

SEMI C64-0308 (Reapproved 1214)

SEMI STATISTICAL GUIDELINES FOR SHIP TO CONTROL

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1 Purpose

1.1 To provide a set of guidelines for the quantitative determination of statistically derived limits from process data for the purpose of defining and maintaining ship to control (STC) limits.

2 Scope

2.1 This Guide applies to specified properties of specific products for which it is desired to use statistically derived control limits upon which customer notification, negotiated disposition of product, or statistical specifications can be based.

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3 Referenced Standards and Documents

3.1 SEMI Standards and Safety Guidelines

SEMI C10 — Guide for Determination of Method Detection Limits

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

4 Terminology

4.1 Abbreviations and Acronyms

4.1.1 MDL — method detection limit

4.1.2 NP — nonparametric

4.1.3 OOC — out of control

4.1.4 STC — ship to control

4.2 Definitions

4.2.1 90th percentile test — a nonparametric test methodology for determining if reference and test data sets differ in the Annual Review Process.

4.2.2 annual review process — the process by which STC limits are reviewed annually for possible change.

4.2.3 batch analysis — a measurement analysis that results in a single reported result for the specified property for the product batch in question. This result is assumed to apply to multiple shipping units when a production batch is divided into multiple product lots and batch sampling is appropriate as opposed to sampling each individual lot.

4.2.4 *censored data* — data whose measured value or non-measurable value has been replaced by a limit such as an MDL.

4.2.5 *family type I error rate* — for any individual sample, the probability that one or more characteristics will read OOC when a process is actually in statistical control.

4.2.6 *method detection limit (MDL)* — a statistically derived figure of merit for a measurement system. Refer to ¶ 3.1 for SEMI's MDL methodology.

4.2.7 *nonprovisional STC limits* — these limits are used to determine whether or not a measured product property is in statistical control. An STC limit is nonprovisional when there is enough uncensored data used in STC limit estimation. Nonprovisional STC limits are changed upon annual review only when significant differences are found between the reference data and the test data.

4.2.8 *NP test methodology* — nonparametric test methodology, a particular combination of the use of Tukey's quick test and the 90th percentile test in the annual review process.

4.2.9 *out of control (OOC) product* — product for which one or more STC parameters exceed its STC upper control limit or, if applicable, fall below its STC lower control limit.

4.2.10 *practical significance test* — a test of whether STC limits have changed by enough to be concerned about in the annual review process.

4.2.11 *provisional STC limits* — an STC limit is provisional when there is too little uncensored data used in STC limit estimation. A provisional STC Limit is always updated upon annual review. How these limits are applied for the purpose of shipping material is left to the individual suppliers and producers to decide.

4.2.12 *reference data* — data from which the current STC limits were calculated (as per ¶ 8.1).

4.2.13 *ship to control (STC)* — the use of statistically derived control limits for the purpose of shipping decisions.

4.2.14 *ship to control (STC) limits* — STC limits calculated by the provisions provided within SEMI Statistical Guidelines for ship to control.

4.2.15 *skewness* — a signed statistical measure of asymmetry in a data distribution.

4.2.16 *test data* — data whose distribution is compared to the distribution of the reference data in the annual review process.

4.2.17 *Tukey's quick test* — a nonparametric test methodology for determining if reference and test data sets differ in the annual review process.

5 Data Requirements

NOTE 1: A series of requirements are set forth regarding data from which ship to control (STC) limits are to be determined.

5.1 Supplier's process data is used to determine STC limits. STC limits are derived solely from the supplier's process and are not broken out into customer specific STC limits or into STC limits that are specific to ship to locations. Data used in STC calculations is to be available for customer review.

5.2 Separate STC limits are required for different supplier manufacturing locations.

5.3 The prior year's data is used to calculate STC limits.

5.4 Supplier's historical process data cannot span a significant process change.

5.5 A minimum of 100 measurements are required to determine STC limits. If the prior year does not provide this minimum sample size continue to sequentially add prior years one at a time until this minimum is achieved. Use the data from this expanded time frame to determine STC limits.

5.6 If application of ¶¶ 5.4 and 5.5 still provide a sample size that is less than 100 or does not include at least a year of data, it is up to the supplier and producer to decide whether or not to proceed with use of STC limits. If small sample size STC limits are used, the supplier and producer need to determine the manner in which such less stable STC limits are applied (Appendix 1, ¶ A1-3.3).

5.7 For measurement properties for which the process data is too highly censored (less than 10 uncensored points or not enough points to perform Tukey's quick test (§ 8.2) in the annual review methodology) then the calculated STC limit is provisional.

5.8 Out of control (OOC) STC data requires a root-cause analysis. If both a cause is found and steps are taken to ensure that the likelihood of such a cause occurring in the future is either eliminated or greatly reduced, then this point will be considered an outlier that is to be removed from use in evaluating STC limits or the annual review status of STC limits.

5.9 For the case where a value from a single production batch is applied to multiple shipped lots (batch analysis data, § 4.2.3), that value should only be used once in the statistical calculations in §§ 8.1 through 8.3. For example, if a batch analysis is performed where a production batch produces 10 shipping lots, there is only one measurement to use in §§ 8.1 through 8.3, not 10.

5.10 When multiple batches are produced from the same raw material lot(s) and the raw material is the main source of product variation; then the use of the average of the batches made from the raw material lot(s) should be considered. This must be agreed on between supplier and producer.

6 Review of STC Limits

6.1 STC is not intended to replace current forms of routine process control monitoring.

6.2 For data sets with less than 100 measurements see §§ 5.4 through 5.6.

6.3 Nonprovisional STC limits will be evaluated for change on an annual basis as per § 8.2. Only those non-provisional STC limits having statistically significantly different distributions and the control limits having a practically significant difference will be modified upon annual review.

6.4 All provisional STC limits will automatically be recalculated upon annual review (§ 8.2). For a provisional limit, when enough uncensored data is available upon annual review to meet § 5.7, the STC limit in question will lose its provisional status upon recalculation and subsequently follow the standard annual review procedure in future annual reviews.

6.5 Changes to STC limits from the annual review process are to be treated as a package of changes. Neither suppliers nor producers get to select a preferred subset of STC limit changes.

6.6 *Process Change Handling* — Whenever a change is made to a process or an analytical measurement system, it may be necessary to adjust STC limits and existing specifications. Transition issues for notified changes need to be handled between suppliers and customers.

7 Application of STC Limits

7.1 Nonprovisional STC limits are used to determine whether product is OOC. These limits as quantified in § 8 have three possible applications.

7.1.1 *Reporting Only* — Supplier reports out of control STC limit product. Such out of control product continues to be shipped and accepted as long as it meets the existing specification for that product grade.

7.1.2 *Negotiated Product* — Supplier reports out of STC limit product. Such product is not shipped unless an exception for the particular type of STC limit violation has already been provided by agreement with the product purchaser or the product purchaser has agreed upon the final disposition of such product.

7.1.3 *Statistical Specification* — The STC limits are treated as product specifications. Out of specification product is not shipped.

7.2 Provisional STC limits as quantified in § 8 also have all the possible applications as nonprovisional STC limits (§ 7.1). Due to the less stable nature of provisional STC limits, suppliers and producers should consider the possibility of applying provisional limits less aggressively than nonprovisional limits.

7.3 Product properties for which STC limits are applied are established by agreement of supplier and producer. In this regard STC limits may apply to all specified product properties, a smaller list of critical parameters, or simply a list of negotiated parameters.

NOTE 2: The number of product properties impacts the calculation of the limits (§ 8.1 and Appendix 1, §§ A1-3.1 through A1-3.4).

7.4 Grace Period for STC Limits Modified Upon Annual Review — When an STC limit changes for a material that met the STC limits in force at the time of production but now no longer does, this material can be shipped as long as the supplier is using a FIFO (first in first out) shipping strategy or as negotiated.

7.5 Relationship to Existing Product Specifications — If material meets the STC limit but fails the nominal specification, then the preexisting rules for handling material that does not meet the nominal specification apply. If material meets the nominal specification but fails the STC limit, then the disposition rules defined in ¶ 7.1 apply. If both the nominal and STC limit are not met, then the more stringent of the rules applies.

7.6 No Additional Statistical Requirements — No additional statistical requirements are part of the STC methodology. This includes additional statistical testing methodologies targeted at detecting shifts and trends, such as the Western Electric rules. It also includes process capability indices such as C_p or C_{pk} ; these measures are inherently incompatible with STC.

8 Procedure

8.1 This section provides a detailed technical description of the STC methodology. Enough information is provided for the user to do the requisite calculations by hand or in a spreadsheet. In some places the calculations are complex. Software will be provided to do all the calculations and apply the necessary logic at all the decision points. The user is strongly encouraged to use the software.

8.1.1 Quantification of STC Limits — The calculation and application of the STC limits are broken into two broad categories. The first calculates control limits based on reference (or historical) data. Some of the calculated control limits are considered provisional and are so noted. A second set of calculations occurs whenever test data is available. The main function here is to determine which, if any, of the analytical results from the test data are OOC. Also, for the purpose of the yearly review new control limits based on the test data can be calculated and tested to determine if any are statistically significantly different from the previous control limits and determine if the difference is practically significant (¶ 8.2). The calculations that define the STC limit for each characteristic and the determination of OOC points is described below. ¶ 8.2 describes the procedures for determining statistical and practical differences between control limits calculated on the reference and test data. ¶ 8.3 works through a sample set of data in detail.

8.1.2 Calculation of STC Limits on Reference Data — The user needs to supply the following information in order to calculate the control limits:

1. Number of samples, n_{ref} (≥ 100).
2. Number of characteristics measured (p). This sets the Type I error for each individual control chart (α_{Ind}):
 $\alpha_{Ind} = 1 - 0.99^{1/p}$, where a family Type I error of 1% is assumed.
3. The analytical results for all the reference data.
4. Whether an upper control limit, lower control limit are both are required for each characteristic.
5. The method detection limit (MDL) for each characteristic. If there is no censoring this information is not needed.
6. The string used to identify that a particular result is below the MDL (i.e., is censored). This can vary from characteristic to characteristic but within a characteristic must always be the same string. Some commonly used identifier strings are ND and <MDL where the actual value of the MDL is used (e.g., <1 when the MDL is 1). It is not recommended that the value of the MDL be used as the identifier string (i.e., <1 is OK but 1 should not be used).

8.1.2.1 The following variables are then calculated for each characteristic:

1. n_j , the total number of non-missing values for characteristic j . Note that $n_j \leq n_{ref}$ and that censored values are not considered missing values.
2. $t_{crit}(\alpha, n_j - 1)$, a t-value with $n_j - 1$ ° of freedom. For one sided control limits $\alpha = \alpha_{Ind}$. For two sided control limits $\alpha = \alpha_{Ind} / 2$. If t_{crit} calculates to be less than 3 then it is set at 3.
3. The skewness correction factor, a , is calculated as follows. This is a function of n_j and p' ,

where p' is p for a one sided limit and p' is $2p$ for a two sided limit.

8.1.2.2 The a factor is then given by:

$$a = (p'/b_0)b_1 \quad (1)$$

where:

$$b_0 = g(1 - \exp(-f(n_j^h)))$$

$$b_1 = (e/n_j)^c + d$$

$$c = 1.18041$$

$$d = 0.246002$$

$$e = 9.804714$$

$$f = 0.024273$$

$$g = 4.151277$$

$$h = 0.478154$$

4. If $n_j < 30$ or $p' > 120$ values for a are extrapolated and should be considered invalid. The STC limits should not be used in these cases.
5. Dual value insertion. It is recommended that the data used to calculate control limits not be censored. This means that all measurement results are recorded as is, even if they are below the MDL. Censoring can occur later, as, for example, on a certificate of analysis. If for whatever reason the data is censored on the left by the MDL then proceed as follows.
6. For each characteristic, when the first MDL designator string is encountered the value 0 is inserted. The second time the designator string is encountered the value of the MDL is inserted. These values are alternately inserted as subsequent censored values are encountered.
7. $\bar{X}_j$, S_j and k_{3j} , where $\bar{X}_j$ is the average, S_j the standard deviation and k_{3j} the sample skewness coefficient for characteristic j in the reference set. These are calculated after the dual value insertion has occurred. For upper control limits if k_3 is less than 0 then k_3 is set to 0. For lower control limits if k_3 is greater than 0 then k_3 is set to 0. These statistics are defined below.

$$\begin{aligned} \bar{X}_j &= \frac{\sum_{i=1}^{n_j} x_{ij}}{n_j} \\ S_j &= \sqrt{\frac{\sum_{i=1}^{n_j} (x_{ij} - \bar{X}_j)^2}{n_j - 1}} \\ k_{3j} &= \frac{n_j \sum_{i=1}^{n_j} (x_{ij} - \bar{X}_j)^3}{(n_j - 1)(n_j - 2)S_j^3} \end{aligned} \quad (2)$$

8. Note that the subscript i ranges over the number of non-missing samples for characteristic j . Also note that the true sample standard deviation is used. Do not use one that is inferred from a moving range.

9. The STC control limits are then given by:

$$\begin{aligned} UCL_j &= \bar{X}_j + (t_{crit}(\alpha, n_j - 1) + ak_{3j})S_j\sqrt{1 + 1/n_j} \\ LCL_j &= \bar{X}_j + (-t_{crit}(\alpha, n_j - 1) + ak_{3j})S_j\sqrt{1 + 1/n_j} \end{aligned} \quad (3)$$

10. For one sided control limits $\alpha = \alpha_{ind}$. For two sided control limits $\alpha = \alpha_{ind}/2$.

11. Some of the control limits are considered provisional. This occurs when the number of uncensored points is less than 10 and less than the critical value of the Tukey test. This will be discussed in detail in ¶ 8.2.

8.1.3 *Calculations on Test Data* — When test data is available the STC limits calculated on the reference data are applied to determine which if any values are OOC. A value from sample i and characteristic j , x_{ij} , is OOC if:

$$x_{ij} > UCL_j \text{ or } x_{ij} < LCL_j \quad (4)$$

8.1.4 The test data can be used to calculate new control limits using the same procedure in ¶ 8.1.2. The new control limits can be tested to see if they are statistically or practically different from the older limits from the reference data. How that is done is the subject of ¶ 8.2.

8.2 *Annual Review Process for STC Limits* — Once a supplier's STC limits have been in effect for a year, and upon each subsequent year, the test data is used to calculate an alternate set of STC limits. These are then tested against the current STC limits to determine if any of the limits need to be changed. There are two sets of tests. One set tests for statistically significant differences between the current and the alternate limits. The second tests for significant practical differences between the two limits. A current limit is changed to the alternate limit only if both the statistical and the practical tests indicate a significant difference. This procedure is followed for each characteristic individually. ¶ 8.2.1 describes the statistical tests. ¶ 8.2.2 describes the test for a difference that is of practical significance. Also, in ¶ 8.2.1.15 the conditions for a STC limit to be provisional are precisely defined.

8.2.1 *Tests for Statistical Significance* — Two nonparametric (NP) tests are used for this purpose: the 90'th percentile test and Tukey's Quick test (or simply Tukey's test). The 90'th percentile test is more powerful than Tukey's test. The later, however, has a wider range of applicability. The logic is to first apply the 90'th percentile test. If this is inconclusive as per ¶ 8.2.1.16 then apply Tukey's test. The 90'th percentile test is described in ¶ 8.2.1.1. Tukey's is described in ¶ 8.2.1.15. The logic that applies to determining which test to use is described in ¶ 8.2.1.16.

8.2.1.1 *90'th Percentile Test* — If an upper control limit is required the first step is to determine the 90'th percentile values for the reference and test sets. These are determined as follows (for the j 'th characteristic).

8.2.1.2 Sort the data from lowest to highest:

Let $pt90 = 0.9 \times (n_j + 1)$

Let $ipt90$ = the integer part of $pt90$

Let $fpt90$ = the fractional part of $pt90$

Let $ipt91 = ipt90 + 1$

Let $J90$ = the value of characteristic J with rank $ipt90$

Let $J91$ = the value of characteristic J with rank $ipt91$

8.2.1.3 Then, the 90'th percentile, $J_{90\%}$, is given by:

$$J_{90\%} = J90 + (J91 - J90) \times fpt90 \quad (5)$$

8.2.1.4 If a lower control limit is required then the 10'th percentile from the reference and test sets must also be determined. This is shown below.

8.2.1.5 Sort the data from lowest to highest:

Let $pt10 = 0.1 \times (n_j + 1)$

Let $ipt10$ = the integer part of $pt10$

Let $fpt10$ = the fractional part of $pt10$

Let $ipt11 = ipt10 + 1$

Let $J10$ = be the value of characteristic J with rank $ipt10$

Let $J11$ = be the value of characteristic J with rank $ipt11$

8.2.1.6 Then, the 10'th percentile, $J_{10\%}$, is given by:

$$J_{10\%} = J10 + (J11 - J10) \times fpt10 \quad (6)$$

8.2.1.7 A 90'th percentile value is said to be clean if there exists at least one non-censored value, x_h , such that $J_{90\%} \geq x_h$. Otherwise, the calculated value for $J_{90\%}$ will be the MDL. In this case the MDL is an upper bound on the actual $J_{90\%}$. Likewise, a 10'th percentile value is clean if there exists at least one non-censored value, x_k such that $J_{10\%} \geq x_k$. Otherwise, the MDL is an upper bound on $J_{10\%}$.

8.2.1.8 The test is performed as follows. For an upper control limit determine which set has the lowest 90'th percentile. Count the number of values in the other set that are greater than the lower 90'th percentile. If the count is equal to or greater than a critical value then the two STC limits are deemed to be statistically significantly different. For a lower control limit determine the set that has the largest 10'th percentile. Count the number of values in the other set that are lower than the larger 10'th percentile. If the count is equal to or greater than a critical value then the two STC limits are deemed to be statistically significantly different.

8.2.1.9 For upper control limits the critical values are determined as follows for the case where the 90'th percentile for the test set is greater than the reference. If the situation is reversed, then interchange ntest and nref:

Let $n3 = n_{test} - 1$

Let $S = (0.9 \times 0.1/n_{ref})^{1/2}$

Let $p3 = 0.1 + 2.326 \times S$

8.2.1.10 Next, find the value of i starting at $i=0$ such that the cumulative binomial distribution, $Bn(i, n3, p3)$, first has a value greater than 0.943. The cumulative binomial distribution for i from 0 to r is given by:

$$Bn(i, n3, p3) = \sum_{i=0}^r \frac{n3!}{i! \times (n3 - i)!} p3^i (1 - p3)^{n3-i} \quad (7)$$

where $x! = 1 \times 2 \times \dots \times (x-1) \times x$ and $0! = 1$

The critical value is then $i + 1$.

8.2.1.11 Some sample critical values for the 90'th percentile test for the case where $n_{ref} = n_{test} = n$ are shown below:

n	Critical Value
100	24
110	25
200	39
400	66

8.2.1.12 The 90'th percentile test as defined above has an individual Type I error of at most 1%.

8.2.1.13 For a lower control limit if the 10'th percentile for the test is greater than the reference then:

Let $n3 = n_{ref} - 1$

Let $S = (0.9 \times 0.1/n_{test})^{1/2}$

Let $p3 = 0.1 + 2.326 \times S$

8.2.1.14 If the situation is reversed then interchange ntest and nref. The rest of the calculations to determine the critical values is the same as for the upper control limit case.

8.2.1.15 *Tukey's Test* — For an upper control limit identify the maximum values in both the reference and test sets. If at least one value in a set is uncensored then the maximum is said to be clean. Otherwise, the maximum is calculated to be the MDL, which is really an upper bound on the maximum. Tukey's test is not applied to lower control limits. This is because if Tukey's can be applied then so can the 90'th percentile test. Since the latter is the more powerful of the two only use the 90'th percentile test for lower control limits.

8.2.1.15.1 The test is run as follows. Determine which set has the smallest maximum. Then, count the number of points in the other set that are greater than that value. If it is greater than or equal to a critical value then the two STC limits are deemed to be statistically significantly different.

8.2.1.15.2 The critical values for the Tukey test are calculated for characteristic j as follows when the maximum for the reference set greater than that of the test set.

Let $critp = 0.99 \times nref / (nref + ntest)$

8.2.1.15.3 Iterate through the following loop until $p3$ is greater than $pcrit$.

$p1 = 1$

$p3 = 0$

$i = -1$

do until $p3 > pcrit$

$i = i + 1$

$p1 = p1 \times (nref - i) / (nref + ntest - i)$

$p3 = p3 + p1 \times ntest / (nref + ntest - i - 1)$

loop

8.2.1.15.4 Increment i by 1 to find the smallest i such that $p3 > critp$. Then the critical value is $i + 2$. If the maximum of the test set is greater than the reference set then switch $nref$ and $ntest$ in the above calculations.

8.2.1.15.5 The following procedure shows how provisional limits are handled at the yearly review. Recall that provisional limits are always changed at this time. First, some terms are defined for each property:

Test set = latest years' worth of data.

C_{Test} = number of uncensored values in the test set.

C_{Ref} = number of uncensored values in the reference set.

TCV = Tukey's critical value for the Test and Reference sets.

8.2.1.15.6 For the first year (no prior reference set exists):

1. If $C_{Test} < 10$ then the STC limits are provisional and the test set becomes the reference set.
2. If $C_{Test} \geq 10$ then the STC limits are nonprovisional and the test set becomes the reference set.

8.2.1.15.7 After the first year if the prior year's STC was provisional then proceed as follows at the annual review.

1. If $C_{Test} \geq 10$ and $\geq TCV$ then the STC limits based on the test data are used and the test data becomes the reference data.
2. If $C_{Test} < 10$ or $< TCV$ then the new reference set becomes the old reference set with the test data set added on.
3. If $C_{Ref}(\text{new}) \geq 10$ then the STC limits based on the new reference set are used and are nonprovisional.
4. If $C_{Ref}(\text{new}) < 10$ then the STC limits based on the new reference set are used and are provisional.

8.2.1.16 *The Procedure for Applying the NP Tests*

8.2.1.16.1 For an upper control limit proceed as follows:

1. If both sets have clean values for the 90'th percentiles then apply the 90'th percentile test. If the count is equal to or greater than the critical value then the two sets are deemed to be statistically significantly different. In that case proceed to the practical significance test. Otherwise the reference control limits are deemed to be unchanged.
2. If only one set has a clean value for the 90'th percentile then apply the 90'th percentile test. If the count is equal to or greater than the critical value then the two sets are deemed to be statistically significantly different. In that case proceed to the practical significance test. Otherwise the test is inconclusive; proceed to step 3.

3. If both sets have clean values for the maximums then apply Tukey's test. If the count is equal to or greater than the critical value then the two sets are deemed to be statistically significantly different. In that case proceed to the practical significance test. Otherwise the reference control limits are deemed to be unchanged.
4. If only one set has a clean value for the maximum then apply the Tukey test. If the count is equal to or greater than the critical value then the two sets are deemed to be statistically significantly different. In that case proceed to the practical significance test. Otherwise the test is inconclusive and the reference control limits are deemed to be unchanged.

8.2.1.16.2 For a lower control limit proceed as follows:

1. If at least one of the sets has a clean value for the 10'th percentile then apply the 90'th percentile test. If the count is equal to or greater than the critical value then the two sets are deemed to be statistically significantly different. In that case proceed to the test for practical significance. Otherwise the reference control limits are deemed to be unchanged.
2. If neither set has a clean value for the 10'th percentile then the 90'th percentile test cannot be applied. In this case the STC limits are deemed to be unchanged.

8.2.2 *Test for Practically Significant Differences* — In order for control limits to be changed at the yearly review they must be both statistically and practically significantly different. This section explains how to test for a practically significant difference. The critical values are calculated using the reference set data. For an upper control limit the critical value, Wu, is:

$$Wu = (t_{crit} + ak_3)S(1 + 1/n_{ref})^{1/2} \quad (8)$$

For a lower control limit the critical value, Wl, is:

$$Wl = abs(-t_{crit} + ak_3)S(1 + 1/n_{ref})^{1/2} \quad (9)$$

8.2.3 For an upper control limit the difference between the reference and test values are deemed to be practically significantly different if:

$$Abs(UCL_{Ref} - UCL_{Test}) > Wu/3 \quad (10)$$

For a lower control limit the difference between the reference and test values are deemed to be practically significantly different if:

$$Abs(LCL_{Ref} - LCL_{Test}) > Wl/3 \quad (11)$$

8.2.4 After the yearly review the reference set is updated. The new reference set consists of the values for the parameters from the previous reference set that were not changed plus the values from the test set for the parameters whose STC limits did change.

8.3 *Example* — A complete set of calculations will be run through on a reference and test set each containing analytical results from 50 samples. It is recommended that the minimum sample size be 100. However, in order to keep the manipulations of the data tractable a smaller sample size will be used. There are 5 characteristics measured per sample. This sets the individual Type I error for each characteristic at:

$$\alpha_{Ind} = 1 - 0.99^{1/5} = 0.002008 \quad (12)$$

8.3.1 The MDL's, MDL designator strings and which control limits are to be calculated are shown below.

	A	B	C	D	E
MDL	0.01	0.01	1	9	1
MDL designator string	ND	ND	ND	ND	ND
UCL? (Y for yes)	Y	Y	Y	Y	Y
LCL? (Y for yes)		Y			

8.3.2 The reference data is shown below.

<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>
3.26	80.45	ND	ND	ND
4.5		ND	ND	ND
2.02	78.96	ND	9.31	ND
2.98	80.04	3.57	ND	ND
4.22		ND	ND	ND
5.38		3.91	9.11	ND
0.75	80.41	3.06	ND	ND
0.86	79.17	ND	ND	ND
0.09	80.52	1.71	ND	ND
0.71	79.29	ND	ND	ND
1.42	80.7	4.09	ND	ND
1.45		1.92	ND	ND
0.75	80.5	1.87	ND	ND
3.56	78.37	ND	ND	ND
0.9	78.23	ND	ND	ND
1.77	79.63	3.73	ND	ND
0.14	80.46	2.65	ND	ND
0.48	78.32	2.46	ND	ND
0.58	81.71	ND	ND	ND
1.89	80.34	ND	ND	ND
1.06	80.07	ND	ND	ND
0.82	79.02	3.47	ND	ND
0.95	80.06	2.87	ND	ND
0.21	79.87	ND	ND	ND
3.14	80.49	ND	ND	ND
0.58	79.6	ND	ND	ND
2.13	80.12	ND	ND	ND
4.62	81.8	ND	ND	ND
1.85	79.89	2.21	ND	ND
2.63	80.98	ND	ND	ND
1.54	79.74	ND	ND	ND
6.76	79.47	2.28	ND	ND
1.37	79.43	ND	ND	ND
1.43	79.78	3.4	ND	ND
0.87	81.22	4.86	13.5	ND
0.78	78.23	ND	ND	ND
1.56	80.97	2.56	ND	ND
0.68	79.42	ND	ND	ND
3.47	79.36	ND	ND	ND
2.35	79.73	ND	ND	ND