EWPAA Guidance for Compliance to AS/NZS 1859 & 1860

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Contents

```r
install.packages("bookdown")
# or the development version
# devtools::install_github("rstudio/bookdown")
```

Chapter 1

Scope

For external control, if required, methods for the initial inspection of a factory and initial type testing of a product, and for the surveillance of the factory production control, are given. In the factory production control small test pieces are used. The statistics of evaluation is based on normal distribution.

Chapter 2

Normative references

Chapter 3

Terms and definitions

For the purpose of this document, the terms and definitions given in EN 326-1 :1994 and the following apply.

3.1 Acceptable quality level

AQL

maximum percentage of non-conforming panels that for the purpose of sampling inspection can be considered satisfactory as a process average

3.2 At Random

sampling of panels in such a way that each panel of the inspection lot has an equal chance of being selected, and cutting of test pieces from a single panel in such a way that each part of the panel has an equal chance of being selected as a test piece

3.3 Batch

panels of the same product type produced in a shift or continuous run

3.4 Defective

panel which does not meet the required specification limit of the relevant characteristic

3.5 Inspection body

body which is responsible for external control

3.6 Inspection by attributes

inspection whereby either the unit of product is classified simply as conforming or non-conforming, or the number of nonconformities in the unit of product is counted, with respect to a given requirement or set of requirements

3.7 Inspection by variables

inspection whereby the conformity of a panel characteristic can be measured on a continuous scale

3.8 Inspection lot (for factory control)

portion of production which is presented for sampling and inspection, consisting of panels of the same type, normally within the same thickness range, coming from the same production line and manufactured under essentially the same conditions

3.9 inspection lot size N

number of panels in one inspection lot

3.10 lower specification limit L

Value required by the AS?NZS specification that 95 % of the panels should have values greater than or equal to

3.11 Panel

piece of wood-based sheet material large enough to permit the cutting of test pieces

3.12 Percent defective

extent of non-conformity of a panel product expressed by percentage defective panels in the total number of panels inspected

3.13 Production site

single production line

3.14 Product type

panel type, irrespective of thickness, as defined in the relevant AS/NZS specification

3.15 Reference population

wood-based panels for which the relationship between test values is relevant

3.16 Quality characteristic

characteristic that is essential for the evaluation of a product or product type in accordance with a relevant AS/NZS specification

3.17 Sample

collection of panels which are drawn from an inspection lot

NOTE Unless otherwise agreed, the panels of the sample are drawn at random.

3.18 Test piece

piece of panel cut to the size required for testing a specific characteristic

3.19 Test value x_{ij}

single value or measurement of a specific characteristic obtained from a test piece

3.20 Thickness range

panels with a thickness for which the same specification limits are valid according to the relevant AS/NZS specification

3.21 Upper specification limit U

value required by the AS/NZS specification that 95 % of the panels should have values lower than or equal to

3.22 Variable

test value or measurement which can be measured on a continuous scale

Chapter 4

Symbols and indices

4.1 Letter symbols (see also EN 326-1:1994)

Ac Acceptance number

AQL Acceptable quality level

a Linear correlation constant

b Linear correlation factor

c_{conv} Conversion factor

F Statistical factor

L Lower specification limit

In Number of test pieces cut from each single panel of the sample, in either test direction

n Sample size (number of panels)

N Number of panels in one inspection lot, i.e. inspection lot size

r Correlation coefficient; coefficient of linear regression

Re Rejection number

$s_{\bar{x}}$ Estimate of the standard deviation of a characteristic between panel means $\bar{x}_j$

$s_{\delta\bar{x}}$ Estimate of the standard deviation of the relative differences of the panel means δx_j

$s_{\Delta\bar{x}}$ Standard deviation between panel differences

s_{w_j}

Estimate of the standard deviation of a characteristic within a panel j of the sample

$s^2_{\bar{x_j},alt}$

Variance of panel means of the alternative testing procedure

$s^2_{\bar{x_j},ref}$

Variance of panel means of the reference standard test

t

Statistical factor, see Table 1

U

U Upper specification limit

δ

t5 Relative difference

Δ

Absolute difference

$V_{w,j}$

Coefficient of variation within a panel j of the sample

$V_{\bar{x}}$

Coefficient of variation between the panel means $\bar{x}_j$

φ_{conv}

Linear conversion function

$X_{i,j}$

Single test value or measurement

$\bar{X}_j$

Mean value of the m test values (or measurements) obtained from a single panel j

$\bar{\bar{x}}_n$

Grand mean of n single panel mean values

$x_{\bar{j},alt}$

Test value of the population of the alternative test procedure

$x_{\bar{j},ref}$

Test value of the population of the reference standard test method

$\Delta\bar{x}$

Test value of the difference between the alternative test procedure and the reference standard test method

4.2 Indices (see also EN 326-1 : 1994)

alt

Related to alternative testing procedure

attr

Related to inspection by attributes

conv

Related to conversion function

cu

Cumulative value

d

Related to double sample plan

ext

Test results from the external control

i

Serial test piece number within a panel (i = 1, 2, ..., m)

ITT

Test results related to initial type testing

j

Test panel identification number within a sample (j = 1, 2, ... , 11)

m

Related to number of test pieces of a panel

n

Related to the number of panels of a sample

ref

Related to reference standard test

si

Related to single sampling plan

w

Characteristic within a panel

Chapter 5

Initial type testing (ITT)

5.1 General

Initial type testing shall be performed at the beginning of the production of a new product type. Initial type testing shall be performed according to this standard where demonstration of compliance is required except where tests were previously preformed in accordance with the provisions of these standards (i.e. same product, same characteristic(s), test method, sampling procedure, system of conformity, etc.). In this case previous data can be used.

5.2 Initial type testing by variables

5.2.1 General

In general, the requirements of the panel properties are fulfilled if at least 95 % of the panel means for each characteristic are above the lower L or below the upper U specification limit respectively. NOTE For examples, see Annex A.

Where non-standard test methods are utilised the value of the test results should be adjusted by a factor based on linear correlations between the two methods as outlined in Appendix E of EN 326-2:2010.

5.2.2 Sampling of panels

The initial type testing shall comprise panels from not less than three production shifts. The minimum number of panels in the initial type testing sample n_{ITT} of a factory production is 12 panels per product type with at least two panels from each production line. The minimum number of panels may be reduced to 6, if the product properties can be documented from internal records of at least 12 tested panels in the start up period.

The number of test pieces selected for each test shall be in accordance with AS/NZS…… or with agreement from the certifying body.

5.2.3 Evaluation

5.2.3.1 Evaluation by using the test results directly

5.2.3.1.1 Compliance of the ITT sample

5.2.3.2 Evaluation by using the test results directly

5.2.3.2.1 Compliance of the ITT sample

Calculate the mean value $\bar{x}_{ITT,j}$ for each panel, the grand mean value $\bar{\bar{x}}_{ITT}$ the panels and, the standard deviation between the panels $S_{\bar{x},ITT}$ for each relevant characteristic in accordance with Equations (1) and (2):

$$\bar{\bar{x}}_{ITT} = \frac{\sum_{j=1}^{j=n_{ITT}} \bar{x}_{ITT,j}}{n_{ITT}}$$

(1)

and

$$s_{\bar{x},ITT} = \sqrt{\frac{\sum_{j=1}^{j=n_{ITT}} (\bar{x}_{ITT,j} - \bar{\bar{x}})^2}{(n_{ITT} - 1)}}$$

(2)

To fulfil the specification requirement the lower 5 % value or upper 95 % value shall be higher than or equal to the lower specification limit L or lower than or equal to the upper specification limit V respectively, when calculated according to the Equation (3) or (4), respectively:

$$L_{5\%} = \bar{\bar{x}} - k_{n_{ITT}} \times s_{\bar{x},ITT}$$

(3) or

$$U_{95\%} = \bar{\bar{x}}_{ITT} + k_{n_{ITT}} \times s_{\bar{x},ITT}$$

(4) where

$k_{n_{ITT}}$ shall be taken from Table 1 with estimated standard deviation with acceptance probability at the 5th percentile set to 0.5.

~~NOTE The table values correspond to a 95 % confidence limit, single-sided case, in accordance with ISO 2602:1980.

Sample Size	Estimated Std.Dev
	Acceptance Prob
	0.50
12	1.691
13	1.687
14	1.684
15	1.681
16	1.679
17	1.676
18	1.674
19	1.673
20	1.671
21	1.670

Sample Size	Estimated Std.Dev
22	1.669
23	1.668
24	1.667
25	1.666
26	1.665
27	1.664
28	1.663
29	1.663
30	1.662

~~NOTE The table values are based on the non-central t distribution and assume only one round of testing is conducted.

5.2.3.2.2 Variability within panels of the ITT sample

The mean standard deviation within panels of the ITT sample $\bar{S}_{w,ITT}$, where "w" is indicating "within" panels, shall be derived from the standard deviation within each panel S_{W_J} of the sample [equation (13)] according to Equation (5):

$$\bar{S}_{w,ITT} = \sqrt{\frac{\sum_{j=1}^{j=n_{ITT}} s_{w,ITT}^2}{n_{ITT}}}$$

(5)

5.2.3.3 Evaluation by using relative test results

If the sample consists of panels which are covered by different lower L and/or upper U specification limits (for example by combining different thickness ranges of the same standard type of panel product), the evaluation shall be carried out on test results related to each specification limit as follows:

Calculate for each individual panel the relative mean δx relevant to either the lower L or upper U specification limit according to Equation (6) or (7), respectively:

$$\delta x_{j,L} = \frac{\bar{x}_j - L}{L}$$

(6)

or

$$\delta x_{j,U} = \frac{\bar{x}_j - U}{U}$$

(7)

Calculate the grand mean of the relative differences of all panels of the inspection sample according to:

$$\delta \bar{x} = \frac{\sum_1^n \delta \bar{x}_j}{x}$$

(8)

and the standard deviation $s_{\delta \bar{x}}$ of the relative differences between the panel means according to:

$$s_{\delta\bar{x}} = \sqrt{\frac{\sum_1^n (\delta\bar{x} - \bar{\delta\bar{x}})^2}{n-1}}$$

(9)

To fulfil the specification requirement the lower 5 % value or the upper 95 % value, respectively, shall be equal to or greater than zero for characteristics with a lower specification limit L or equal to or less than zero for characteristics with an upper specification limit U when calculated according to Equation (10) or (11), respectively:

$$L_{\delta,5\%} = \bar{\delta\bar{x}} - k_n \times s_{\bar{\delta\bar{x}}}$$

(10)

or

$$U_{\delta,95\%} = \bar{\delta\bar{x}} - k_n \times s_{\bar{\delta\bar{x}}}$$

(11)

Chapter 6

Factory production control

6.1 General

The manufacturer shall control in each separate production line those characteristics of panels which are required by AS/NZS? with further reference to other relevant specific product standards.

In cases where the manufacturer chooses to claim panel characteristics higher than the specification levels of AS/NZS?, with further reference to relevant specific product standards, the factory production control shall be carried out according to the characteristic levels claimed.

Samples shall be drawn from each product type and thickness range. The production may be further subdivided, for example, by thickness.

Procedures alternative to the standardised procedure (for example, unconditioned or in-line testing) may be used for the determination of panel characteristics, provided that a statistically significant relationship can be established between the specified characteristic and the measured characteristic. See de3tails in section 5.2.1/

Systematic differences arising from the use of alternative procedures shall be taken into account by individual correction factors which shall be determined by experiment. The correction factors shall be verified from time to time.

6.2 Sampling

6.2.1 General

Sampling shall be carried out in accordance with the relevant AS/NZS specification.

6.2.2 Sample size

The following tables give the required sample size (number of panels per batch) that are to be tested so as to achieve a desired probability of acceptance with a specified quality level (proportion of batch means above the lower or upper specification limit).

6.2.2.1 Estimated sd, No retesting, Acc Prob=0.5

	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.96	5	15							
0.97	2	4	8	13	21				
0.98	2	3	4	5	8	12	17	25	
0.99	2	2	2	3	4	5	7	10	16
0.995	2	2	2	2	3	4	5	6	9

6.2.2.2 Rolling sd, No retesting, Acc Prob=0.5

	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.96	9	15							
0.97	5	6	8	11	18				
0.98	3	4	4	5	6	9	12	21	
0.99	3	3	3	3	4	4	5	7	10
0.995	2	2	3	3	3	3	3	4	6

6.2.2.3 Known sd, No retesting, Acc Prob=0.5

	0.55	0.6	0.65	0.7	0.75	0.8	0.85	0.9	0.95
0.96	2	6	14	25					
0.97	1	2	3	5	9	13	20	30	
0.98	1	1	1	2	3	5	7	10	17
0.99	1	1	1	1	1	2	3	4	6
0.995	1	1	1	1	1	1	2	2	4

The current quality level can be calculated as

$$\Phi\left(\frac{\bar{x} - L}{\sigma_B}\right)$$

where $\Phi()$ is the cumulative Normal distribition, $\bar{\bar{x}}$ is the process mean, L is the Lower Specification limit, and σ_B is the between panel standard deviation.

Samples should be selected at random. This can be achieved from a continuous process by randomising the sample cutting pattern. In a multi-daylight process daylight selection and location within the daylight/board should be randomised.

6.3 Control of production

6.3.1 General

For assessing compliance of a product by variables the following methods shall be used: Factory production control by variables for batch production according to 6.3.2, or Internal records of an established product according to 6.3.4.

6.3.2 Factory production control by variables for batch production

In order to evaluate the compliance of the last batch production with the requirements of AS/NZS standards, with further reference to other relevant specific product standards, the manufacturer shall use the following procedure unless alternative procedures are adopted giving at least the same level of confidence.

6.3.2.1 Batch factory production control where no retesting is carried out

To establish the conformity of the panels with the requirements, estimates shall be calculated of the lower ${}_1L_x$, or upper ${}_1U_x$ confidence limit, respectively, for the production period, according to Equations (17) and (18), respectively:

$$ {}_1L_x = \bar{x} - k_n \times s_{\bar{x}} $$

(17)

or

$$ {}_1U_x = \bar{x} - k_n \times s_{\bar{x}} $$

(18)

where n is the number of panels sampled.

The k_n-values in relation to the number panels sampled are given in the table below.

If ${}_1L_x$ is equal to or greater than the lower specification limit L, or if ${}_1U_x$ is equal to or less than the upper specification limit U, respectively, the panel characteristics shall be considered to be in conformity with the requirements. If the requirements are not met, the panels of the respective production period shall be down-graded.

Sample Size	Estimated Std.Dev	Rolling Std. Dev	Known Std. Dev
	Acceptance Prob 0.50	Acceptance Prob 0.50	Acceptance Prob 0.50
2	2.339	1.660	1.645
3	1.939	1.660	1.645
4	1.830	1.660	1.645
5	1.779	1.660	1.645
6	1.751	1.660	1.645
7	1.732	1.660	1.645
8	1.719	1.661	1.645
9	1.709	1.661	1.645
10	1.702	1.661	1.645
11	1.696	1.661	1.645
12	1.691	1.661	1.645
13	1.687	1.661	1.645
14	1.684	1.661	1.645
15	1.681	1.661	1.645
16	1.679	1.661	1.645
17	1.676	1.661	1.645
18	1.674	1.661	1.645
19	1.673	1.662	1.645
20	1.671	1.662	1.645
21	1.670	1.662	1.645
22	1.669	1.662	1.645

Sample Size	Estimated Std.Dev	Rolling Std. Dev	Known Std. Dev
23	1.668	1.662	1.645
24	1.667	1.662	1.645
25	1.666	1.662	1.645
26	1.665	1.662	1.645
27	1.664	1.662	1.645
28	1.663	1.662	1.645
29	1.663	1.662	1.645
30	1.662	1.662	1.645

~~NOTE The table values are based on the non-central t distribution and assume only one round of testing is conducted.

6.4 Batch factory production control where retesting is allowed

To establish the conformity of the panels with the requirements, estimates shall be calculated of the lower ${}_1L_x$, or upper ${}_1U_x$ confidence limit, respectively, for the production period, according to Equations @ref{eq:lower} and (18), respectively:

$$ {}_1L_x = \bar{x} - k_n \times s_{\bar{x}} \tag{6.1} $$

or

$$ {}_1U_x = \bar{x} - k_n \times s_{\bar{x}} $$

(18)

where: the n is the number of panels sampled.

The k_n-values in relation to the number panels sampled are given in the table below.

If ${}_1L_x$ is equal to or greater than the lower specification limit L, or if ${}_1U_x$ is equal to or less than the upper specification limit U, respectively, the panel characteristics shall be considered to be in conformity with the requirements.

If the requirements are not met, a further set of panels shall be sampled with the same sample size. In this case the grand mean values $\bar{\bar{x}}_{1,2}$, shall be calculated according to Equation (21):

Note: If a data point from a sample is suspected to be an outlier a Grubbs test should be carried out and if the result of the test identifies the data point as an outlier it should be discarded and a new sample taken.

Sample Size	Estimated Std.Dev	Rolling Std. Dev	Known Std. Dev
	Acceptance Prob	Acceptance Prob	Acceptance Prob
	0.50	0.50	0.50
2	2.731	2.499	1.824
3	2.195	2.117	1.791
4	2.038	1.992	1.772
5	1.960	1.927	1.758
6	1.913	1.886	1.748
7	1.880	1.857	1.741
8	1.857	1.836	1.735
9	1.839	1.819	1.729

Sample Size	Estimated Std.Dev	Rolling Std. Dev	Known Std. Dev
10	1.824	1.805	1.725
11	1.812	1.794	1.721
12	1.802	1.784	1.718
13	1.794	1.776	1.715
14	1.786	1.769	1.713
15	1.780	1.763	1.710
16	1.774	1.757	1.708
17	1.769	1.752	1.706
18	1.765	1.747	1.705
19	1.761	1.743	1.703
20	1.757	1.739	1.702
21	1.753	1.736	1.700
22	1.750	1.732	1.699
23	1.747	1.729	1.698
24	1.745	1.727	1.697
25	1.742	1.724	1.696
26	1.740	1.721	1.695
27	1.738	1.719	1.694
28	1.736	1.717	1.693
29	1.734	1.715	1.692
30	1.732	1.713	1.691

~~NOTE The table values are based on the non-central t distribution and assume two rounds of testing are allowed.

6.4.0.1 Factory production control using a rolling standard deviation and continuous monitoring

In the previous tables, the testing is performed at the end of a production run. In most cases it would be desirable to sample and test during the production run. In that case, different k factors can be used. At the beginning of the run, the planned sample size needs to be specified. As regular intervals during the run, a panel is sampled and tested. To establish the conformity of the panels with the requirements, estimates shall be calculated of the lower ${}_1L_x$, or upper ${}_1U_x$ confidence limit, respectively, for the immediately preceeding production period, respectively:

$$ {}_1L_x = \bar{x} - k_p \times \bar{s}_r $$

or

$$ {}_1U_x = \bar{x} - k_p \times \bar{s}_r $$

where: the p is the number of panels which are planned to be sampled during the run, and $\bar{s}_r$ is the rolling standard deviation based on the last 30 panel means. If the criteria above are satisfied (with retesting if allowed), then production can continue, while if the criteria are not satisfied, then the immediately preceding production should be downgraded.

Note: If a data point from a sample is suspected to be an outlier a Grubbs test should be carried out and if the result of the test identifies the data point as an outlier it should be discarded and a new sample taken.

The k factors are chosen so that the probability of acceptance of the entire run at the 5th percentile is set to 0.5 for all parameters. The k factors are given in the table below. Note that the k factors are negative when retesting is not allowed and the planned sample size is greater than 13 panels when the acceptance probability is 0.5, and the planned sample size is greater than 27 panels when the acceptance probability is 0.25.

Sample Size	No Retesting	Retesting
	Acceptance Prob	Acceptance Prob
	0.50	0.50
1	1.659	2.057
2	1.104	1.543
3	0.828	1.290
4	0.649	1.127
5	0.518	1.009
6	0.415	0.917
7	0.332	0.841
8	0.261	0.778
9	0.200	0.724
10	0.147	0.676
11	0.100	0.634
12	0.057	0.596
13	0.019	0.562
14	-0.017	0.530
15	-0.049	0.501
16	-0.079	0.475
17	-0.107	0.450
18	-0.134	0.427
19	-0.158	0.405
20	-0.181	0.384
21	-0.203	0.365
22	-0.224	0.347
23	-0.243	0.329
24	-0.262	0.313
25	-0.280	0.297
26	-0.297	0.282
27	-0.313	0.268
28	-0.329	0.254
29	-0.349	0.241
30	-0.359	0.228

~~NOTE The table values are based on the non-central t distribution and assume no retesting and two rounds of testing are allowed, respectively.

6.4.0.1.1 Method of updating the rolling standard deviation

There is no need to recalculate the rolling standard deviation based on Equations (1) and (2). Instead, a simple updating formula can be used. Assume that the last 30 panel means are, in production order, given by $x_0, x_1, \ldots, x_{29}$, with grand mean $\bar{\bar{x}}_O$ and standard deviation s_O. When an additional panel mean, x_{30} is available, the first panel mean, x_0 is discarded and the new panel mean, x_{30} is added to the calculations to give a new grand mean $\bar{\bar{x}}_N$ with standard deviation s_N. This can be calculated using Equations (1) and (2), or by the updating formalae

$$\bar{\bar{x}}_N = \bar{\bar{x}}_O + \frac{x_{30} - x_0}{30}$$

and

$$s_N = \sqrt{s_O^2 + \frac{(x_{30} - x_0)(x_{30} - \bar{\bar{x}}_N + x_0 - \bar{\bar{x}}_O)}{29}}.$$

6.4.0.2 Metod of establishing and monitoring the known standard deviation

Monitoring of the statistical control of the standard deviation is desirable. If the process is in control then the known standard deviation k values can be used.

For each bath the grand mean of the panel means, $\bar{\bar{x}}$ should be calculated, as well as the standard deviation of the of the panel means, $s_{\bar{x}}$.

An overall average standard deviation should be calculated. This should be the square root of the average squared standard deviation of the panel means, weighted by the number of sampled panels in the batch minus 1, i.e.

$$\bar{s} = \sqrt{\frac{\sum((n_b - 1)s_{\bar{x}}^2}{\sum((n_b - 1)}}.$$

At least 30-40 batches should be included in the calculation of $\bar{s}$ and the value should be reviewed/updated from time to time (e.g. monthly).

To monitor the standard deviation, an s control chart should be used. The standard deviation of the panel means should be plotted against the batch number. The lower control limit is given by

$$\text{LCL} = c_{n_b} \times \bar{s},$$

while the upper control limit is given by

$$\text{UCL} = d_{n_b} \times \bar{s},$$

with tables of c_{n_b} and d_{n_b} are given below, where n_b is the number of panels sampled per batch.

n_b	c_{n_b}	d_{n_b}
2	0.002	3.205
3	0.037	2.571
4	0.1	2.283
5	0.163	2.11
6	0.218	1.991
7	0.266	1.903
8	0.306	1.835
9	0.341	1.78
10	0.371	1.735
11	0.398	1.697
12	0.422	1.664
13	0.443	1.635
14	0.461	1.609
15	0.479	1.587
16	0.494	1.566
17	0.508	1.548
18	0.522	1.531
19	0.534	1.516
20	0.545	1.502
21	0.555	1.489
22	0.565	1.477
23	0.574	1.466
24	0.583	1.456

n_b	c_{n_b}	d_{n_b}
25	0.591	1.446
26	0.599	1.437
27	0.606	1.428
28	0.613	1.42
29	0.619	1.412
30	0.625	1.405

Note that the LCL and UCL depend on the number of panels sampled per batch and if these vary then so do the control limits. Also note that the control limits have nothing to do with the specification limits.

Values of the standard deviation outside the limits indicate that the process is out of statistical control and adjustments to the process must be made.

6.4.0.3 Standardised Control Chart

It may be desirable to standardize the control chart for ease of reviwing it. This can be done in the following way:

If $G_{n_b-1}(x)$ is the cumulative distribution of the chi-square distribution with $n_b - 1$ degrees of freedom, and $\Phi^{-1}(p)$ is the inverse Normal distribution, then a standardised control chart can be made by transforming the standard deviations using the transformation

$$h(s) = \Phi^{-1}\left(G_{n_b-1}\left(\frac{(n_b-1)s_b^2}{\bar{s}^2}\right)\right)$$

with $LCL = -3$ and $UCL = 3$.

6.4.0.4 Setting a process mean value

It may be useful to establish target values for the process mean to aid in factory process control. For an individual factory the targeted process mean value of a property shall be calculated in accordance with the following equations:

$$PV_L = L + K_T\sigma_B$$

$$PV_U = U - K_T\sigma_B$$

where σ_B is the standard deviation between panel means and K_T depends on the target quality as follows:

Target Quality	K_T
0.96	1.751
0.97	1.881
0.98	2.053
0.99	2.326
0.995	2.576

Chapter 7

Annex A

(informative)

7.1 Example 1, Initial type testing, Estimated Standard Deviation.

Single sampling with 16 mm IB, Lower Specification is 0.3 Mpa. 12 panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
0.3	0.16	0.24	0.32	0.255
0.36	0.5	0.37	0.41	0.41
0.41	0.48	0.46	0.45	0.45
0.39	0.38	0.35	0.41	0.3825
0.52	0.43	0.48	0.46	0.4725
0.43	0.45	0.36	0.43	0.4175
0.38	0.37	0.42	0.28	0.3625
0.44	0.46	0.5	0.48	0.47
0.58	0.58	0.51	0.57	0.56
0.58	0.51	0.52	0.62	0.5575
0.43	0.42	0.41	0.36	0.405
0.53	0.47	0.59	0.5	0.5225

The grand mean is given by 0.439 while the standard deviation between panel means is given by 0.087. The 5% comparison value is then

$$0.439 - 1.691 \times 0.087 = 0.292$$

which is less than 0.30 Mpa, and hence the initital type testing is not achieved.

7.2 Example 2, Initial type testing, Estimated Standard Deviation.

Single sampling with 16 mm IB, Lower Specification is 0.3 Mpa. 12 panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
0.51	0.42	0.51	0.61	0.5125
0.62	0.53	0.62	0.61	0.595
0.62	0.57	0.51	0.5	0.55
0.53	0.41	0.54	0.44	0.48
0.36	0.33	0.35	0.4	0.36
0.66	0.59	0.68	0.69	0.655
0.47	0.55	0.58	0.49	0.5225
0.71	0.72	0.67	0.59	0.6725
0.41	0.5	0.54	0.52	0.4925
0.46	0.41	0.45	0.57	0.4725
0.52	0.66	0.48	0.51	0.5425
0.6	0.58	0.51	0.47	0.54

The grand mean is given by 0.533 while the standard deviation between panel means is given by 0.084. The 5% comparison value is then

$$0.533 - 1.691 \times 0.084 = 0.391$$

which is greater than 0.30 Mpa, and hence the initital type testing is achieved.

7.3 Example 3, Single sampling, Estimated Standard Deviation (Fails).

Single sampling with 18 mm MOR, Lower Specification is 12 Mpa. Three panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
14.1	12.2	13.6	13.9	13.45
15.5	19.6	16.9	19.1	17.78
15.5	16.9	18.9	18.3	17.4

The grand mean is given by

$$\frac{13.45 + 17.775 + 17.4}{3} = 16.208$$

while the standard deviation between panel means is given by

$$\sqrt{\frac{(13.45 - 16.208)^2 + (17.775 - 16.208)^2 + (17.4 - 16.208)^2}{2}} = 2.396.$$

The 5% comparison value is then

$$16.208 - 1.939 \times 2.396 = 11.562$$

which is less than 12 Mpa, and hence the specification limit is not achieved.

7.4 Example 4, Single sampling, Estimated Standard Deviation (Passes).

Single sampling with 18 mm MOR, Lower Specification is 12 Mpa. Three panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
16.5	17.5	15.6	16	16.4
17.7	19	19.9	17	18.4
17.4	18.9	16.1	17.4	17.45

The grand mean is given by

$$\frac{16.4 + 18.4 + 17.45}{3} = 17.417$$

while the standard deviation between panel means is given by

$$\sqrt{\frac{(16.4 - 17.417)^2 + (18.4 - 17.417)^2 + (17.45 - 17.417)^2}{2}} = 1.$$

The 5% comparison value is then

$$17.417 - 1.939 \times 1 = 15.478$$

which is greater than 12 Mpa, and hence the specification limit is achieved.

7.5 Example 5, Single sampling, Known Standard Deviation (Passes).

Single sampling with 18 mm MOR, Lower Specification is 12 Mpa. The long run standard deviation is 1.680. Three panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
16.7	13.4	16.2	14.9	15.3
18.6	17.3	16.9	16.8	17.4
16.9	21.9	18.3	17.7	18.7

The grand mean is given by

$$\frac{15.3 + 17.4 + 18.7}{3} = 17.133$$

The 5% comparison value is then

$$17.133 - 1.645 \times 1.680 = 14.369$$

which is greater than 12 Mpa, and hence the specification limit is achieved.

7.6 Example 6, Single sampling, Known Standard Deviation (Fails).

Single sampling with 18 mm MOR, Lower Specification is 12 Mpa. The long run standard deviation is 1.680. Three panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
18.7	11.5	15.1	14	14.82
11.7	12.8	14.3	14.1	13.23
15.2	15.3	14.9	17.9	15.82

The grand mean is given by

$$\frac{14.825 + 13.225 + 15.825}{3} = 14.625$$

The 5% comparison value is then

$$14.625 - 1.645 \times 1.680 = 11.861$$

which is less than 12 Mpa, and hence the specification limit is not achieved.

7.7 Example 7, Retesting, Estimated Standard Deviation (Passes on first round).

Single sampling with 25 mm IB, Lower Specification is 0.25 Mpa. Five panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
0.69	0.69	0.69	0.69	0.69
0.51	0.51	0.51	0.51	0.51
0.72	0.72	0.72	0.72	0.72
0.51	0.51	0.51	0.51	0.51
0.45	0.45	0.45	0.45	0.45

The grand mean is given by

$$\frac{0.69 + 0.51 + 0.72 + 0.51 + 0.45}{5} = 0.576$$

while the standard deviation between panel means is given by

$$\sqrt{\frac{(0.69 - 0.576)^2 + (0.51 - 0.576)^2 + (0.72 - 0.576)^2 + (0.51 - 0.576)^2 + (0.45 - 0.576)^2}{4}} = 0.121.$$

The 5% comparison value is then

$$0.576 - 1.960 \times 0.121 = 0.273$$

which is greater than 0.25 Mpa, and hence the specification limit is achieved.

7.8 Example 8, Retesting, Estimated Standard Deviation (Fails first round, Passses on second round).

Single sampling with 25 mm IB, Lower Specification is 0.25 Mpa. Five panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
0.39	0.39	0.39	0.39	0.39
0.3	0.3	0.3	0.3	0.3

1	2	3,	4	panel mean
0.42	0.42	0.42	0.42	0.42
0.35	0.35	0.35	0.35	0.35
0.51	0.51	0.51	0.51	0.51

The grand mean is given by

$$\frac{0.39 + 0.3 + 0.42 + 0.35 + 0.51}{5} = 0.394$$

while the standard deviation between panel means is given by

$$\sqrt{\frac{(0.39 - 0.394)^2 + (0.3 - 0.394)^2 + (0.42 - 0.394)^2 + (0.35 - 0.394)^2 + (0.51 - 0.394)^2}{4}} = 0.079.$$

The 5% comparison value is then

$$0.394 - 1.960 \times 0.079 = 0.239$$

which is less than 0.25 Mpa, and hence the specification limit is not achieved. An additional five panels were sampled, with four tests per sample.

1	2	3,	4	panel mean
0.35	0.35	0.35	0.35	0.35
0.44	0.44	0.44	0.44	0.44
0.55	0.55	0.55	0.55	0.55
0.47	0.47	0.47	0.47	0.47
0.39	0.39	0.39	0.39	0.39

The mean of the second set of tests is given by

$$\frac{0.35 + 0.44 + 0.55 + 0.47 + 0.39}{5} = 0.44$$

while the standard deviation of the second set of tests is given by

$$\sqrt{\frac{(0.35 - 0.44)^2 + (0.44 - 0.44)^2 + (0.55 - 0.44)^2 + (0.47 - 0.44)^2 + (0.39 - 0.44)^2}{4}} = 0.077.$$

The new grand mean is therefore given by

$$\frac{0.394 + 0.44}{2} = 0.417$$

while the pooled standard deviation for the two tests is give by

$$\sqrt{\frac{0.006241 + 0.005929}{2}} = 0.078$$

The grand mean is now given by 0.417 while the pooled standard deviation between panel means is given by 0.078. The 5% comparison value is then

$$0.417 - 1.960 \times 0.078 = 0.264$$

which is greater than 0.25 Mpa, and hence the specification limit is achieved.

7.9 Example 9, Retesting, Estimated Standard Deviation (Fails both rounds).

Single sampling with 25 mm IB, Lower Specification is 0.25 Mpa. Five panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
0.35	0.35	0.35	0.35	0.35
0.3	0.3	0.3	0.3	0.3
0.46	0.46	0.46	0.46	0.46
0.53	0.53	0.53	0.53	0.53
0.35	0.35	0.35	0.35	0.35

The grand mean is given by

$$\frac{0.35 + 0.3 + 0.46 + 0.53 + 0.35}{5} = 0.398$$

while the standard deviation between panel means is given by

$$\sqrt{\frac{(0.35 - 0.398)^2 + (0.3 - 0.398)^2 + (0.46 - 0.398)^2 + (0.53 - 0.398)^2 + (0.35 - 0.398)^2}{4}} = 0.094.$$

The 5% comparison value is then

$$0.398 - 1.960 \times 0.094 = 0.214$$

which is less than 0.25 Mpa, and hence the specification limit is not achieved. An additional five panels were sampled, with four tests per sample.

1	2	3,	4	panel mean
0.41	0.41	0.41	0.41	0.41
0.49	0.49	0.49	0.49	0.49
0.29	0.29	0.29	0.29	0.29
0.45	0.45	0.45	0.45	0.45
0.44	0.44	0.44	0.44	0.44

The mean of the second set of tests is given by

$$\frac{0.41 + 0.49 + 0.29 + 0.45 + 0.44}{5} = 0.416$$

while the standard deviation of the second set of tests is given by

$$\sqrt{\frac{(0.41 - 0.416)^2 + (0.49 - 0.416)^2 + (0.29 - 0.416)^2 + (0.45 - 0.416)^2 + (0.44 - 0.416)^2}{4}} = 0.076.$$

The new grand mean is therefore given by

$$\frac{0.398 + 0.416}{2} = 0.407$$

while the pooled standard deviation for the two tests is give by

$$\sqrt{\frac{0.008836 + 0.005776}{2}} = 0.085$$

The grand mean is now given by 0.407 while the pooled standard deviation between panel means is given by 0.085. The 5% comparison value is then

$$0.407 - 1.960 \times 0.085 = 0.24$$

which is less than 0.25 Mpa, and hence the specification limit is not achieved.

7.10 Example 10, Retesting, Known Standard Deviation (Passes on first round).

Double sampling with 12 mm IB, Lower Specification is 0.35 Mpa. The long run standard deviation is 0.085. Five panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
0.66	0.66	0.66	0.66	0.66
0.52	0.52	0.52	0.52	0.52
0.58	0.58	0.58	0.58	0.58
0.82	0.82	0.82	0.82	0.82
0.67	0.67	0.67	0.67	0.67

The grand mean is given by

$$\frac{0.66 + 0.52 + 0.58 + 0.82 + 0.67}{5} = 0.65$$

while the standard deviation between panel means is given by

$$\sqrt{\frac{(0.66 - 0.65)^2 + (0.52 - 0.65)^2 + (0.58 - 0.65)^2 + (0.82 - 0.65)^2 + (0.67 - 0.65)^2}{4}} = 0.113.$$

The 5% comparison value is then

$$0.65 - 1.758 \times 0.113 = 0.621$$

which is greater than 0.35 Mpa, and hence the specification limit is achieved.

7.11 Example 11, Retesting, Known Standard Deviation (Fails first round, Passses on second round).

Double sampling with 12 mm IB, Lower Specification is 0.35 Mpa. The long run standard deviation is 0.085. Five panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
0.48	0.48	0.48	0.48	0.48
0.48	0.48	0.48	0.48	0.48
0.45	0.45	0.45	0.45	0.45
0.51	0.51	0.51	0.51	0.51
0.44	0.44	0.44	0.44	0.44

The grand mean is given by

$$\frac{0.48 + 0.48 + 0.45 + 0.51 + 0.44}{5} = 0.472$$

while the standard deviation between panel means is given by

$$\sqrt{\frac{(0.48-0.472)^2 + (0.48-0.472)^2 + (0.45-0.472)^2 + (0.51-0.472)^2 + (0.44-0.472)^2}{4}} = 0.113.$$

The 5% comparison value is then

$$0.472 - 1.758 \times 0.085 = 0.323$$

which is less than 0.35 Mpa, and hence the specification limit is not achieved. An additional five panels were sampled, with four tests per sample.

1	2	3,	4	panel mean
0.59	0.59	0.59	0.59	0.59
0.57	0.57	0.57	0.57	0.57
0.5	0.5	0.5	0.5	0.5
0.42	0.42	0.42	0.42	0.42
0.43	0.43	0.43	0.43	0.43

The mean of the second set of tests is given by

$$\frac{0.59 + 0.57 + 0.5 + 0.42 + 0.43}{5} = 0.502$$

The new grand mean is therefore given by

$$\frac{0.472 + 0.502}{2} = 0.487$$

while the standard deviation remains as 0.085.

The grand mean is now given by 0.487 while the pooled standard deviation between panel means is given by 0.085. The 5% comparison value is then

$$0.487 - 1.758 \times 0.085 = 0.338$$

which is greater than 0.35 Mpa, and hence the specification limit is achieved.

7.12 Example 12, Retesting, Known Standard Deviation (Fails both rounds).

Double sampling with 12 mm IB, Lower Specification is 0.35 Mpa. The long run standard deviation is 0.085. Five panels were randomly selected and four tests were conducted per panel. The results and the calculated panel means are given in the table below.

1	2	3,	4	panel mean
0.33	0.33	0.33	0.33	0.33
0.15	0.15	0.15	0.15	0.15
0.49	0.49	0.49	0.49	0.49
0.24	0.24	0.24	0.24	0.24
0.36	0.36	0.36	0.36	0.36

The grand mean is given by

$$\frac{0.33 + 0.15 + 0.49 + 0.24 + 0.36}{5} = 0.314$$

while the standard deviation between panel means is given by

$$\sqrt{\frac{(0.33 - 0.314)^2 + (0.15 - 0.314)^2 + (0.49 - 0.314)^2 + (0.24 - 0.314)^2 + (0.36 - 0.314)^2}{4}} = 0.085.$$

The 5% comparison value is then

$$0.314 - 1.758 \times 0.085 = 0.165$$

which is less than 0.35 Mpa, and hence the specification limit is not achieved. An additional five panels were sampled, with four tests per sample.

1	2	3,	4	panel mean
0.48	0.48	0.48	0.48	0.48
0.28	0.28	0.28	0.28	0.28
0.42	0.42	0.42	0.42	0.42
0.35	0.35	0.35	0.35	0.35
0.33	0.33	0.33	0.33	0.33

The mean of the second set of tests is given by

$$\frac{0.48 + 0.28 + 0.42 + 0.35 + 0.33}{5} = 0.372$$

The new grand mean is therefore given by

$$\frac{0.314 + 0.372}{2} = 0.343$$

while the standard deviation remains as 0.085.

The grand mean is now given by 0.343 while the pooled standard deviation between panel means is given by 0.085. The 5% comparison value is then

$$0.343 - 1.758 \times 0.085 = 0.194$$

which is less than 0.35 Mpa, and hence the specification limit is not achieved.

7.13 Example 13, Rolling Std Deviation and Continuous Testing

Using rolling std deviation with 16 mm IB, Lower Specification is 0.30 Mpa. Four samples are planned during the production run with four tests per board and retesting is allowed. The k value is 1.127. The table below gives the last 30 test panels for this product, with corresponding panel means.

1	2	3	4	panel mean
0.376	0.473	0.5	0.458	0.452
0.558	0.564	0.639	0.636	0.599
0.528	0.516	0.603	0.478	0.531
0.451	0.411	0.373	0.339	0.394
0.546	0.643	0.57	0.543	0.576
0.403	0.426	0.292	0.537	0.414

1	2	3	4	panel mean
0.485	0.504	0.567	0.562	0.53
0.599	0.555	0.462	0.474	0.522
0.605	0.586	0.527	0.546	0.566
0.575	0.536	0.515	0.558	0.546
0.43	0.387	0.481	0.447	0.436
0.338	0.365	0.419	0.376	0.374
0.509	0.45	0.401	0.375	0.434
0.58	0.582	0.539	0.572	0.568
0.466	0.556	0.422	0.544	0.497
0.48	0.48	0.452	0.479	0.473
0.53	0.521	0.473	0.472	0.499
0.445	0.327	0.425	0.379	0.394
0.497	0.492	0.569	0.522	0.52
0.549	0.504	0.506	0.522	0.52
0.37	0.39	0.307	0.368	0.359
0.406	0.416	0.498	0.287	0.402
0.402	0.418	0.488	0.487	0.449
0.458	0.442	0.551	0.511	0.491
0.416	0.495	0.529	0.554	0.498
0.398	0.455	0.321	0.351	0.381
0.483	0.619	0.606	0.525	0.558
0.49	0.454	0.439	0.487	0.468
0.45	0.566	0.572	0.51	0.524
0.517	0.519	0.479	0.463	0.494

The grand mean of the last 30 panel means is 0.482, while the stand deviation of the last 30 panel means is 0.067.

The results of the first panel of the curent production run are:

1	2	3	4	panel mean
0.487	0.629	0.588	0.486	0.548

Since

$$0.548 - 1.127 \times 0.067 = 0.472 > 0.30,$$

the standard criteria is achieved and the production can proceed.

The updated mean is

$$0.482 + \frac{0.548 - 0.452}{30} = 0.485,$$

and the updated standard deviation is

$$\sqrt{0.067^2 + \frac{(0.548 - 0.452) \times (0.548 - 0.485 + 0.452 - 0.482)}{29}} = 0.068$$

The results of the second panel of the curent production run are:

1	2	3	4	panel mean
0.376	0.473	0.5	0.458	0.452
0.558	0.564	0.639	0.636	0.599

1	2	3	4	panel mean
0.528	0.516	0.603	0.478	0.531
0.451	0.411	0.373	0.339	0.394
0.546	0.643	0.57	0.543	0.576
0.403	0.426	0.292	0.537	0.414
0.485	0.504	0.567	0.562	0.53
0.599	0.555	0.462	0.474	0.522
0.605	0.586	0.527	0.546	0.566
0.575	0.536	0.515	0.558	0.546
0.43	0.387	0.481	0.447	0.436
0.338	0.365	0.419	0.376	0.374
0.509	0.45	0.401	0.375	0.434
0.58	0.582	0.539	0.572	0.568
0.466	0.556	0.422	0.544	0.497
0.48	0.48	0.452	0.479	0.473
0.53	0.521	0.473	0.472	0.499
0.445	0.327	0.425	0.379	0.394
0.497	0.492	0.569	0.522	0.52
0.549	0.504	0.506	0.522	0.52
0.37	0.39	0.307	0.368	0.359
0.406	0.416	0.498	0.287	0.402
0.402	0.418	0.488	0.487	0.449
0.458	0.442	0.551	0.511	0.491
0.416	0.495	0.529	0.554	0.498
0.398	0.455	0.321	0.351	0.381
0.483	0.619	0.606	0.525	0.558
0.49	0.454	0.439	0.487	0.468
0.45	0.566	0.572	0.51	0.524
0.517	0.519	0.479	0.463	0.494

Since

$$0.473 - 1.127 \times 0.068 = 0.396 > 0.30,$$

the standard criteria is achieved and the production can proceed.

The updated mean is

$$0.485 + \frac{0.473 - 0.599}{30} = 0.481,$$

and the updated standard deviation is

$$\sqrt{0.068^2 + \frac{(0.473 - 0.599) \times (0.473 - 0.481 + 0.599 - 0.485)}{29}} = 0.065$$

The results of the third panel of the curent production run are:

1	2	3	4	panel mean
0.567	0.617	0.515	0.633	0.583

Since

$$0.583 - 1.127 \times 0.065 = 0.51 > 0.30,$$

the standard criteria is achieved and the production can proceed.

The updated mean is

$$0.481 + \frac{0.583 - 0.531}{30} = 0.483,$$

and the updated standard deviation is

$$\sqrt{0.065^2 + \frac{(0.583 - 0.531) \times (0.583 - 0.483 + 0.531 - 0.481)}{29}} = 0.067$$

The results of the fourth panel of the curent production run are:

1	2	3	4	panel mean
0.344	0.34	0.331	0.26	0.319

Since

$$0.319 - 1.127 \times 0.067 = 0.243 < 0.30,$$

the standard criteria is not achieved and another panel needs to be tested.

The results of the retesting for the fourth panel of the curent production run are:

1	2	3	4	panel mean
0.511	0.483	0.49	0.598	0.52

The grand mean of the two panel means is given by

$$\frac{0.319 + 0.52}{2} = 0.486$$

Since

$$0.486 - 1.127 \times 0.067 = 0.41 > 0.30,$$

the standard criteria is achieved and the production does not need to be downgraded.

Two sets of updates need to be applied.

The first updated mean is

$$0.483 + \frac{0.319 - 0.394}{30} = 0.481,$$

and the first updated standard deviation is

$$\sqrt{0.067^2 + \frac{(0.319 - 0.394) \times (0.319 - 0.481 + 0.394 - 0.483)}{29}} = 0.072$$

The second updated mean is

$$0.481 + \frac{0.52 - 0.576}{30} = 0.479,$$

and the second updated standard deviation is

$$\sqrt{0.072^2 + \frac{(0.52 - 0.576) \times (0.52 - 0.479 + 0.576 - 0.481)}{29}} = 0.07$$

7.14 Example 14, Rolling Std Deviation and Continuous Testing

Using rolling std deviation with 18 mm MOR, Lower Specification is 12 Mpa. Five samples are planned during the production run with two tests per board and retesting is allowed. The k value is 1.4. The table below gives the last 30 test panels for this product, with corresponding panel means.

1	2	panel mean
14.99	14.59	14.79
9.731	14.41	12.07
14.53	13.44	13.98
10.31	18.51	14.41
14.93	7.783	11.36
14.41	15.76	15.09
13.49	10.69	12.09
17.22	16.92	17.07
8.098	13.97	11.03
14.17	14.23	14.2
9.037	10.52	9.779
9.499	14.21	11.86
13	12.36	12.68
15.05	14.45	14.76
13.6	11.38	12.49
13.35	13.9	13.63
9.172	12.21	10.69
10.68	11.5	11.09
10.82	11.4	11.11
13.96	13.04	13.5
14.03	14.86	14.44
13.88	14.46	14.17
13.06	15.42	14.24
12.61	13.89	13.25
14.28	10.27	12.27
16.6	18.52	17.56
11.48	16.41	13.95
17.77	13.67	15.72
16.33	16.71	16.52
16.44	17.8	17.12

The grand mean of the last 30 panel means is 13.564, while the standard deviation of the last 30 panel means is 2.031.

The results of the first panel of the current production run are:

1	2	panel mean
12.7	17.64	15.17

Since

$$15.17 - 1.4 \times 2.031 = 12.327 > 12,$$

the standard criteria is achieved and the production can proceed.

The updated mean is

$$13.564 + \frac{15.17 - 14.79}{30} = 13.577,$$

and the updated standard deviation is

$$\sqrt{2.031^2 + \frac{(15.17 - 14.79) \times (15.17 - 13.577 + 14.79 - 13.564)}{29}} = 2.04$$

The results of the second panel of the current production run are:

1	2	panel mean
12.22	15.69	13.95

Since

$$13.954 - 1.4 \times 2.04 = 11.098 < 12,$$

the standard criteria is not achieved and another panel needs to be tested.

The results of the retesting for the second panel of the current production run are:

1	2	panel mean
16.53	14.57	15.55

The grand mean of the two panel means is given by

$$\frac{13.954 + 15.547}{2} = 14.751$$

Since

$$14.751 - 1.4 \times 2.04 = 11.895 < 12,$$

the standard criteria is not achieved and the production needs to be downgraded. No updating of the rolling mean or rolling standard deviation should be applied at this stage.

The results of the third panel of the current production run are:

1	2	panel mean
14.24	16.24	15.24

Since

$$15.242 - 1.4 \times 2.04 = 12.386 > 12,$$

the standard criteria is achieved and the production can proceed.

The updated mean is

$$13.577 + \frac{15.242 - 13.982}{30} = 13.619,$$

and the updated standard deviation is

$$\sqrt{2.04^2 + \frac{(15.242 - 13.982) \times (15.242 - 13.619 + 13.982 - 13.577)}{29}} = 2.061$$

The results of the fourth panel of the current production run are:

1	2	panel mean
13.06	12.96	13.01

Since

$$13.011 - 1.4 \times 2.061 = 10.126 < 12,$$

the standard criteria is not achieved and another panel needs to be tested.

The results of the retesting for the fourth panel of the current production run are:

1	2	panel mean
17.62	16.85	17.23

The grand mean of the two panel means is given by

$$\frac{13.011 + 17.234}{2} = 15.123$$

Since

$$15.123 - 1.4 \times 2.061 = 12.238 > 12,$$

the standard criteria is achieved and the production does not need to be downgraded. Two sets of updates need to be applied.

The first updated mean is

$$13.619 + \frac{13.011 - 11.356}{30} = 13.572,$$

and the first updated standard deviation is

$$\sqrt{2.061^2 + \frac{(13.011 - 11.356) \times (13.011 - 13.572 + 11.356 - 13.619)}{29}} = 2.058$$

The second updated mean is

$$13.572 + \frac{17.234 - 15.085}{30} = 13.768,$$

and the second updated standard deviation is

$$\sqrt{2.058^2 + \frac{(17.234 - 15.085) \times (17.234 - 13.768 + 15.085 - 13.572)}{29}} = 2.119$$

The results of the fifth panel of the current production run are:

1	2	panel mean
16.46	16.73	16.59

Since

$$16.591 - 1.4 \times 2.119 = 13.624 > 12,$$

the standard criteria is achieved and the production can proceed.

The updated mean is

$$13.768 + \frac{16.591 - 15.085}{30} = 13.627,$$

and the updated standard deviation is

$$\sqrt{2.119^2 + \frac{(16.591 - 15.085) \times (16.591 - 13.627 + 15.085 - 13.768)}{29}} = 2.171$$