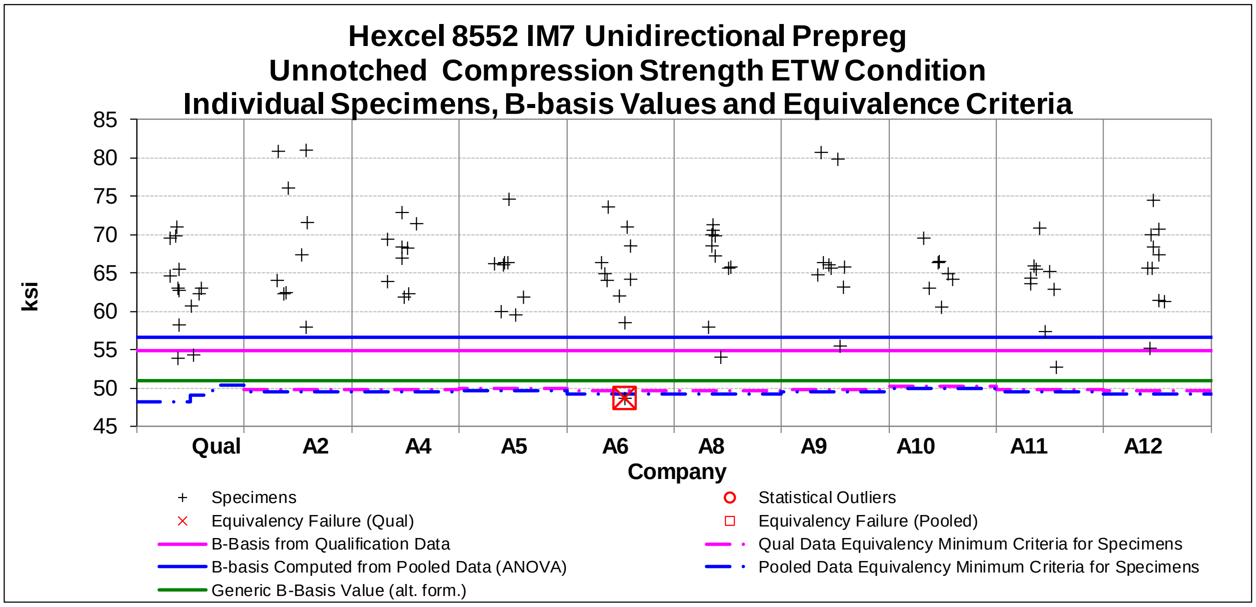


Figure 34: UNC0 ETW Strength Means by company

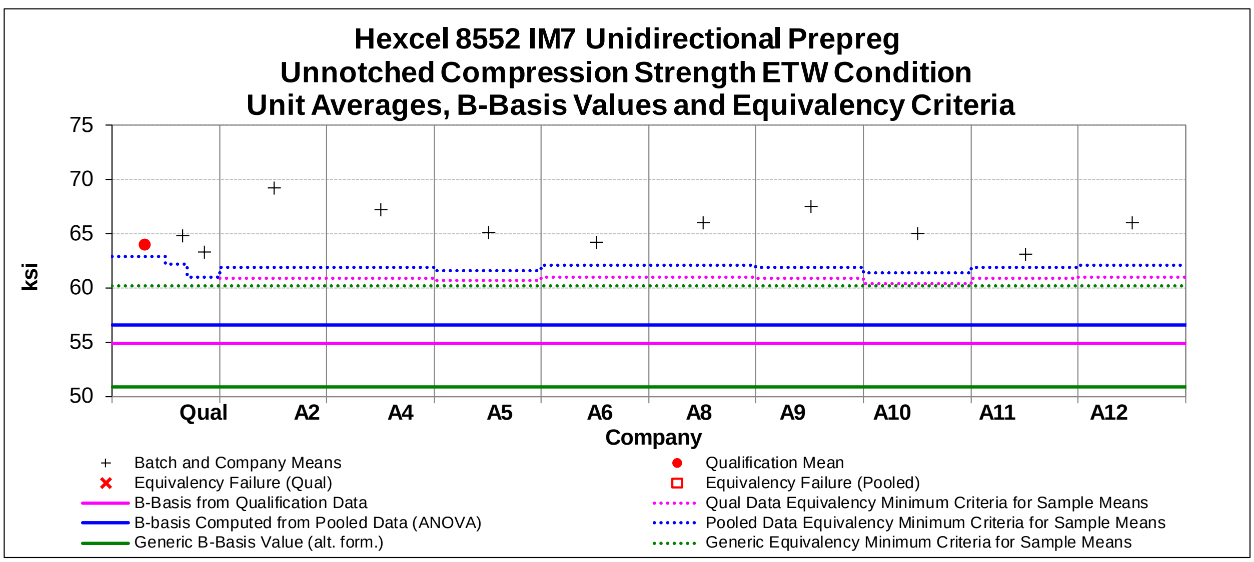
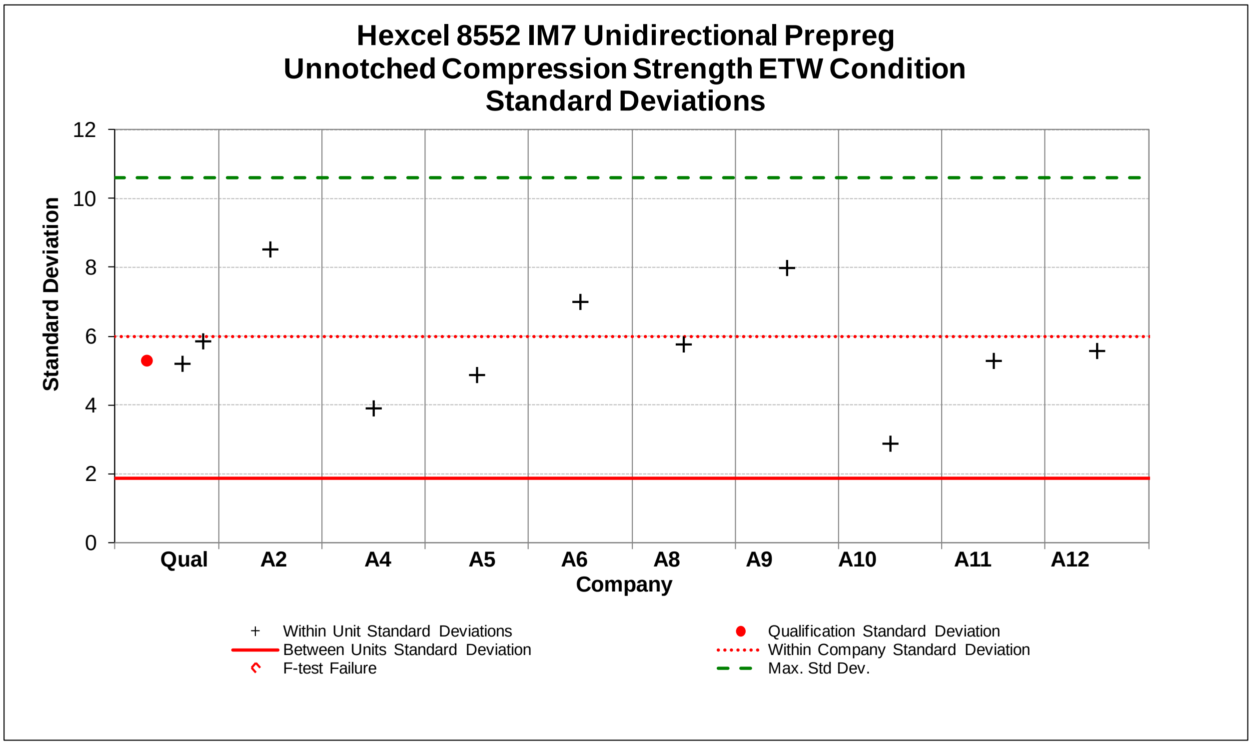


Figure 35: UNC0 ETW Strength Standard Deviations by Company



4.1.4 OHC1 RTD Condition

There were a total of 99 specimens from the ten different companies in the NCAMP dataset. There were three specimens identified as statistical outliers. The lowest values in units A01 and A03 of the qualification samples were outliers for their respective units. The highest value in unit A5 was an outlier for unit A5. None were outliers for the pooled dataset.

The within company standard deviation was significantly higher than the between units standard deviation, so the alternate formula for computing the generic basis value was used. There were no failures of the F-test when comparing the unit standard deviations to the within company standard deviation.

Using the HYTEQ software to run equivalency tests for strength, there were no failures when compared with the qualification sample, but qualification sample unit A03, and units A9 and A10 all failed equivalency when compared with the pooled dataset. They all failed the equivalency test due to the minimum specimen value being too low. The sample means were acceptable for all units.

Unit A6 failed the generic basis values equivalency criteria for strength, but was above the minimum criteria for this property and passed the F-test for equal variance, so it can be considered 'Acceptable, but not Equivalent' for this property.

The summary statistics for all units are shown in Table 20 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 36. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 37. The standard deviations for strength by company are shown in Figure 38. All outliers and test failures are indicated in these graphs.

Table 20 OHC1 RTD Strength Summary Statistics by Unit

OHC1 Normalized Strength RTD Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	Dataset
Average	49.083	49.778	48.719	48.638	49.030	49.289	49.866	49.335	48.983	48.580	48.416	50.349	49.253	49.193
Std Dev.	1.793	1.679	0.997	2.475	1.187	1.498	1.618	2.020	0.790	1.846	1.715	1.517	1.160	1.591
Coeff Var.	3.65%	3.37%	2.05%	5.09%	2.42%	3.04%	3.24%	4.10%	1.61%	3.80%	3.54%	3.01%	2.36%	3.23%
Max	50.993	50.993	49.756	50.974	51.308	51.588	53.547	52.313	50.105	49.835	50.580	52.684	50.851	53.547
Min	43.909	46.316	47.400	43.909	47.019	46.152	47.783	45.453	47.607	44.643	44.805	48.378	47.320	43.909
Count	19	7	6	6	9	9	9	9	9	9	9	8	9	99

Figure 36: OHC1 RTD Strength Specimen Data

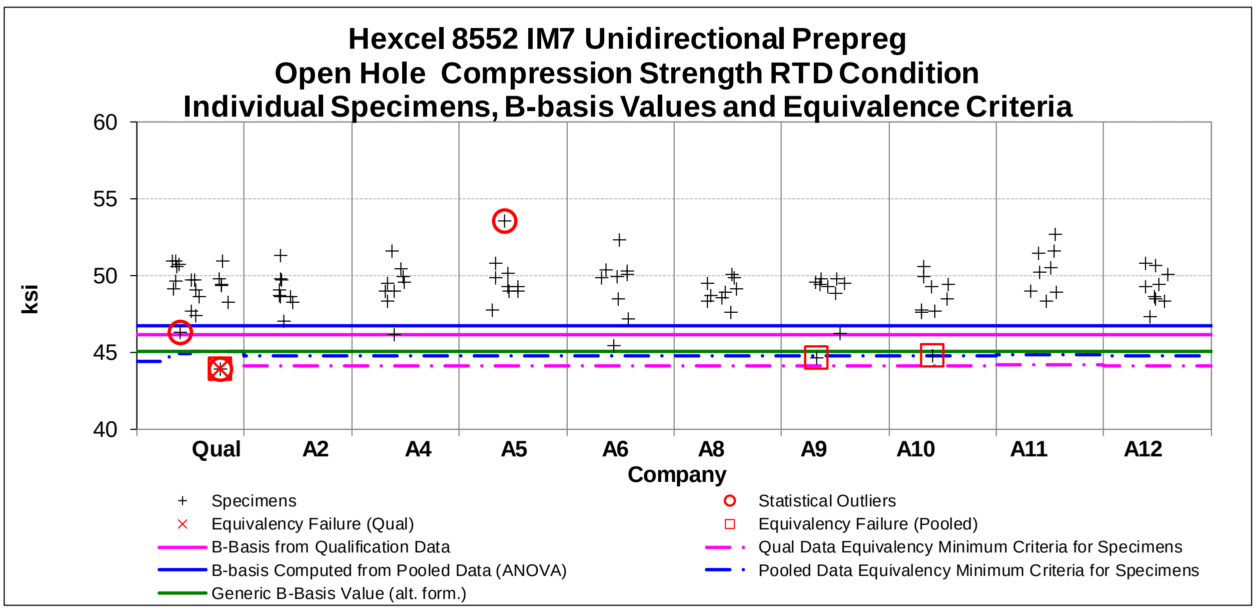


Figure 37: OHC1 RTD Strength Means by company

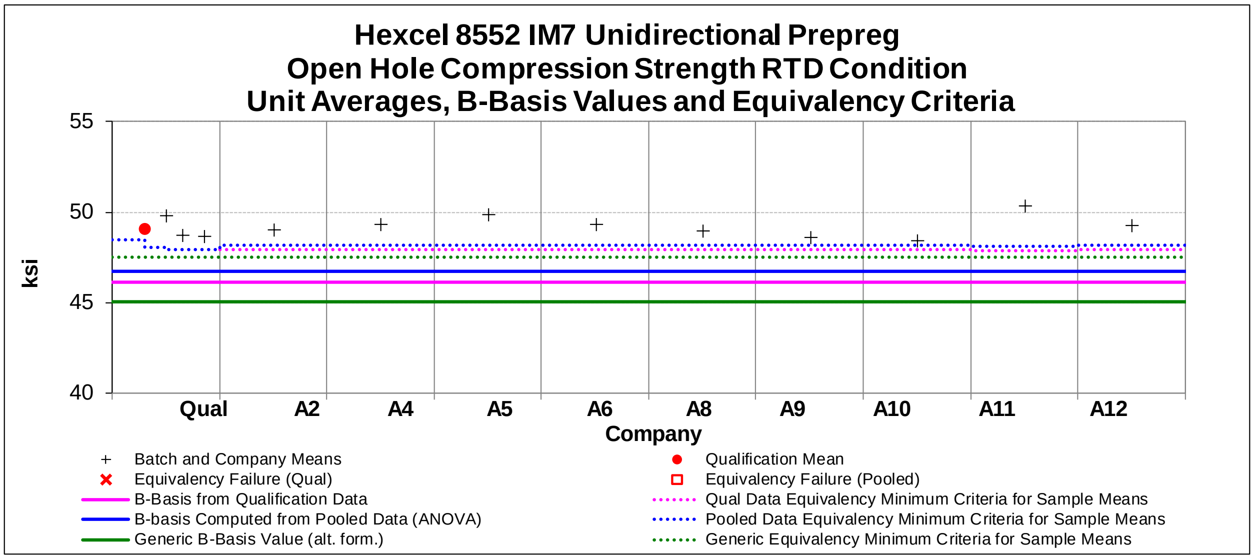
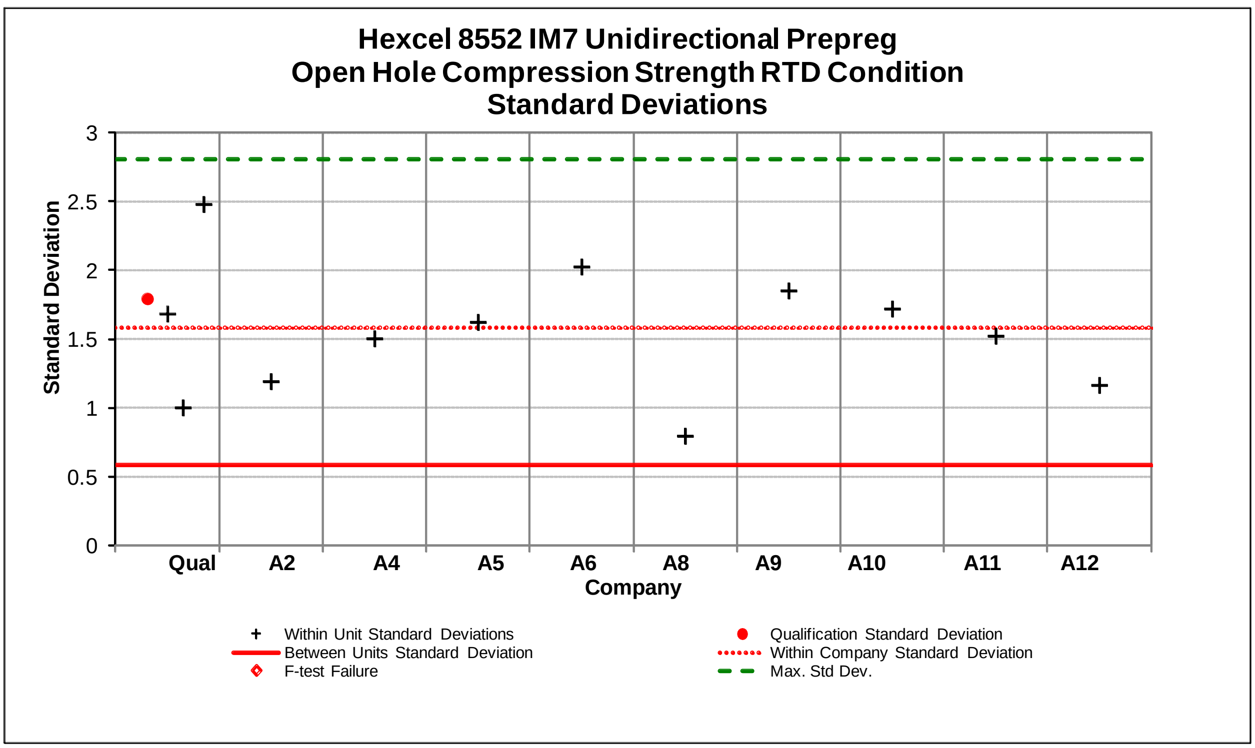


Figure 38: OHC1 RTD Strength Standard Deviations by Company



4.1.5 OHC1 ETW Condition

There were a total of 100 specimens from the ten different companies in the NCAMP dataset. No specimens were identified as being a statistical outlier.

The within company standard deviation was significantly higher than the between units standard deviation, so the alternate formula for computing the generic basis value was used. There were no failures of the F-test when comparing the unit standard deviations to the within company standard deviation.

Using the HYTEQ software to run equivalency tests for strength, there were no equivalency failures.

Unit A6 failed the generic basis values equivalency criteria for strength, but was above the minimum criteria for this property and passed the F-test for equal variance, so it can be considered 'Acceptable, but not Equivalent' for this property.

The summary statistics for all units are shown in Table 21 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 39. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 40. The standard deviations for strength by company are shown in Figure 41. All outliers and test failures are indicated in these graphs.

Table 21 OHC1 ETW Strength Summary Statistics by Unit

OHC1 Normalized Strength ETW Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	Dataset
Average	35.515	36.526	35.204	34.647	35.792	35.998	34.969	35.025	35.405	35.242	35.018	35.853	36.876	35.556
Std Dev.	1.445	1.611	0.896	1.072	1.883	1.498	1.067	0.993	1.383	1.393	1.166	1.620	1.867	1.486
Coeff Var.	4.07%	4.41%	2.54%	3.09%	5.26%	4.16%	3.05%	2.83%	3.91%	3.95%	3.33%	4.52%	5.06%	4.18%
Max	38.956	38.956	36.163	36.278	39.216	38.771	36.170	36.542	37.292	37.424	36.905	38.458	39.780	39.780
Min	33.080	33.628	34.144	33.080	33.148	34.256	33.309	33.362	33.659	33.322	33.378	34.354	34.143	33.080
Count	19	7	6	6	9	9	9	9	9	9	10	8	9	100

Figure 39: OHC1 ETW Strength Specimen Data

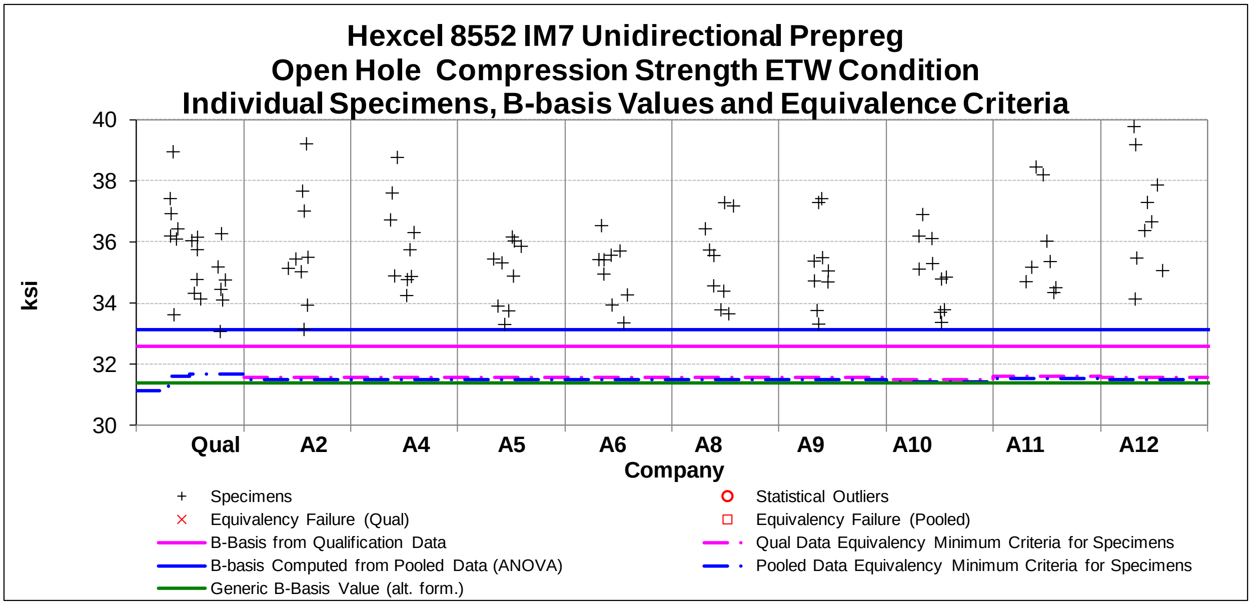


Figure 40: OHC1 ETW Strength Means by company

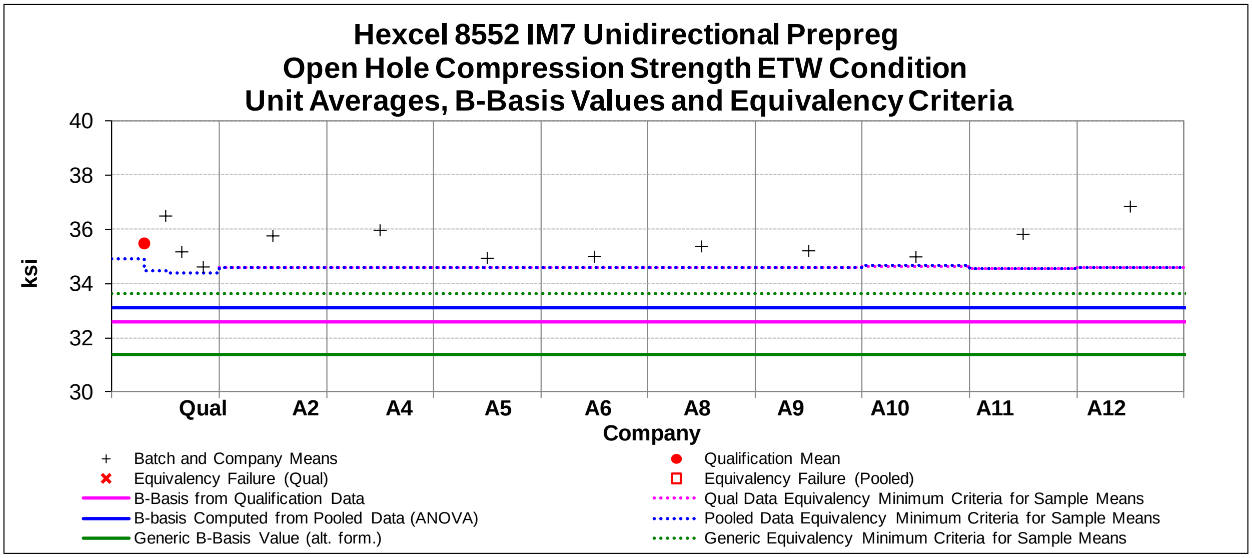
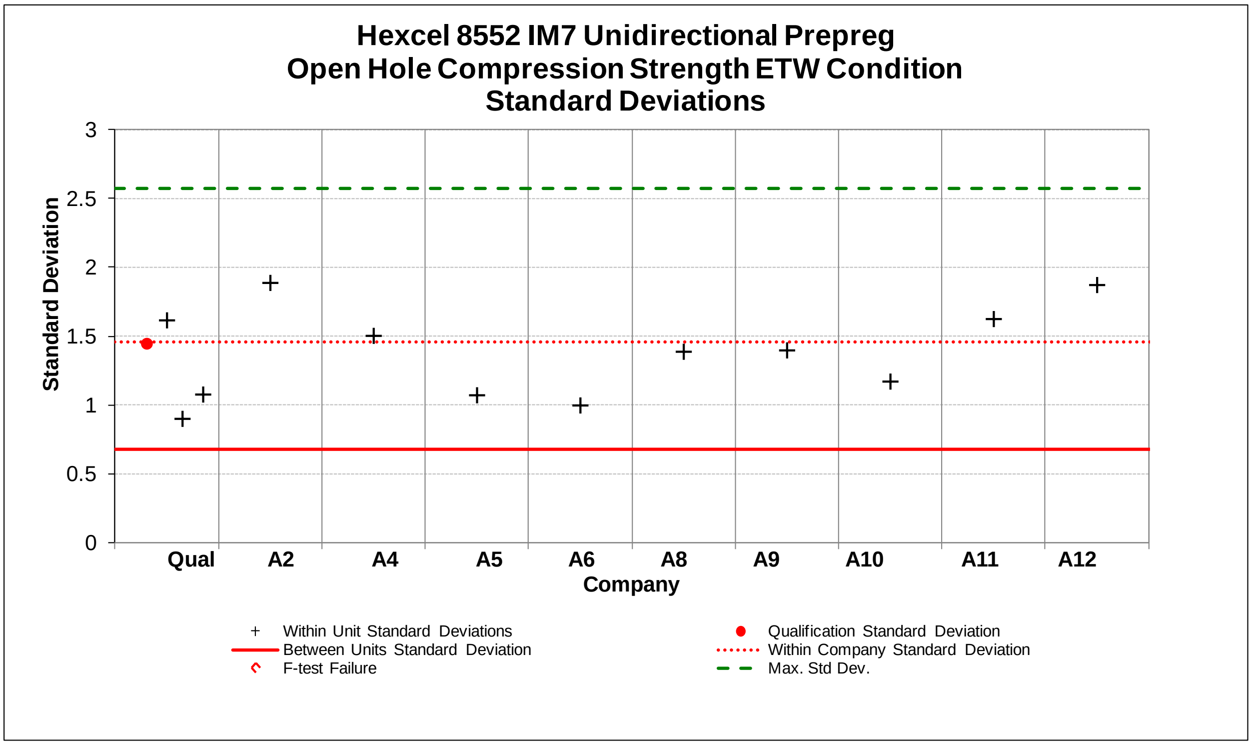


Figure 41: OHC1 ETW Strength Standard Deviations by Company



4.2 Tension Strength

4.2.1 LT CTD Condition

There were a total of 101 specimens from the ten different companies in the NCAMP dataset. No specimens were identified as being a statistical outlier.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, six units (A5, A6, A8, A9, A10, A11) failed equivalency when compared with the qualification dataset. All six units failed due to the mean being too low, with five of the six also having a minimum specimen value too low. Two units (A8, A11) failed equivalency when compared with pooled dataset. Unit A8 failed only for the mean being too low. Unit A11 failed the equivalency test for both the mean and the minimum specimen value being below the minimum criteria in both cases.

There were no failures of the mean for the generic basis values equivalency criteria for strength.

The summary statistics for all units are shown in Table 22 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 42. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 43. The standard deviations for strength by company are shown in Figure 44. All outliers and test failures are indicated in these graphs.

Table 22 LT CTD Strength Summary Statistics by Unit

LT Normalized Strength CTD Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	Dataset
Average	357.389	351.032	363.543	357.659	350.159	371.548	337.760	343.444	333.909	347.337	346.235	321.642	392.378	350.559
Std Dev.	12.620	13.152	12.182	9.681	15.153	12.333	15.833	18.719	18.050	11.168	21.918	28.359	9.942	24.097
Coeff Var.	3.53%	3.75%	3.35%	2.71%	4.33%	3.32%	4.69%	5.45%	5.41%	3.22%	6.33%	8.82%	2.53%	6.87%
Max	379.970	365.950	379.970	373.715	370.680	389.723	359.500	362.058	359.779	363.285	372.951	363.820	404.634	404.634
Min	325.692	325.692	341.805	346.196	327.699	350.960	314.821	313.344	295.696	329.043	310.287	269.227	373.673	269.227
Count	22	8	8	6	9	9	8	9	9	8	9	10	8	101

Figure 42: LT CTD Strength Specimen Data

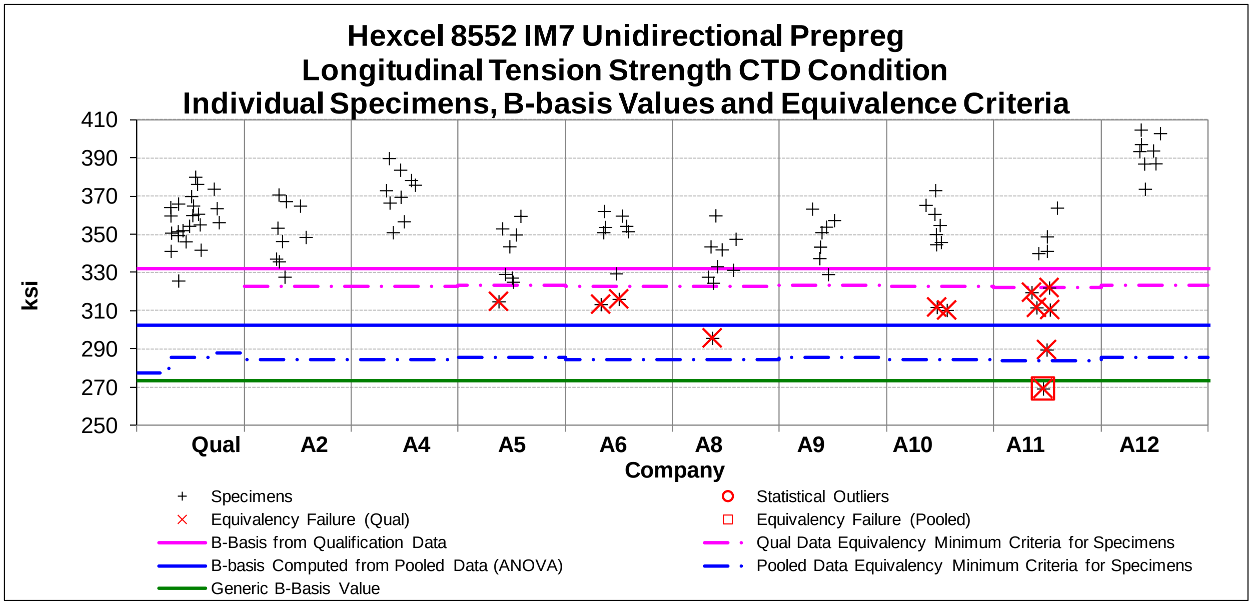


Figure 43: LT CTD Strength Means by company

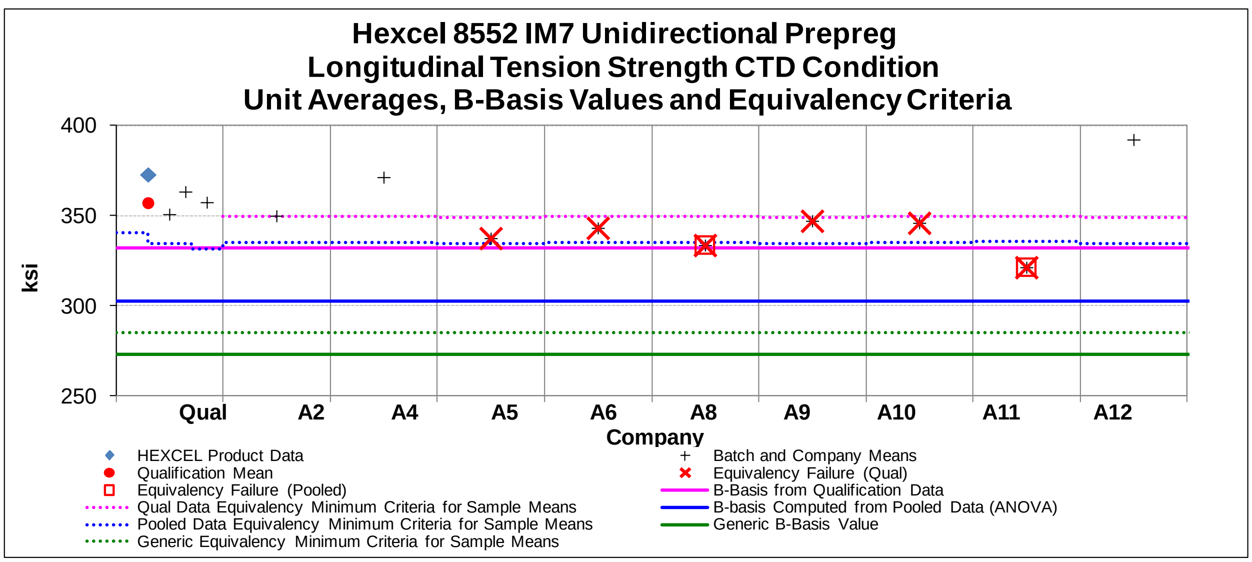
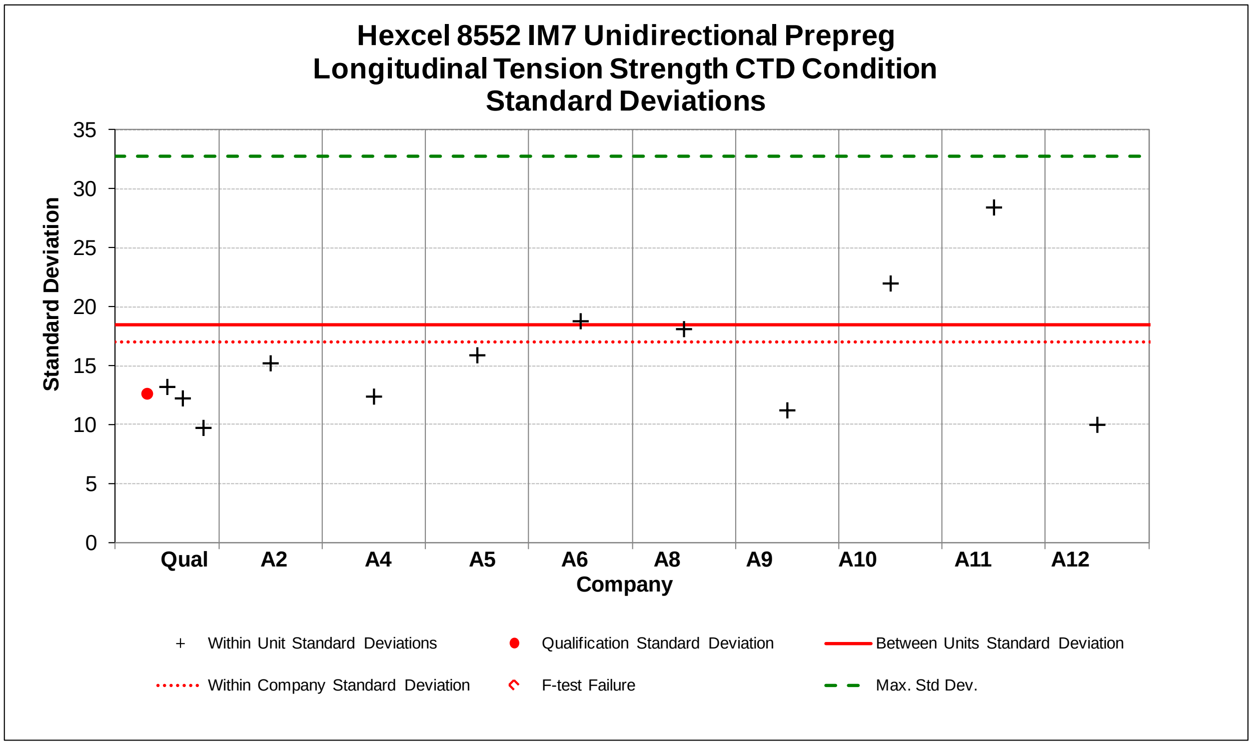


Figure 44: LT CTD Strength Standard Deviations by Company



4.2.2 LT RTD Condition

There were a total of 99 specimens from the ten different companies in the NCAMP dataset. One specimen was identified as being a statistical outlier. The lowest value in unit A2 was a statistical outlier for unit A2. It was not an outlier for the pooled dataset.

The within company standard deviation was slightly higher than the between units standard deviation, but not significantly higher. The standard deviation from company A8 failed the F-test. Computing an estimate of the B-basis for that unit using the normal distribution and the mean and standard deviation of unit A8, the estimate falls below the generic B-basis. Additional testing for this property is recommended for company A8.

Using the HYTEQ software to run equivalency tests for strength, four units (A6, A8, A10, A11) failed equivalency when compared with the qualification dataset. All four units failed due to the mean and minimum specimen value being too low. One of the four units (A11) also failed equivalency when compared with pooled dataset. It failed the equivalency test for both the mean and the minimum specimen value.

There were no failures of the mean for the generic basis values equivalency criteria for strength.

The summary statistics for all units are shown in Table 23 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 45. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 46. The standard deviations for strength by company are shown in Figure 47. All outliers and test failures are indicated in these graphs.

Table 23 LT RTD Strength Summary Statistics by Unit

LT Normalized Strength RTD Condition by Batch and Company													
Statistics	Qualification Data				Equivalency Companies								Pooled
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	Dataset
Average	362.693	357.495	371.282	359.303	379.118	361.100	366.255	343.153	346.532	381.931	346.382	330.608	400.749	361.929
Std Dev.	16.057	9.558	12.270	22.359	24.063	13.734	28.312	29.001	34.603	11.884	27.057	30.924	18.310	29.775
Coeff Var.	4.43%	2.67%	3.30%	6.22%	6.35%	3.80%	7.73%	8.45%	9.99%	3.11%	7.81%	9.35%	4.57%	8.23%
Max	392.322	370.552	392.322	391.912	407.079	379.155	402.359	373.059	401.632	404.009	375.023	366.703	428.406	428.406
Min	325.685	343.573	360.049	325.685	323.035	334.033	328.854	294.158	300.382	370.857	298.688	278.318	367.311	278.318
Count	18	6	6	6	9	9	9	9	9	9	9	9	9	99

Figure 45: LT RTD Strength Specimen Data

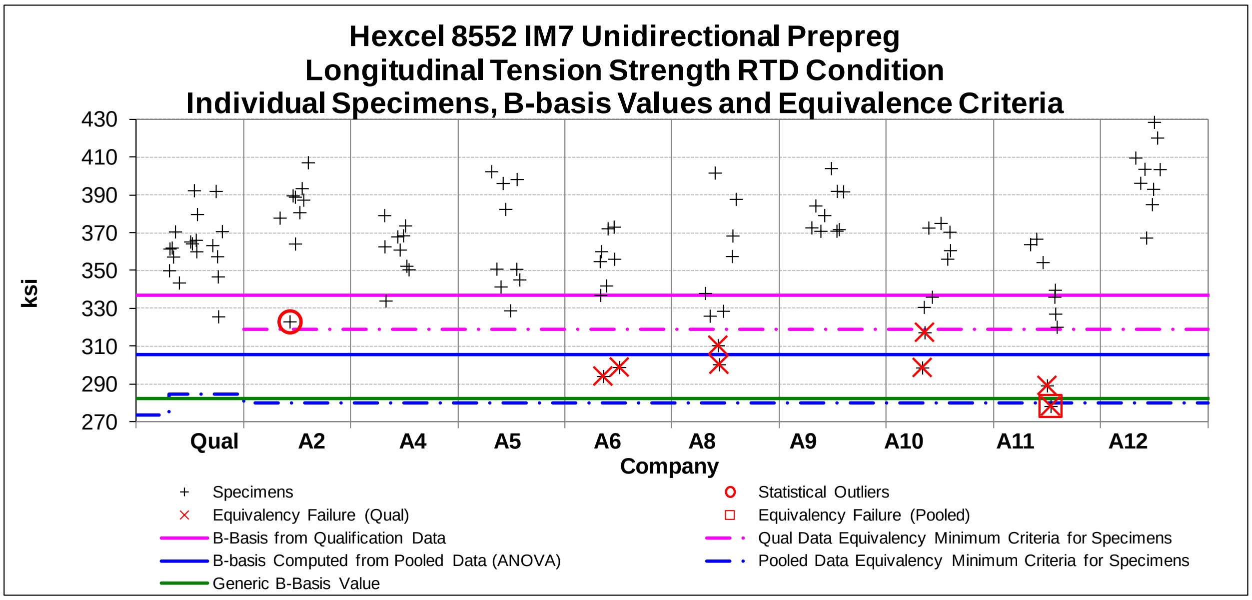


Figure 46: LT RTD Strength Means by company

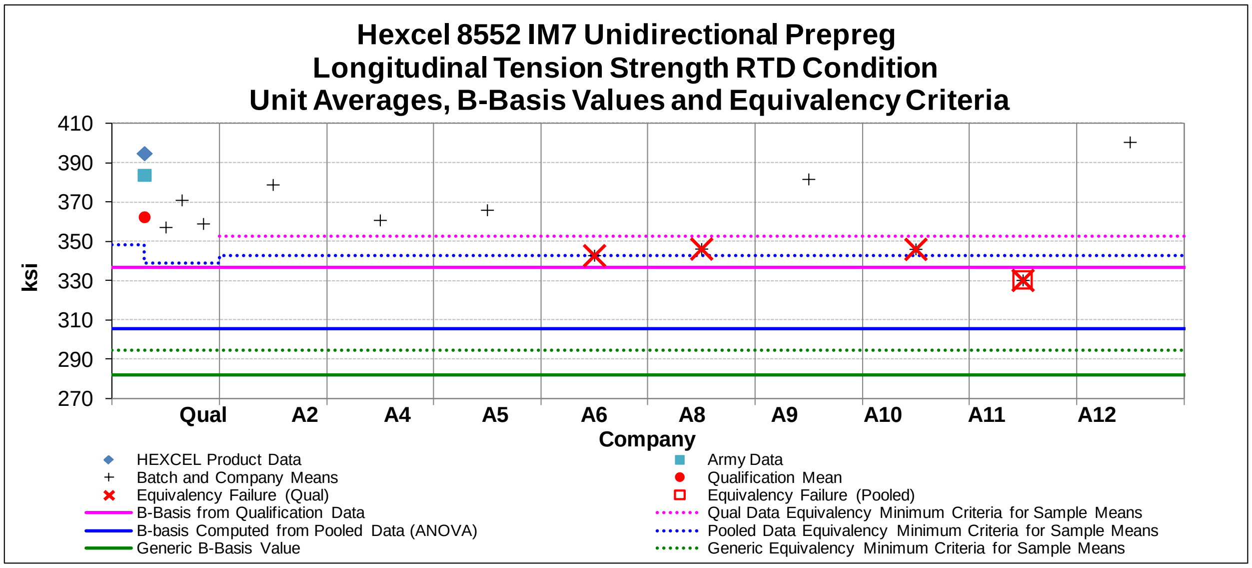
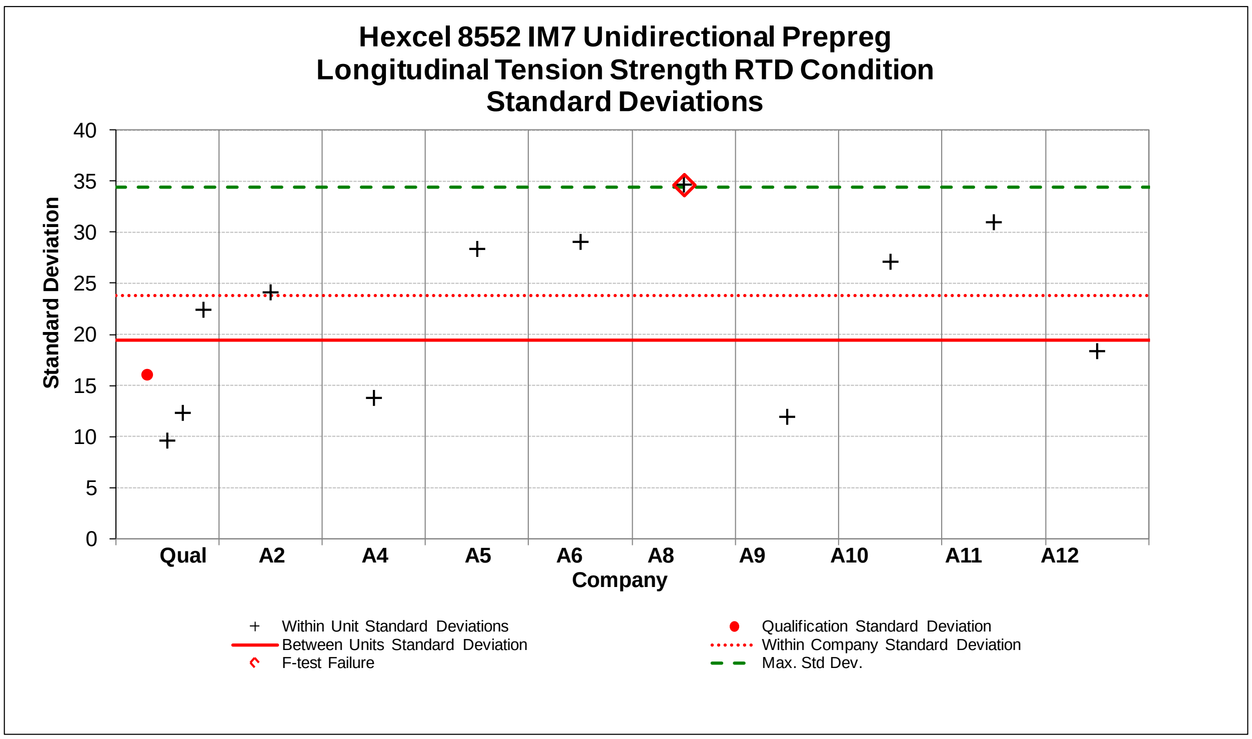


Figure 47: LT RTD Strength Standard Deviations by Company



4.2.3 LT ETW Condition

There were a total of 88 specimens from the ten different companies in the NCAMP dataset. No specimens were identified as being statistical outliers.

The within company standard deviation was slightly higher than the between units standard deviation, but not significantly higher. The standard deviation of the qualification sample (units A01, A02 and A03 combined) and unit A01 individually, but calculations indicate that the qualification company can be considered 'Acceptable but not Equivalent' for this property.

Using the HYTEQ software to run equivalency tests for strength, one units (A11) failed equivalency when compared with the both the qualification dataset and the pooled dataset. It failed the equivalency test for both the mean and the minimum specimen value in both cases. In addition, the qualification sample failed equivalency when compared with the pooled database due to the minimum specimen value from Unit A01 being too low.

There were no failures of the mean for the generic basis values equivalency criteria for strength.

The summary statistics for all units are shown in Table 24 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 48. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 49. The standard deviations for strength by company are shown in Figure 50. All outliers and test failures are indicated in these graphs.

Table 24 LT ETW Strength Summary Statistics by Unit

LT Normalized Strength ETW Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	333.504	317.517	342.287	348.964	315.613	331.085	336.173	327.714	332.217	373.061	334.144	289.018	360.110	334.837
Std Dev.	38.823	47.214	31.354	25.623	36.305	11.681	23.450	24.456	28.623	17.806	14.219	14.355	11.714	32.161
Coeff Var.	11.64%	14.87%	9.16%	7.34%	11.50%	3.53%	6.98%	7.46%	8.62%	4.77%	4.26%	4.97%	3.25%	9.61%
Max	373.234	366.596	365.481	373.234	373.828	347.789	363.381	362.519	362.887	399.874	363.083	306.996	379.264	399.874
Min	244.533	244.533	296.033	309.103	267.229	313.086	304.802	293.684	287.692	340.226	315.959	272.831	344.398	244.533
Count	18	8	4	6	9	9	6	7	7	9	8	6	9	88

Figure 48: LT ETW Strength Specimen Data

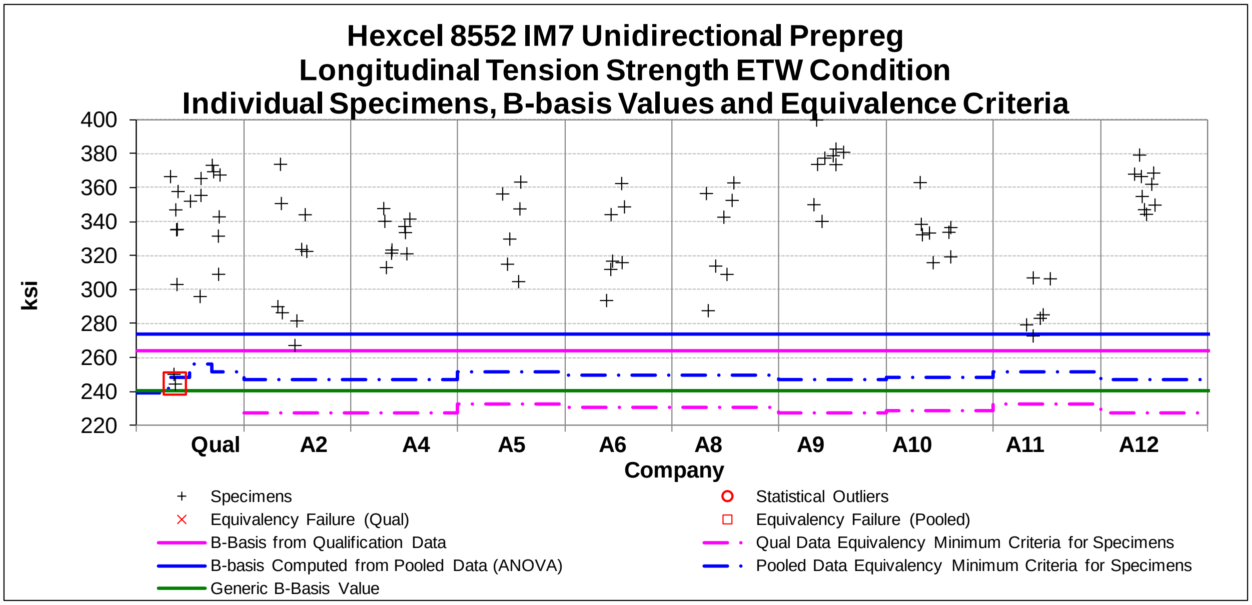


Figure 49: LT ETW Strength Means by company

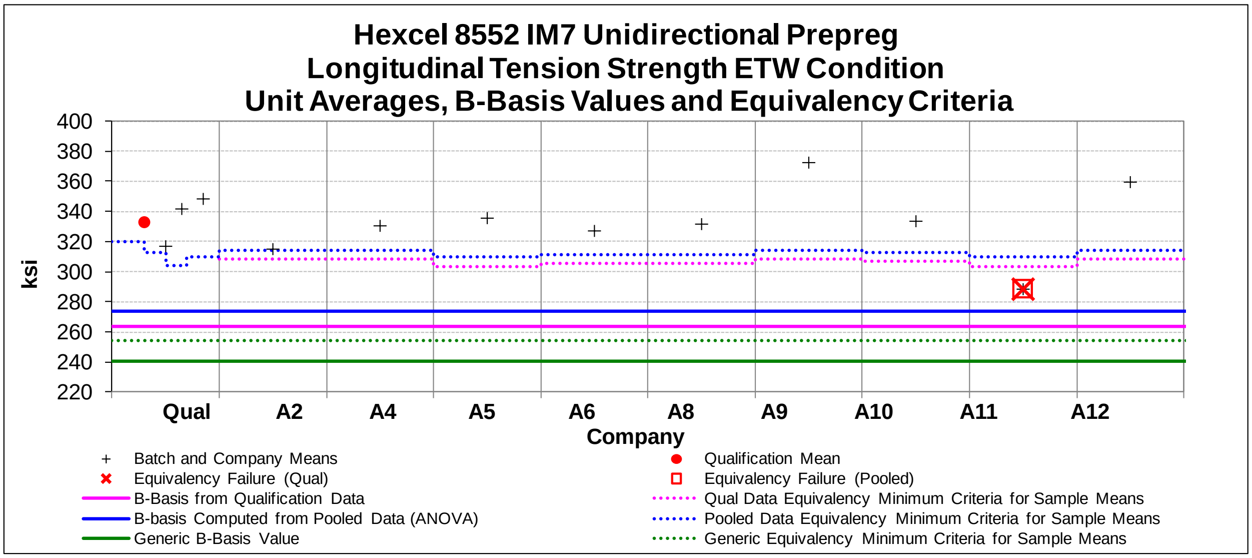
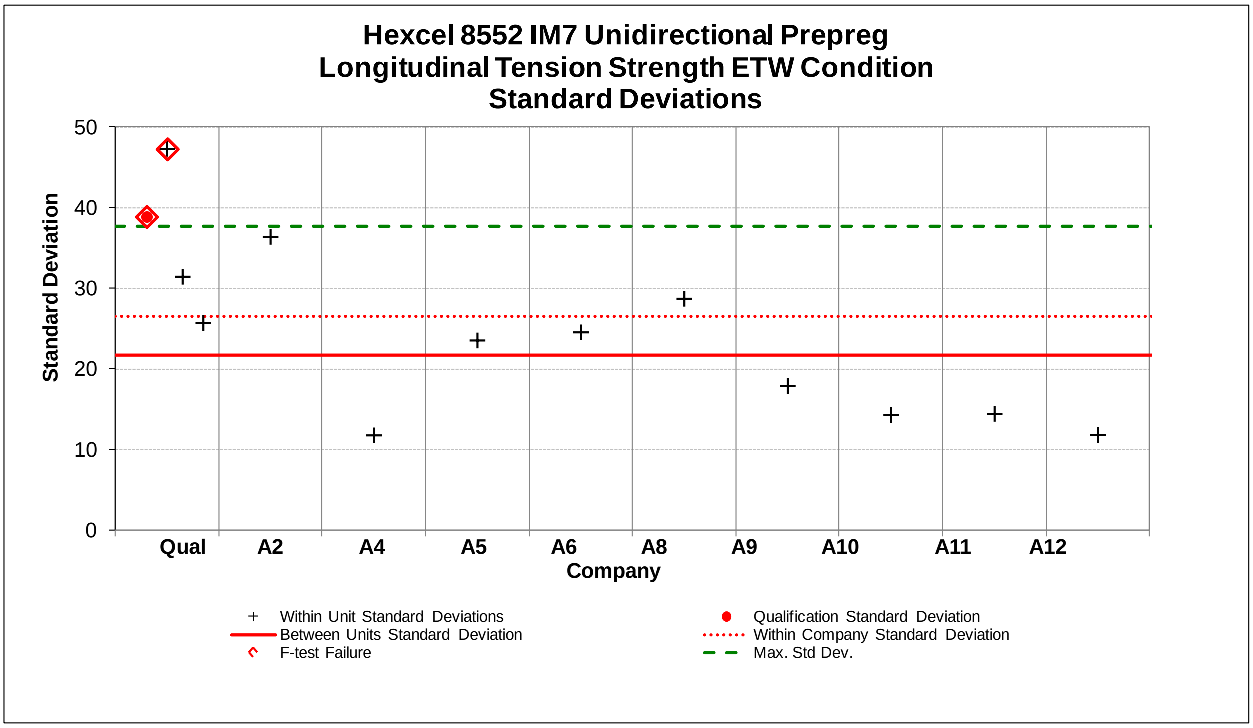


Figure 50: LT ETW Strength Standard Deviations by Company



4.2.4 UNT0 CTD Condition

There were a total of 99 specimens from the ten different companies in the NCAMP dataset. One specimen was identified as being a statistical outlier. The lowest value in unit A11 was a statistical outlier for unit A11. It was not an outlier for the pooled dataset.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, four units (A5, A6, A8, A11) failed equivalency when compared with the qualification dataset. All four units failed the equivalency test for both the mean and the minimum specimen value. Three of those four units (A5, A6, A11) also failed equivalency when compared with the pooled dataset because the mean was too low. Unit A11 also failed equivalency when compared with the pooled dataset because the minimum specimen value was too low.

There were no failures of the mean for the generic basis values equivalency criteria for strength.

The summary statistics for all units are shown in Table 25 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 51. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 52. The standard deviations for strength by company are shown in Figure 53. All outliers and test failures are indicated in these graphs.

Table 25 UNT0 CTD Strength Summary Statistics by Unit

UNT0 Normalized Strength CTD Condition by Batch and Company													
Statistics	Qualification Data				Equivalency Companies								Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	152.578	150.313	151.415	156.382	160.545	160.704	141.912	133.841	143.028	156.635	160.965	126.733	170.879	151.206
Std Dev.	5.172	6.820	2.379	2.941	3.299	4.609	5.084	7.758	3.288	4.139	3.399	6.204	4.411	13.283
Coeff Var.	3.39%	4.54%	1.57%	1.88%	2.06%	2.87%	3.58%	5.80%	2.30%	2.64%	2.11%	4.90%	2.58%	8.78%
Max	159.854	158.607	153.556	159.854	167.134	168.782	149.406	144.259	147.253	161.809	166.757	132.016	177.646	177.646
Min	142.064	142.064	147.675	153.462	155.401	154.202	133.441	120.953	137.207	151.140	155.138	113.463	163.256	113.463
Count	19	7	6	6	9	9	9	9	9	9	9	8	9	99

Figure 51: UNT0 CTD Strength Specimen Data

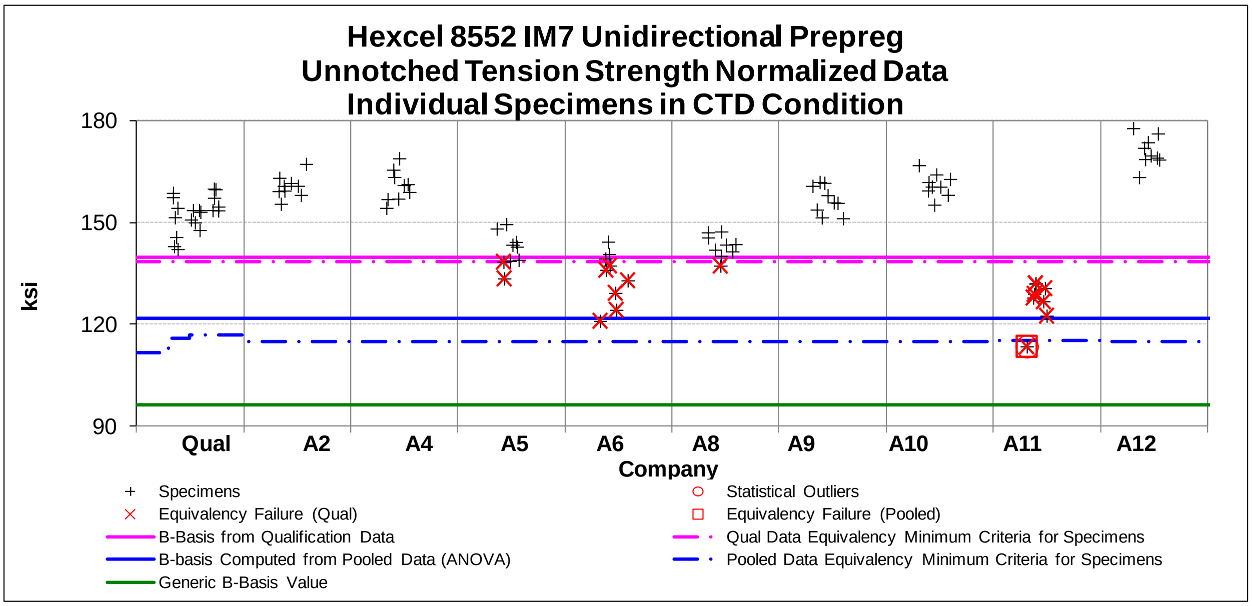


Figure 52: UNT0 CTD Strength Means by company

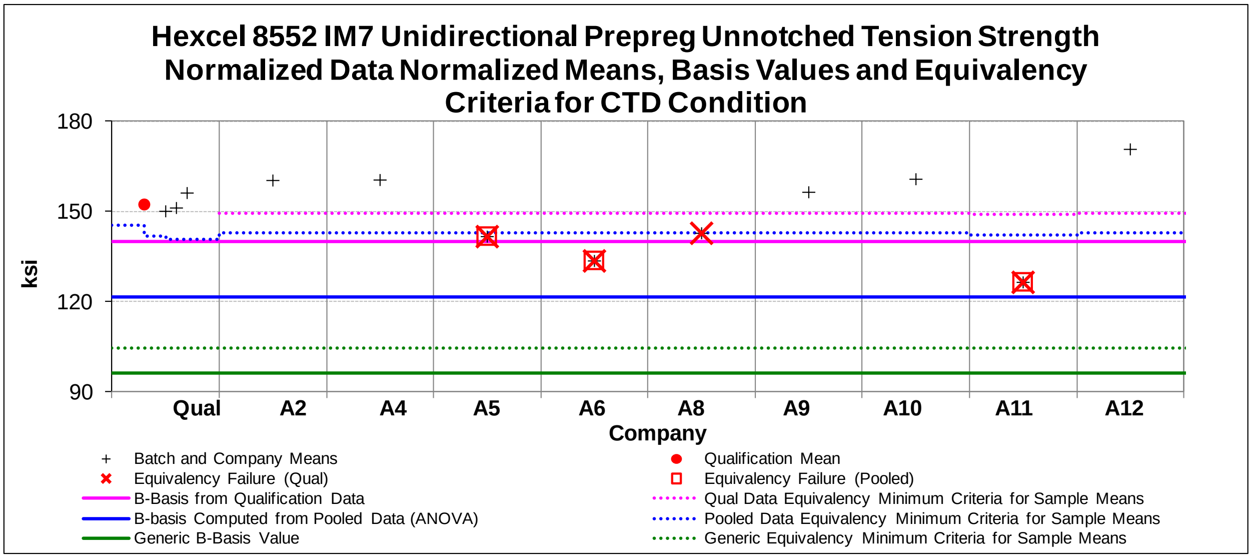
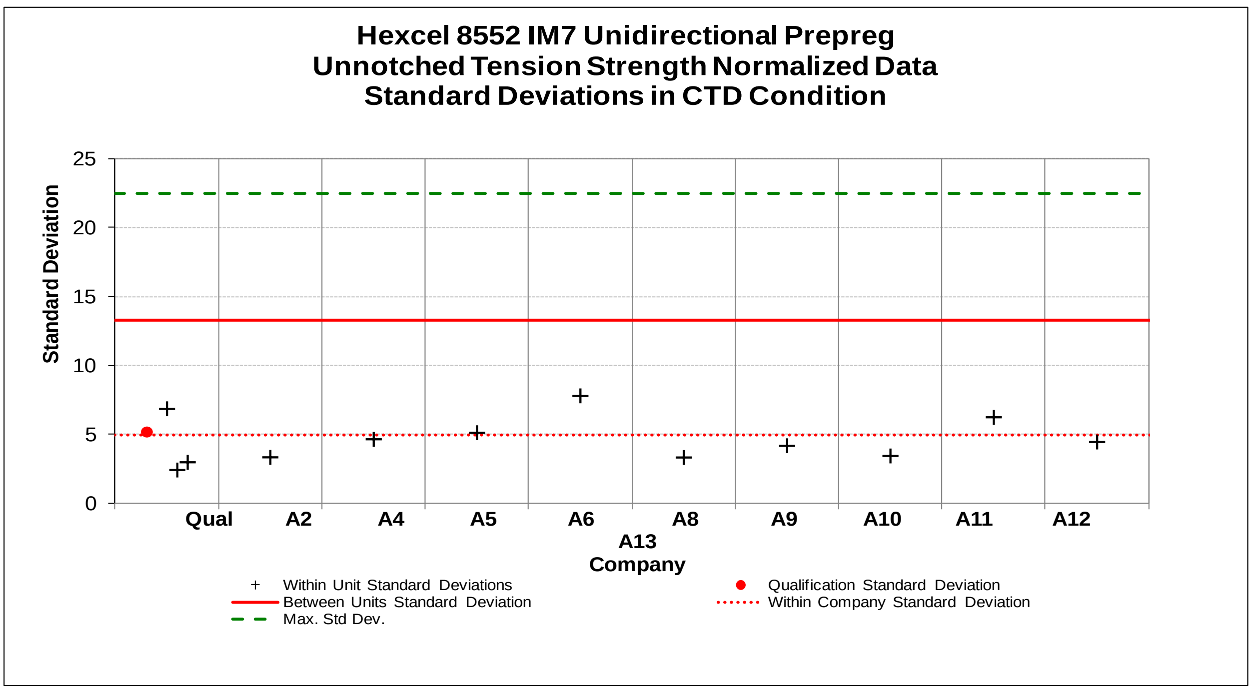


Figure 53: UNT0 CTD Strength Standard Deviations by Company



4.2.5 UNT0 RTD Condition

There were a total of 98 specimens from the ten different companies in the NCAMP dataset. Three specimens were identified as being statistical outliers. The lowest value in units A03, A2, and A6 were statistical outliers for their respective units, but not for the pooled dataset.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, four units (A5, A6, A8, A11) failed equivalency when compared with the qualification dataset and when compared with the pooled dataset. All four units failed due to the mean value being too low. One of the four units (A6) also failed the equivalency test due to the minimum specimen value being too low.

There were no failures of the mean for the generic basis values equivalency criteria for strength.

The summary statistics for all units are shown in Table 26 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 54. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 55. The standard deviations for strength by company are shown in Figure 56. All outliers and test failures are indicated in these graphs.

Table 26 UNT0 RTD Strength Summary Statistics by Unit

UNT0 Normalized Strength RTD Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	171.385	172.748	169.150	172.257	178.860	183.087	165.177	160.538	163.784	181.508	180.872	155.636	188.427	172.962
Std Dev.	9.304	5.910	7.024	14.175	9.913	6.950	5.331	9.896	4.453	6.246	2.966	2.683	5.315	12.108
Coeff Var.	5.43%	3.42%	4.15%	8.23%	5.54%	3.80%	3.23%	6.16%	2.72%	3.44%	1.64%	1.72%	2.82%	7.00%
Max	182.904	181.648	178.704	182.904	189.105	191.406	171.385	169.709	170.317	188.463	184.239	159.397	194.189	194.189
Min	143.990	165.214	157.619	143.990	153.692	171.712	156.701	136.687	154.525	171.726	174.416	151.992	179.462	136.687
Count	18	6	6	6	9	9	9	9	9	9	9	8	9	98

Figure 54: UNT0 RTD Strength Specimen Data

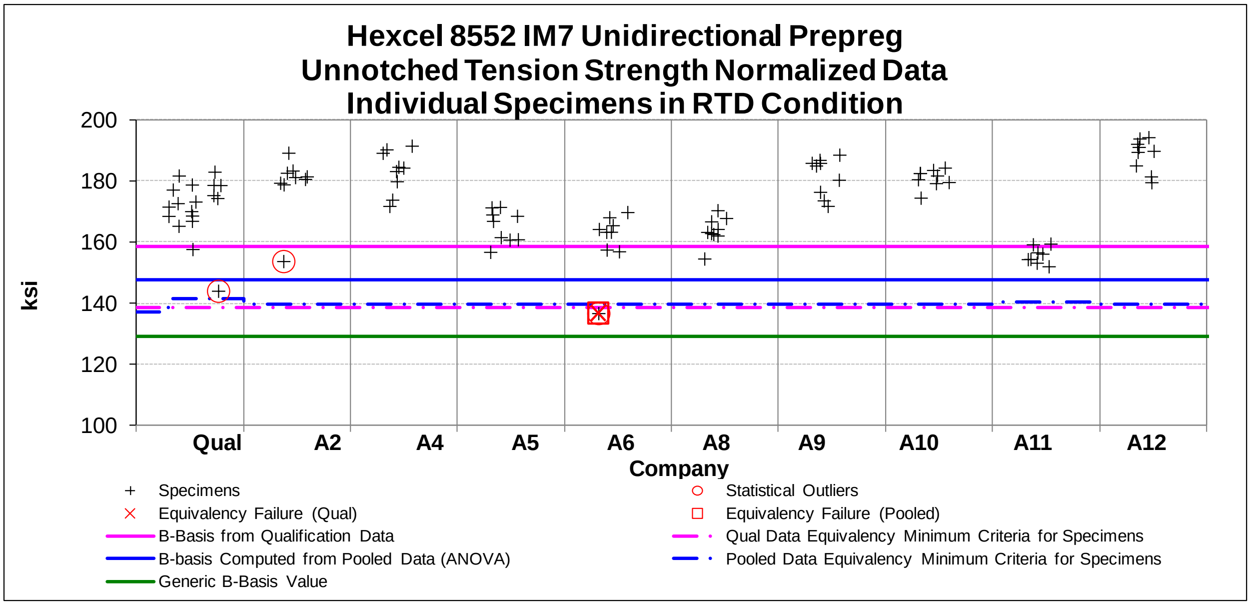


Figure 55: UNT0 RTD Strength Means by company

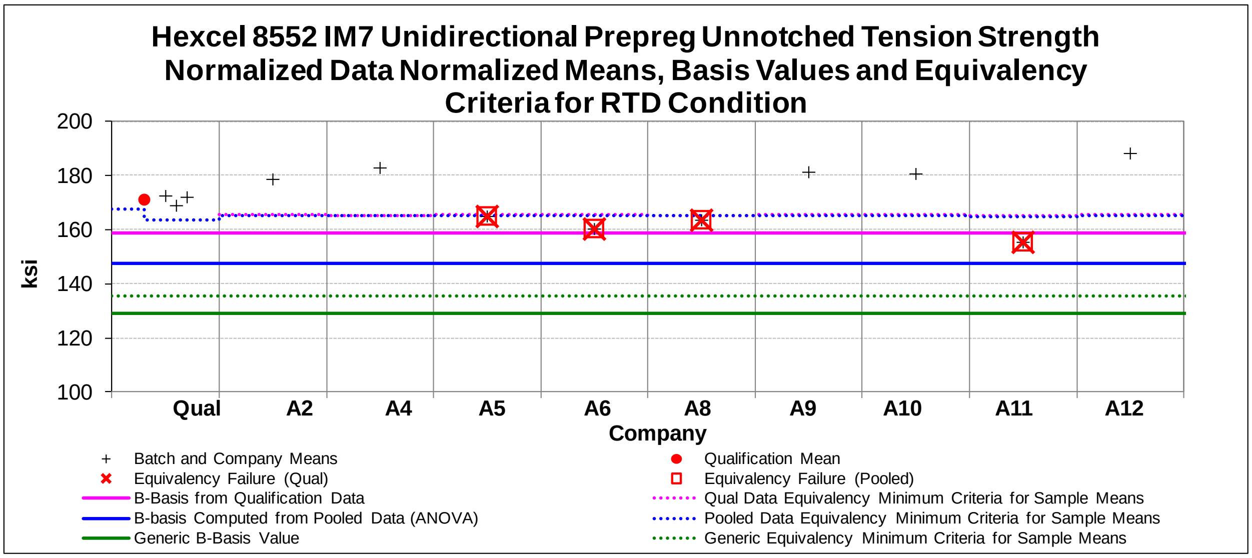
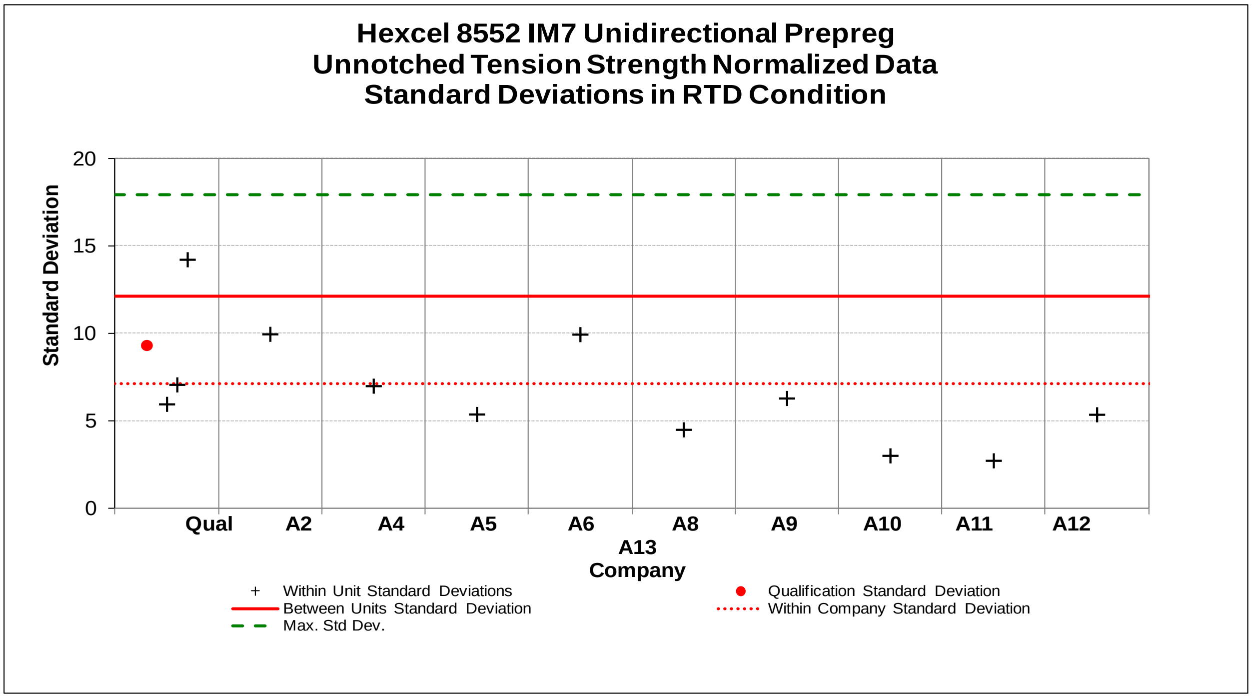


Figure 56: UNT0 RTD Strength Standard Deviations by Company



4.2.6 UNT0 ETW Condition

There were a total of 99 specimens from the ten different companies in the NCAMP dataset. Two specimens were identified as being statistical outliers. The lowest value in units A4 and A6 were statistical outliers for the pooled dataset, but not for their respective units.

The within company standard deviation was significantly higher than the between units standard deviation, so the alternate formula for computing the generic basis value was used. There were no failures of the F-test when comparing the unit standard deviations to the within company standard deviation.

Using the HYTEQ software to run equivalency tests for strength, four units (A4, A6, A9, A11) failed equivalency when compared with the qualification dataset. Three of those units (A4, A6, A11) failed due to the mean being too low. Three of the units (A4, A6, A9) failed the equivalency test due to the minimum specimen value being too low.

Three units (A4, A6, A11) also failed equivalency when compared with the pooled dataset. Unit A4 failed equivalency due to the minimum specimen value being too low. Unit A11 failed equivalency due to the sample mean being too low. Unit A6 failed equivalency due to both the mean and the minimum specimen value being too low.

There were no failures of the mean for the generic basis values equivalency criteria for strength.

The summary statistics for all units are shown in Table 27 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 57. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 58. The standard deviations for strength by company are shown in Figure 59. All outliers and test failures are indicated in these graphs.

Table 27 UNT0 ETW Strength Summary Statistics by Unit

UNT0 Normalized Strength ETW Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	179.232	178.706	175.673	183.317	183.973	173.691	177.571	165.442	175.659	178.973	179.938	171.329	181.909	176.995
Std Dev.	6.718	3.991	8.062	6.081	3.727	11.586	4.405	9.501	4.002	10.624	4.195	4.524	2.584	8.259
Coeff Var.	3.75%	2.23%	4.59%	3.32%	2.03%	6.67%	2.48%	5.74%	2.28%	5.94%	2.33%	2.64%	1.42%	4.67%
Max	189.181	185.594	188.028	189.181	187.946	182.432	185.620	173.958	183.062	190.235	188.827	175.745	185.944	190.235
Min	165.977	174.889	165.977	172.579	177.497	151.088	171.280	146.660	169.796	158.753	174.355	162.050	177.063	146.660
Count	18	6	6	6	9	9	9	9	9	9	9	9	9	99

Figure 57: UNT0 ETW Strength Specimen Data

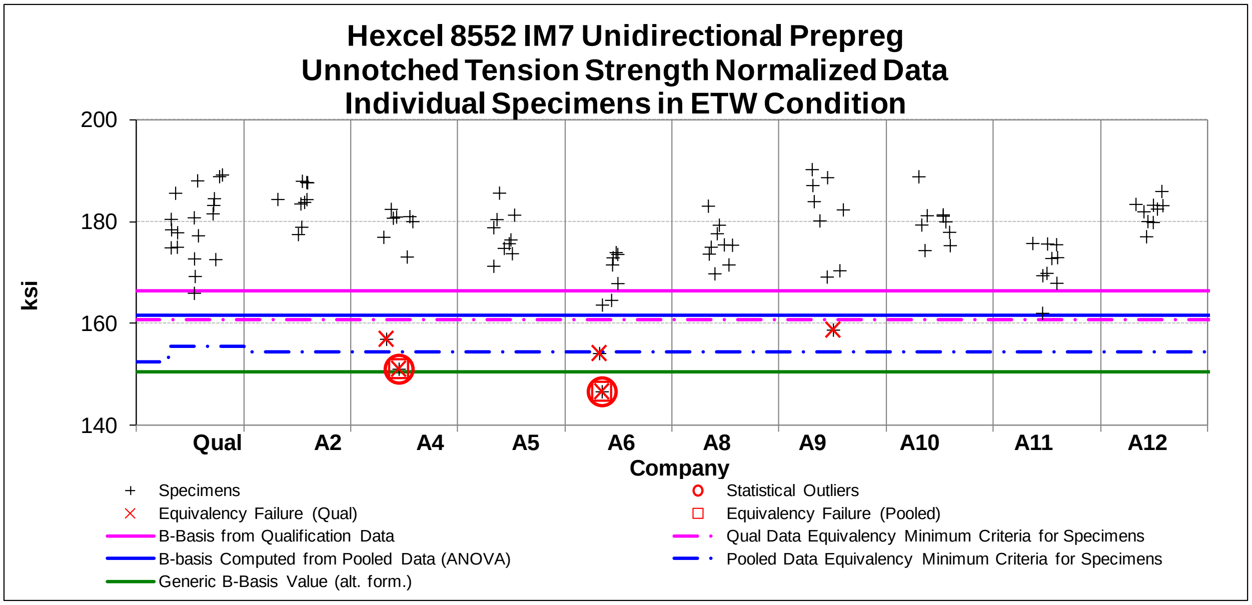


Figure 58: UNT0 ETW Strength Means by company

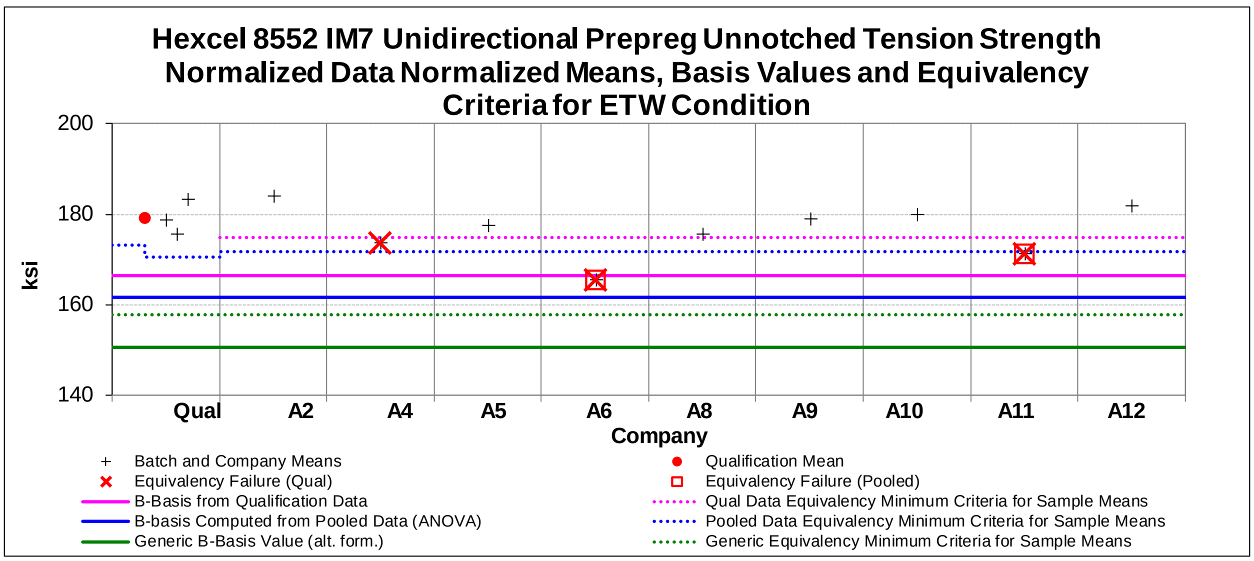
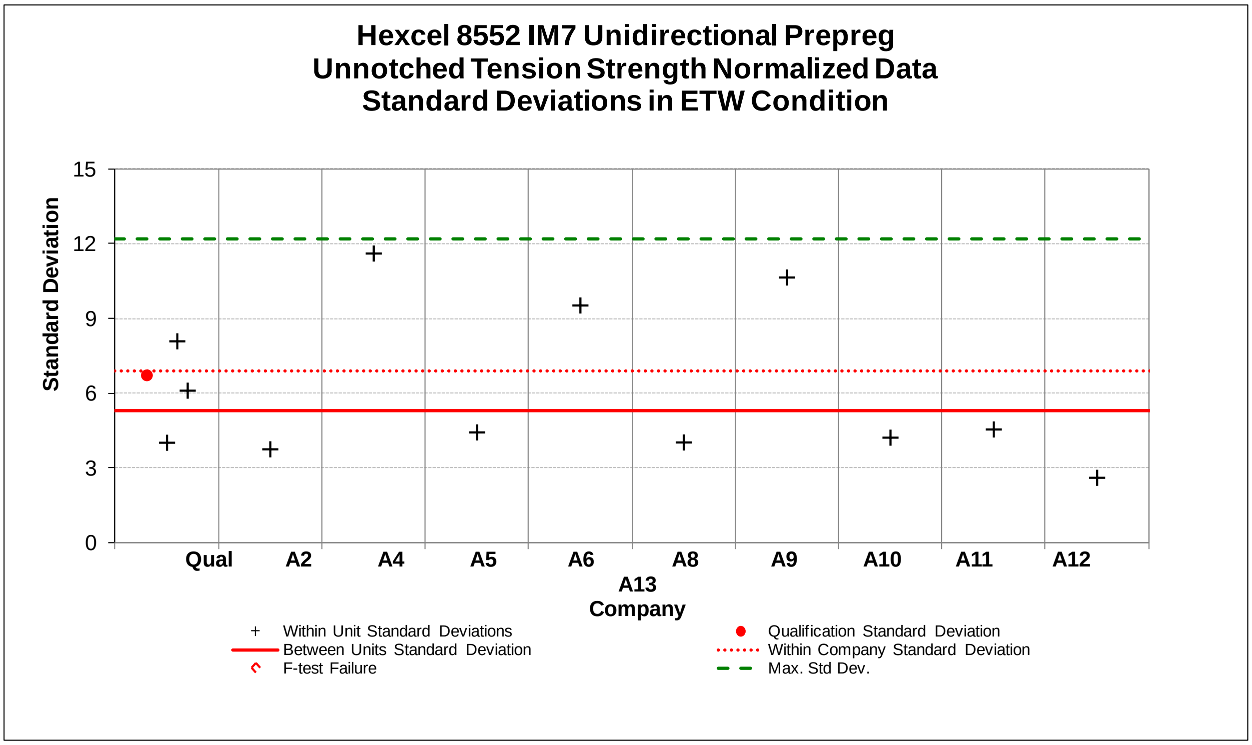


Figure 59: UNT0 ETW Strength Standard Deviations by Company



4.2.7 OHT1 CTD Condition

There were a total of 100 specimens from the ten different companies in the NCAMP dataset. One specimen was identified as being a statistical outlier. The largest value in unit A5 was a statistical outlier for unit A5. It was not an outlier for the pooled dataset.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, five units (A5, A6, A8, A10, A11) failed equivalency when compared with the qualification dataset. All five units failed equivalence due to the mean being too low. Units A6, A10, and A11 also failed due to the minimum specimen value being too low. Units A8 and A11 also failed equivalency when compared with pooled dataset due to the mean being too low.

There were no failures of the mean for the generic basis values equivalency criteria for strength.

The summary statistics for all units are shown in Table 28 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 60. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 61. The standard deviations for strength by company are shown in Figure 62. All outliers and test failures are indicated in these graphs.

Table 28 OHT1 CTD Strength Summary Statistics by Unit

OHT1 Normalized Strength CTD Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	Dataset
Average	57.754	55.653	57.885	60.076	57.886	57.753	54.437	55.963	53.153	58.310	54.026	49.113	61.996	56.211
Std Dev.	2.433	1.581	1.772	1.582	1.965	1.140	2.398	3.857	1.362	2.163	1.815	2.806	1.943	3.927
Coeff Var.	4.21%	2.84%	3.06%	2.63%	3.39%	1.97%	4.41%	6.89%	2.56%	3.71%	3.36%	5.71%	3.13%	6.99%
Max	62.524	57.344	60.531	62.524	59.950	59.298	59.852	61.129	55.073	61.403	56.628	54.382	65.221	65.221
Min	53.645	53.645	55.549	58.229	54.387	55.944	51.134	49.420	51.389	54.873	50.937	46.315	57.993	46.315
Count	19	7	6	6	9	9	9	9	9	9	9	9	9	100

Figure 60: OHT1 CTD Strength Specimen Data

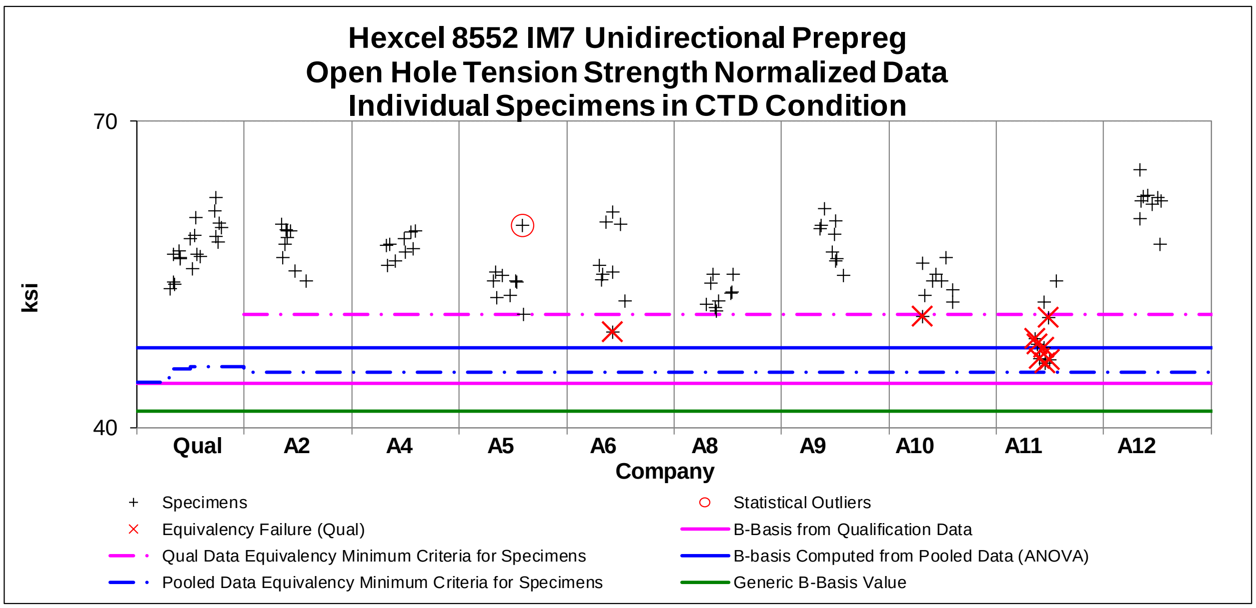


Figure 61: OHT1 CTD Strength Means by company

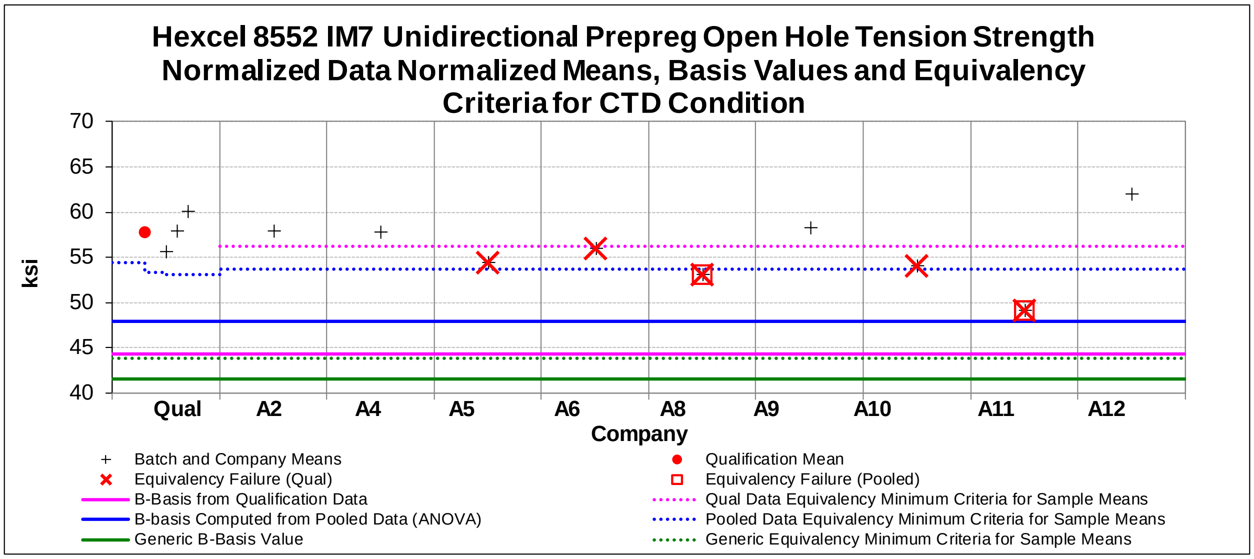
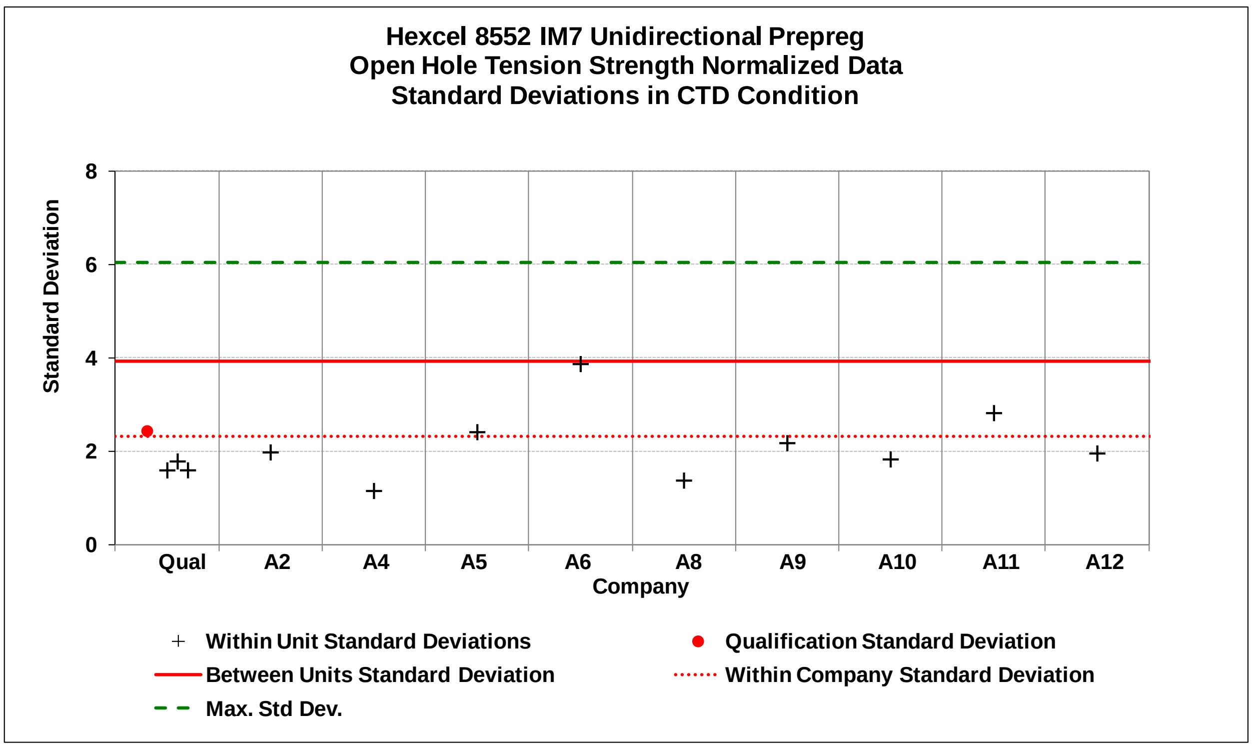


Figure 62: OHT1 CTD Strength Standard Deviations by Company



4.2.8 OHT1 RTD Condition

There were a total of 100 specimens from the ten different companies in the NCAMP dataset. No specimens were identified as being statistical outliers.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, two units (A8, A11) failed equivalency when compared with both the qualification dataset and the pooled dataset. Unit A8 failed only for the mean being too low. Unit A11 failed the equivalency test for both the mean and the minimum specimen value.

There were no failures of the mean for the generic basis values equivalency criteria for strength.

The summary statistics for all units are shown in Table 29 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 63. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 64. The standard deviations for strength by company are shown in Figure 65. All outliers and test failures are indicated in these graphs.

Table 29 OHT1 RTD Strength Summary Statistics by Unit

OHT1 Normalized Strength RTD Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	Dataset
Average	59.003	57.688	58.629	60.913	60.007	60.613	58.605	58.378	56.641	61.317	59.922	51.947	64.438	59.079
Std Dev.	2.350	2.133	0.705	2.636	0.864	2.257	1.713	2.348	1.209	1.458	3.697	2.471	1.501	3.589
Coeff Var.	3.98%	3.70%	1.20%	4.33%	1.44%	3.72%	2.92%	4.02%	2.13%	2.38%	6.17%	4.76%	2.33%	6.08%
Max	64.610	60.825	59.915	64.610	61.112	64.590	61.951	62.687	57.908	63.748	68.039	54.940	67.266	68.039
Min	54.120	54.120	57.922	57.440	58.594	58.015	56.184	54.486	54.665	59.638	54.411	47.802	61.973	47.802
Count	19	7	6	6	9	9	9	9	9	9	9	9	9	100

Figure 63: OHT1 RTD Strength Specimen Data

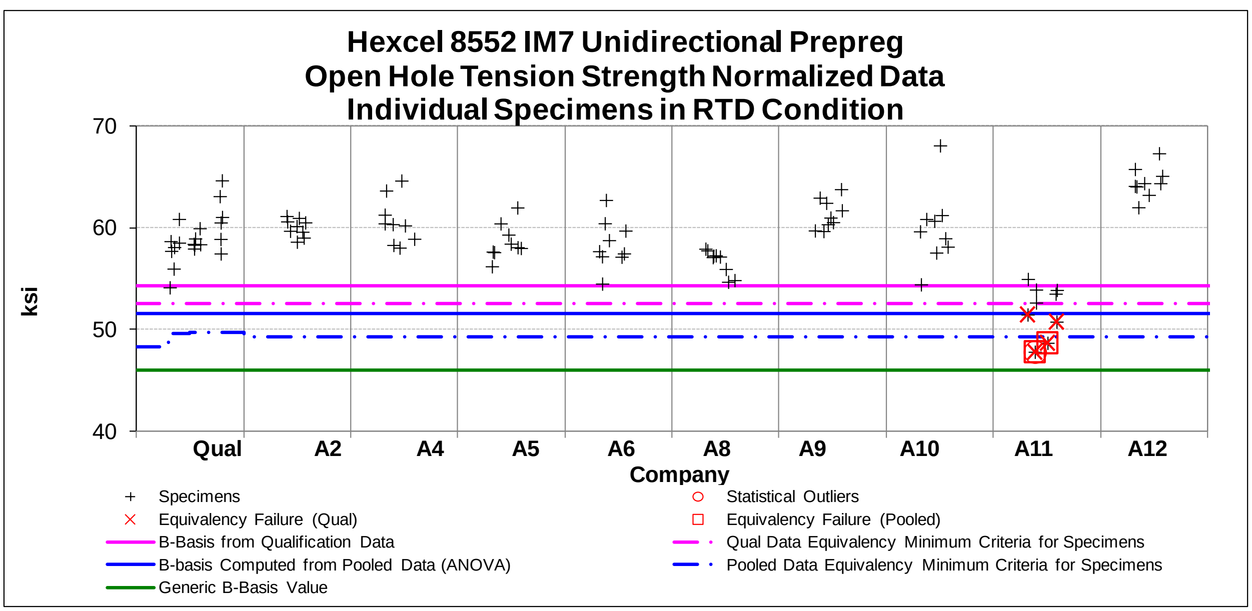


Figure 64: OHT1 RTD Strength Means by company

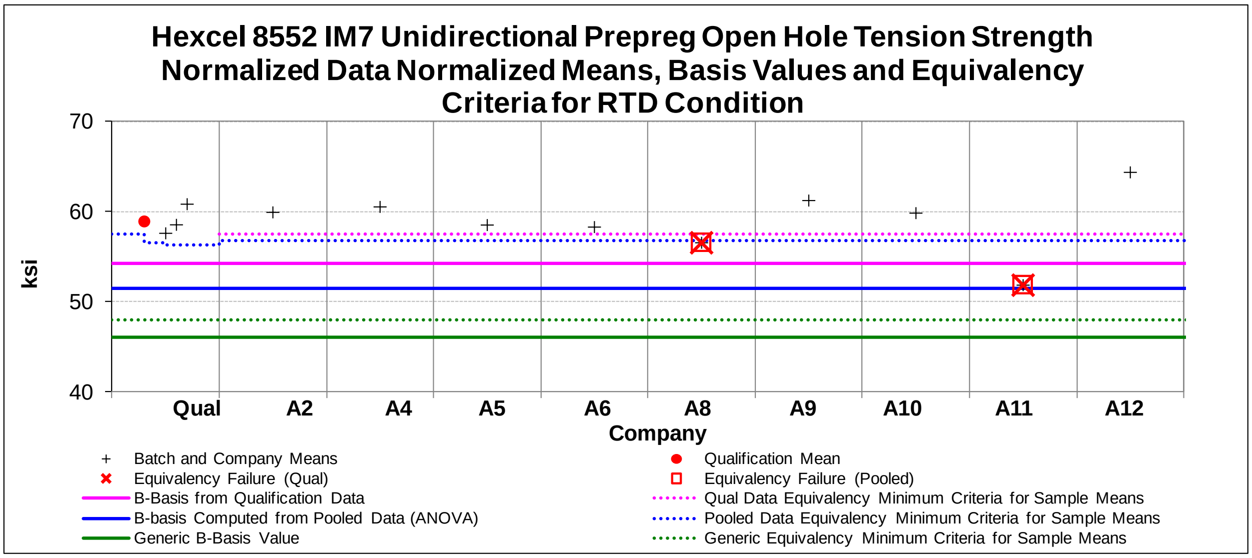
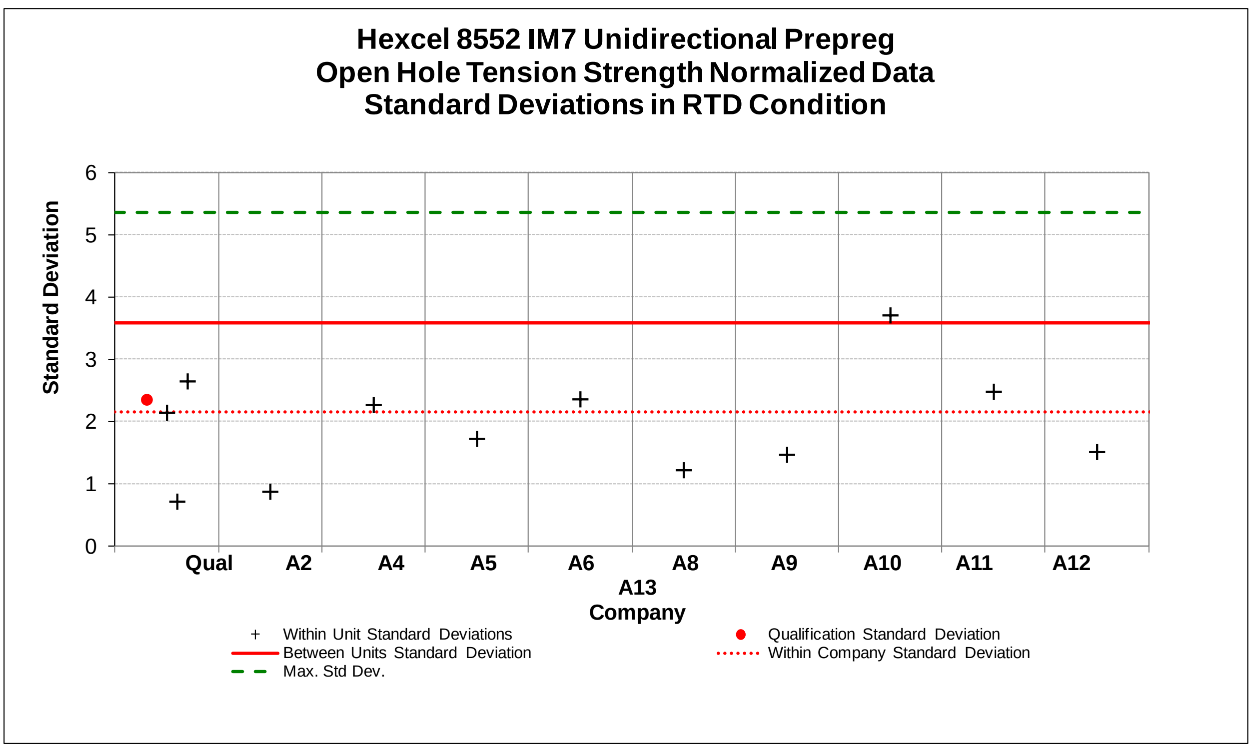


Figure 65: OHT1 RTD Strength Standard Deviations by Company



4.2.9 OHT1 ETW Condition

There were a total of 103 specimens from the ten different companies in the NCAMP dataset. One specimen was identified as being a statistical outlier. The lowest value in unit A5 was a statistical outlier for unit A5. It was not an outlier for the pooled dataset.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, three units (A5, A6, A11) failed equivalency when compared with the qualification dataset. Two of those units (A5, A11) also failed equivalency when compared with pooled dataset. In all cases, the units failed the equivalency test because the mean value was too low.

There were no failures of the mean for the generic basis values equivalency criteria for strength.

The summary statistics for all units are shown in Table 30 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 66. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 67. The standard deviations for strength by company are shown in Figure 68. All outliers and test failures are indicated in these graphs.

Table 30 OHT1 ETW Strength Summary Statistics by Unit

OHT1 Normalized Strength ETW Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	66.966	65.543	67.701	67.760	68.805	65.555	64.132	64.733	65.451	67.390	69.816	62.664	69.311	66.570
Std Dev.	2.850	2.608	3.847	1.715	1.295	1.730	1.257	2.157	3.304	2.051	1.171	1.881	1.847	2.976
Coeff Var.	4.26%	3.98%	5.68%	2.53%	1.88%	2.64%	1.96%	3.33%	5.05%	3.04%	1.68%	3.00%	2.66%	4.47%
Max	72.587	69.218	72.587	70.579	70.541	67.941	65.768	69.044	69.278	69.944	71.326	65.975	71.048	72.587
Min	62.154	62.926	62.154	65.716	66.650	63.188	61.153	61.231	59.869	64.211	67.260	60.096	65.204	59.869
Count	20	7	6	7	9	9	9	9	9	10	9	9	10	103

Figure 66: OHT1 ETW Strength Specimen Data

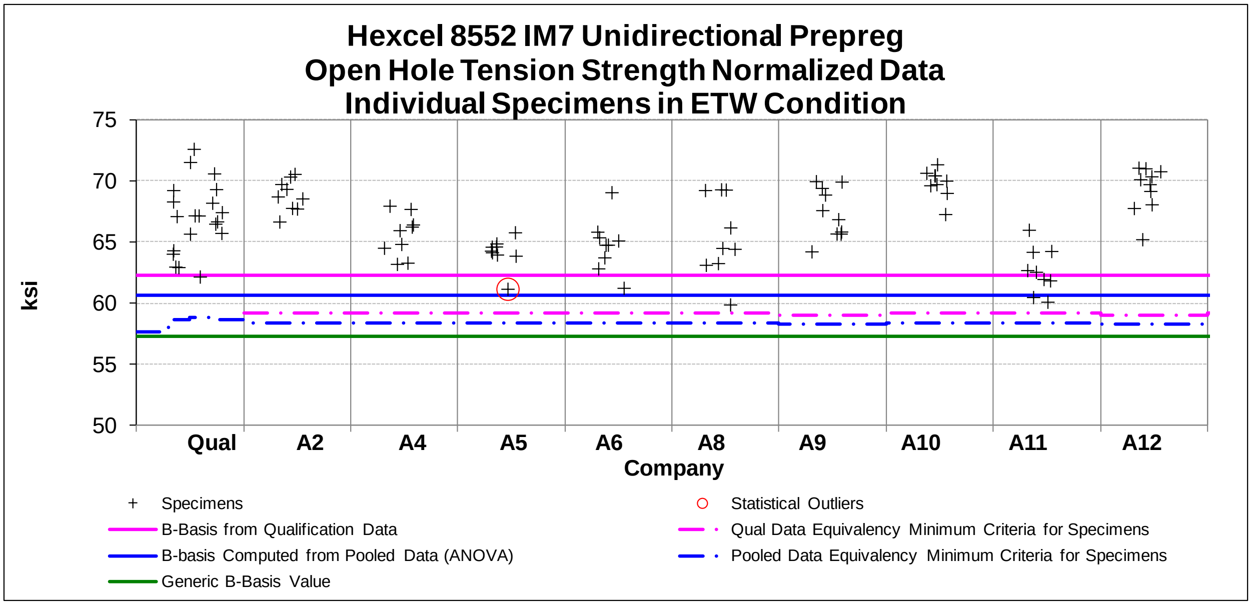


Figure 67: OHT1 ETW Strength Means by company

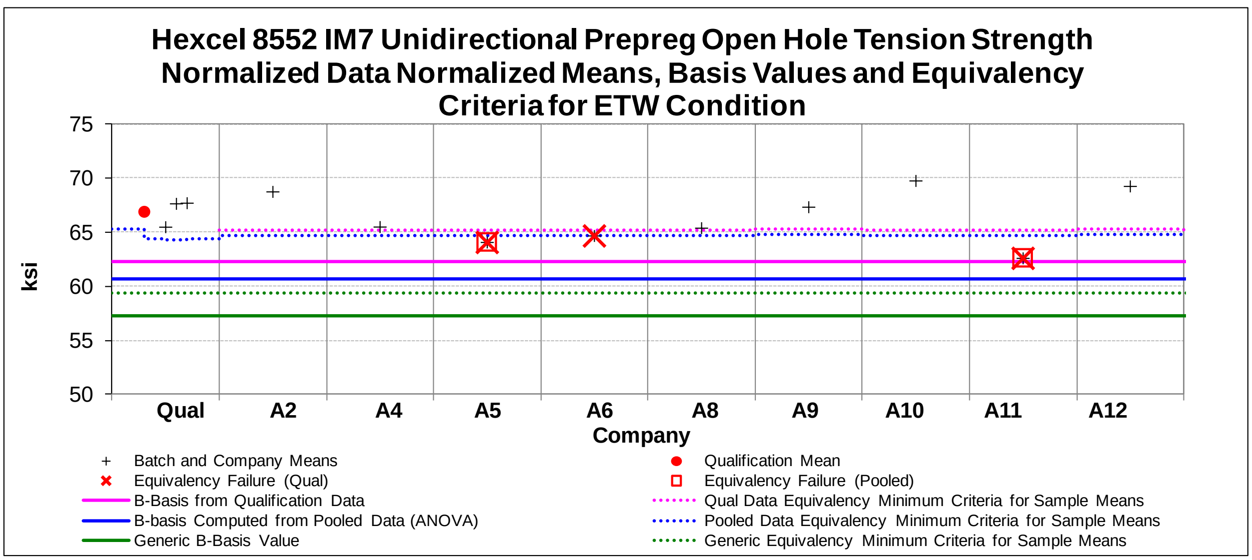
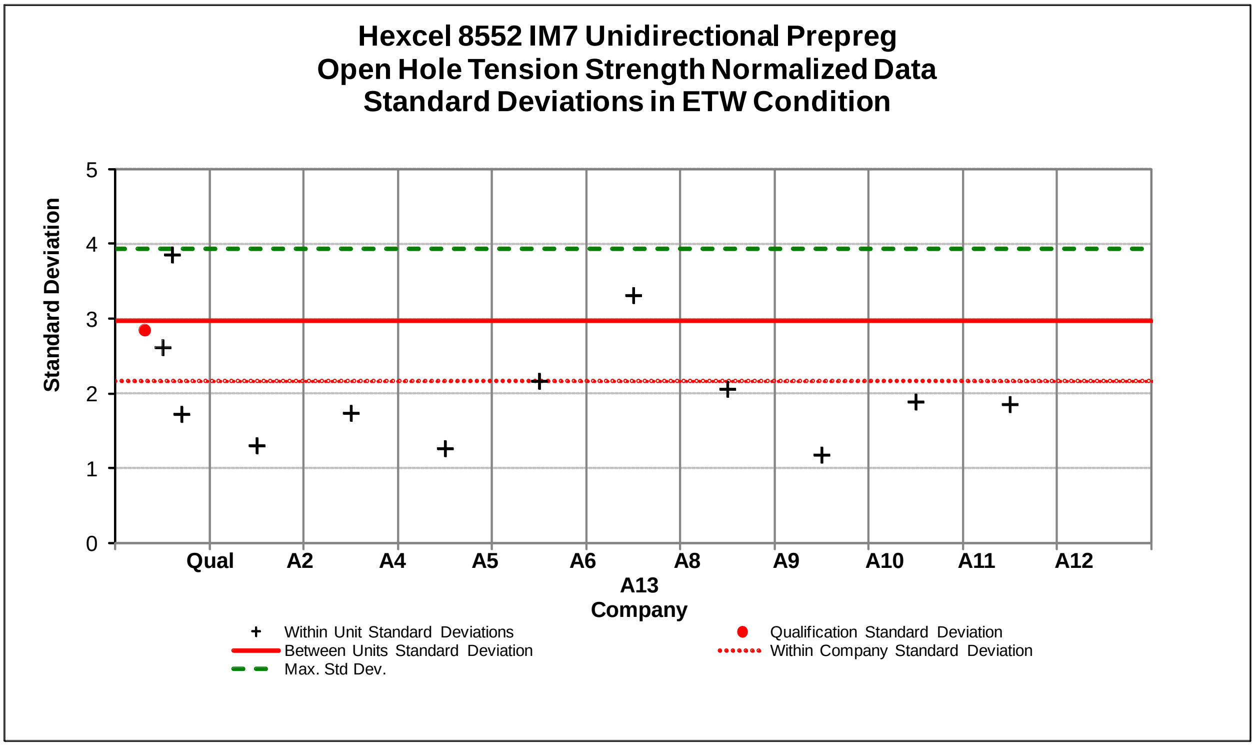


Figure 68: OHT1 ETW Strength Standard Deviations by Company



4.3 Shear Strength

4.3.1 SBS RTD Condition

There were a total of 100 specimens from the ten different companies in the NCAMP dataset. Seven specimens were identified as being statistical outliers. The lowest value in unit A4 was a statistical outlier for unit A4. It was not an outlier for the pooled dataset. The lowest value in unit A10 and the five lowest values in unit A11 were all identified as outliers for the pooled dataset, but they not outliers for their respective units.

The within company standard deviation was lower than the between units standard deviation. There was one failure of the F test. Unit A11 had a standard deviation that exceeded the maximum standard deviation for generic basis values.

Using the HYTEQ software to run equivalency tests for strength, two units (A10, A11) failed equivalency when compared with the qualification dataset. Both units failed the equivalency test for both the mean and the minimum specimen value being below the minimum criteria in both cases. Unit (A11) also failed equivalency when compared with pooled dataset. It failed the equivalency test for both the mean and the minimum specimen value being below the minimum criteria in both cases.

While were no failures of the mean for the generic basis values equivalency criteria for strength, Unit A11 did not fall in the equivalency region and should not be considered equivalent. With a low mean and the failure of the F-test, unit A11 **cannot** be considered 'Acceptable but not Equivalent' for this property.

The summary statistics for all units are shown in Table 31 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 69. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 70. The standard deviations for strength by company are shown in Figure 71. All outliers and test failures are indicated in these graphs.

Table 31 SBS RTD Strength Summary Statistics by Unit

Short Beam Strength as measured RTD Condition by Batch and Company													
Statistics	Qualification Data				Equivalency Companies								Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	17.125	17.396	16.980	16.999	17.302	17.489	17.367	16.904	18.019	17.366	16.820	15.383	17.210	17.098
Std Dev.	0.430	0.328	0.586	0.214	0.323	0.333	0.218	0.147	0.083	0.238	0.663	1.258	0.159	0.786
Coeff Var.	2.51%	1.88%	3.45%	1.26%	1.87%	1.90%	1.25%	0.87%	0.46%	1.37%	3.94%	8.18%	0.92%	4.60%
Max	17.780	17.780	17.649	17.398	17.719	17.893	17.598	17.111	18.129	17.710	17.321	17.088	17.433	18.129
Min	16.198	16.916	16.198	16.794	16.638	16.732	16.911	16.681	17.912	17.047	15.382	13.531	16.944	13.531
Count	18	6	6	6	9	9	9	9	9	9	10	9	9	100

Figure 69: SBS RTD Strength Specimen Data

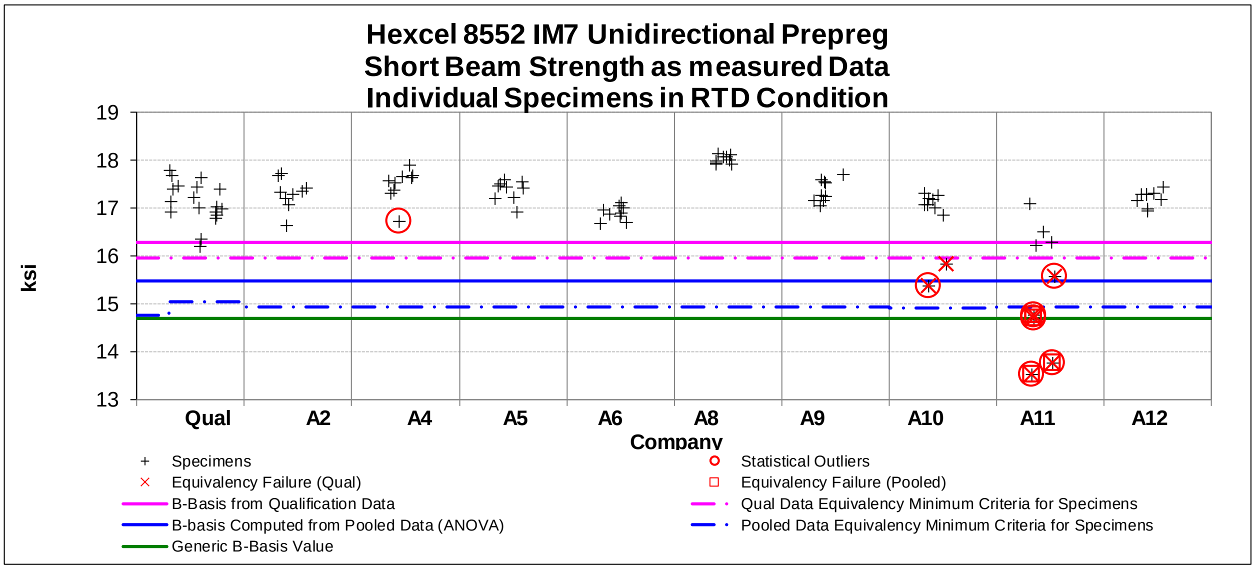


Figure 70: SBS RTD Strength Means by company

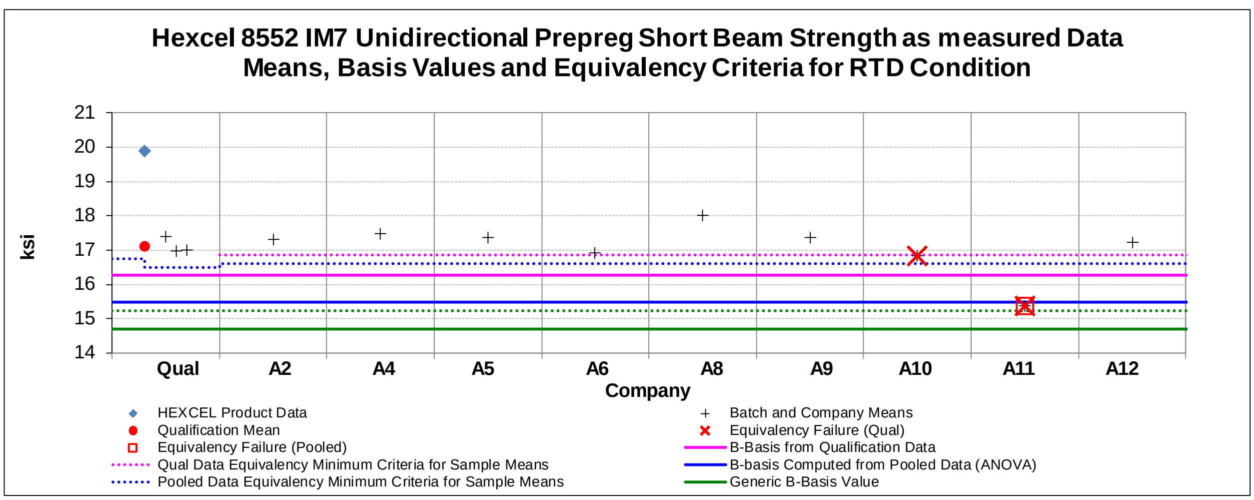
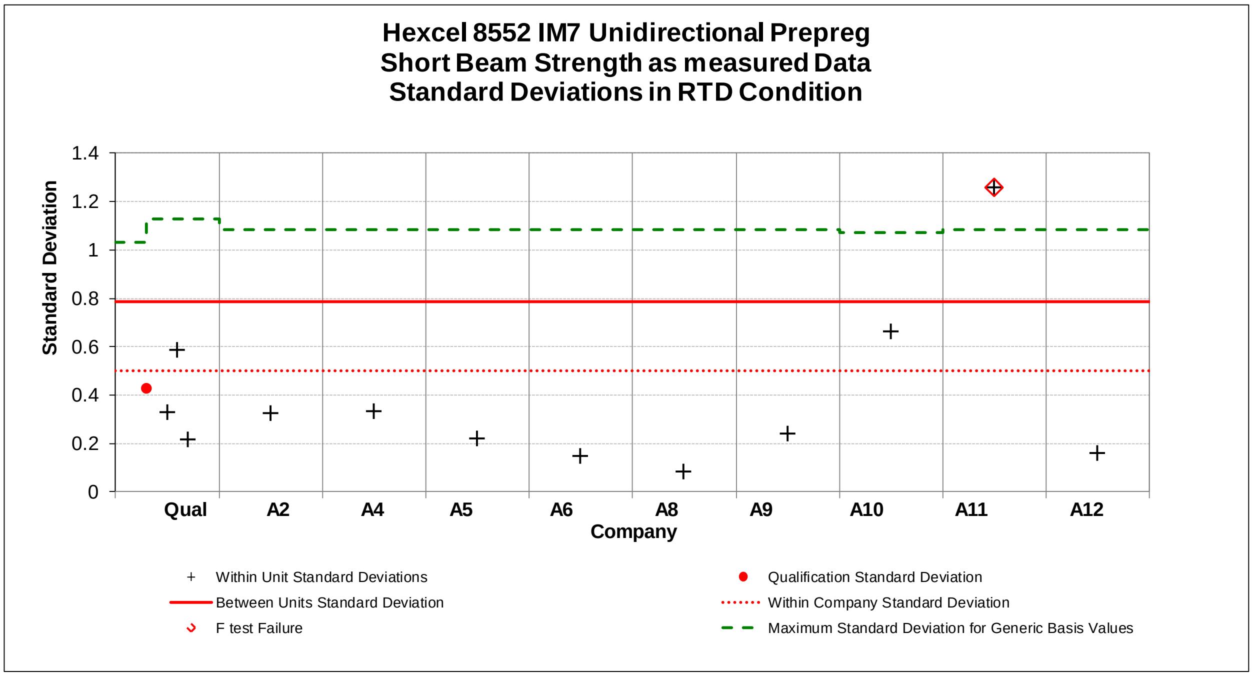


Figure 71: SBS RTD Strength Standard Deviations by Company



4.3.2 SBS ETW Condition

There were a total of 97 specimens from the ten different companies in the NCAMP dataset. Two specimens were identified as being statistical outliers. The largest value in units A01 and A2 were statistical outliers for their respective units, but not for the pooled dataset.

The within company standard deviation was lower than the between units standard deviation. There was one failure of the F test. Unit A11 had a standard deviation that exceed the maximum standard deviation for generic basis values.

Using the HYTEQ software to run equivalency tests for strength, three units (A5, A11, A12) failed equivalency when compared with the qualification dataset. Units A5 and A12 failed due to the mean being too low while their minimum specimen value was acceptable. Unit (A11) also failed equivalency when compared with pooled dataset as well as with the qualification dataset. It failed the equivalency test for both the mean and the minimum specimen value being below the minimum criteria in both cases.

While were no failures of the mean for the generic basis values equivalency criteria for strength, Unit A11 did not fall in the equivalency region and should not be considered equivalent. With a low mean and the failure of the F-test, unit A11 **cannot** be considered 'Acceptable but not Equivalent' for this property.

The summary statistics for all units are shown in Table 32 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 72. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 73. The standard deviations for strength by company are shown in Figure 74. All outliers and test failures are indicated in these graphs.

Table 32 SBS ETW Strength Summary Statistics by Unit

Short Beam Strength as measured ETW Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	Dataset
Average	8.252	8.175	8.257	8.338	8.368	8.107	8.007	8.212	8.643	8.690	8.219	7.688	8.054	8.229
Std Dev.	0.242	0.119	0.175	0.381	0.189	0.276	0.097	0.446	0.216	0.423	0.123	0.490	0.187	0.388
Coeff Var.	2.93%	1.45%	2.12%	4.57%	2.26%	3.41%	1.22%	5.43%	2.50%	4.87%	1.50%	6.37%	2.32%	4.72%
Max	8.820	8.419	8.538	8.820	8.788	8.629	8.193	9.093	8.982	9.452	8.413	8.540	8.303	9.452
Min	7.863	8.038	8.074	7.863	8.168	7.862	7.869	7.839	8.366	8.246	8.103	7.068	7.871	7.068
Count	19	7	6	6	9	7	9	8	9	9	9	9	9	97

Figure 72: SBS ETW Strength Specimen Data

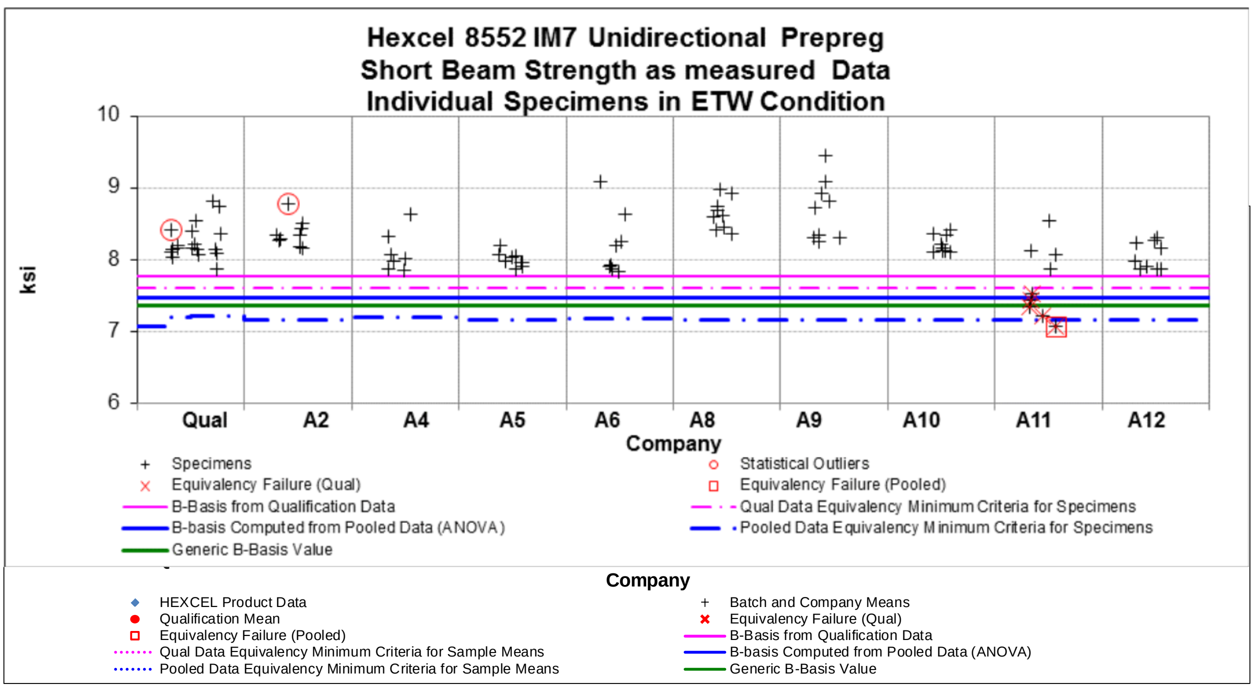
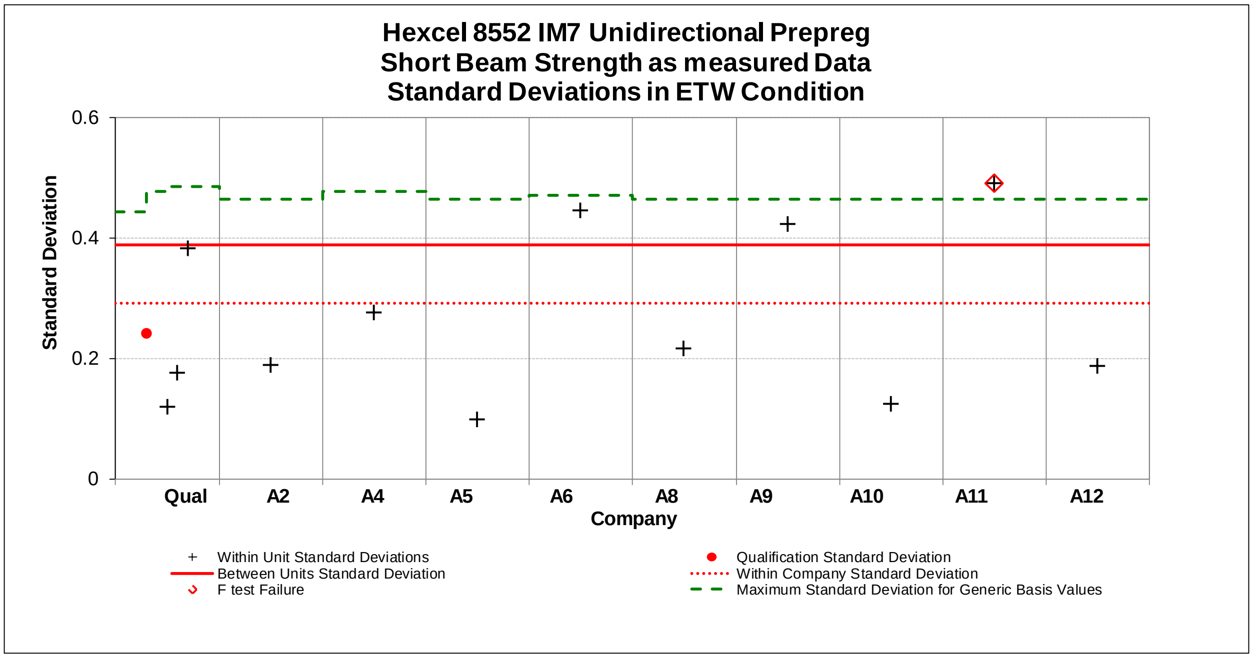


Figure 74: SBS ETW Strength Standard Deviations by Company



4.3.3 IPS CTD Condition 0.2% Offset Strength

There were a total of 99 specimens from the ten different companies in the NCAMP dataset. One specimen was identified as being a statistical outlier. The largest value in unit A8 was a statistical outlier for unit A8, but not for the pooled dataset.

The within company standard deviation was lower than the between units standard deviation. There was one failure of the F test. Unit A11 had a standard deviation that exceeded the maximum standard deviation for generic basis values.

Using the HYTEQ software to run equivalency tests for strength, all equivalency units (A2–A12) failed equivalence when compared with the qualification dataset. All units failed the equivalency test for both the mean and the minimum specimen value. Three units (A4, A6, A11) also failed equivalency when compared with pooled dataset as well as with the qualification dataset. Units A4 and A6 failed only due to the mean being too low. Unit A11 failed due to both the mean and the minimum specimen value being too low.

While were no failures of the mean for the generic basis values equivalency criteria for strength, Unit A11 did not fall in the equivalency region and should not be considered equivalent. With a low mean and the failure of the F-test, unit A11 **cannot** be considered 'Acceptable but not Equivalent' for this property.

The summary statistics for all units are shown in Table 33 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 75. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 76. The standard deviations for strength by company are shown in Figure 77. All outliers and test failures are indicated in these graphs.

Table 33 IPS CTD 0.2% Offset Strength Summary Statistics by Unit

IPS 0.2% Offset Strength as measured CTD Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	11.295	11.091	11.374	11.420	10.733	10.456	10.605	10.325	10.915	10.898	10.712	10.472	10.583	10.776
Std Dev.	0.238	0.200	0.226	0.151	0.225	0.122	0.141	0.137	0.289	0.377	0.083	0.626	0.134	0.413
Coeff Var.	2.10%	1.81%	1.98%	1.33%	2.10%	1.17%	1.33%	1.33%	2.65%	3.46%	0.77%	5.98%	1.27%	3.83%
Max	11.661	11.460	11.661	11.565	11.143	10.610	10.895	10.600	11.611	11.604	10.815	11.787	10.839	11.787
Min	10.779	10.779	11.067	11.211	10.442	10.287	10.421	10.110	10.630	10.207	10.599	9.615	10.416	9.615
Count	21	7	7	7	9	9	8	9	9	9	9	8	8	99

Figure 75: IPS CTD 0.2% Offset Strength Specimen Data

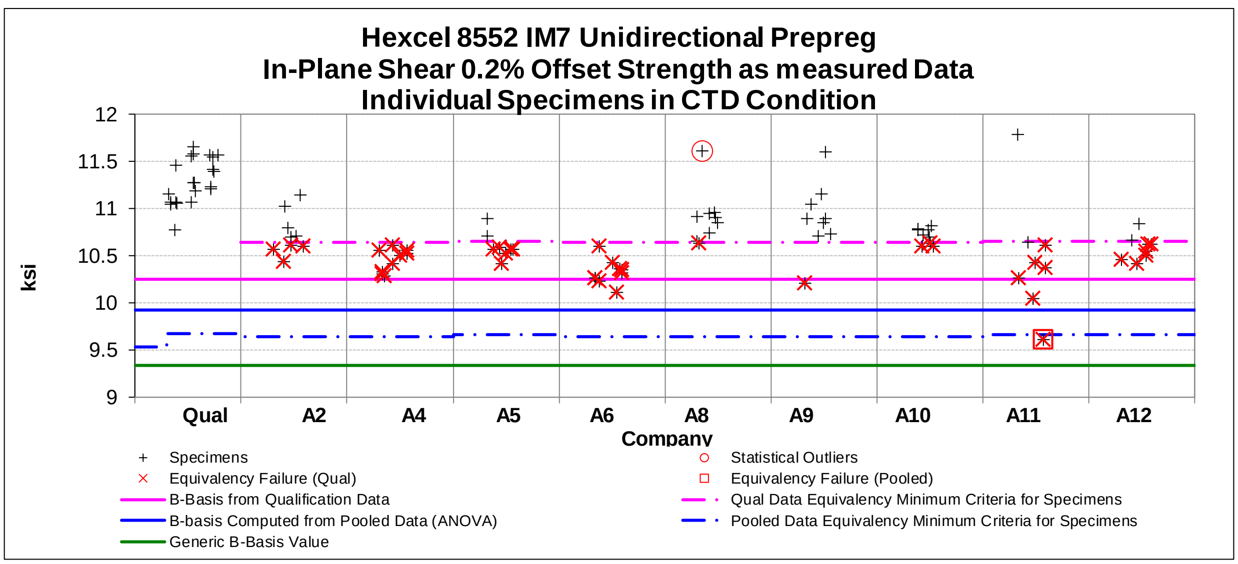


Figure 76: IPS CTD 0.2% Offset Strength Means by company

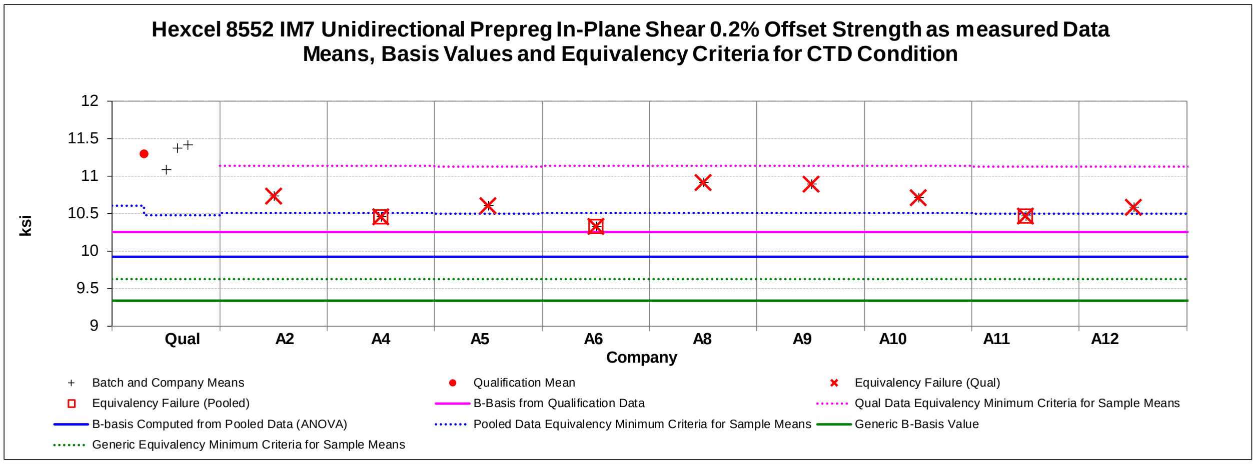
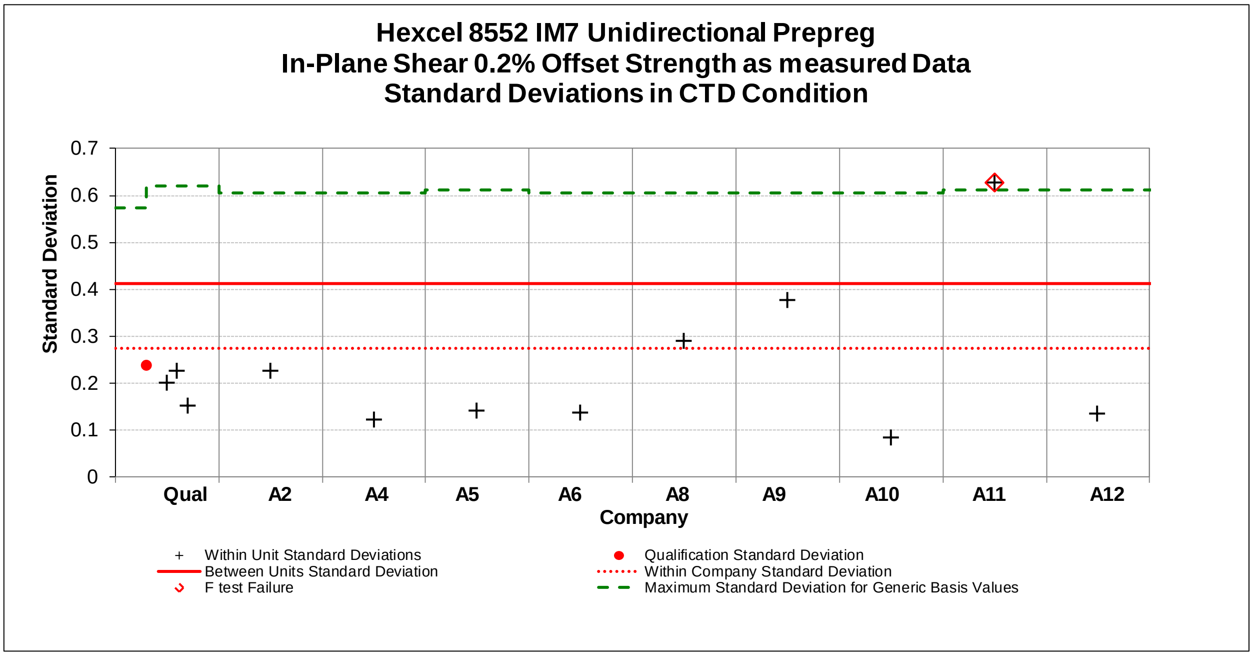


Figure 77: IPS CTD 0.2% Offset Strength Standard Deviations by Company



4.3.4 IPS RTD Condition 0.2% Offset Strength

There were a total of 106 specimens from the ten different companies in the NCAMP dataset. One specimen was identified as being a statistical outlier. The lowest value in unit A5 was a statistical outlier for unit A5, but not for the pooled dataset.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, three units (A5, A6, A11) failed equivalency when compared with the both the qualification dataset and the pooled dataset. Units A6 and A11 failed due to the mean being too low while their minimum specimen value was acceptable. Unit A5 failed equivalence when compared with the qualification dataset due to both the mean and the minimum specimen value being too low, but only failed for the minimum specimen value being too low when compared with the pooled dataset.

While were no failures of the mean for the generic basis values equivalency criteria for strength, Unit A11 did not fall in the equivalency region and should not be considered equivalent. However, calculations indicate that unit A11 can be considered 'Acceptable but not Equivalent' for this property.

The summary statistics for all units are shown in Table 34 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 78. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 79. The standard deviations for strength by company are shown in Figure 80. All outliers and test failures are indicated in these graphs.

Table 34 IPS RTD 0.2% Offset Strength Summary Statistics by Unit

IPS 0.2% Offset Strength as measured RTD Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	7.756	7.591	7.799	7.869	7.811	7.632	7.568	7.433	7.772	7.693	7.800	7.440	7.797	7.679
Std Dev.	0.218	0.077	0.195	0.268	0.112	0.148	0.190	0.094	0.208	0.099	0.076	0.090	0.076	0.195
Coeff Var.	2.81%	1.02%	2.51%	3.40%	1.44%	1.94%	2.51%	1.26%	2.68%	1.28%	0.97%	1.20%	0.98%	2.54%
Max	8.279	7.698	8.117	8.279	8.003	7.892	7.694	7.628	8.157	7.847	7.905	7.575	7.942	8.279
Min	7.481	7.481	7.600	7.591	7.655	7.424	7.016	7.296	7.530	7.535	7.694	7.296	7.653	7.016
Count	16	5	6	5	11	9	11	10	9	9	9	9	13	106

Figure 78: IPS RTD 0.2% Offset Strength Specimen Data

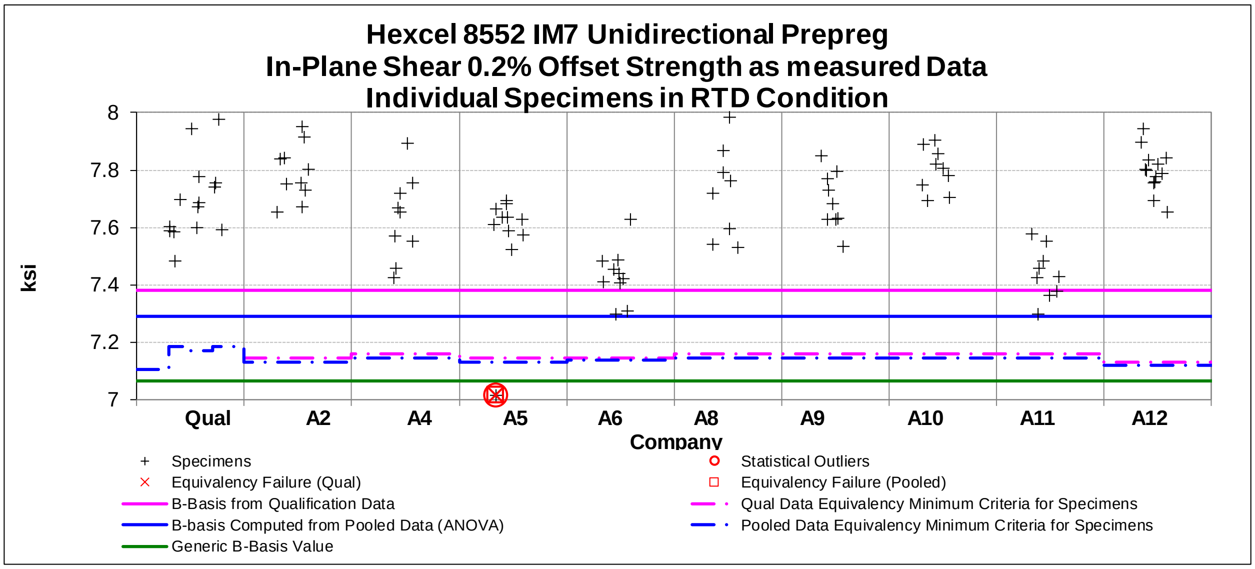


Figure 79: IPS RTD 0.2% Offset Strength Means by company

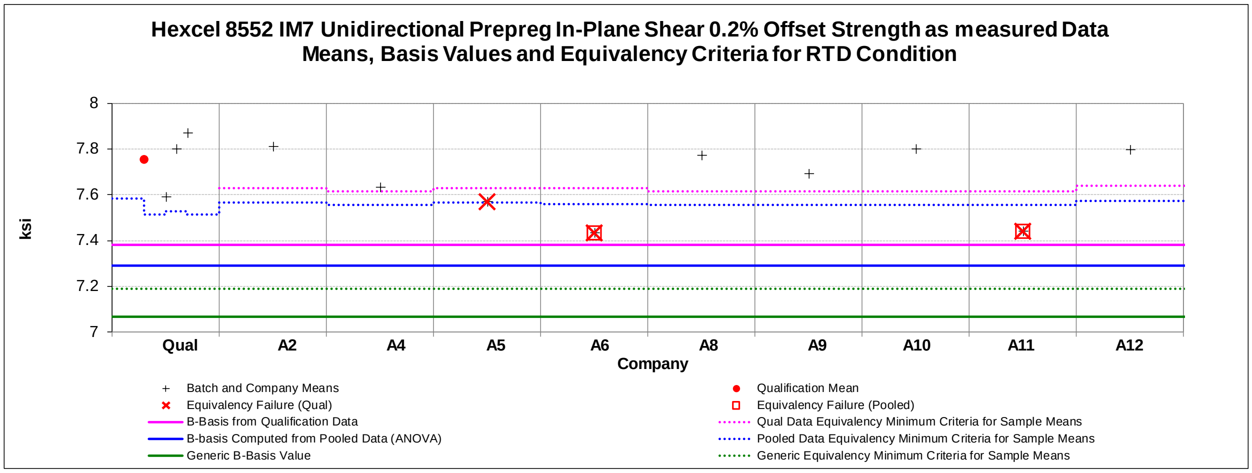
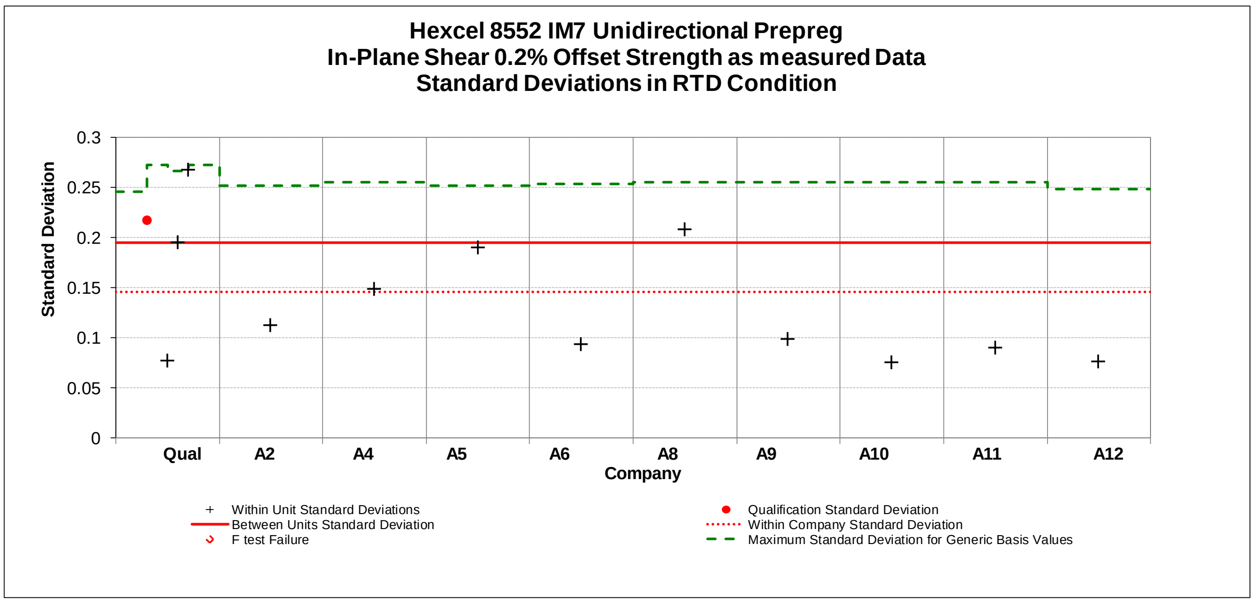


Figure 80: IPS RTD 0.2% Offset Strength Standard Deviations by company



4.3.5 IPS RTD Condition Strength at 5% Strain

There were a total of 88 specimens from the ten different companies in the NCAMP dataset. There were no statistical outliers.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, four units (A5, A6, A8, A11) failed equivalency when compared with the qualification dataset. Units A5 and A8 failed due to the mean being too low while their minimum specimen value was acceptable. Units A6 and

A11 failed equivalence due to both the mean and the minimum specimen value being too low. Two units (A6, A11) also failed equivalency when compared with pooled dataset as well as with the qualification dataset. Both units failed when compared with pooled dataset due to the mean being too low while their minimum specimen value was acceptable.

While were no failures of the mean for the generic basis values equivalency criteria for strength, Unit A11 did not fall in the equivalency region and should not be considered equivalent. Calculations indicate that unit A11 **cannot** be considered 'Acceptable but not Equivalent' for this property.

The summary statistics for all units are shown in Table 35 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 81. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 82. The standard deviations for strength by company are shown in Figure 83. All outliers and test failures are indicated in these graphs.

Table 35 IPS RTD Strength at 5% Strain Summary Statistics by Unit

IPS Strength at 5% Strain as measured RTD Condition by Batch and Company														
Statistics	**Qualification Data**				**Equivalency Companies**									**Pooled Dataset**
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	13.225	13.036	13.238	13.401	13.283	13.163	13.052	12.959	13.078	13.178	13.446	12.847	13.429	13.157
Std Dev.	0.211	0.170	0.131	0.167	0.206	0.195	0.147	0.234	0.317	0.181	0.186	0.189	0.164	0.263
Coeff Var.	1.60%	1.30%	0.99%	1.25%	1.55%	1.48%	1.12%	1.80%	2.42%	1.37%	1.38%	1.47%	1.22%	2.00%
Max	13.609	13.228	13.405	13.609	13.622	13.426	13.297	13.260	13.581	13.375	13.670	13.149	13.733	13.733
Min	12.855	12.855	13.092	13.200	13.017	12.835	12.875	12.482	12.730	12.870	13.215	12.530	13.169	12.482
Count	12	4	4	4	9	9	9	8	9	9	4	9	10	88

Figure 81: IPS RTD Strength at 5% Strain Specimen Data

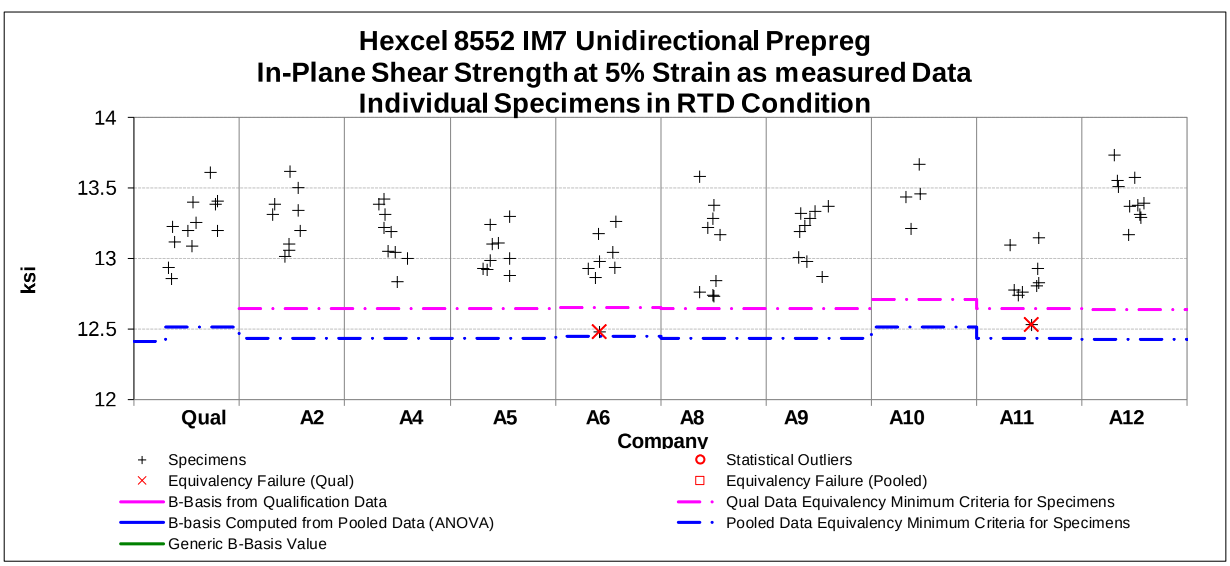


Figure 82: IPS RTD Strength at 5% Strain Means by Company

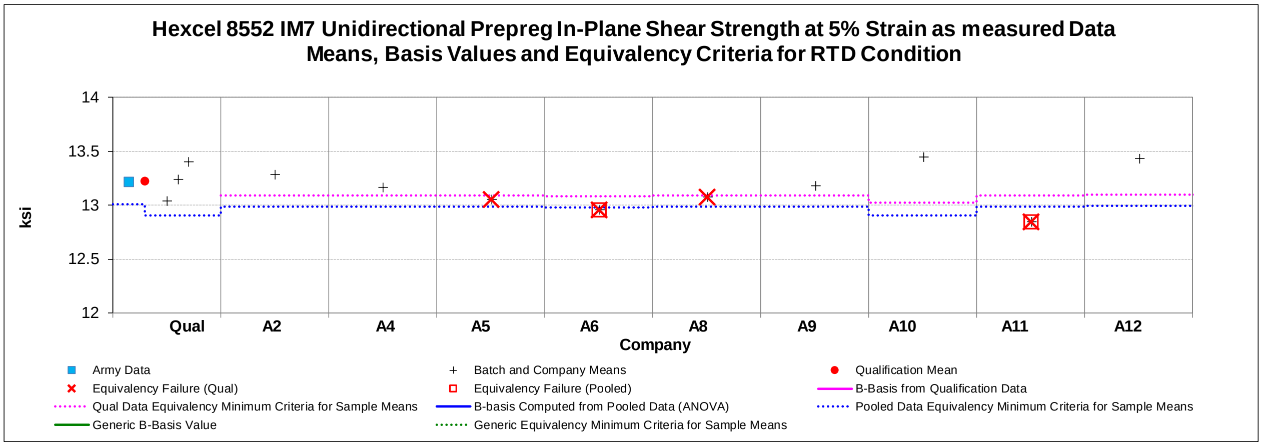
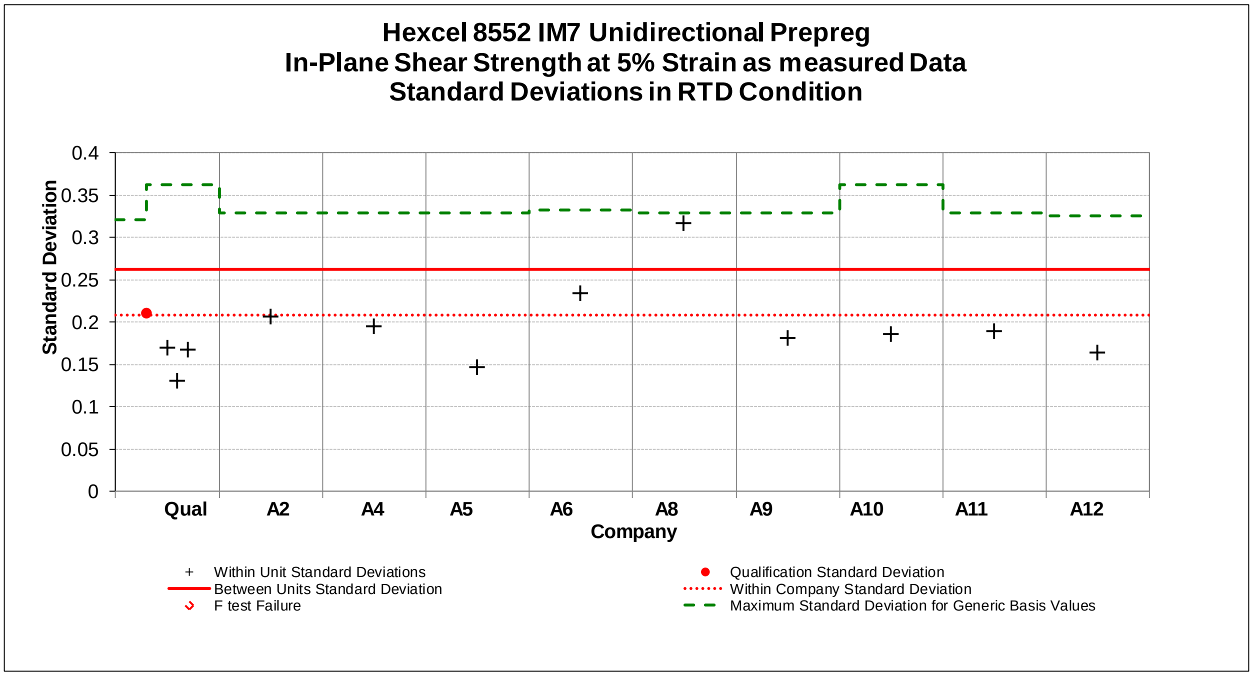


Figure 83: IPS RTD Strength at 5% Strain Standard Deviations by company



4.3.6 IPS ETW Condition 0.2% Offset Strength

There were a total of 103 specimens from the ten different companies in the NCAMP dataset. There were no statistical outliers.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, five units (A2, A4, A5, A6, A11) failed equivalency when compared with the qualification dataset. Units A2, A5, A6, and A11 failed due to the mean being too low while their minimum specimen value was acceptable. Unit A4 failed equivalence due to both the mean and the minimum specimen value being too low. Two units (A6, A11) also failed equivalency when compared with pooled dataset as well as with the qualification dataset. Both units failed when compared with pooled dataset due to the mean being too low while their minimum specimen value was acceptable.

While were no failures of the mean for the generic basis values equivalency criteria for strength, Unit A11 did not fall in the equivalency region and should not be considered equivalent. Calculations indicate that unit A11 can be considered 'Acceptable but not Equivalent' for this property.

The summary statistics for all units are shown in Table 36 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 84. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 85. The standard deviations for strength by company are shown in Figure 86. All outliers and test failures are indicated in these graphs.

Table 36 IPS ETW 0.2% Offset Strength Summary Statistics by Unit

IPS 0.2% Offset Strength as measured ETW Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled Dataset
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	
Average	3.307	3.325	3.407	3.169	3.154	3.138	3.129	3.093	3.260	3.263	3.273	2.968	3.420	3.214
Std Dev.	0.153	0.053	0.171	0.115	0.138	0.158	0.134	0.051	0.050	0.112	0.083	0.063	0.042	0.163
Coeff Var.	4.63%	1.60%	5.03%	3.63%	4.37%	5.03%	4.27%	1.65%	1.53%	3.43%	2.54%	2.12%	1.23%	5.06%
Max	3.627	3.408	3.627	3.304	3.404	3.462	3.376	3.167	3.331	3.416	3.374	3.068	3.479	3.627
Min	3.050	3.262	3.090	3.050	3.034	2.864	2.890	3.022	3.168	3.030	3.137	2.895	3.349	2.864
Count	20	7	7	6	10	9	9	9	9	9	9	9	10	103

Figure 84: IPS ETW 0.2% Offset Strength Specimen Data

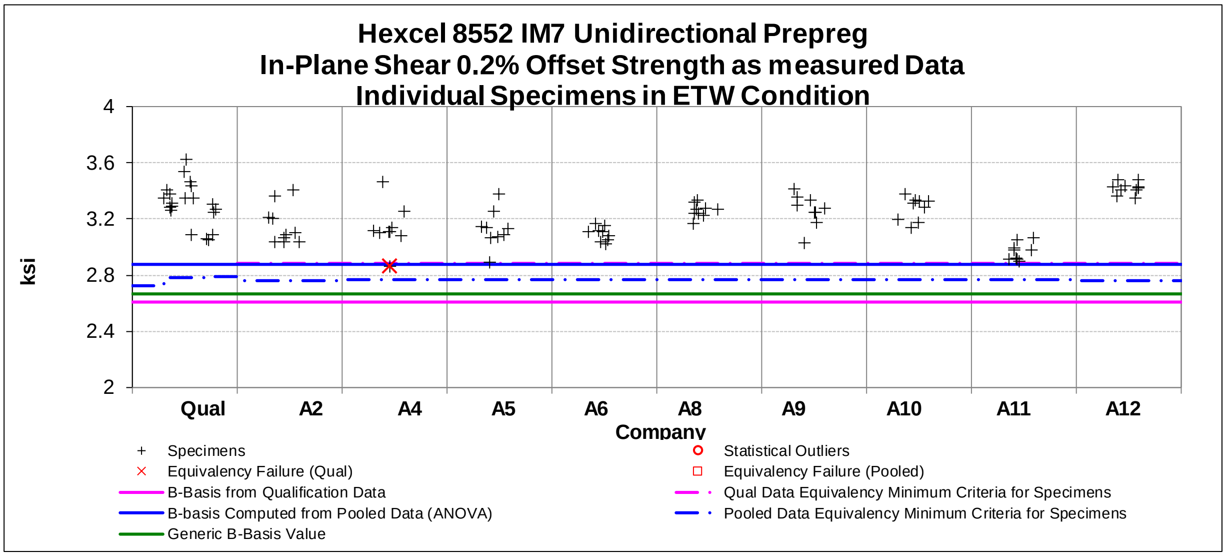


Figure 85: IPS ETW 0.2% Offset Strength Means by Company

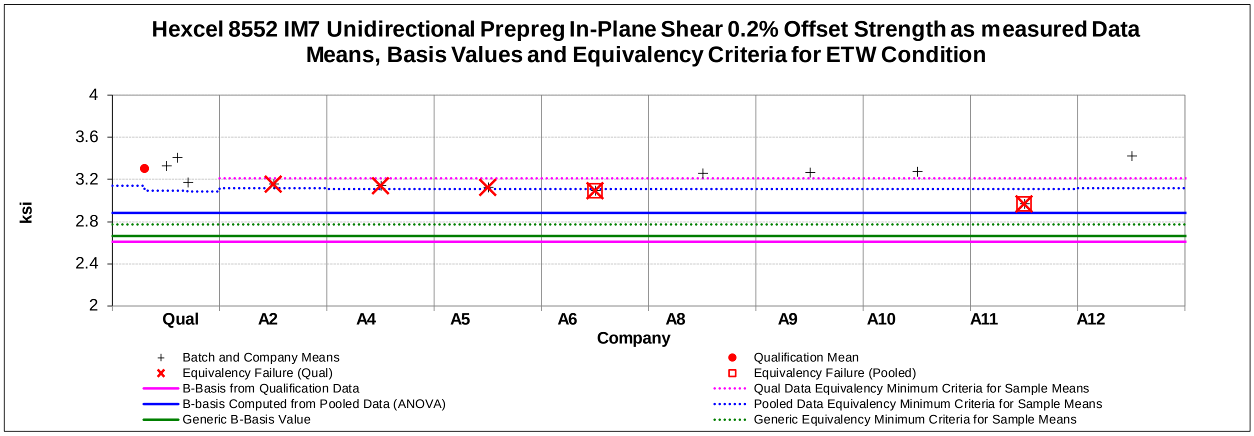
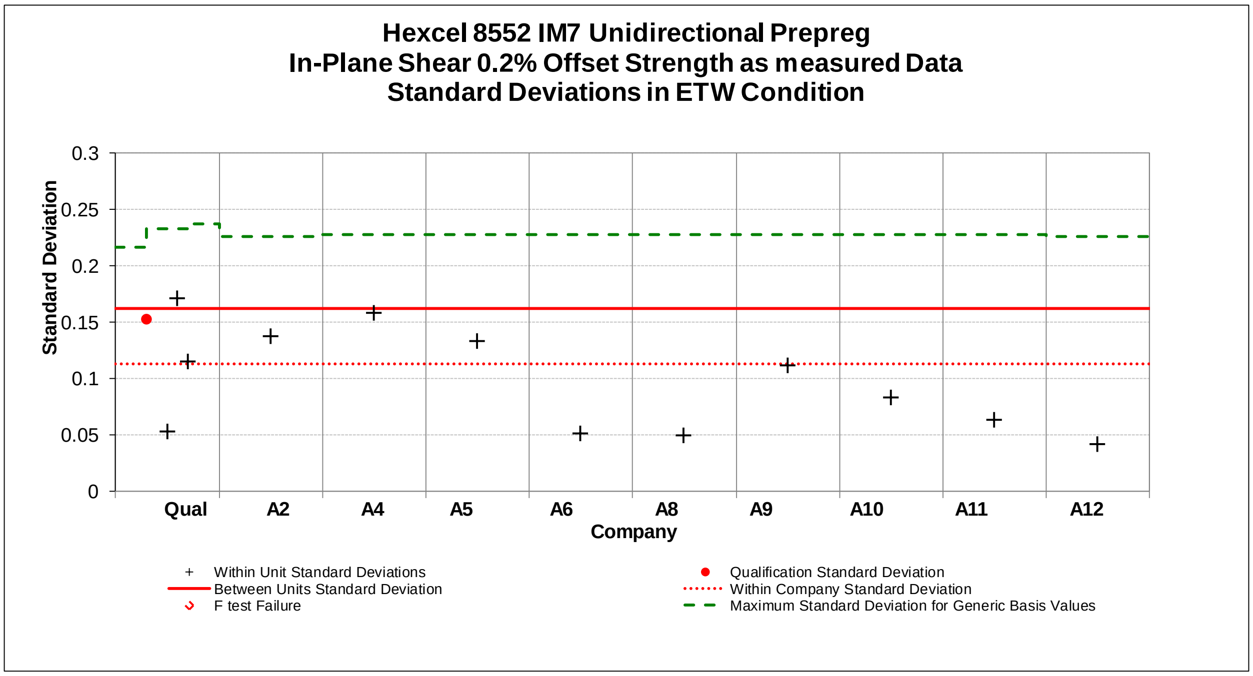


Figure 86: IPS ETW 0.2% Offset Strength Standard Deviations by company



4.3.7 IPS ETW Condition Strength at 5% Strain

There were a total of 100 specimens from the ten different companies in the NCAMP dataset. There were no statistical outliers.

The within company standard deviation was lower than the between units standard deviation. There were no failures of the F test.

Using the HYTEQ software to run equivalency tests for strength, four units (A4, A5, A6, A11) failed equivalency when compared with the qualification dataset. Units A4, A6 and A11 failed due to the mean being too low while their minimum specimen value was acceptable. Unit A5 failed equivalence due to both the mean and the minimum specimen value being too low. All four of these units (A4, A5, A6, A11) also failed equivalency when compared with pooled dataset as well as with the qualification dataset. These units all failed when compared with pooled dataset due to the mean being too low while their minimum specimen value was acceptable.

While were no failures of the mean for the generic basis values equivalency criteria for strength, Unit A11 did not fall in the equivalency region and should not be considered equivalent. Calculations indicate that unit A11 can be considered 'Acceptable but not Equivalent' for this property.

The summary statistics for all units are shown in Table 37 for strength. The individual strength values for each specimen along with the B-basis values computed by the different methods and the corresponding equivalency minimum values for specimens are shown in Figure 87. The mean values for each company along with the B-basis values computed by the different methods and the corresponding equivalency minimum criteria for means are shown in Figure 88. The standard deviations for strength by company are shown in

Figure **89**. All outliers and test failures are indicated in these graphs.

Table 37 IPS ETW Strength at 5% Strain Summary Statistics by Unit

IPS Strength at 5% Strain as measured ETW Condition by Batch and Company														
Statistics	Qualification Data				Equivalency Companies									Pooled
	Qual.	A01	A02	A03	A2	A4	A5	A6	A8	A9	A10	A11	A12	Dataset
Average	5.538	5.569	5.696	5.343	5.523	5.282	5.225	5.302	5.491	5.481	5.587	5.202	5.777	5.451
Std Dev.	0.187	0.097	0.167	0.101	0.216	0.196	0.198	0.098	0.114	0.147	0.155	0.092	0.176	0.231
Coeff Var.	3.38%	1.74%	2.94%	1.90%	3.91%	3.71%	3.79%	1.84%	2.07%	2.68%	2.78%	1.77%	3.05%	4.24%
Max	5.954	5.706	5.954	5.456	5.937	5.621	5.566	5.452	5.632	5.779	5.915	5.366	6.119	6.119
Min	5.178	5.447	5.434	5.178	5.231	5.063	4.979	5.186	5.267	5.269	5.417	5.045	5.542	4.979
Count	19	7	6	6	9	9	9	9	9	9	9	9	9	100

Figure 87: IPS ETW Strength at 5% Strain Specimen Data

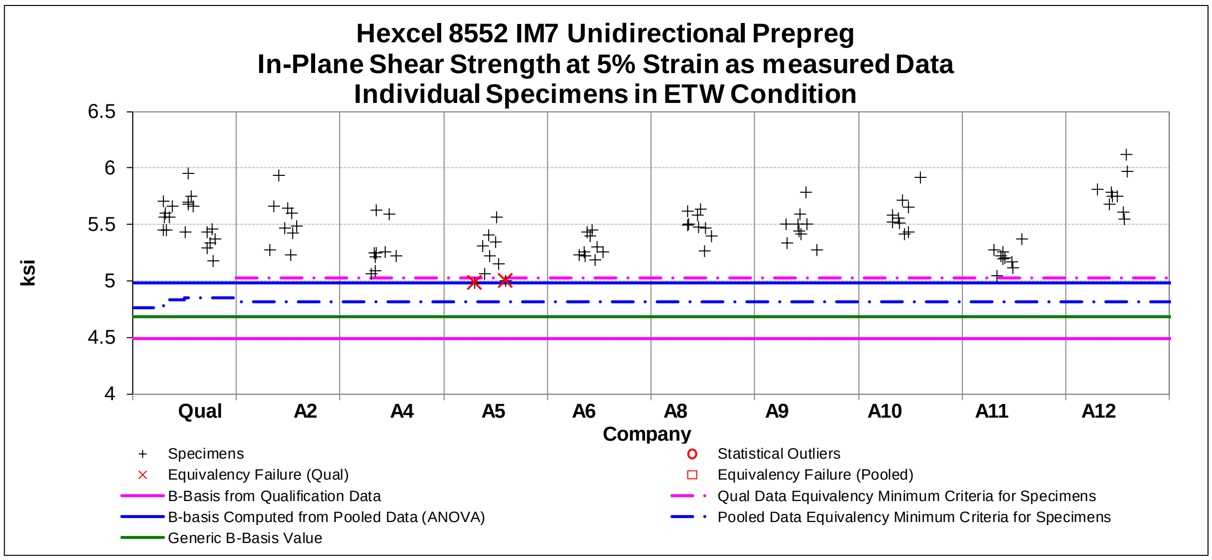


Figure 88: IPS ETW Strength at 5% Strain Means by company

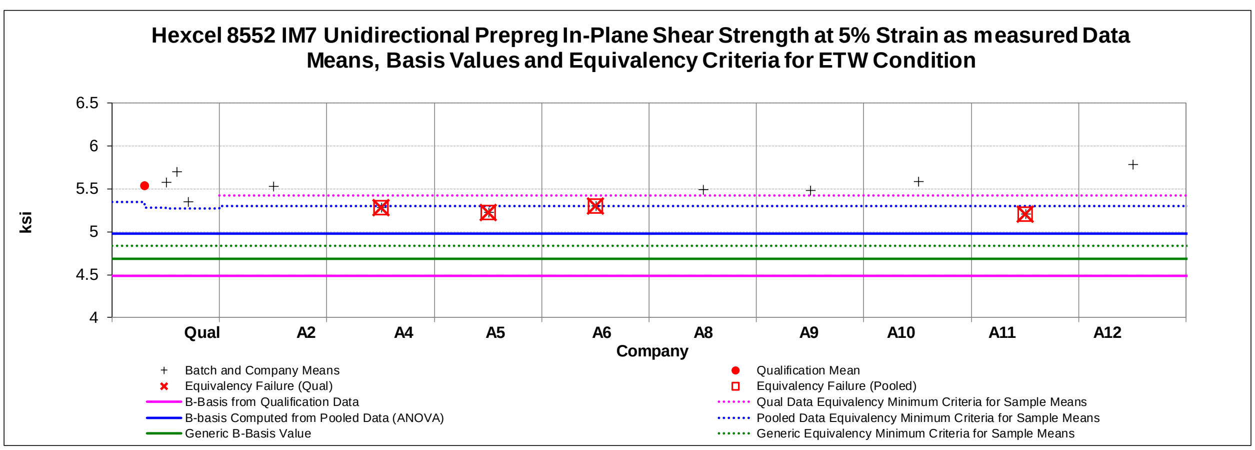
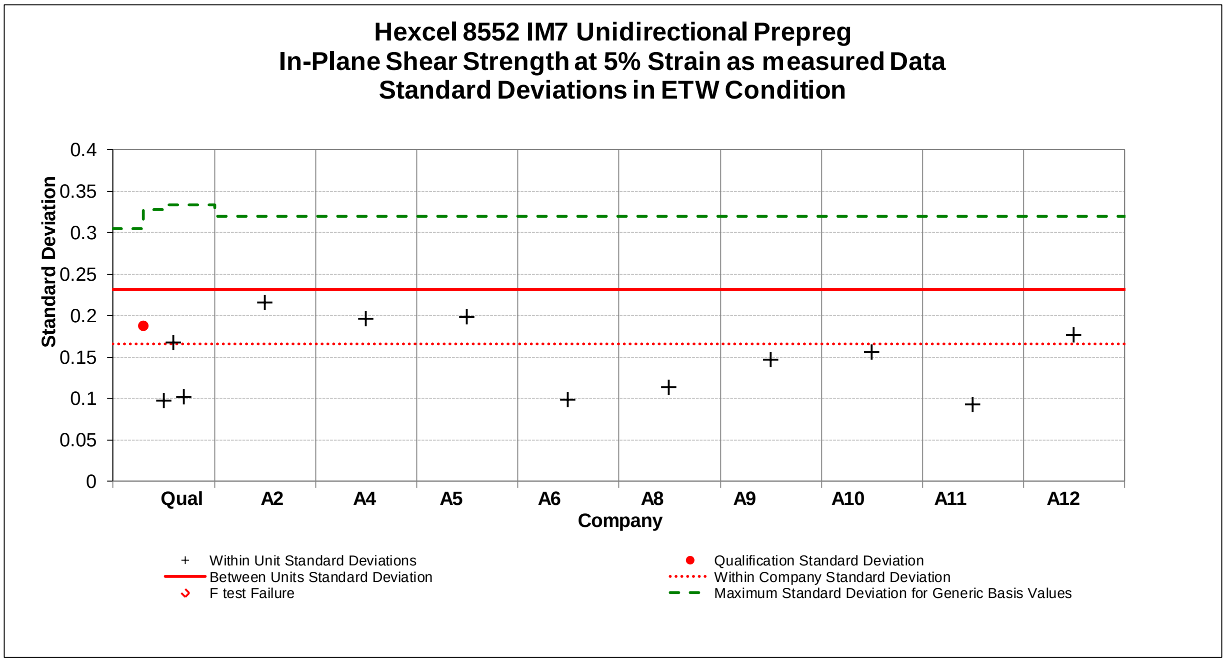


Figure 89: IPS ETW Strength at 5% Strain Standard Deviations by company



5. References

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